VAN NOSTRAND GRASSLAND FARM SERIES

Editor

W. A. WHEELER
ORAGE AND PASTURE CROPS

A Handbook of Information about the Grasses and Legumes Grown for Forage in the United States

BY

W. A. WHEELER

Prepared under the Auspices of

THE FIELD SEED INSTITUTE OF NORTH AMERICA

With the cooperation and assistance of the agronomists, forage crop specialists, and other specialists of the United States Department of Agriculture and the State agricultural colleges and experiment stations.
FOREWORD

Civilized peoples the world over have only recently become intensely interested in the pasture and forage crops—the grasses and legumes. Dust storms, floods and other evidences of soil erosion have developed in most of us an appreciation of the need for a better application of soil-conserving practices. At the same time we know now that even the best of our soils are losing their original productivity, and that continued cropping by present methods will increase production costs as well as produce foods that do not have the best in nutritive value.

This interest is not confined to those of us directly concerned with production problems and procedures, for groups like the American Forestry Association, Friends of the Land, and the Conservation Foundation have helped to make dwellers in towns and cities conscious of the need for using and conserving our soils in such a way as to insure a continued agricultural production adequate for our food, shelter, and clothing needs.

The results of accumulated years of experience and research with our food crops, such as wheat and corn, have long been available and generally applied. With this knowledge, an ever-increasing efficiency in production has resulted. It was for research on these food crops that public funds were first made available, and it was to them that our early agricultural specialists gave their efforts, in the hope of producing better kinds and of developing more efficient methods of production. In more recent years the need has been realized for similar work with the forage crops which can so effectively carpet our fields, holding our soils against erosion losses and at the same time increasing their fertility.

As this forage research work got under way here and there, by individuals and agencies, results as important and meaningful as those from the work on the cereal crops came to light. But the information generally has been scattered and not available to those interested in applying it in the solution of cropping problems. The widely felt need for someone to bring this considerable fund of information together and make it readily usable has increased with the passing of the years, but only now has this demand crystallized into action.

I know of no one better able to do this much needed job than W. A. Wheeler. His background experience through fifty years has been such as to prepare him especially for the task. Trained at the University of Minnesota, where he taught for five years before going to South Dakota State College in 1903 as professor of botany in charge of forage crop breeding, his interest from the very first was with the forages. At South Dakota State College he developed what probably was the first extensive forage-breeding nursery in this country, with special attention to alfalfa and the native grasses.

In 1907 he entered the commercial seed field, making improved varieties of the more important forages a specialty. He pioneered in this field. His years in this activity, interspersed as they were between his college and State experiment station work, and his thirty years with the United States Department of Agriculture, gave
him an insight and a viewpoint of inestimable value in the varied responsibilities
he has undertaken, most of them having to do with seed in one way or another.

Always forward-looking, Mr. Wheeler evolved a plan and made recommenda-
tions to the United States Department of Agriculture some thirty-five years ago for
increasing, processing and distributing the seed of improved forages. The essential
features of that plan are embodied in a program now getting under way for the
production and distribution of foundation seed.

In 1916, Mr. Wheeler joined the United States Department of Agriculture
to inaugurate a program of seed marketing studies and procedures which envisioned
the increase and general availability of seed of the improved varieties of forage crops.
His plan for seed-source verification, which has functioned through the Seed Veri-
fication Service of the U. S. D. A. during a relatively long period of years, proved
to be of inestimable value, both to the seed trade and to the buyer of seed. This
plan insures a knowledge of the source of origin of certain forage seed, very impor-
tant for such crops as alfalfa.

His knowledge of seed production, processing and distribution practices made it
possible for him to plan and direct a most effective and important program of seed
production and procurement for the United States and the United Nations, during
and immediately following World War II.

Now, his four-year program under the auspices of the Field Seed Institute
of North America, covering the preparation of this reference work on forage and
pasture crops, climaxes more than fifty productive years. In this volume he has
brought together the more important information on the different forage and pas-
ture crops and their uses. This information has been accumulating through the
years, from experience and research.

The need for the general availability of such information as is contained in this
volume has become increasingly acute as the need for a greater acreage and the
more effective use of grass and legume crops has come to be better understood.
The availability of this information will be of the greatest value not only to
teachers, students in organized classes, soil conservation specialists, county agents,
and other extension workers, but also to forward-looking farmers, stockmen, and
seedsman.

H. D. Hughes
Professor of Farm Crops, Iowa State
College of Agriculture and Agricultural
Experiment Station, and Past President,
American Society of Agronomy
The need for a standard reference work to include all the grasses and legumes grown for forage in the United States has been recognized for some time. Piper's work, "Forage Plants and Their Culture" was last revised in 1924, more than 25 years ago. That work was not intended by the author as a comprehensive treatise on all forage crops at the time. Also, since then, new crops have been discovered in foreign countries and introduced into culture in the United States, native grasses have been brought under cultivation, improved varieties have been developed, and much has been learned about the old ones that we did not know before.

Since this work is intended to cover all domesticated grasses and legumes used for harvested forage and for pasture in the United States, the title "Forage and Pasture Crops" has been adopted in order to make it all-inclusive. In the text of this work, however, the term "forage crops" is employed mostly in the broad sense to include those crops used for both harvested forage and pasture.

The numerous bulletins on forage crops from the 48 states and the United States Department of Agriculture are valuable as to their content, but there are so many of them and from such scattered sources that they are not always readily available when desired. To get a good portion of the basic information on every crop especially grown for forage in the United States readily available within the confines of one cover is the purpose of this book.

Perhaps there is no single group of persons more interested in the mass of information contained herein than the field seedsmen. Because of this, a group of field seedsmen, both members and non-members of the Field Seed Institute of North America, a research organization, has undertaken the financing of the preparation of this book under the sponsorship of the Institute, as a valuable enterprise, not only for the information of seedsmen, but for the use of agronomists, livestock men, farmers, college and school teachers and students, county agricultural agents, bankers, and other financial agencies, processors and manufacturers, and anybody and everybody associated with forage or forage seed production, or with producing, processing, or distributing forage for livestock. To the field seedsmen who sponsored this work should go, therefore, the principal credit for initiating, promoting, and financing the enterprise. They also assisted materially in the collection of data on seed production.

No one person could prepare the vast quantity of material for this work directly from basic data. In fact, it would be better not to have it done that way, even if it were feasible. An effort has been made in this volume to assemble the most useful available material on all forage crops grown in the United States and arrange it in a convenient and accessible form for use. Where it has been published or otherwise made available in a form that is suitable for use in this book, it has been so used, with perhaps only minor changes.

Agronomists, forage crop specialists, and other specialists from agricultural colleges and experiment stations all over the United States and from the United States
Department of Agriculture have been called upon for suggestions and to review the chapters of this work. They have responded generously to these calls. Without their assistance, its preparation would have been difficult, in fact, impossible, in its present form and scope.

It would not be easy to name all the persons to whom I am indebted for help, and particularly for the tedious work of reviewing the manuscript, sometimes the same person several times, in an effort to get it into acceptable shape. Even so, some errors and oversights have undoubtedly crept in. These will not be the fault of the reviewers, but rather will be due to the handling of the material by so many persons, and in trying to carry out the many suggestions received. Among those who have been called upon most frequently, and who have given most generously of their time, are the forage crop specialists of the Division of Forage Crops and Diseases of the Department.

Those of this Division located at the Plant Industry Station, Beltsville, Md., who have been consulted most freely are Mason Hein, E. A. Hollowell, Roland McKee, W. J. Morse, and H. M. Tysdal. Among those of this Division located in the field are Harry Schoth of Oregon, George A. Rogler of North Dakota, V. G. Sprague of the Northeast Pasture Laboratory, E. Marion Brown of Missouri, David A. Savage of Oklahoma, L. C. Newell of Nebraska, G. E. Ritchey of Florida, and G. W. Burton of Georgia. Others in the same Division and in other branches of the Department who have made liberal contributions of their time and assistance in the preparation and reviewing of the manuscript are O. S. Aamodt, W. M. Myers, John H. Martin, L. W. Erdman, J. K. Ableiter, L. W. Kephart, and J. L. Allison of the Bureau of Plant Industry, Soils, and Agricultural Engineering; George C. Edler and Thomas J. Kuzelka of the Bureau of Agricultural Economics; J. B. Shepherd of the Bureau of Dairy Industry, C. M. Packard of the Bureau of Entomology and Plant Quarantine, W. H. Hosterman, of the Grain Branch, Production and Marketing Administration, and W. A. Dayton of the Forest Service.


I am indebted to the Grain Branch of the Production and Marketing Admin-
istration for secretarial and clerical help, office space, and other necessary facilities for carrying on this work. I am especially appreciative of the services rendered by the administrative officers of this Branch, by the Director, Leroy K. Smith, and the Assistant Directors, William McArthur, E. J. Murphy, and Fred D. Entermille; by E. O. Pollock, Arnold S. Dahl, Wilbur H. Youngman, and Wilson Westbrook; by Daisy Welter Duncan and Ophia Clark, and by my secretary, Emma M. Appleby.

In the Office of Information of the United States Department of Agriculture, Keith Himebaugh, Director, M. C. Merrill in charge of Publications, and Albert D. Stefferud, Editor of the Yearbook, gave much encouragement and help to the project.

The illustrations were selected largely from the voluminous collections of the Division of Forage Crops and Diseases, B.P.I.S. and A.E., the Soil Conservation Service, and the Forest Service, and were furnished by these agencies.

To all persons and agencies who have so kindly contributed to this work, the author and the sponsoring group wish to express their grateful acknowledgment and appreciation for the services rendered.

An early effort was made in the preparation of the manuscript to adopt a standard method of arrangement and preparation of material, and to be consistent in presentation and treatment of subject matter. Because of the desirability of using much of it in its present form and language, this was difficult or impossible, so a proportion of the material is in much the same form in which it was first published. An effort was made to regulate the quantity used for each subject or each crop in accordance with the importance or interest in the crop. In considerable measure this has been carried out. However, the large interest in some crops, and the lack of interest in some others, the large quantity of material available on some crops and the small quantity on others which may not be wholly in proportion to the extent of their present culture or importance, may have influenced the extent of the space given them.

At the close of each chapter is a paragraph headed "This Chapter" which gives the principal sources of the material used in the particular chapter. This has been done with most material in lieu of using specific citations in the text and quoting the reference material. This method has given both the compiler and the reviewer an opportunity to adjust the material to the context and also to modify it as he saw fit to bring it up to date.

In bringing together in convenient form in one volume the more important available information on forage crops in the United States, it is hoped that this book will contribute something to a better understanding and knowledge of the characteristics, adaptation, culture, and utilization of the grasses and legumes used as forage and soil-conserving crops, and will give encouragement to a greater and better grassland agriculture. If these ends are accomplished, the book will have served its purpose, and the sponsors and the author will feel well repaid for engaging in its preparation.

Washington, D. C.

W. A. Wheeler
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PART I
FORAGE AND PASTURE CROPS—GENERAL
CHAPTER I

GRASSES AND LEGUMES AS FORAGE AND PASTURE CROPS

Nature did a superb job with the grasses and legumes, spreading them over much of the earth, adapting them to an immense range of climates. They would still be there to feed our flocks and herds and to hold and build the soil if there were no other crop plants whatever in the world. In agricultural work, one should know about the adaptability of the grasses and legumes from coast to coast and north to south in the United States—where they came from, what species thrive in different regions and areas, and in general what is being done to make them still more useful in modern agriculture. (US-1)

In all climates, whatever the degree of latitude or longitude and at almost every altitude from seacoast to alpine heights, grasses and legumes provide the principal source of feed for livestock, at the same time helping to hold the land surface in place against the beating action of raindrops, the rush of floodwaters and the force of wind.

Of the many kinds of grasses and legumes, only a few are adapted to any particular climate. Those that thrive on sand dunes along the seacoast would perish on alpine ranges, species found in arid wastes fail in more humid environments, and those common to warm climates succumb to cold, while species hardy in cold climates fail to survive tropical or even subtropical heat.

In the United States, where 60 percent of the land area is covered with grasses and legumes, many of those important on ranges and in pastures and meadows are native species. Many other species, particularly those found in pasture and meadows in the East and Mid-west, were gathered in foreign countries and sent home by U.S.D.A. workers, explorers, missionaries, or other travelers, or they were brought in by immigrants. These have proved to be very valuable supplements to the native plants.

Thousands of such introductions failed to find suitable conditions in this country; others reacted favorably to the environment characterizing one or another part of the country; still others awaited improvement by selection or breeding or the development of suitable cultural methods.

To determine the range of adaptation of introduced species, to develop systems of culture, to bring about improvement by breeding and selection, and to relate these advances to climatic requirements are now and have been the objectives of intensive research by the United States Department of Agriculture and the State experiment stations. It is through such research that the United States has acquired and is currently acquiring new and valuable species for agricultural and, as in the case of soybeans, even industrial use, under the different climatic conditions.

GRASSLAND AGRICULTURE

In his introduction to “Grass” (US-30) Cardon says in part: “Grass in the concept of grassland agriculture is not limited to the grasses; it embraces also their common associates of the legume family (Leguminosae)—the clovers, lespedezas, alfalfas, and many others.”

“Grassland agriculture does not mean necessarily extensive agriculture. In some areas it is very intensive—as much so as vegetable farming.
"Inseparably linked to livestock production, grassland agriculture under good management may equal or increase the production of digestible nutrients to the acre and reduce materially the labor needed to grow and utilize a given amount of those nutrients. It may also lower significantly the cost of supplying the protein—often bought as concentrates—required for high levels of animal nutrition. Grassland agriculture envisions the use of grasses and legumes, alone or in combination, in rotations according to systems of management best suited to land use under various environments, with ample provision for root crops, leafy vegetables, fruits, fibers, forests, and specialty crops as needed.

"Thus grassland agriculture differs from other types of farming chiefly with respect to the emphasis placed on grasses and legumes. They are dominant in a flexible pattern designed to conserve the land and its productivity but at the same time keep it adjustable to emergency needs." * * * * 

"Soil and climate in the various sections determine the intensity of grassland farming that is most likely to prove satisfactory, and even they must be considered in terms of more specific physical, biological, and managerial factors that govern species, cultural and grazing practices, and the place of grass in the cropping systems.

"Take grass in the rotation—grass-legume mixtures or legumes alone. There grass becomes a farm crop—a crop with a lofty purpose and a high value. More than any other crop, it provides organic matter for return to the soil and, being a sod crop, exerts on the soil none of the adverse influences of intertilled crops. It harbors and nurtures beneficial organisms, as nitrogen-fixing bacteria on various legumes; its innumerable roots pervade the soil and aid in preserving its tilth. Grass is green manure, or it is forage which comes back to the land as barnyard manure. Grass responds productively to fertilizers, thereby providing organic matter and nitrogen in greater abundance. Lime makes possible better legumes, which in turn make better forage and, in the long run, better land.

"On sloping lands, for controlling soil erosion, grass is indispensable. Besides all its values in the cropping system, it has the unique value of simplifying the maintenance of contours, terraces, and watercourses.

"Grass is important in uses other than those common to the farm—important for the same reason, namely, the preservation of balance in the productive capacity of the land." * * * *

"But many farmers are not producing as good grass as they could, and more educational work is required to bring about widespread application of grass-improvement practices.

"Of equal importance is the development of a more general understanding of the superior nutritional value of good grass and of ways in which this value can be preserved for use in livestock feeding." * * * *

"Thus grass in Aroostook County, Maine may be of different composition and managed differently from grass in Pointe Coupee Parish in Louisiana. So also grassland agriculture in Tama County in Iowa may differ widely from that of Woodward County in Oklahoma, and both may differ from that of Cache County in Utah, Snohomish County in Washington, or the Salt River Valley of Arizona.

"But regardless of variation in the degree of intensity of the grassland farming suited to different regions, underlying principles to be observed are much the same everywhere. Those principles relate to the productive capacity of the soil—the factors that conduce to its deterioration on the one hand, or its improvement on the other—and to the control of factors that soil management can exert." * * * *

"Fortunately, factors of soil improvement are better understood today than ever before, and they will be still better understood as science continues to advance. An understanding of them enables farmers to remain on the land and plan hopefully for permanency—instead of
moving, like the old tribemen, to other land when the old is worn out. The farmer of today can, in fact, eat his cake and have it too. He can offset, and on some soils more than offset, factors of soil deterioration by factors of improvement, and make the most of all of them. Some of the factors of deterioration are beneficial, if utilized—microbiological activity in breaking down the organic matter, for example. The aim is not to stop such activity but to take advantage of it.

"To accomplish the balance between these forces, the farmer has many aids and practices: Crop rotation, barnyard manure, green-manure crops, fertilizers, lime, contouring, strip cropping, and other devices. And for inclusion with all of these—as a part of them, in fact—he has grass." * * *

"Grassland agriculture is not simple. On the contrary, it is so complex as to command a high type of managerial ability if it is to prove successful in any given situation. The grassland farmer is required not only to decide upon the place grass is to have in his cropping system; he has to manage grass in relation to other crops and to livestock." * * *

"But the complexities of grassland agriculture are surmountable and need not impede the more general spread of grassland agriculture in this country. Many farmers have made decisions relative to grassland agriculture and are far advanced in its practice. Moreover, experience in other countries, including western Europe, Great Britain, New Zealand, and Australia, points to the feasibility of grassland farming under such a wide variety of conditions that its feasibility in appropriate form in all parts of the United States seems to be a fact."

Bender (NJ-11) calls special attention to the need for considering the use of grasses and legumes, not only as soil-conserving crops, but in their relation to economic and profitable crop and livestock production. He says, "conserving the soil by only holding it in place and building up the water table only to raise its level, will never solve the problems of the food supply for a growing population. The mere conservation of any resource in the minds of too many people has a passive connotation. Too frequently the term is understood to mean to save for some future period of use, or to use it slowly.

"The agricultural soils which for the most part are readily tilled are the ones upon which our nation depends for its sustenance. To these soils conservation is more or less a misnomer; it is too static a term. These soils can be built up in productivity through fertilization, held in place through the use of the right crops with sound crop and livestock management, and play a vital role in water conservation.

"In the first place, when grass is grown for soil and water conservation, if it is to contribute to our food supply it must be palatable enough to be grazed by livestock or harvested for livestock feed. If it does not fall into this category then its use is limited mostly in its harvested form for livestock bedding or mulch purposes.

"The first use of this grass should be by the grazing animal. The nutrients in the grasses are thus presented to the livestock in the cheapest form, with a minimum of labor and with no loss of nutrients.

"The main problems of concern in this type of utilization are those of grazing management to prevent overgrazing, fertilization to keep the stands productive, and harvesting the excess grass for winter feed for livestock.

"By proper grazing management, which includes rotation grazing, and fertilization, stands of legumes and grasses will carry more livestock, prevent erosion, and reduce or eliminate water run-off.

"The harvesting of grasses and legumes for winter feeding is another problem entirely. To many livestock men the harvesting of these crops is a matter of getting them off the field as hay and stored in the mow or stacks without regard to nutrient losses or quality of product.

"In the humid sections of the country losses of hay nutrients may run as high as 20-50 percent due to rain and subsequent leaching, bleaching, and over-handling of the crop. Feeding hay of this
quality to livestock reduces milk production or weight gains unless the lack of these plant nutrients is made up by increased grain feeding.

“The harvesting of first cuttings of grasses and legumes for grass silage reduces these losses tremendously. The nutrients in these grass crops can best be preserved through the use of 80 pounds of molasses or 200-250 pounds of corn and cob meal per ton of green material.

“When these first cuttings are harvested early for grass silage, second cuttings can usually be made into hay when the weather is better suited to haymaking.

“Through a program of sound grassland management which embraces pasture, grass silage and hay of high nutrient quality, a level of milk production as high as 85 percent of a cow’s potential production may be maintained without supplemental grain feeding. The feeding of this high quality roughage to other classes of livestock will produce cheaper gains on smaller acreages of land. At the same time, the well managed grassland program will build up soil fertility, keep it in place, and conserve water.”

The grasslands of the United States constitute approximately a billion acres, or nearly 60 percent of the total land area. These lands supply about one-half of the feed for all livestock. By maximizing forage crops in the feeding program, grasslands could furnish up to 70 percent or more of the feed for all livestock. The proper utilization of this great area to supply feed most efficiently for an increased livestock population, and at the same time conserve our land resources, is the great challenge of grassland agriculture.

THE GRASSES

The true grasses comprise several thousand species and are found in all parts of the world, but it is in the drier, temperate regions where they often form the chief vegetation. They owe their dominance in such regions to their ability to make a living under all conditions where flowering plants can live at all, to their aggressive methods of natural vegetative propagation, and to their usually abundant seed crop and its wide dispersal by natural agencies, such as wind and water.

Many grasses, also, are adapted to dispersal by animals; such seeds as those of needlegrasses, three-awn grasses and others with spines or needle-like bases attach themselves to the hair or fur of animals or the clothing of man. Grasses have spread over continents and across the seas, often without intent, by man-made devices.

CHARACTERISTICS OF GRASSES

Except for the fact that sedges, rushes, and a few other plants or groups of plants, are often confused with grasses because of a superficial resemblance, grasses are sufficiently distinctive in appearance to be readily recognized as such. In grasses, the vegetative parts are more uniform and characteristic than in most other families. If one has the stem and leaves of a grass plant, he can decide readily whether or not it is a grass. The only plants that may reasonably be mistaken for grasses are the sedges in which the culms are not jointed and are commonly three-sided, and the leaves are always three-ranked.

In details of flowers, leaves, and growth habits, grasses show considerable diversity. Many species can be recognized readily by outstanding characters but accurate identification often depends upon minute characters difficult of determination. This is especially true in groups which have many rather similar species, such as the bluegrasses, fescues, and panicgrasses.

Most of the species in which we are interested as forage grasses are perennials. Our cereal grains, many sorghums, and millets are annual grasses and we have a number of annual grasses which are weeds—pigeongrass, wild oats, barnyard grass, and others. Some perennial species, such as orchardgrass and timothy, are bunchgrasses which tiller and form dense clumps; others, such as Kentucky bluegrass, Johnsongrass, and western wheatgrass, form more of a solid sod.

Stems and roots: The stems of grasses
GRASSES AND LEGUMES

are jointed, usually cylindrical (as distinguished from the usually triangular stems of sedges) with cross partitions at the nodes and commonly hollow, but solid in such species as corn and sorghum, and woody in bamboos and a few other grasses. Those above ground may be erect, procumbent, or prostrate; some species like buffalograss and Bermuda-grass spread above ground by means of stolons which root at the joints and form a continuous turf. The stems below-ground are either short as in bunchgrasses, or develop into long or short rootstocks or rhizomes and form a dense sod as in johnsongrass and quackgrass. The true roots of both annual and perennial grasses are fibrous, though there is some variation even in these.

The distinction between bunchgrasses and sod-forming grasses might seem quite sharp, but there is considerable variation in development of rhizomes. Side-oats grama and switchgrass have rhizomes, but they are short, so that a broad, thick clump usually results, rather than a firm sod. The density of the sod depends greatly upon the growing conditions. Western wheatgrass sometimes makes a rather dense turf, but in poor soil or in competition with other grasses, it may produce only scattered stalks. Sometimes these will be observed in definite lines where they have come from a single rhizome.

Leaves: Grass leaves are generally long and narrow, but there is considerable variation. Those of Kentucky bluegrass are scarcely an eighth of an inch wide, very blunt at the tips, and practically the same width throughout. Those of cordgrass which reach a length of from 1 to 2 feet, taper gradually toward the tip. Leiberg's panicgrass has unusually short, broad leaves, about 3 inches long and one-half inch wide. The leaves of western wheatgrass are quite thick and stiff, with prominent ridges on the upper side. Those of quackgrass and bromegrass are somewhat wider and much softer. Hairs are sometimes present on the surface. The edges of the leaves of some species are often sharp enough to cut one's fingers if handled incautiously. This is due to minute saw-teeth, strongly impregnated with silica.

The leaf consists of two portions, sheath and blade. It begins at the node where it is attached to the stem, the sheath wrapping around the stem for an inch or more, at which place the flat blade diverges from the stem. Usually the sheath is "open," its edges overlapped as one would wrap a robe about his body, but in bromegrass and also in the sedges, the sheath is "closed," like a sweater or a stocking. The sheaths are usually shorter than the internodes (portion of stem between two nodes or joints) so that a portion of the stem and the next node protrude above the sheath arising from the node below. In some grasses, however, and always in very young stems, the sheaths are the longer so that two or more may enclose part of a stem. The leaves are always two-ranked, the blades forming two vertical rows up the stem. In the sedges the stems are usually 3-sided, the leaves forming three vertical rows.

Some minute structures occur at the base of the leaf blade which are useful when one needs to identify grasses without the flowering parts. The bend beneath sheath and leaf blade is usually thickened forming a collar. The angles of the base of the blade sometimes are elongated into two points, the auricles, which may clasp around the stem. These are conspicuous in common barley and are present in many of the grasses which belong to its group. Projecting upward from the collar, between the stem and base of the blade is a little membranous ligule, the length and nature of which may be quite characteristic. At the most it is hardly a quarter of an inch long. Sometimes it is invisible or is represented by a fringe of small hairs.

Flowers: The flowers have to do with perpetuating the species. Most grasses flower every year. But some perennials, which spread by specialized underground stems (rhizomes or rootstocks), may cover extensive areas, especially in salt or brackish marshes, without flowering regularly; bamboos flower mostly at intervals of a few to many years.
Being wind-pollinated, the flowers of grasses need no gay colors, no fragrance, no honey to attract insects. The flower consists of a single pistil with one ovule, two styles, each with a feathery stigma, and three (rarely one or six) stamens. Only three, or two, delicate little scales (lodicules) remain of the floral envelope, the calyx and corolla, of other flowers. These minute flowers are born singly or two to many together in spikelets, which are really little flowering branches. The hypothetical flower-bearing branchlet is never elongated. The palea is immediately above the lemma, and the flower immediately above the palea. The axis of the spikelet (rachilla) is jointed as is the culm of a grass, and the lemmas (specialized leaves reduced to a blade-like sheath) are two-ranked as are the leaves.

In grasses, specialization takes place mostly in the spikelet. By its vegetative characters a given plant is shown to be a grass, but it is the spikelets and their arrangement which indicate the kind of grass it is. In the spikelet of cheat or chess, the two glumes are at the base, the florets (lemma, palea, and enclosed flower together) are born on opposite sides of the jointed rachilla, and the flower is concealed. The palea with two nerves, its back to the rachilla, subtends and usually surrounds the flower. The glumes bear no flowers and are without palcas. This simple fundamental floral structure is subject to all manner of modification, but every organ found in the most highly specialized spikelet is to be interpreted as an elaboration or reduction of some part of this structure. The floret is the unit of the spikelet; the spikelet is the unit of the inflorescence. (See illustrations of flower clusters on opposite page.)

The spikelets of wheat are sessile, that is, borne directly (without pedicel) on opposite sides of a stout axis, being placed flatwise against it; those of Italian rye-grass are borne in like manner but are placed edgewise to the axis.

In wild oats, the glumes are enlarged and the fertile florets are but two, with an additional sterile one. The lemmas bear a stout twisted bristle (awn) from the back near the base. In timothy, the spikelet has but one floret, which is enclosed in a pair of rigid-pointed glumes. In bluejoint, the one floret is surrounded by long silky hairs at the base and the lemma bears a slender awn from the back. A segment of the rachilla is produced beyond the base of the palea, suggesting that this spikelet is derived from a form with more than one floret. In the needlegrasses, the lemma bears a stout twisted awn from the summit, and in three-awn grasses the awn is divided into three branches.

In all grasses mentioned so far, the structure is simple and all florets in a spikelet are alike. In some groups single spikelets may contain two very different kinds of florets, at least one perfect (that is, enclosing a flower having stamens and pistil, and perfecting a grain) and one or more reduced sterile florets. The graminoids have spikelets of this kind. In this and allied genera the spikelets are borne in spikes; that is, sessile, as in wheat, but all on one side of the rachis, not on opposite sides, as in wheat. (The axis of a single spike or of a branching panicle is termed axis; that of a secondary spike or raceme is termed rachis.)

In graminoids, of which there are 17 very valuable forage grasses in this country, the lemmas of the sterile florets are greatly altered. The fertile and sterile florets fall together, the sterile with their long hairs and awns serving to disperse the seed. Bermuda-grass, goosegrass, the cordgrasses, and Rhodcosgrass are familiar examples of this group.

The most curious is buffalograss, in which the staminate and pistillate spikelets are usually borne on separate plants and are so different in appearance as to suggest no relationship. The hardened second glumes, grown together at their bases on a short, hardened rachis, form little hard white heads which are borne near the ground, much overtopped by the leaves.

The millets and their relatives form a group characterized by spikelets which fall entire and which are dorsally compressed. They have one perfect floret and below this a sterile floret represented by a sterile lemma. This sterile lemma and
INFLORESCENCES OF NINE GRASS SPECIES, SIX OF WHICH SHOW DETAIL OF SPIKELET:
1. Orchardgrass (Dactylis glomerata);
2. Dallisgrass (Paspalum dilatatum);
3. Rhodesgrass (Chloris gayana);
4. Reed canarygrass (Phalaris arundinacea);
5. Big bluestem (Andropogon gerardi);
6. Tall oatgrass (Arrhenatherum elatius);
7. Redtop (Agrostis alba);
8. Tall fescue (Festuca arundinacea);
9. Blue grama (Bouteloua gracilis).
the second glume are similar. The fertile floret is hardened and permanently encloses the grain which germinates within it, sending its rootlet through a thin place in the back of the lemma and its shoot out the summit between the lemma and palea.

In true millets, the spikelets are much like those of *Panicum* but are surrounded by bristles, which are sterile, reduced branches of a contracted panicle. A further specialization of sterile branches is seen in the sandbur. Here the bristles grow together into a sort of spiny cup which contains from 2 to 5 spikelets. The grains of the sandbur germinate within the spikelets and send out rootlets and shoots between the spines.

In the *Sorghum* tribe the spikelets fall entire as in *Panicum* and its group, but here it is the glumcs which are hardened and enclose the entire floret. The spikelets are in pairs at each node of a jointed rachis—one is sessile and perfect and the other pedicellate and usually sterile; the pair fall together with the rachis-segment and pedicel. Bluestem of the prairies and broomsedge of the Southeast show this arrangement. In sorghum the racemes of spikelets are reduced to a few segments and are borne in a panicle.

The most highly specialized grass in the world and the most useful is maize, or Indian corn. The staminate and pistillate spikelets are borne in different parts of the plant—the staminate, in the terminal tassel; the pistillate, crowded in 8 to 16 rows (always an even number) on a greatly thickened axis (the cob), forms the ear, which terminates a shortened branch and is enveloped by numerous leafy bracts or husks from the summit of which the long styles and stigmas of the flowers (the silk) protrude. The staminate spikelets show much the same structure as those of bluestem and sorghum, and the pistillate are exceptional only in their arrangement on the axis, standing at right angles to it. Rarely in grasses does the grain protrude beyond the glumes as it does in maize, but it also occurs in pearl millet.

**Fruit:** The fruit of grasses is a caryopsis or grain, the seed and fruit being united, the seed adhering throughout to the thin outer fruit-covering, or pericarp. This type of one-seeded, dry, indehiscent fruit is characteristic of the grasses and is possessed by no other family of plants.

**Classification of Forage Grasses**

With such a large family of plants as the grasses having, in general, great similarity in their vegetative structure as well as in many of their floral arrangements and so distinctly different from all other families (except a superficial similarity to some of the sedges and rushes), a natural classification is difficult and one is forced to depend largely upon an artificial grouping. Hitchcock (US-93) divides the grass family into two subfamilies (which is admittedly more or less artificial), and each of these subfamilies into 10 and 4 tribes, respectively. Forage grasses are fairly well distributed among the 14 tribes, but there are certain tribes that have very few or no forage species, and others in which forage types are many. The distribution of some of the grasses grown on arable land as economic crops, particularly forage crops, among the 14 tribes, is as follows:

1. **Bamboo tribe (Bambuseae).** There are no forage crops in this tribe grown in the United States.

2. **Fescue tribe (Festuceae).** This is a large and important tribe of 37 genera in the United States among which are the bronce grasses, fescues, blue grasses, love grasses, and orchard grass.

3. **Barley tribe (Hordeae).** This tribe is small but important. In its 12 genera are included such important cereals as wheat, barley, and rye, and the ryegrasses, wheatgrasses, wild rye, and squirrel tail.

4. **Oat tribe (Avenae).** A tribe of 10 genera, including oats, oatgrass, tall oatgrass, velvet grass, hair grasses, and prairie junegrass.

5. **Timothy tribe (Agrostideae).** A large tribe of 25 genera which include such important grasses as timothy, red top, the bent grasses, and also others of minor importance as meadow foxtail,
GRASSES AND LEGUMES

ricegrasses, reedgrasses, bluejoint, muhly grasses, dropseed grasses, needlegrasses, and three-awn grasses.

6. Zoysia tribe (Zoysieae). This is a small and relatively unimportant tribe which includes the zoysias, Manilagrass, curly mesquite, Galleta, and Tobosa grass.

7. Grama tribe (Chlorideae). A large and rather important tribe confined mostly to warm regions. Among its 18 genera are included the gramas, buffalograss, Bermuda-grass, Rhodesgrass, and cordgrass.

8. Canarygrass tribe (Phalarideae). A small tribe of only three genera in the United States which includes sweetgrass, sweet vernal grass, and canarygrass.

9. Rice tribe (Oryzeae). Rice is the only important crop in this tribe which includes no plants of particular value for forage.

10. Wild rice tribe (Zizanieae). A small tribe of aquatic and subaquatic grasses of no economic importance, except the Indian wild rice.

11. Molassesgrass tribe (Melinideae). A small tribe represented in the United States only by molassesgrass, a tropical grass introduced into southern Florida.

12. Millet tribe (Paniceae). A large tribe, confined mostly to warm regions and containing a few important forage species, and a number of minor importance. Among those best known are Bahiagrass, Dallisgrass, witchgrass, broomcorn millet, Guineagrass, Natalgrass, switchgrass, barnyardgrass, pigeongrass, foxtail millet, pearl millet, and Napiergrass.

13. Sorghum tribe (Andropogoneae). A large tribe, confined mostly to warm regions. The most important economic plants in this tribe are sugar cane and sorghum. It also includes the bluestems, broom sedge, Johnson grass, Sudan grass and Indiangrass.

14. Maize tribe (Tripsaceae or Maydeae). This small tribe of seven genera is closely related to the sorghum tribe. Its most important member is Indian corn. It also includes the gama grasses, teosinte, and Job's tears.

ADAPTATIONS OF GRASSES

The distribution in the United States of more than 1,200 species of grasses, both native and introduced, is largely determined by individual characteristics of the different grasses and legumes, and their reaction to the various climatic factors. About 100 of the above grasses are of economic importance to agriculture, and this number is divided almost equally between those adapted to humid and to dry-land conditions. Moisture has played an important role in determining the well-defined centers of development of these species. The predominating grasses adapted to arid and semiarid regions are native to the United States; introduced species predominate in the humid regions.

Natural adjustments: The grasses that persist naturally in any given region over a long period of time are those that have been successful in adjusting themselves to the factors that limit growth. In order to survive, they have to withstand the extremes of drought, cold, and wind, as well as the diseases and insects of the region, and compete successfully with other plants. The species and varieties that can grow to maturity and reproduce in competition with other plants are the ones selected by nature's cut-and-try process to cover the land. Darwin has given a vivid picture of this struggle for existence, calling the selective process the "survival of the fittest." Over a period of hundreds of thousands of years nature has produced an adapted vegetation the distribution of which is governed almost entirely by climate.

The first settlers on our eastern shores destroyed the natural vegetation and substituted for it various kinds of cultivated and grassland crops. This substitution gradually progressed westward until crops replaced the natural vegetation developed by nature on practically all land of any agricultural value. When the farmers brought with them crop seeds from the Old World, they carried on a process of cut-and-try very much as nature did to find out which crops were best adapted. The only difference was
that the farmer took only a few hundred years to make his pattern, whereas nature took many thousands of years in perfecting hers.

**Influence of intensive land use:** The climatic conditions common to the various regions of the United States are essentially the same today as when the first European settlers arrived. The environment, however, has been modified through intensive land use and there is a great need for more complete utilization of grass. The plant breeder is developing new forms of grasses better adapted to the ever-changing cropping environment and the intensive management practices now in use. In the arid and semiarid regions the native grasses are well adapted to the prevailing climatic conditions, and provide an abundance of types that can be fitted into the changing environment and changing management practices.

In the more humid areas of the United States, for example, particularly in the Southeast, emphasis is often placed on adaptation to lower levels of soil fertility and to use in more intensive cropping systems. Introduced species from similar climatic regions in other parts of the world are the best source of improved varieties for this region. The general objectives of the breeder are to produce varieties resistant to drought, disease, and insects, tolerant to temperate extremes and repeated defoliation, adapted for growing in association with other desirable species, palatable, productive, and with growth habits that can take full advantage of the seasonal changes favorable to plant growth.

**Influence of moisture:** Moisture requirements determine the distribution of grasses not only in broad regions but also within regions. For example, in the humid South, carpetgrass and St. Augustinegrass are best adapted to moist areas and Bermuda-grass and centipedegrass to the drier situations. In the humid North, reed canarygrass and redtop are considered wet-land grasses, while Canada bluegrass and bromegrass are good examples of grasses adapted to conditions of limited moisture. In the subhumid and semiarid regions the graminas and buffalograss can endure long periods of limited rainfall, while the bluestems and certain of the wheatgrasses, such as western wheatgrass, require relatively moist situations for survival.

Sudangrass is able to grow vigorously in relatively dry soils at midsummer
temperatures. It is well adapted to the prevailing climatic conditions in the central and southern Great Plains. It is also grown extensively as a supplementary pasture and hay crop in the North Central States. This grass appears to be well adapted to the Southeastern States, but the climate is so favorable for the growth of disease organisms parasitic on Sudangrass that the crop is greatly limited. The plant breeder now has promising strains highly resistant to the more common diseases in the region. The indirect effect of climate in favoring disease on an otherwise well-adapted crop plant is greatly reduced by the production of resistant varieties.

**Drought resistance:** Crested wheatgrass is one of the most cold- and drought-resistant grasses grown commercially in the United States. For this reason it is particularly well suited to the northern Great Plains, where its use for hay and pasture has expanded greatly in recent years. It has also given good results in eastern Washington and Oregon where the moisture is limited, and at altitudes of 5,000 feet or more farther south. It is not adapted to the milder climate of the southern Plains, and under the more favorable moisture conditions of the Eastern States it is not equal to brome- grass or timothy and other adapted grasses.

There has been an erroneous idea that the native dry-land grasses adapted to the Great Plains would be desirable for dry summers in the humid East. Numerous tests with dry-land grasses in the humid sections, have shown that they become established slowly and fail to compete with the cool-weather grasses such as bromegrass, timothy, orchardgrass or tall fescue. Bromegrass, originally considered of value mainly for dry-land conditions, has become important in the humid East, where it is of value as a summer drought-resistant grass. Reed canarygrass is interesting in that even though especially useful for very wet places, it will make excellent growth with limited moisture—an unusual characteristic for a grass adapted to moist conditions.

**Winter survival:** Moisture is a factor also in the winter survival of grasses, especially those in the dry northern Plains. The loss of grass stands during the winter months is often ascribed to winter killing or low temperatures, when in reality it is due to lack of moisture, or desiccation of plant tissues. No doubt this factor has played a part in determining the grass cover in different areas. In such cases the effects of moisture and temperature are closely related.

In general it can be said that the grasses adapted to the humid regions are more influenced by varying temperatures than are those adapted to the dry lands. Blue grama grass, one of the most widely distributed and desirable species of the Plains, continues to make growth under temperatures varying from 60° to 110° F. Under favorable moisture conditions, summer temperatures have never been high enough to retard the growth of the common summer-growing native species. On the other hand, crested wheatgrass makes little or no growth during periods of high temperature. Its behavior is similar to that of Kentucky bluegrass in the humid regions; both make their maximum growth during the months of medium temperature in spring and fall, and become dormant during months of high temperature. Lack of cold resistance limits the distribution of many desirable pasture grasses.

**Influence of light:** The effect of shade or light influences the growth and development of grasses to a lesser degree. Certain grasses have the inherent ability to survive under reduced light, while many others are adversely affected. Development of grasses adapted to growing in partial shade is especially important for lawns. In the North the fescues—red fescue and chewings fescue—and rough stalk bluegrass are the most important, while in the South St. Augustinegrass is best adapted to the shade. The latter two, however, require ample moisture for growth, while the fescues will grow with limited moisture. Orchardgrass, one of the better pasture grasses, will grow under partial shade. Intensity of light and length of day have
a marked influence on leaf and seed development of many native grasses. The effect of shade in retarding the growth of undesirable grasses may be beneficial, as in the control of crabgrass in lawns. Crabgrass requires ample light for growth, and if desirable grasses are allowed to grow tall enough to shade the crabgrass seedlings, they may be materially reduced or eliminated.

THE LEGUMES

The Importance of Legumes

In the most successful pasture and hay production grasses and legumes represent a symbiotic relationship—each requiring the other for best results. McKee (US-158) in his “Legumes of Many Uses” emphasizes the great importance of legumes not only in their contribution towards the success of grass-legume mixtures, but also in other ways.

“Legumes have been known to man from the time of earliest records. Tares, as referred to in the Bible, are thought to be the common vetch. Alfalfa was among the earliest of cultivated crops, as indicated by early historical writings. Its native habitat is presumed to be Persia. In China the soybean dates back to the earliest of preserved writings and probably long antedates written records. Alfalfa can thus be considered the earliest cultivated forage crop, and soybeans probably the earliest legume food crop. This early use of these crops suggests that even in the first period of recorded history the superiority of legumes was recognized. Their early use in pastures and crop rotations suggests this conclusion.

“The legumes today are universally thought of as having higher feeding value than nonlegumes and this, for the most part, is true. One of the main reasons why they are superior is the fact that in general they contain a higher percentage of protein and minerals than non- legumes, and these are essential food constituents. The seeds of legumes are particularly high in protein, but the leaves and stems also contain a relatively higher amount than is contained in other plants when they are harvested at a like stage of maturity.

“It is true that seeds of some nonlegumes have a high protein content and the leaves and stems of some are comparatively high in this constituent, but for the most part, legumes can be considered decidedly superior. Legumes not only have a higher percentage of protein, they also have high quality protein. This is of prime importance and helps greatly in obtaining high nutritive value in feeds for animals as well as food for human consumption. The quality of the protein of legumes is such as to make them especially valuable as feed to supplement the cereal grains, which do not have the proper protein for a balanced livestock feed.

“Legumes are also valuable because they contain a comparatively large amount of calcium and have a fair amount of phosphorus, which is necessary in proper nutrition. Likewise, legumes are recognized as the best source of vitamins A and D for livestock feed and are largely depended upon for supplying these constituents.

“Besides being of special value for feed and food, legumes are superior for soil improvement. This is due to the large amount of nitrogen they are able to supply the soil for the use of subsequent crops. It is not, however, merely that they return a large amount of nitrogen to the soil that makes them superior for soil improvement; it is the fact that much of the nitrogen contained in a legume is taken from the air rather than from the soil, as is the case with other plants, and in this way new and additional nitrogen is added to the already existing soil supply. Legumes thus add to the soil nitrogen that it did not previously contain. Non-legumes merely take nitrogen from the soil and return it again.

“The total amount of nitrogen that legumes take from the air cannot be known with any exactness since the condition under which they are grown influences the relative amounts taken from the air and soil. In a soil that is low in
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nitrogen, much more of the element is taken from the air than is the case when there is a large soil supply of nitrogen. It also is probable that the relative amount taken from the air and soil varies with the different legumes. It is generally assumed, however, that at least half the nitrogen in legumes comes from the air.

"The total acreage of legumes in the United States, both in cultivated and pastured areas, can only be estimated. Data are available covering acreage cut for hay and seed of the major legume crops but are lacking for acreage used for pasturage and cover crops. From the general information that is available, however, it is estimated, in round numbers, that the acreage of all legumes cut for hay is 40 million acres; cut for seed, 15 million acres; used for cover crop, 5 million acres; and pastured, 40 million acres.

"Assuming that this acreage averaged a ton per acre dry weight of tops and roots and that this growth averaged 2 per cent nitrogen, the total nitrogen produced would be 2 million-odd tons.

"Studies that have been made on roots of legumes indicate that the weight of the roots generally is about one-third that of the tops and that the percentage of nitrogen in the roots is slightly less than that in the tops. The percentage of nitrogen in roots of a number of legumes that have been analyzed ranges from 1.40 per cent to 2.30 per cent, and in tops from 2.10 per cent to 2.80 per cent.

"As previously stated, it is generally assumed that more than half the nitrogen in legumes is taken from the air. This means then that more than a million tons of nitrogen is taken by legumes each year from the air. Of course, all that amount would not be returned to the soil because the hay, pasturage, and seed fed to animals would only be returned in part and mostly as manure. As has been indicated, about one-third of the total nitrogen of most legumes is in the root; this, with the amount returned to the soil would no doubt be well over half of the amount taken from the air.

"The nitrogen taken from the soils by legumes, of course, does not add to the total nitrogen of the soil, but such nitrogen when again returned to the soil, is usually considered to be more readily available for use in plant growth and in this way adds to the nitrogen supply. The total nitrogen in the form of commercial fertilizer used annually in the United States has been less than 500,000 tons. It is thus seen that the nitrogen supplied by the legume crops is greater than the amount used in commercial fertilizers.

"Getting nitrogen from the air usually is considered a special function of legumes, although it is known that a few other plants can do so too. In the case of legumes, taking nitrogen from the air is accomplished through symbiotic bacteria (Rhizobia) that develop in nodules on the roots of the legumes. The bacteria take nitrogen directly from the air as they grow and multiply in the nodule. The nitrogen in turn becomes available to the legume plant and aids in its nourishment and growth. It is this symbiotic association of legumes and Rhizobia that gives legumes a distinct advantage over nonlegume plants.

CHARACTERISTICS OF LEGUMES

The legumes (Leguminosae or pea family) are said to comprise some twelve to fifteen thousand species of trees, shrubs, vines and herbs, being surpassed in numbers only by the thistle family (Compositae). Though of the greatest agricultural importance, the legumes do not cover, as do the grasses, large areas of vegetation, almost to the exclusion of species of other families of plants. The legumes and composites usually occur as scattered secondary components of the native vegetation.

Although no exhaustive check list has recently been compiled, it is estimated that there are nearly 2,000 species of leguminous plants native to the United States. Many foreign species are naturalized here, and over 40 introduced species are grown in this country as forage crops.

Leaves: The leaves of legumes vary con-
sidely, for although usually alternate, they may be simple, trifoliate, palmately or digitately divided, or variously pinnate. Simply pinnate leaves may have even or odd numbers of leaflets, hence the terms “even-pinnate” and “odd-pinnate.” Odd-pinnate leaves may have the terminal leaflet transformed into a tendril, as in the garden pea. Pinnate leaves may be further divided into twice pinnate, or bipinnate leaves, or still further into thrice pinnate or tripinnate forms.

Flowers and fruit: The flowers vary from regular form, with the sepals and petals alike to a highly irregular form in which they assume the shape of the typical pea flower with the five petals highly differentiated. In the pea flower the upper petal forms the broad standard or banner; the two lateral ones more or less parallel with each other, form the two wings; and the lower two are united into the keel. By far the greater number of species in the family have flowers exhibiting some modification of this irregular form which is the typical pea flower. The arrangement of the stamens likewise varies. They are usually distinct and frequently numerous in the regular flowers, but in the irregular blossoms they are usually ten in number, united at the base and clustered within the keel of the flower.

Although there are marked differences in the flowers, the chief character that associates various leguminous plants is the type of fruit, the pod or legume which is characteristic of the pea family. This fruit is developed from a simple pistil (single carpel), and at maturity usually splits along two opposite longitudinal sutures. Frequently it splits with considerable force, the two halves twisting and throwing the seeds some distance.

Classification of Forage Legumes

A large number of legumes form a part of the native prairie and range flora of the United States, and as such, probably form a part of the diet of livestock on the range, even though most of such legumes may be of relatively minor importance as forage plants. The number of species of legumes that are important cultivated forage crops is relatively small, and most of them have been introduced from Europe or Asia, and a few from Africa. Several legumes are important food crops among which are peas, beans, peanuts, and soybeans. All of these forage and food crops are included in six of the ten tribes of the Leguminosae or Papilionaceae. The more important genera are distributed among these six tribes as follows:

- **Lupine tribe** (Genisteae). Lupines and crotalaria.
- **Clover tribe** (Trifolieae). The true clovers (Trifolium spp.), sweetclovers, and sourclover (Mellilotus spp.), and alfalfa, black medic, and burclover (Medicago spp.).
- **Lotus-trefoil tribe** (Lotae). Birdsfoot trefoil and big trefoil (Lotus spp.).
- **Lespedeza tribe** (Hedysareae). Lespedeza.
- **Pea tribe** (Viceae). Vetches and horsebeans (Vicia spp.), peas (Pisum spp.), and pea vine (Lathyrus spp.).
- **Bean tribe** (Phaseoleae). Beans (Phaseolus spp.), soybeans (Glycine max), and cowpeas (Vigna sinensis).

Adaptations of Legumes

**Alfalfa**: The wide distribution of alfalfa in the world indicates a remarkable adaptation to various climates and soils. Though the crop requires considerable moisture to produce profitable yields, it does best in a relatively dry climate where water is available for irrigation. It will survive a long period of drought but is not productive under such conditions. It is not so well adapted to a very humid climate, partly because acid soils are developed under heavy precipitation, and partly because diseases are more destructive in humid regions. Acidity can be corrected by liming, however, and there are disease-resistant varieties adapted to fertile soils throughout most of the United States.

It is generally believed that the native habitat of alfalfa is southwestern Asia. The climate in this region is characterized by cold winters and hot summers.
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The precipitation, which except at high altitudes is rather limited, occurs mainly in late fall, winter, and early spring. The summers are relatively dry, with low humidity. Historical accounts indicate that it was in this general region that alfalfa was first cultivated. From there it was taken to the Mediterranean countries and to other parts of the world, succeeding best where climatic conditions, particularly humidity, were somewhat similar to those of its native habitat and where sufficient soil moisture was available from subirrigation or surface irrigation. With increased knowledge of other requirements such as those for lime, for inoculation with nitrifying bacteria, and for certain plant-food elements, the culture of the crop has spread to all parts of the world. It is now grown successfully under a wide range of climatic conditions, but it has never been as long-lived in humid as in dry climates.

Alfalfa has a relatively high water requirement, about 750 pounds of water being required to produce 1 pound of dry matter. As previously indicated, it succeeds best under conditions of low humidity, provided sufficient soil moisture is available. Under such conditions fields 15 and 20 years old were not uncommon until insects and diseases became increasingly destructive. Where humidity is high, it has seldom been possible to maintain a satisfactory stand for more than 5 or 6 years, partly because of the prevalence of diseases under such conditions. A combination of high humidity, high precipitation, and high temperatures is particularly unfavorable. In some instances where the precipitation is less than 20 inches annually and irrigation is not possible, the high water requirement of alfalfa has resulted in the exhaustion of the subsoil moisture. This has occurred in parts of the Great Plains where good yields were obtained for several years on land sown to alfalfa for the first time. Where it was sown a second time on the same land the yields were far from satisfactory.

A careful study showed that in some instances the first sowing had exhausted the subsoil moisture to a depth of 40 feet so that subsequent sowings had to depend upon the annual precipitation, which was not sufficient to meet the requirements for maximum production.

Winter killing is often associated with lack of sufficient moisture during the preceding summer and fall by which the vigor of the plants has been reduced to such an extent that they are unable to endure low temperatures. Heaving from freezing and thawing is responsible for serious losses in some of the Eastern States, usually where the soil is saturated with moisture.

Alfalfa is more tolerant of extremes of heat and cold than most perennials. Yellow-flowered alfalfa has been reported as growing in Siberia where temperatures as low as -84°F. have been reported. Other conditions being favorable, certain varieties of alfalfa have been grown successfully where maximum summer temperatures exceed 120°F. Productivity and longevity vary with the species and variety. Yellow-flowered alfalfa, for instance, is usually able to endure a greater degree of cold than either Common or variegated alfalfa, but it is not usually productive or long-lived where the winters are mild and summers long and hot. Certain varieties of Common alfalfa, on the other hand, are not cold-resistant and are most productive where the winters are mild and the summer long and warm, but they continue to grow during the winter after the more cold-resistant alfalfas become dormant. Between these extremes are found all gradations that have resulted either from natural selection or natural crossing.

The response of alfalfas to length of day (photoperiodism) appears to be correlated in some way with their reaction to low temperatures. Under controlled greenhouse tests the nonhardy alfalfas were more vigorous and produced more growth with short days than the hardy alfalfas, while with long days the reverse was true.

Clovers: Red clovers are adapted generally to the northern half of the United States, excluding the drier portions of the Great Plains. The various strains have little in common, as far as climatic
adaptation is concerned, with the European stocks from which they originated. When red clover was first introduced by the early settlers in the Eastern States it was exposed to low winter temperatures which only the more hardy plants survived. As it was carried westward, red clover encountered high midsummer temperatures and drought. The acclimated surviving plants were attacked by a new foe in the form of leafhoppers, and only the hairy types that the hoppers did not like survived. Then the plant diseases took their toll. The plant breeders finally had a hand in the selection process and assisted in evolving new types adapted to the climatic hazards in the New World.

The true clovers, species of the genus *Trifolium*, annual or perennial, are found in every continent of the world, and in all except Australia certain species form a part of the native flora. Only in very limited areas are climatic factors favorable for the continual growth of the perennial species throughout the year. In the cool part of the Temperate Zones the perennials may persist from year to year, but in countries with a more equatorial climate, the winter annual species are most abundant, and the perennials behave principally as winter annuals. The three most important climatic factors affecting the distribution and development of the true clovers are rainfall, temperature, and light. A copious, uniform supply of soil moisture furnished by precipitation or irrigation and cool temperatures are most favorable for growth.

Most of the species of agricultural importance appear to have originated in southern Europe and Asia Minor, where the annual rainfall, ranging from 17 inches upward, occurs principally during the winter months when the temperature is relatively cool. Rainfall and temperature are more favorable for clover in northern latitudes than in the Mediterranean regions, but the limitation of light due to the competition of the original tree and shrub growth was critical. Only when man gradually destroyed the tall-growing vegetation, permitting the encroachment of the low-growing species, did the clovers become widely distributed.

The sweetclovers, annuals and biennials, appear to have originated in the more arid regions of western Europe and Asia Minor. Once established, the biennial species are tolerant of drought, though a good supply of soil moisture and cool temperatures are necessary for the germination and early growth of the seedling plants. The requirements of the winter-annual species of sweetclovers for moisture and temperature are similar to those of the winter-annual species of the true clovers.

Sweetclovers may be grown in any part of the United States where the spring and summer rainfall amounts to 17 inches or more; on acid soils, the application of lime is necessary. Production of sour or bitter clover is confined to the territory bordering the Gulf of Mexico and to southern California, New Mexico, and Arizona; where rainfall is insufficient, it may be grown under irrigation. Throughout the Intermountain States, sweetclover and some of the true clovers—principally red clover, white clover, and alsike clover—are widely grown either under irrigation or at high altitudes where rainfall is sufficient. Strawberry clover is particularly well adapted to wet, lightly saline, or alkaline soils of this region. On the Pacific coast, red clover is grown from central Oregon to the Canadian boundary and sweetclovers and the winter-annual species of the true clovers throughout the region where sufficient moisture is available.

Wide differences in the adaptation of varieties and strains of most of the clovers and their direct reaction to temperature, moisture, and length of day exist in all species. Such responses limit the use of any variety for maximum production. In the field the effect of a single climatic factor on plant behavior cannot be distinctly segregated from the interaction of other factors, and interpretations must be tempered accordingly.

Low winter temperatures definitely limit the distribution and adaptation of the winter-annual species of all clovers.
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Low hop clover and crimson clover appear to be the most tolerant and are the species responsible for extending the winter-annual clover belt so far north. Sour or bitter clover and berseem clover are among the species least tolerant of winter cold. Good fall vegetative growth before the advent of minimum temperatures is the best protection against winter killing.

Wherever clovers are grown in the United States high summer temperatures are not fatal, provided soil moisture is abundant and the root systems of the plants are large enough to absorb the moisture required for transpiration. Often, however, even under favorable conditions, the removal of a mature companion grain crop from a vigorous growth of red clover, exposing the young plants to the direct rays of the sun, results in the death of many plants. The fact that there are different temperature requirements for germination among species contributes to their range of adaptation, since these requirements are related to latitude, soil type, and plant associations. High summer temperatures inhibit the germination of the seed of most of the winter-annual species.

For the true clovers rainfall is probably more important than any other climatic factor. All clovers require a moist soil at the time of germination and establishment of seedlings, and a deficiency in soil moisture at this time is probably responsible for more losses than any other factor of climate. Seeds of certain species absorb moisture rapidly (this is a common characteristic of crimson clover), so that when rainfall periods of short duration are followed by dry weather, the young seedlings are killed before the plants are established.

Sweetclovers, when well established, send their extensive taproots to the lower soil levels and persist under drought conditions, though little vegetative growth may be made. As already noted, when clovers are grown in association with companion crops the limitation of light is often fatal to the seedlings. Even when a stand is established, growth is slow and poor unless the plants get direct light for at least a considerable part of the day.

The winter-annual species when planted in the spring in the Cotton Belt or the Corn Belt make only a few inches of growth before flowering is induced by the increasing length of day. If the clover is planted in August or later, when day length is decreasing, vegetative growth occurs without reproduction. Crimson clover, a true winter annual of the Southeastern States, when planted in May in northern Maine behaves as a summer annual. Growth is rapid with the cool temperatures and adequate rainfall, but blossoming begins in late August. At this time the length of day is rapidly decreasing, and vegetative growth is again stimulated. In the greenhouse true biennial sweetclovers blossom freely a few weeks after planting when subjected to 20 or more hours of illumination. The double-cut or medium forms of red clover blossom freely in the fall in short days, provided the plants have made vigorous vegetative growth during the spring and summer months, but the single-cut forms, which require a longer photoperiod, remain in vegetative growth.

Lespedeza: In the areas of heavy rainfall in the Southern and Southeastern States, much of the lime-deficient soil is too acid for successful and profitable production of such legumes as red clover and alfalfa. A well-adapted, acid-tolerant, nitrogen-fixing legume in the cropping system of this region was badly needed to keep up the productivity of the soil. Plant explorers and plant breeders finally found such a legume in lespedeza. In the short period of approximately two decades its use spread to about 20 million acres of land.

The climate of the southeastern part of the United States is especially favorable to lespedeza. West of the one-hundredth meridian in the Great Plains region the crop has not been successful. The relative importance of the various factors of climate in their influence on growth has not been definitely determined, but a high rainfall, well distributed throughout the growing season, together with relatively high humidity.
and temperature, seems essential for the best results with this very useful crop. The heavy rainfall of the East results in leaching and an acid soil condition which, together with other changes, is detrimental to the growth of many plants, but lespedeza is able to make successful growth under these conditions and to overcome the competition of other plants. However, it too will make a better growth when the soil is limed and fertilized.

Length of clay as determined by latitude also affects the adaptation of varieties of lespedeza. Common lespedeza succeeds best in the southern half of the eastern part of the United States and Korean lespedeza in the central and more northcentral part. Only the earliest maturing varieties of Korean lespedeza mature seed directly south of the Great Lakes section, and only common lespedeza succeeds in the area bordering the Gulf of Mexico.

Soybean: Though soybeans are grown in widely separated parts of the world, successful production is largely dependent on climate. Further, their use within a given area is dependent on the adaptation of varieties to local climatic conditions. Through the centuries an almost endless number of varieties, ranging in time required for maturity from 75 to 200 or more days, have been developed, and though each of these has for the most part a rather limited range of adaptation, the large number of varieties with their differing climatic requirements has extended the culture of the crop far beyond the limits that would otherwise have been possible. It is this adaptation of varieties that has made possible the extensive use of soybeans in the United States. Differences in behavior of the same variety in different localities are often so striking as to make it seem to be of another variety. The Manchu, Dunfield, Illini, and other varieties used in the North are not suited for the South, while the Mammoth Yellow, Otootan, Laredo, and others adapted to the South do not mature seed in the shorter growing season of the North. Climate has played a major role in developing varieties and determining the limitations of their use through the centuries during which the crop has been grown. Today this same influence is the most prominent factor in directing the course of soybean production in the United States.

The general climatic requirements of the soybean are about the same as for corn. The wild soybean from which the cultivated form is thought to have been derived, occurs throughout China, Manchuria, Japan, Korea, and southern Siberia. Cultivated soybeans are grown to the greatest extent in China, where they occupy about 9 percent of the total cultivated area. Other countries of the Far East, in order of importance in acreage and production, are Manchuria, Korea, and Japan.

In a study of soybean culture in Germany and of the differences between the climate of that country and Manchuria, it was found that it is quite possible to grow soybeans successfully in any region in which there is a 5-month period of growth with a total heat accumulation of 2,400°C (4,320°F.) from May to September and an annual precipitation of 12 inches. Lack of sufficient moisture and warmth during the growing season undoubtedly accounts for the poor results obtained in the northwestern part of the United States, which is in the same latitude as Manchuria. In the Philippines plantings made during the rainy season produced taller plants with more branches and gave greater yields of seed than those made in the dry season.

Soybeans are sensitive to length of day and no one variety is suitable over a wide range of latitude. In the North, where the days are long during the summer, the tall-growing varieties adapted to the Southern States often fail to bloom and will not mature seed. Conversely, a tall, high-seed-yielding, late-maturing northern variety planted in the Southern States grows only a few inches high, blooms within a few weeks after planting, and matures a small crop of seed in midsummer under the relatively short day length.

In high altitudes in the Western States, where cool nights prevail during the growing season, varieties normally adapted to
these latitudes produce abundant vegetative growth but fail to mature seed.

Climate has been found to have a marked influence on the composition of soybean seed; the percentages of oil and protein and the iodine number in any variety vary from season to season on the same type of soil.

Miscellaneous legumes: Crotolaria, like lespedeza, is also adapted to poor acid soils and a humid climate, but it demands higher temperatures than lespedeza. This limits it to the Southeast, where, on sandy and sandy loam soils, it is an excellent cover and soil-improving crop. Climatic conditions in the western half of the United States do not seem to be favorable to the growth of crotalaria.

Although the area planted to velvetbeans each season exceeds 2 million acres, they are limited to the lower Cotton Belt and were extended into Georgia and Alabama only by the use of early-maturing varieties. Velvetbeans like a warm climate with plenty of moisture. The cowpea can be grown somewhat farther north, and the total acreage exceeds 6 million. Diseases and parasites that thrive in warm climates have tended to lessen the usefulness of this crop and have necessitated the development of resistant varieties. Because cowpeas and velvetbeans are among the few legumes well adapted to the lower South, they are vital in the economic life of the southern farmer.

Climatic factors very largely determine the possible use of cover and green-manure crops for soil improvement. Field peas, vetches, bur-clovers, and crimson clover, which are winter annuals under mild climatic conditions, require comparatively high mean minimum winter temperatures for successful growth. The minimum growth temperature varies with the different crops and this determines which ones can be used most advantageously in a given locality. Since the zero growth point—the minimum temperature at which a plant will make any growth—is directly correlated with its winter hardness, or its ability to stand low temperatures without being killed, the absolute minimum temperature as well as the mean, or average, minimum is a factor in determining the possible use of certain crops in a given area.

Austrian winter field peas, for instance, commonly used as a winter cover crop in the South, have a lower zero growth point than hairy vetch; this means that the latter is more winter hardy because it stops growing sooner than the field peas. Thus hairy vetch stands the occasional low temperatures in the South with less injury and can be grown as a winter crop farther north.

When a plant has made succulent or rapid growth by reason of comparatively high temperatures, it will be much more severely injured by a sudden drop in temperature than by a gradual change. The not uncommon sudden winter changes in the Southeastern States and the frequent comparatively high prevailing temperatures limit the use of winter cover crops to the more winter hardy, except in the milder sections, where low temperatures are only occasionally experienced.

In the northern latitudes, where low temperatures preclude the growing of cover crops in the winter, the same crops—field peas, crimson clover, and hairy vetch—used in the South for winter cover, can be grown in the summer.

Climatic factors not only determine the region in which certain cover crops can be used effectively but also the areas in which seed can be produced. It is not possible to produce seed of field peas and hairy vetch economically in the Cotton Belt, principally because of unfavorable light and temperature conditions. In the Pacific coast areas and at northern latitudes farther east, seed production of these crops is possible, and the South is supplied with seed from these areas.

HIGHLIGHTS OF GRASSES AND LEGUMES

1. Both grasses and legumes have habits of growth and qualities which adapt them ideally, either singly or in combination, to forage production and use, and which are possessed in such ideal combinations by no other family of plants.

2. Most forage grasses and legumes reproduce themselves readily from seed and

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quickly establish themselves in meadows and pastures.

3. The methods of vegetative propagation among most perennial grasses and legumes enable them to form turfs and to perpetuate themselves indefinitely.

4. The compatibility of both grasses and legumes with other species in the same or different groups makes possible ideal combinations for productive meadows and pastures.

5. Grasses and legumes cover a wide range of adaptation to climate and soil conditions, both within the same species and among the different species.

6. Many useful grasses and legumes are adapted to, and survive under, continuous or rotated pasturing under either favorable or adverse conditions.

7. Grasses and legumes fit into varied cultural practices, including both long and short crop rotations.

8. The soil-binding properties of grasses and legumes make them especially valuable in soil-erosion control on cropland and pastures, and for special erosion control uses in retaining banks, shoulders and waterways, and in contour strip cropping. A good cover of grass and legume vegetation furnishes the best blanket of protection for the soil.

9. The adaptation of grasses and legumes to any particular locality or region is determined by their requirements or tolerances as to heat, moisture, length of day, winter survival, and competition with other crops.

10. There are many useful species of both native and introduced grasses and legumes among which it is always possible to select one or more which are adapted to almost any agricultural use or almost any combination of conditions.

11. The long seasonal period of growth of many grasses and legumes enables them to be pastured either continuously or in rotation over long periods, or to be cut for hay from two to several times in a single season.

12. No other group of plants is as valuable as either the grasses or the legumes as feed for all kinds of livestock, since they furnish roughage, vitamins, protein, carbohydrates and minerals in available form in almost any desired combination.

13. Legumes contain more nitrogen than any other family of flowering plants, which makes them especially valuable either as feed for animals or as fertilizers for succeeding crops.

14. The legumes furnish a home for certain species of bacteria which take nitrogen from the air and make it available to the host plant and other associated plants, thus stimulating their growth and usually making unnecessary after establishment the addition of nitrogen in the form of fertilizers.

15. Probably considerably more than one million tons of nitrogen are taken from the air and used by legumes or added to the soil annually in the United States through the activities of legume bacteria.

16. A billion acres of land in the United States, or about 50 percent more than that occupied by all other crops, form the grasslands which supply about one-half of the feed used by all kinds of livestock.

17. About 100 million acres of land, or 10 percent of the total grassland in the United States is occupied by forage legumes of which about 40 percent is pastured, 40 percent cut for hay, 15 percent harvested for seed, and 5 percent is in cover crops.

18. Grassland agriculture is inseparably linked with soil conservation and livestock production. Under good management it will increase total feed production and reduce the labor and other costs on most livestock farms.

19. Most of the cultivated grasses and legumes grown for forage in the eastern half of the United States and along the Pacific Coast, such as timothy, Kentucky bluegrass, orchardgrass, ryegrass, bromegrass, redtop, red clover, white clover, vetches, winter peas, and alfalfa, have been introduced from Europe and Asia. Many of the grasses grown in the Great Plains are native species.

20. Not only are grasses and legumes the principal forage crops, but most of the food and feed crops where the dry seed is utilized are also grasses or legumes, the grasses represented by wheat, corn, oats, barley, rye, grain sorghums and rice, and the legumes by peas, beans, peanuts and soybeans.

21. A better knowledge of grasses and legumes, their special characteristics, their extensive climatic and soil adaptations, and their various uses as forage and soil conserving crops, will enable one to better appreciate their value both collectively and individually and to use them more intelligently and efficiently in farm operations.
THIS CHAPTER

A comprehensive understanding of the real significance and importance of grasses and legumes as forage crops and their utilization in our national economy has only in recent years been recognized and given adequate consideration. The basic material used in this chapter is largely quoted from or based upon the writings of Aamodt (US-1) on adaptations of grasses and legumes; Cardon (US-30) on grassland agriculture; McKee (US-158) on importance of legumes; Chase (US-37) and Stevens (ND-15) on grass characteristics; Graham (US-75) on legume characteristics; and Hitchcock (US-93) on botanical classification of grasses. The manuscript was reviewed by McKee of the U.S.D.A., and Pierre of the Soil Conservation Service from Illinois.

Chapter reference numbers: 1 IOWA-1; MINN-2; NJ-11; ND-15; TENN-11; US-1, 2, 3, 30, 37, 49, 75, 77, 93, 158, 195, 203, 209, 299.

1 The reference numbers given here refer to references which are given in full by State, U.S.D.A., and Miscellaneous, on pages 682 to 724, and which are cross-referenced by author on pages 725 to 731. Citations in the text are indicated by abbreviation and number in parentheses.
CHAPTER II

SOILS AND FERTILIZERS FOR FORAGE AND PASTURE CROPS

SOIL REQUIREMENTS OF FORAGE PLANTS

It is often assumed that soil requirements are a minor consideration with forage crops, inasmuch as such crops generally have value for soil improvement purposes, and many of them are productive under conditions that are not suited to cereal or inter-tilled crops. This is far from correct. Certain species of grasses and legumes will withstand conditions under which our most important food and feed crops will not thrive, but maximum forage production of most of our desirable forage crops is obtained only on our most fertile soils. Such crops ordinarily respond to adequate fertilization in much the same manner and degree as other crops.

Morgan, Gourley, and Ableiter (US-172) have discussed certain conditions that must be met in the production of forage plants in a region climatically adapted to them. These may be summarized as follows:

Topography and soil erosion: The lay of the land is often the determining factor in deciding on the suitability of a given crop for a specific cropping program, both with respect to cultural operations and soil erosion. Undesirable physical properties of heavy clay soils may make it difficult to operate them with profit. The presence of boulders adds to the expense of cultivation. The ready erodability of certain silt loams and very fine sandy loams makes it difficult to use them for many valuable cultivated crops to which they are otherwise adapted.

Moisture supply: An adequate moisture supply is not possible on great areas of excessively sandy soils unless irrigation water is available. The supply of both water and oxygen for plant roots is determined by such conditions as the size and arrangement of the soil particles, and the depth to the water table.

Aeration: Adequate aeration is not possible in many soils with a water table near the surface, or with heavy subsoils that cannot be drained satisfactorily. In many regions where well-drained, suitably aerated soils, with mellow or friable subsoils overlying porous substrata, are available, the water-logged soils are left to native vegetation or to low-grade grazing provided by certain grasses and sedges that withstand such a condition. Soils with only slightly imperfect aeration may be satisfactory except for seasons of especially heavy rainfall, or with increase of the agricultural age of the land.

Plant nutrients: The supply of plant nutrients is readily adjusted. Greater availability of fertilizer materials and better knowledge of plant nutrition tend to lessen the difficulty of combating the unfavorable economic position of a chemically "poor" soil. But a naturally fertile soil requires a comparatively small investment of fertilizer for the growing of the common farm crops. High-priced good land is often a better investment than low-priced poor land, but there are many exceptions to this rule.

Soil reaction: The acidity or alkalinity of the soil is an important factor influencing plant growth. Under strongly alkaline conditions the development of excessive amounts of alkali carbonates may be harmful. This may be corrected by the use of gypsum or sulphur. In very acid soils such toxic constituents as aluminum...
and manganese come into solution. This may be corrected by the use of lime. The availability of phosphorus and the rate at which nitrate is released for plant use is determined largely by the degree of acidity or alkalinity of the soil. The best conditions are found at approximately the neutral point.

Suitable soil types: A careful study of soil characteristics, such as is possible by digging a deep hole and examining the soil profile, gives a good picture of how the conditions discussed above are expressed. Thus, the soil may show by a mottled color or hard subsoil that aeration is difficult; the texture of the upper layers and the lay of the land indicate cultural possibilities; and the moisture relationships must be studied on the basis of supply and storage ability. The fertility of a virgin soil is dependent upon the way it was formed and the length of time required to do it, as well as upon the chemical nature of the parent soil material.

The natural characteristics of a soil are capable of modification by cultural practices, the effects of lime, crops, and destruction of organic matter or depletion of chemical fertility by long-continued cropping and accelerated erosion. Hence, many soils once favorable for a particular crop are no longer suitable, while in many instances naturally infertile soils have been built up to become much more productive. A study of the characteristics of soils which support profitable crops of a given plant in each climatic region, however, affords a basis for the evaluation of the soil requirements of the plant.

In this discussion climatic conditions are considered to be favorable. Actually, however, climate is a most important factor in determining plant distribution. Since climate is a factor in soil formation, a discussion of soils favorable for specific crop plants necessarily implies also a favorable climate. In discussing crop production, therefore, climate cannot be considered as something apart from the soil.

Broadly speaking, relatively permeable and fertile soils of good waterholding capacity are favorable for the growth of most forage crop plants. With a favorable climate, some soils seem to possess an especially wide range of crop adaptation.

PRINCIPLES OF FERTILIZER PRACTICE

Grass and legume crops provide more and better pasture if use is made of fertilizers. In proportion as better growth is obtained, the larger root systems associated therewith have greater effects in improving the physical properties of the soil. If the crop is a legume, a larger quantity of nitrogen is accumulated from the air and more of it will be left behind in the roots and sod.

Let us examine some principles that determine the best use of fertilizer for grass crops. Four points are a part of such an examination: (1) The peculiar nutrient needs of the crop or crops to be grown, (2) the natural capacity of the soil to supply the necessary nutrients, (3) the capacity of the soil to retain the fertilizer against loss by leaching, and (4) its capacity to fix in unavailable form the elements applied.

Soils vary greatly in the kind and quantity of fertility elements they can supply to the growing crop. In the Southeast, lime, phosphate, potash, and some of the minor elements as well must be applied to the soil for crop production. Good yields can be obtained on the better soils of the Northcentral region with only moderate to small applications of lime and phosphate. In some of the western irrigated regions, legume crops can be grown for years without fertilization. The soils of the West are normally calcareous and initially were high in fertility.

Soils differ locally as well as between regions. In some areas the local differences may be marked. The fact that one farmer gets excellent results by the use of large quantities of fertilizer does not mean that his neighbor a few miles away can get similar results. Local differences in soil fertility are common in the East.

Nutrient requirements of forage crops high: The nutrient requirements of the better grass crops are high. This thesis runs counter to the belief that grasses, because they have certain desirable effects
on the soil, find their best use in soils of low fertility. Some grass crops will survive and grow on poor soils, but they respond markedly to the application of fertilizer. At the Virginia Agricultural Experiment Station, orchardgrass yields were increased from 1,100 to 5,100 pounds of dry matter per acre when a hundred pounds of nitrogen was applied. The protein yields were raised from 100 to 528 pounds per acre.

In South Dakota the average dry-weight yield of grasses from experiments in 4 counties was 1,964 pounds an acre when no fertilizer was applied, 3,093 pounds when nitrogen was used, and 3,240 pounds when both nitrogen and phosphorus were applied.

In Ohio, pasture yields over a 7-year period averaged over 21 percent higher following an application of a ton of lime and 400 pounds of 20 percent superphosphate every four years. The addition of 55 pounds of nitrate of potash brought the increase to 26 percent. The superphosphate, alone or with lime, improved the mineral quality of the grass.

*Forage plants vary greatly in foraging powers:* Such crops as peanuts, soybeans, lespedezas, and kudzu are effective foragers for plant nutrients. They can survive on poor soils and successfully compete with other associated crops under adverse fertility conditions. They grow best, however, under conditions of moderate to high fertility and respond markedly to additions of fertilizer. When such crops are grown on poor soils without fertilization, their contribution is mostly in the small quantities of nitrogen they accumulate, and in their prevention of soil erosion. They merely postpone the time when fertility must be added to the soil if productivity is to be maintained. When such crops as tobacco and cotton follow these legumes, they often develop severe symptoms of potash deficiency. This is because of the high nutrient requirements of these legumes and their ability to take up large quantities of plant nutrients even from soils in a low state of fertility.

*Plant nutrients removed by crop:* The quantities of plant nutrients removed in a year’s growth of a legume crop that is harvested for hay are more than double those contained in the harvested portion of a cotton or corn crop, and more than three times those removed by a small grain crop. A 3-ton crop of alfalfa contains about 140 pounds of nitrogen, 35 pounds of phosphoric acid, and 135 pounds of potash. A ½ ton crop of timothy contains about 40 pounds of nitrogen, 15 pounds of phosphoric acid, and 45 pounds of potash.

The legume crops that are adapted to poor soils also tend to be high in mineral elements. Each ton of peanut or soybean hay contains about 10 pounds of phosphoric acid and 25 pounds of potash. A 1,500-pound crop of peanuts and the accompanying 2,000 pounds of hay remove approximately 15 pounds of phosphoric acid and 55 pounds of potash from the soil.

*Plant nutrients required by roots:* Large amounts of plant nutrients also are immobilized in the extensive root systems of many forage crops. Approximately one-third of the plant nutrients taken up by alfalfa the first year is contained in roots. Similar proportions of plant nutrients are retained by the roots of other grass crops.

Yields of as high as 10,000 pounds an acre have been reported in the roots of native prairie grasses. Root development in many of the cultivated grasses is large in comparison to other crops. Root yields from bluegrass range from 2,300 to 5,000 pounds of dry matter per acre, and from bromegrass from 2,000 to 4,000 pounds. For alfalfa, root yields range from 2,000 pounds dry matter an acre in young plants to 3,500 pounds in mature stands. Root yields of Sudangrass and sweetclover range from 800 to 1,400 pounds an acre. Most of these root yields are large compared with those of small grains, sorghums, and corn which produce from 700 to 1,300 pounds of roots an acre. The roots of potatoes, peas, tomatoes, and similar crops usually range from 200 to 500 pounds an acre.

*Recovery of applied nutrients:* Crops seldom recover more than 75 percent of the nitrogen supplied in the fertilizer, and a 50 percent recovery is what may reasonably be expected. The remainder escapes
largely in the drainage water. Soil fixation may commonly prevent from two-thirds to three-fourths of the phosphorus that is applied from contributing to plant growth. With potassium the story is much the same. Leaching may account for some of the losses, but there is normally considerable fixation by the soil. Part of the phosphorus and potassium that is fixed by the soil may ultimately become available to crops, but the immediate crop may not get it. One must provide considerably larger quantities of nutrients than are to be contained in the crop increase that is expected.

Because of the tendency for fertilizer elements to be lost from the soil by leaching, or to be fixed in unavailable form, placement and timing of fertilizer applications are important. Fixation of phosphorus and potassium is much less if the fertilizer is concentrated in bands that are conveniently located with respect to the plant roots, than if it is applied broadcast. The band-placed fertilizer is in intimate contact with a smaller quantity of soil and the nutrients remain available to the plant for much longer periods.

Because nitrogen is readily leached from the soil by heavy rains or excessive amounts of irrigation water, delayed applications are often more efficient than all-at-one-time applications when the crop is planted. If the nitrogen is applied too early, much of it may be lost before it can be utilized. Delayed applications may be so timed that the critical needs of the crop are satisfied with the least loss by leaching.

Maximum efficiency in fertilizer use depends upon having the proper nutrient balance in the soil. For each crop there is a definite ratio in which each of these necessary elements must be supplied to maintain optimum growing conditions. The ratio varies also with the soil and with the climatic conditions under which the crop is grown. Failure to get response to high rates of fertilization, provided lack of moisture and poor physical conditions in the soil are not limiting factors, may be because the fertilizer practices that were followed did not result in having the nutrient elements supplied in suitable ratios.

Fertilizer needs of forage crops: Legumes respond markedly to the use of potassium and phosphorus fertilizer, to the use of minor elements, and to additions of lime. Some species respond also to the use of nitrogen fertilizers. Most of the leguminous crops need small amounts of available nitrogen in the early stages of growth before fixation in the nodules commences. Soybeans, for optimum growth on some Iowa soils, were found to respond to moderate amounts of nitrogen fertilizer in the later stages of growth.

The fertilizer needs of forage crops cannot be considered entirely apart from the need of the associated crops in the rotation. The total rotation requirement is of major importance, and consideration must be given to the most advantageous place in the rotation at which to apply each of the fertilizer elements.

For example, corn, clover, and alfalfa have higher potassium requirements than wheat or oats. When these crops are grown in rotation, the potassium should be applied largely to the corn and legumes. On the other hand, wheat, clover, and alfalfa have higher phosphorus requirements than corn, oats, and soybeans. In the rotation, therefore, phosphorus should be applied more largely to wheat and the legume hay crop that follows.

The most general practice in the Corn Belt is to apply most of the lime and a large part of the phosphorus and potash at the time of establishment of the legume or grass crop. In rotations containing potatoes, tobacco, vegetables, or other high-acre-value crops, it is generally most efficient to apply the larger part of the fertilizer to the high-value crop and only meager amounts to any associated forage crop.

When perennial forage crops are continued for a number of years, it is generally necessary to make applications of fertilizers annually for maintenance purposes. In New Jersey, for example, a yearly application of 500 to 1,000 pounds of 0-12-12 fertilizer is recommended for
alfalfa. If boron is lacking, it should be supplemented with 80 pounds of borax per ton of fertilizer.

Summary of principles: The National Joint Committee on Fertilizer Application ( Misc-35) has summarized the principles involved in fertilizer use as follows:

1. Adequate quantities of plant nutrients in correct balance within the root zone, in addition to optimum moisture, proper aeration, and other favorable conditions, are necessary for maximum yields.

2. Irregular distribution can lower fertilizer efficiency if some plants or plant roots are given too much and others too little.

3. Early stimulation of the seedling is usually advantageous; thus, at least a part of the plant food should be placed within reach of the young seedling roots.

4. Soluble salts go into solution in moist soil and move to some extent. The rate and distance of movement depend upon the chemical nature of the soluble salts and upon the character of the soil. They may move upward during dry periods or be carried downward with rain or irrigation water.

5. Nutrient elements when in dry soil are of little or no benefit to the plant. Such conditions may exist in the surface soil during prolonged dry periods.

6. Excessive concentration of soluble material in contact with either seed or roots causes injurious effects. Crops, however, vary in their tolerance of soluble salts. Concentration of relatively small amounts of fertilizer directly above, immediately under, closely around, or in the furrow with the seed is generally hazardous for most crops, and a large amount so applied may severely injure the initial roots of the seedling or even impair germination.

7. Water-soluble fertilizers of relatively low plant-food content have a greater salt concentration per unit of plant food and a greater tendency to produce salt injury than do equal amounts of plant food in the more concentrated fertilizers.

8. In commonly used fertilizers, because the nitrogen and potash carriers are more readily soluble than the phosphate material, they cannot be safely concentrated in as large amounts near the seed or roots.

9. Reduction of soil moisture increases the concentration of the soil solution; therefore, relatively large amounts of fertilizer placed too near the seed or seedling roots are most likely to cause injury during unusually dry periods, particularly when such periods occur soon after fertilizer application. Concentration also depends upon the water-holding capacity of the soil.

10. Fertilizers applied on the soil surface and plant nutrients moved to the soil surface during dry weather are subject to removal in the surface runoff water of sudden intensive rain.

11. Leaching is greater from sandy soils than from heavier textured soils. This means that more frequent applications or split applications of nitrogen carriers, and sometimes of phosphates and potash as well, are desirable on sandy land.

12. Progressive fixation of phosphates and potash by soil clays continues to diminish their efficiency for a considerable period following their application to the soil. Fixation refers to any chemical or physical interaction between soluble plant nutrients and the soil whereby the nutrients become less available to the crops. Soils with high iron content tend to fix phosphates more readily than do those with low iron content. Acid and alkaline soils fix phosphates more readily than nearly neutral soils. Soils with high mica content tend to promote high fixation of potash. Fertilizer nitrogen is readily available for plant growth, and any soil fixation is only temporary. The ammonia form of nitrogen is absorbed by clay particles in the soil and held against movement in the soil but is available to plant roots and to soil organisms. Nitrogen used by soil organisms and plants is slowly released in available form as these organisms decompose.

13. Since phosphate moves slowly from the point of placement, it should be placed where it will be readily accessible to the plant roots.
14. Crop rotations may be so planned as to conserve available plant nutrients that might otherwise be lost by erosion or leaching. Green-manure crops, both legumes and nonlegumes, grown between cash crop seasons utilize much of the available plant food and retain it for use of the crop that follows. They also increase the supply of soil organic matter, improve aeration, and favorably influence soil structure and water relations. Deep-rooted legumes, such as sweetclover, are particularly beneficial, because under many conditions they can penetrate and help break up compacted soil layers, thus increasing the root-feeding area of succeeding crops.

15. Localized placement of fertilizers near the seed or seedling roots is usually desirable for three important reasons:
   (a) Restricted contact of fertilizer with soil lessens fixation of phosphate and potash.
   (b) Necessary plant food is placed within easy reach of plant roots, and possibility of injurious concentrations is minimized if the proper placement is accurately controlled.
   (c) Fertilizer placed in a band along the row does not readily furnish nutrients to weeds growing between the rows.

16. Localized application when too far from seed or roots can result in retarded growth until the roots reach the supply of plant food.

17. Broadcasting and thorough incorporation of the fertilizer in the plowed layer of soil by disk or similar tillage operations brings the plant nutrients into intimate contact with a large amount of soil, which is a condition most favorable for fixation of phosphates and potash. Such methods are sometimes employed, however, for closely spaced plants, for preventing excessive salt concentration, for incorporating into the soil slowly available materials, or for mising the general fertility level of the entire tilled layer of soil.

18. Top dressing and side dressing with nitrogen, and sometimes with potash, are useful in minimizing the concentration of salts when heavy total applications are made, in providing nutrients at a critical or opportune stage of crop development, and in replacing plant food when losses result from leaching and other causes. Nutrients applied as side dressings are of most immediate benefit to the plant when placed in moist soil in the root zone, but in making the application excessive mechanical destruction of the root system must be avoided.

19. Zinc, copper, and a number of other mineral elements can be absorbed directly from sprays on the leaves of plants and from injections into trunks of trees.

PRINCIPLES OF NITROGEN UTILIZATION

A sub-committee on nitrogen utilization on haylands and pastures (Misc-36) has issued a report giving a "Statement of Facts" and "Approved Areas for Recommendations" which may be used as a guide in the application of nitrogen fertilizers to meadows and pastures.

Statement of facts: First, we would list some statements accepted as proven facts.

1. Legumes are a source of high quality hay and pasture, usually running higher in protein and calcium than grasses. The desirability of their inclusion in hay and pasture mixtures is not dependent alone upon the beneficial effect they may have upon the yield and protein content of grass.

2. This being true, it is sound practice generally to use legumes to the fullest practical extent as a means of improving the quality and yield of hay and pasture.

3. The availability of commercial nitrogen does not generally preclude the desirability of the adequate use of lime and fertilizing materials for the optimum production of legumes in hay and pasture mixtures.

4. Grasses, too, have feed, conservation, and economic values. Their exclusion would generally be more serious than the exclusion of legumes.

5. The function of commercial nitrogen is to do that which cannot economi-
cally, under the conditions of any particular situation, be accomplished by means of legumes.

6. Generally for hay and pasture production under farm conditions, commercial nitrogen should not replace legumes but should be used to aid in the accomplishment of one or more of the purposes for which legumes are used.

7. The more and bigger the plants grown on a fixed area, the greater the competition and the more difficult it becomes for all to survive. This accounts in part for the frequently observed downward trend of legumes in a grass-legume mixture where commercial nitrogen has encouraged an excessive growth of unutilized grass. This same fact also explains why, in other experiments where the additional growth of grass has been promptly removed, little or no reduction in the legume content has resulted from the use of nitrogen. It is possible to reduce the amount of grass by legume competition as well as to reduce the amount of legume by grass competition.

8. It is possible under farm conditions in many instances to use commercial nitrogen on a legume-grass mixture without reducing or greatly retarding the increase of legume content.

9. Under conditions favorable to permanent pasture legume growth in the Northeast, these legumes produce pasture about as abundantly and more economically during July and August than it can be obtained during this same period from nitrogen applications on permanent pasture grasses. Under weather conditions too dry for legume growth in July and August, nitrogen on permanent pasture grasses does not give a satisfactory response.

10. There are many instances in which, because of the failure of a legume or because of one or more of many other reasons it is not present in sufficient quantity, commercial nitrogen becomes not only the quickest but the only practical means of producing the extra hay or pasture when and where needed.

Recommendations: In consideration of these facts, the committee feels that instances in which the use of commercial nitrogen to produce needed hay and pasture should under certain conditions be recommended, include the following:

1. On hay type grasses and low legume grass mixtures, for the production of hay needed to meet the requirements of livestock on the farm.

2. On hay and pasture type grasses and low legume grass mixtures to provide for extra early grazing, thus relieving the necessity of buying feed for continued barn feeding in the spring when livestock might be on pasture.

3. On hay and pasture type grasses and low legume-grass mixtures to provide additional pasture during the main pasture season, May and June, in instances where the supply is otherwise not adequate at that time.

4. In the South on grasses and legume-grass mixtures for the production of winter pasture.

5. On small grains and other temporary emergency grass crops for the production of fall, early spring, or midsummer pasture.

6. On grasses to encourage seed production.

7. In fertilizer mixtures used when establishing grasses and legume-grass mixtures to insure more rapid establishment and development.

8. Where commercial nitrogen is used, amounts in excess of those commonly used in the past should be recommended. Forty pounds of nitrogen per acre is probably the minimum for top-dressings of meadows and pastures.

INFLUENCE OF FERTILIZERS ON CHEMICAL COMPOSITION OF FORAGE CROPS

The chemical composition of forage crops depends on the conditions under which they are grown. Natural factors that have a bearing on the chemical composition and correspondingly on the nutritive value include the kind of plant, the climate, the fertility of the soil, the weather preceding and during the harvest, the age of the plant at harvest time,
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and the season of the year during which the crop was grown.

Young clover, for example, averages higher in protein and calcium, and lower in fiber than grass, but when grown in fertile soil, young grass may contain a high percentage of protein. Depending upon the crop and the condition of growth and harvest, one may have a high-protein or a high-carbohydrate plant to fit his needs.

Mature forages show similar differences. Alfalfa hay contains 12 to 16 percent of protein (on the dry basis) and 1.0 to 1.7 percent of calcium; timothy hay contains only 6 to 10 percent of protein, and only 0.25 to 0.35 percent of calcium. Depending on their relative amounts of grasses and legumes, mixed herbage has a composition intermediate between grasses and legumes. Protein percentages tend to be lower in midsummer than in the spring or fall. Temperature, light intensity, length of day, and moisture supply also control plant development and consequently chemical composition. No one factor works alone.

Influence of soil fertility: Soil fertility not only regulates the amount of crop growth but also influences quality. Soils of high fertility produce forages of higher nutritive value than inferior soils. Essential mineral elements are obtained only from the soil, and proteins and vitamins are produced in quantity only when minerals are adequate.

It has been stated, "any increase in the percentage of protein, phosphorus, or calcium that forage crops may contain as a result of fertilizer applications may be considered to be an improvement in the quality of these crops as livestock feeds."

Influence of fertilizer applications: Fertilization affects the chemical composition of mixed forage by favoring the growth of some plants rather than others. For example, clover responds more readily to mineral fertilizers than grass. As clover becomes more abundant the protein and calcium of the mixed herbage increase. Fertilizers also affect the quality of herbage by changing the chemical composition of the individual plant. The application of a nitrogen fertilizer tends to effect an increase in the protein content of plants. Likewise, applications of phosphorus promote a greater uptake of these elements, and the same applies to lime.

But, application of nitrogen, phosphorus, and other nutrient elements may not increase the plant's content of these elements. For example, if a moderate amount of phosphate is applied to a phosphorus-deficient soil, some of the phosphorus will be taken up by the plants, which will thenceupon make more rapid growth. But the percentage of phosphorus in the plant may not be any greater because the total dry matter will also increase. If larger doses of phosphate are applied, however, the percentage of phosphorus in the plant will rise.

Phosphorus is an especially important element when considered from the point of view of both yield and quality of forage. It is a constituent of every living cell of plants and animals. In plants it is found in largest concentration in the seeds. In animals, phosphorus and calcium are the essential elements in bones. Adequate amounts of available phosphorus in soils stimulate rapid growth and development of plants, hasten maturity, and improve their quality. A high percentage of phosphorus in forages and pasture crops increases the feeding value of the forage crop and improves its palatability as shown by preference of the cattle for phosphated hay and pasture.

Data from Minnesota (Minn-9) show that phosphated alfalfa on five soil associations contained 20 percent more phosphorus than that grown on the unphosphated land. The protein content of the hay also tended to be increased. There was no great difference in the lime content of the hay grown on untreated and the phosphated land of the different soil associations. The percentage increase in total digestible nutrients averaged 40 percent greater following applications of phosphate.

Results vary with stage of growth: If growth is accelerated by fertilizer, the chemical composition of the plant
changes because of the increase of rapidly growing new tissue. This may result in an increase of protein in grass after the addition of potassium to a potash-low soil or an increase of carotene (provitamin A) after the application of ammonium sulfate.

Nitrogen applied to young pasture grass may increase yield or protein content, or both. Applied to more mature grass, it increases the percentage of protein but is less likely to affect yield. When ammonium sulfate was applied to timothy in New Jersey 21 days before harvest, the protein was increased 50 percent over that in hay from the unfertilized area, but no yield benefit resulted.

Effect of nitrogen applications: If there is a deficiency of nitrogen in the soil, a very large proportion of the stems or shoots of timothy are short and leafy, with no heads. When the meadow is fertilized with nitrogen, a greater proportion of the shoots produce heads, the heads are longer, and the yield of seed is increased. The older a timothy stand, the less nitrogen there is likely to be in the soil unless this element is added as a fertilizer; hence, low yields of seed may be expected.

Any effect of nitrogen fertilizer in increasing protein is usually apparent for a short time only. In Connecticut, when it was applied to bluegrass and bentgrass in the spring, only the first of successive monthly cuttings showed greater protein contents than that from unfertilized areas.

If high protein throughout the season is desired, the nitrogen must be applied frequently. Otherwise, nitrogenous fertilizer will not affect protein percentage. In Ottawa, where fertilizers were applied to grasses in pure stands, various fertilizer combinations had no effect on the protein content, but yields of dry matter were increased in most cases.

When nitrogen fertilizer was applied to timothy at different rates in three different seasons at the Ohio Agricultural Experiment Station, the percentage increase in yield was greater for seed than for hay. Unfertilized timothy yielded 1.3 tons of hay or 3 bushels of seed per acre. Where 48 pounds of nitrogen (the equivalent of about 235 pounds of sulfate of ammonia) were used per acre, a hay yield of 1.9 tons was obtained or 5.7 bushels of seed. This was an increase of 46 percent for hay and 90 percent for seed. Forty to fifty pounds of nitrogen per acre seem to be about an optimum annual rate of application.

Treatments have been made experimentally on several different dates between November and the following May. All these dates have given satisfactory increases. As a rule, spring applications are somewhat more effective than late fall applications, but it is often difficult in the spring to get on the land to apply the fertilizer as early as necessary for best results.

Brown and Munsell (Conn-12) have summarized the results of their Connecticut experiments on "the yields and quality of several grasses fertilized with nitrogen for hay and pasture as compared with those from legumes and legume-grass mixtures."

"During a 5-year period, the yields of timothy were increased markedly by 28 or 56 pounds of nitrogen per acre annually, but in the same seasons alfalfa on nearby plots, unfertilized since sowing, produced more dry matter and over twice as much protein."

"Ladino clover-orchardgrass seedlings also yielded more dry matter and much more protein than another stand of timothy fertilized with 28 pounds of nitrogen in each of the months of April and June."

"The sowing of Ladino clover with either Kentucky bluegrass or Rhode Island bentgrass, lawnmowed eight times per season for seven years, resulted in slightly larger total and better distributed yields than the application of nitrogen at 28 pounds in each of the months of April, June, and August on the grasses alone."

"On grazed permanent pastures, spring-applied nitrogen stimulated a 30 percent increase in total yields over mineral fertilization. Most of the additional growth occurred before June 16. Spring
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and summer nitrogen resulted in less May but more summer feed than from applying all of the nitrogen in April. The most uniform seasonal distribution of pasturage was obtained by adding nitrogen only in the summer, but the returns per unit of nitrogen were about half those from the spring treatments.

Even though fertilizer experiments are carried out in a similar manner, the results do not always agree. Vandecaveye and Baker (Wash-26) stated that "on the basis of the experimental results there can be no doubt that the nitrogen, phosphorus, potassium, and calcium content of forage crops is affected markedly by differences in soil types. The effects of fertilizers on the composition of these crops is less certain. Since good responses from fertilizers were obtained on certain soil types in each group used for statistical analysis and not on others, it seems that the variability in soil characteristics was too large, or the number of soils involved too few, to serve as an indication that the changes in composition of the forage crops as affected by fertilizer applications are significant, except in a few cases.

"Like fertilizers applied to different soils produced markedly different effects on the protein, phosphorus, potassium, and calcium content of forage crops. Certain forage crops were more responsive to fertilizers than others. Pasture herbage proved to be the most responsive, indicating that the effect of fertilizers on the composition of forage crops is more pronounced in the early than in the more advanced stages of growth.

"In the majority of cases applications of nitrogen and phosphate fertilizers supplying about 40 to 50 pounds of nitrogen (N) and 80 to 90 pounds of phosphoric acid (P₂O₅) per acre, and complete fertilizer supplying 80 to 100 pounds of potash (K₂O) per acre in addition to the amounts of nitrogen and phosphoric acid mentioned caused marked increases in the protein and phosphorus content of pasture herbage produced in soils in the areas represented by the experiments. With minor exceptions, the complete fertilizer under these conditions resulted also in a larger potassium content of the herbage.

"The response of mixed grass hay to these fertilizers was similar in character to that of the pasture herbage, but in a less pronounced degree. The general effect of mixtures of phosphate and potash fertilizers was to increase the amount of clover in mixed grass hay and, consequently, to bring about appreciably larger percentages of protein, phosphorus, and potassium in the hay.

"The chemical composition of alfalfa and oats at the hay stage of maturity was less influenced by fertilizer treatments than was the chemical composition of pasture herbage or of mixed grasses in the hay stage of maturity, although the trend of the response of the former crops was in the same direction as that of the latter.

"The calcium content of the forage crops was affected markedly by differences in soil types, but did not appear to be influenced to any significant degree by fertilizer treatments, except that applications of complete fertilizers for alfalfa resulted in a reduced content of the hay."

In a Virginia experiment, annual fertilization of a limed pasture with superphosphate and either ammonium sulfate or nitrate of soda increased the average protein of a bluegrass and white clover mixture from 15.5 to 18.5 percent, digestible protein from 11.3 to 14.1 percent, and phosphorus from 0.25 to 0.43 percent. Fertilization had brought in more grass at the expense of weeds.

"Phosphate and lime, with or without nitrates and potash, raised the protein, calcium, phosphorus, and potassium contents of West Virginia pastures. Under all the fertilizer treatments, Kentucky bluegrass and white clover came in to replace weeds and povertygrass. Nitrates increased protein in years when clover was light but did not affect it in the "clover" years. Carotene of mixed herbage in South Africa increased 28 percent as a result of monthly applications of sulfate of ammonia or nitrate of soda. Potash, also applied monthly, increased the carotene 6.2 percent.
The more commonly applied fertilizers promote an increase in one or more of the desirable major nutritive elements and thus may be said to increase forage quality. The percentage content of minor elements such as manganese, copper, iron, and cobalt, may also be increased in forage, either by applications of carriers of these elements to the soil, or by the use of such fertilizers as will stimulate better growth of legumes which seem to be higher in these elements than are the grasses.

Blaser and Stokes (Fia-6), summarized, in part, the results obtained from applications of fertilizer to carpetgrass on 4 soil types in Florida, as follows:

"Growth of established carpetgrass was stimulated primarily by nitrogen fertilizer. Lime, phosphorus, and potash increased the efficiency of the nitrogen fertilizer greatly on 3 of the 4 soil types. March applications of nitrogen increased the early season growth greatly, but September and other late-season applications of nitrogen did not augment the late-season growth of carpetgrass appreciably. The most desirable yield curve occurred when all of the nitrogen was applied in March, or March and June. Smaller yields and less early feed resulted with late-season nitrogen applications.

"Omission of either lime, superphosphate, or potash from a lime and fertilizer mixture generally retarded growth and produced grass low in the mineral content of the nutrient material omitted. The omission of phosphorus or potassium from the lime and fertilizer mixture on the Bladen fine sand caused phosphorus or potassium deficiency symptoms of carpetgrass.

"The calcium, phosphorus, and potassium content of grass treated with lime and complete fertilizer was significantly higher than that of unfertilized grass on the Leon and Bladen fine sands. Grass treated with nitrogen alone was lower in calcium, phosphorus, and potassium than unfertilized grass on all soils.

"Plucked carpetgrass samples taken in 1940 from five experiments on different soil types showed that the phosphorus, calcium, and potassium content of carpetgrass was increased 78 percent, 21 percent, and 38 percent, respectively, when compared with unfertilized grass. Phosphorus from four sources (superphosphate, basic slag, rock and colloidal phosphate) increased the phosphorus content of carpetgrass greatly.

"Carpetgrass samples taken from numerous pastures on ranches during 1941 showed the following increases in minerals over unfertilized grass: calcium 48 percent, phosphorus 75 percent, potassium 31 percent, and nitrogen 13 percent. The magnesium content was reduced 5 percent.

"Test plots located on various virgin soils in peninsular Florida show that a low phosphorus supply is the primary factor limiting growth and development of grass sods. After phosphorus is supplied insufficient amounts of other elements, potassium, nitrogen, calcium, and minor elements, limit growth."

Dangers of heavy fertilization: The question may be asked, what would be the nutritional significance of fertilizers applied in amounts beyond those economically profitable? We have no exact answer at present as to the effect of massive doses on nutritive values, but we may safely conjecture what may happen in some cases. More than 1 or 2 percent of nitrates in plants as a result of very heavy fertilization or of excessive amounts in soils is known to be poisonous to stock. Heavy nitrogenous fertilization of pastures may also increase other nitrogen compounds as well as proteins, and the former in extreme amounts may cause digestive disturbances.

Excessive quantities of certain other fertilizers may upset the mineral balance of animals. For example, too much potassium may lower the calcium, magnesium, or sodium content of plants. This may result in their being reduced to a dangerously low level in the blood of animals to which the forage is fed. Grass tetany is suspected to be such an unbalance of minerals. Excess lime also lowers the uptake by plants of certain soil elements necessary in nutrition, such as iron, copper, and manganese, and the
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forages may become deficient in these minerals as a result.

SOILS AND FERTILIZER HIGHLIGHTS

1. Fertile soils and intelligent use of fertilizers are as important with forage crops as with any other crops.
2. Some of the more essential qualities of a soil for maximum productivity are adequate moisture storage, adequate aeration, sufficient available plant nutrients for the crop, and freedom from objectionable chemicals.
3. The natural characteristics of a soil are capable of improvement by cultural practices, the use of lime, the incorporation of crop residues, and the application of fertilizers.
4. Naturally infertile soils may often be built up to a much more productive state than is normal for such soils through suitable cropping and management practices.
5. Because soils are an expression of environment, including climatic forces, the evaluation of a particular soil must of necessity give consideration to climate.
6. Since grasses and legumes under proper management tend to overcome to a considerable degree certain soil shortcomings, less attention need be given to such shortcomings in growing forage crops than in the production of cultivated crops.
7. Proper balance in the supply of available plant nutrients in the soil is usually more important than a large supply of any one element.
8. Soil fertility determines in large measure both the quantity and the quality of forage produced. Soils of high fertility produce high yields of high quality forage.
9. Fertilizer, though not the only factor influencing yield and chemical composition of forage crops, is one of the most important.
10. The only plant nutrients that forage plants can add to the soil are those contained in their organic residues and the nitrogen that is obtained by legume bacteria from the air.
11. Chemical analysis of the plants grown on a soil gives an accurate measure of the nutrients removed by the crop, but it is not an accurate guide to the quantity needed to be applied to produce the crop.
12. Grasses and legumes in a crop rotation can often make good use of fertilizer residues remaining from applications made to the crops grown previously in the rotation. Applications made to grass and legume crops stimulate root and top growth and increase the organic matter in the soil for use of the crops that follow in the rotation.
13. The chemical composition of forage crops depends upon the relative percentages of the various kinds of plants and the conditions under which they grow, such as climatic conditions, soil fertility, weather at harvest, age of plant, and season of year.
14. Although there are natural factors affecting chemical composition and nutritive value of crop that are not under the farmer's control, he can effect improvement through better crop management, the growth of more legumes, and the use of lime and fertilizers.
15. The application of certain plant nutrients to a soil tends to increase the percentage of those nutrients in the crop produced, but this is not always the case, and it is usually not proportional to the quantity of fertilizer applied.
16. In a grass-legume mixture, the percentage of each can be determined by the liming and fertilizing program. In general, the greater the rate of application of lime, phosphate, and potash, the higher the legume content of the mixture. The greater the quantity of nitrogen applied, the higher the percentage of grass.
17. Since nitrogen can, in most established pastures and meadows, be supplied largely by the legume component, phosphorus and potassium become the most important elements in their fertilization. Occasionally some of the minor elements, such as boron, come into the picture.
18. Phosphorus and nitrogen are both essential elements in a nutritive forage. The value of many forages is in large part determined by the percentages of phosphorus and protein they contain.
19. Large applications of phosphates to alfalfa have not only increased the phosphorus content of the hay, but have definitely increased the protein content as well.
20. Many factors, other than soils and fertilizers, influence yield and chemical composition of forage.
THIS CHAPTER

The material used in this chapter came largely from Bartholomew (US-14), Sullivan and Wilkins (US-251), Morgan, Gourley, and Ableiter (US-172), and reports of the National Joint Committee on Fertilizer Application (MISC-35) and National Joint Committee on Nitrogen Utilization (MISC-36), supplemented by abstracts from Vandecaveye and Baker (WASH-26), Blaser and Stokes (FLA-6), Brown and Munsell (CONN-12), and Burson, Harris, and Rost (MINN-9). The preliminary manuscript was reviewed by Ableiter of U.S.D.A. Soil Survey, and Beeson of the Plant, Soil and Nutrition Laboratory, Ithaca, N.Y., and the final manuscript by Bear of the N.J. Agr. Exp. Sta.

Chapter reference numbers: ¹ ALA-24-28, 35; ARIZ-10; ARK-2; CONN-1, 2, 5, 6, 11, 12, 15, 16, 17; DEL-8; FLA-6, 8, 9, 12, 14; CA-10, 16; HAW-1; IDA-8; IOWA-23; KAN-11, 19; KY-25; LA-10; MD-5, 18; MINN-9; MISS-1, 2; MO-1, 2, 6, 7, 9, 18; NEB-16; NJ-5, 6, 8; NJ-9, 24; NM-3, 4, 8; NY-18, 22, 24-27, 29; NC-6, 7, 14, 15, 16, 18, 21; ND-13; OKLA-6, 18, 21; OREG-3; PA-8, 11, 14, 15, 16, 21, 23; RI-10; SC-8, 12, 18; TENN-9; TEX-3, 5, 6, 13-15, 17, 53; VT-8, 12; VA-2, 3, 7, 8, 10-14; WASH-2, 23, 26; WVA-6-9; WIS-10, 20; US-5, 14-20, 32, 72, 81, 118, 132, 172, 187, 213, 216, 217, 233, 251, 254, 275; MISC-2, 35, 36, 38, 40.

¹The reference numbers given here refer to references which are given in full by State, U.S.D.A., and Miscellaneous, on pages 682 to 724, and which are cross-referenced by author on pages 725 to 731. Citations in the text are indicated by abbreviation and number in parentheses.
CHAPTER III

INOCULATION OF LEGUMES

More than sixty years have passed since the discovery by Hellriegel of the beneficial association of bacteria with legumes, proving beyond any question of doubt, that with the help of these bacteria this great family of plants is able to use the nitrogen from the air as well as from the soil and in addition enrich the soil in which they grow. This epochal discovery had such tremendous practical implications that, almost immediately, numerous laboratory and field studies were started in this country and in Europe to learn more about the activities of these microorganisms now known to most agriculturists as legume bacteria.

In 1901 the U.S. Department of Agriculture began its investigations on the methods of inoculation of legumes. Since then a number of publications have been issued by this Department to give farmers accurate knowledge of this practice of increasing crop yields, and also to point out to scientific workers the precautions that must be observed in order to obtain satisfactory results. Many agricultural experiment station bulletins, circulars, scientific papers, and several books on the subject of legume bacteria have been published.

As our knowledge increases, and more and more legume bacteria secrets are revealed, greater numbers of legume inoculation problems are encountered. This is especially true in our changing soil and climatic conditions, and particularly with the introduction of new species or varieties of legumes. Even now the subject of improvement in legume inoculation provides the stimulus for much-needed research work. Altogether too few scientists are at work in the laboratory, the greenhouse and the field, gathering information which will help to formulate general recommendations to enable farmers to inoculate their legume crops more successfully.

THE LEGUMES

Legumes are plants that bear their seeds in pods like beans. They belong to the family of plants called by the botanists Leguminosae. More than 10,000 species have been described, but of this number, about 200 species are cultivated by man. In the United States only about 50 species are grown commercially. These species are further divided into varieties, and in the case of soybeans more than 100 varieties have been named and grown in this country. The best known and most widely used legumes are alfalfas, sweetclovers, bur-clovers, black medic, red, white, crimson, hop and Persian clovers, soybeans, peas, beans, vetches, cowpeas, lespedezas, lupines, crotalarias, scabina, alyceclover, garbanzo, and the trefoils.

The legumes are rich in high quality protein, which is one of the essential food constituents not only for human consumption but also for domestic animals. Legumes are also high in calcium, fairly well supplied with phosphorus, and a good source of vitamins, especially A and D. These qualities make legumes one of our best foods for man, and almost indispensable for efficient, economical livestock feeding.

The protein content of legumes is directly related to their high nitrogen content, and in this respect they differ markedly from the grasses or other non-
legumes. Analyses of eight important legume hays cut at the optimum stage of maturity show the average quantity of protein per ton to be around 300 pounds. Similarly, eight important grasses average only about 160 pounds per ton, or only a little more than half that of the legumes. The quantity of protein will vary with the stage of maturity, as for example, early cut timothy may contain 175 to 200 pounds of protein per ton, while that cut in late bloom when much of it is cut, may contain only 115 pounds per ton.

Legumes have gained great popularity and economic importance wherever they are grown: (1) because of their higher nitrogen content and feeding value; (2) because of their large quantity of readily decomposable organic matter; and (3) because of their versatility in fitting into special farm practices, especially soil conservation.

NITROGEN AND ROOT NODULES

The air we breathe is primarily a mixture of nitrogen and oxygen gases. About 80 percent by volume is pure nitrogen in a free or uncombined state. It has been estimated that over every single acre of land surface there are about 35,000 tons of this free nitrogen, which, as such, is totally useless to plant or animal life. Nitrogen has been called the aristocrat of all the elements—it is very stubbornly opposed to entering into combination with other elements. However, under powerful influences, such as lightning discharges, and chemical reactions brought about by tremendous heat, the air nitrogen does combine to form compounds which are used to supply industrial and agricultural needs.

Fortunately, Nature has provided farmers with a more simple and less expensive method of obtaining atmospheric nitrogen for their farming operations. This is accomplished by growing inoculated legumes. Soon after the legumes begin to grow, the legume bacteria invade the tiny root hairs and multiply in large numbers causing plant to form growths called nodules. A definite partnership is established—one representing a true symbiosis—the legume plant furnishes the necessary sugar or energy and the bacteria uses this energy material to fix the free nitrogen of the atmosphere. This is called symbiotic nitrogen fixation.

Roots of lespedeza plant showing nodule formation.

Just how these bacteria do this job still remains to be proved, but apparently they work with remarkable ease, because in controlled experiments visible evidence of nitrogen fixation may be seen after two or three weeks. A deeper, darker green color in inoculated legumes as compared to a lighter green color in uninoculated legumes is one sure sign of nitrogen fixation by the bacteria. In fact, color differences are more reliable for judging nitrogen fixation than numbers of nodules.

Inoculated legumes growing in normal soils show definite characteristic types of nodule formation. Generally, when
nODULES ARE CLUSTRED AROUND THE TAP ROOT AT THE POINT WHERE THE INOCULATED SEED IS PLANTED, THIS INDICATES THAT IN ALL PROBABILITY THESE NODULES WERE FORMED BY THE BACTERIA ADDED IN THE INOCULANT. NODULES SCATTERED OVER THE LATERAL ROOTS ARE USUALLY FORMED BY THE LEGUME BACTERIA NATURALLY PRESENT IN THE SOIL. (SEE ILLUSTRATIONS OF NODULES ON ROOTS OF LESPEDEZA AND AUSTRIAN WINTER PEA AND, IN CHAPTER 16, NODULES ON ROOTS OF BIRDSFOOT TREFOIL.)

ROOTS OF AUSTRIAN WINTER PEA PLANT SHOWING NODULE FORMATION.

In observing the effects of legume seed inoculation it is always well to dig plants at different stages of growth. Nodules come and go with varying moisture levels in the soil. As a general rule nodule examinations should be made about three or four weeks after planting, during the middle of the growing period (if moisture conditions are favorable) and when the legume is in full blossom. As the legumes mature, the reserve food stored in the nodules is translocated to the seeds and on some legumes the nodules begin to disintegrate rather rapidly.

NITROGEN FIXATION BY LEGUMES

The quantity of nitrogen taken from the air and fixed by the legume bacteria for different legumes is difficult to calculate. It varies with (1) kind of legume, (2) effectiveness of the legume bacteria, (3) soil conditions, and (4) the presence of necessary plant food elements exclusive of nitrogen. In soils well supplied with available nitrate nitrogen there may be little or no fixation of nitrogen as the legume plants seem to use this available nitrogen rather than encourage the bacteria to fix more nitrogen.

Because of these many factors, and our lack of an accurate method for determining fixation under field conditions, we have meager information on the relative quantities of nitrogen fixed by inoculated legumes. Available estimates have been calculated in most cases from controlled pot experiments which, when magnified to the acre basis, give results higher than the actual figures.

The average number of pounds of nitrogen fixed per acre by some of the important forage legumes is as follows: sweetclover 117 pounds, alfalfa 100 pounds, red clover 89 pounds, cowpeas 86 pounds, and hairy vetch 79 pounds. From these figures and other data it has been estimated that considerably more than a million tons of nitrogen from the air may be fixed annually by legume bacteria and made available for the use of field crops in the United States.

THE LEGUME BACTERIA

For a long time the existence of different kinds of legume bacteria has been known. For example, the bacteria which work on alfalfa and sweetclover will not function on the clovers or on peas, beans, soybeans, and other legumes. Conversely, the clover organisms fail to work on alfalfa and sweetclover, etc. This fact of definite specificity for the legume bacteria was responsible for the creation of so-called crossinoculation groups of leguminous plants. Any plant...
group could be inoculated with a culture of the proper bacteria, usually comprising several strains known to effectively inoculate all the legumes in that particular group. The crossinoculation groups have been open to criticism because of overlapping of strains of bacteria from one group to another. But for all practical purposes these groups offer a convenient and workable plan for the preparation of inoculant cultures. Farmers have been accustomed to ordering legume cultures according to group designations such as the alfalfa group, the clover group, pea and vetch group, etc. The seven groups now recognized together with a listing of the forage legumes and certain others in each group are given below:

The alfalfa group: In this group are alfalfas, bur-clovers, black medic, and button clover (all of which are *Medicago* spp.) and sweetclovers and sourclover (*Melilotus* spp.).

The clover group: In this group are the true clovers (*Trifolium* spp.) which include among others, red, alsike, crimson, white, strawberry, Persian, subclover, and the hop clovers.

The pea and vetch group: In this group are the true peas (*Pisum* spp. and *Lathyrus* spp.), and true vetches (*Vicia* spp.).

The bean group: In this group are garden beans, kidney beans, pea beans, Great Northern beans, Pinto beans, and scarlet runner beans, none of which are in common use as forage crops.

The cowpea group: In this group are cowpeas, asparagus bean, lespedezas, velvet bean, Lima bean, Topary bean, Adzuki bean, mung bean, Florida beggarweed, tick trefoil, peanuts, kudzu, alyceclover, pigeon pea, and hairy indigo.

The soybean group: In this group are all varieties of soybeans.

The lupine group: In this group are all the lupines (*Lupinus* spp.), and serradella.

Miscellaneous legume bacteria: In addition to the above seven groups, the following legumes appear to require specific strains of legume bacteria for their effective inoculation; birdfoot trefoil, big trefoil, sanfoin, hemp sesbania, trailing wild bean, crown vetch, and certain others.

This grouping of legume plants has proved to be of great value from the practical viewpoint. It is obviously not necessary to have a culture of legume bacteria for each and every legume to be planted. It is necessary and extremely important, however, to have a sufficient number of different strains of known effectiveness in an inoculant to properly inoculate all the legumes specified on the culture label.

**STRAIN VARIATION AMONG THE LEGUME BACTERIA**

It has been emphasized that not all the legume bacteria are the same. Some prefer to work with a specific kind or group of plants, whereas others work only with another group. Still others will function only on a single legume species. Another difference among the legume bacteria is the variation in effectiveness between strains of bacteria isolated from the same legumes and from different legumes within the same group. This type of strain variation among the legume bacteria has great practical significance.

Different strains of bacteria when tested on legumes grown under controlled conditions show great variations in effectiveness. Some strains are high nitrogen fixers, others are poor nitrogen fixers, and still others may show gradations between these extremes.

The method for studying this strain variation has also shown the existence of parasitic strains of legume bacteria. These are able to enter the plant legume root and form numerous small nodules but fail to fix any nitrogen or otherwise benefit the plant.

This discovery of parasitic or ineffective strains of legume bacteria has put less credence in the number of nodules as a measure of the value of a legume inoculant. Numbers of nodules fail to tell the whole story of the effectiveness of the bacteria in fixing nitrogen. It is necessary to measure plant growth re-
INOCULATION OF LEGUMES

sponses, particularly mass, vigor, color and if possible, total nitrogen analyses. Producers of commercial cultures today realize the great importance of using only highly effective nitrogen fixing strains of legume bacteria in the preparation of their legume inoculants. The search for new and better strains is continuous, for the cultures that prove of greatest benefit under field conditions will be the ones in greatest demand by farmers.

Some interesting and important observations of strain variation among legume bacteria should be emphasized.

1. The alfalfa and sweetclover strains will work on alfalfa or sweetclover equally well but they fail to produce nitrogen fixation in bur-clovers or fenugreek. Strains from bur-clover and fenugreek, on the other hand, will work and fix nitrogen on bur-clovers, fenugreek, alfalfa and sweetclovers.

2. Strains from red and white trifolium clovers fix nitrogen on their host plants, but not all of them effectively inoculate crimson clover. One strain isolated from berseem clover was effective on all clovers tested except white and red clovers.

3. Strains of legume bacteria show definite varietal preferences. For example, some soybean bacteria work on one or two soybean varieties better than on other varieties. The same is true for different varieties of canning or freezing peas.

4. Strains of legume bacteria from birdsfoot trefoil (Lotus corniculatus and L. tenuis) may be highly effective on their host but totally ineffective on big trefoil (L. uliginosus). Big trefoil strains fail to work on birdsfoot trefoil, though they may be highly effective on big trefoil. Strains have been discovered recently that are effective on all three species, or on one species and certain strains of the other species, so it is probable that commercial cultures will soon be available that can be used for all cultivated lotus-trefoils.

Strain variation studies have opened the way for soil bacteriologists and producers of commercial inoculants to prepare more effective cultures for all kinds of legumes. In many instances, specific strains have been shown to be more efficient for specific legumes. Preparation of such cultures have been particularly desirable for experimental plantings of new legumes in new areas.

NECESSITY FOR INOCULATION

Not all agricultural soils contain the necessary legume bacteria to promote the successful growth of legumes. In some cultivated soils, the legume bacteria naturally present are of the mediocre or relatively ineffective type of nitrogen fixers. For example, in Wisconsin one hundred soybean fields were examined and nodules collected for isolating the soybean bacteria. When these strains were tested on soybeans it was found that 25 percent were considered highly effective, 50 percent were only average and the rest were poor or ineffective. Even though the bacteria for a certain legume may be present in a given soil, the question always arises, are they there in sufficient numbers and are they the high nitrogen fixing strains?

Before a legume is planted farmers cannot be sure that sufficient legume bacteria of the proper kind are present in their soils. Neither can they be sure that the bacteria in the nodules on a previous legume were of maximum benefit to that crop. It is entirely possible that the bacteria left in the soil may lose their beneficial properties, that is, their ability to fix appreciable quantities of air nitrogen.

Too often it is taken for granted that inoculation is not necessary because the
legume was grown in the same soil. If the proper bacteria are not present the young legume plants look spindly, sickly or yellow and may or may not show nodules on the roots. Such cases present a real problem because it is so much more difficult to get growing plants inoculated. Greater success is assured if the seeds are inoculated before planting.

The one fundamental purpose of legume inoculation is to add a fresh culture of effective strains of legume bacteria to the seed (preferably), so that when the young plant begins to grow, the bacteria will be right there to enter the tiny root hairs and begin their beneficial work in the early stages of the plant’s growth.

Now that farmers can purchase legume inoculants prepared with the most efficient strains which are adapted to their legumes, the simplest, easiest and most economical way to insure the successful growth of legumes is to inoculate legume seeds before each planting. Good sound advice to all farmers is “Inoculate in all cases of doubt and always on new land.”

CONDITIONS THAT AFFECT LEGUME BACTERIA

Under natural conditions of competition between inhabitants of the soil, legume bacteria have an advantage by their protection in nodules from time to time. Without this association, the nodule bacteria must meet adverse soil conditions successfully if they are to survive. Conditions essential to the satisfactory growth of legumes is to inoculate legume seeds before each planting. Good sound advice to all farmers is “Inoculate in all cases of doubt and always on new land.”

Nodule bacteria of alfalfa, sweetclover, and red clover, are representative of those that are not very acid-tolerant, while soybean, velvetbean, cowpea, vetch, lespe-deza, and lupine bacteria belong to the acid-tolerant types.

Cultures of nodule bacteria are alive and should be treated as living things. They will tolerate low temperatures much better than high ones. If exposed to a heat that is unbearable by man, or even uncomfortable, the efficiency of the bacteria may be impaired. Inoculating material should, therefore, be stored in a cool place until used.

Although legume bacteria will tolerate sunlight to some degree, unnecessary exposures either of the unopened containers or of the seed that has been treated should be avoided. Bacteria when dried on seed soon die. If conditions require that inoculated seed be kept for 48 hours, it is advisable to reincoculate. For this reason the purchase of preinoculated seed is not advisable.

Seed treated with legume bacteria should not come in direct contact with caustic lime or concentrated mixed fertilizers. Inoculated seed may be drilled down the same spout with superphosphate or basic slag without injury to the bacteria. Generally it is safe to conclude that if the concentration of fertilizer does not injure seed germination it will not harm the legume bacteria.

Most seed disinfectants are toxic to the legume bacteria and consequently legume seeds which have been treated with these compounds should not be inoculated in the usual manner. In large scale operations, the inoculum is mixed with wheat middlings, sawdust or other inert material and drilled in advance of planting. This practice, called “Pre Planting” of the bacteria is successful in those areas where the necessity of seed treatment is indicated.

PREPARATION AND USE OF COMMERCIAL CULTURES

Soon after the discovery of the legume bacteria and their power to fix nitrogen in nodules on leguminous plant roots, soil
bacteriologists began to cultivate these organisms on artificial media in the laboratory. A few years later, prepared cultures were offered for sale to farmers. These early cultures were made with specific bacteria for a specific kind of legume and their use resulted in varying degrees of success under field conditions.

The few failures did not discourage the originators of commercial cultures. They developed more suitable media and improved methods of application that made for greater success, and gradually a demand for legume inoculants was created by farmers. This gave rise to the formation of a number of companies who manufactured legume cultures and sold them mostly through seed dealers.

To prepare effective cultures for legumes, the persons engaged in the work must have specialized training and experience. Adequate laboratory facilities, equipment for controlled production, and greenhouse space or other suitable means for growing plants, are prerequisites to satisfactory production.

Routine in such a laboratory calls for periodic tests and transfers of all strains of legume bacteria used in the production of commercial inoculants. These tests are made for purity and efficiency on growing legume plants. The isolation of new strains is an important feature of the work. These must be purified and tested also. A selection is made of the most effective strains and a given number is used for the production of the different culture groups. The bacteria are either grown in liquid media or on the surface of agar. Heavy suspensions of bacteria are used for mixing with the carrier, which may be a finely ground peat or mixtures of peat and charcoal, peat and sand or other materials.

The three types of carriers generally used for legume bacteria are (1) moist humus or finely ground peat; (2) agar; and (3) liquid. The great bulk of the commercial inoculants is prepared in the moist humus. Most seed suppliers handle one or more brands of commercial legume inoculants, and they are therefore readily available to the consumer trade. Because of the perishable nature of these living bacteria, dealers are cautioned not to store the cultures in places with excessive heat or drying conditions. Be sure that the culture is prepared for the seed you wish to plant, and use it before the expiration date.

In using agar cultures add a small quantity of clean cool water to the bottle, shake it vigorously to get the bacteria in suspension, add more water and then pour the bacterial suspension on the legume seeds and mix them until all are moistened. With the peat or humus-type inoculant the seeds are either moistened with water and the contents of the container emptied on the seeds and mixed until all seeds are coated with the black substance; or, a specified amount of water is added to the inoculant to form a thin paste which is poured on the legume seeds. A thorough mixing is essential in all cases, and care should be taken not to use too much water. Soaking the seeds should be avoided.

After legume seeds are inoculated with legume bacteria cultures they should be sown as quickly as possible. Ideal conditions prevail if a gentle rain follows shortly after planting. However, there are times, especially in the South, when inoculated small legume seeds remain on or near the surface of the soil exposed to the hot drying winds for several weeks. Experience has shown that in such cases supplemental inoculation is advisable. This may be done by mixing a legume inoculant with materials like cottonseed meal, wheat middlings, or even sand, and broadcasting over the soil when moisture conditions are favorable.

In other cases where young legume plants show a lack of proper inoculation, it may be desirable to resow the area with inoculated seeds. The bacteria added on the seed may eventually gain access to the root hairs of the growing plants and produce successful inoculation.

The demand for effective legume inoculants has shown a rapid and steady increase during the past two decades. In 1929 estimates gathered from producers and agricultural colleges indicated that there were distributed in the United States in the neighborhood of 1,500,000
bushel-size units per year. A survey of the industry made in 1940 indicated that about 11,135,000 units were distributed. The estimated gross income for 1940 for the industry was around $950,000. A survey completed for the year 1946, showed a total of around 17,500,000 bushel units were prepared for distribution to farmers and large growers of various legumes. The gross income to the producers for 1946 was estimated at around $1,500,000. In actual dollars, representing the amount paid out by farmers, the total for 1946 would be about $4,000,000.

These data supply evidence to show that the legume inoculant industry has grown to considerable proportions and certainly plays an important role in our American agriculture.

Probably there is no other commodity purchased by farmers, that gives greater returns per dollar invested than do legume inoculants. The average cost for soybean inoculants when purchased in the larger sizes is around 10 cents per bushel. The cost of the one bushel size unit for alfalfas and clovers is around 50 cents. This size will inoculate from 3 to 5 acres depending upon the rate of sowing. Legume seed inoculation is cheap legume crop insurance.

**INSPECTION OF LEGUME INOCULANTS**

To protect farmers from buying worthless cultures, certain control agencies have been set up. In 1916 the United States Department of Agriculture began testing commercial legume inoculants in accordance with an Act of Congress, providing for soil microbiological investigations—including the testing of samples procured in the open market of cultures for inoculating legumes, other crops, or soil, and if any such samples are found to be impure, nonviable, or misbranded, the results of the tests may be published, together with the names of the manufacturers and of the persons by whom the cultures were offered for sale. The testing process consists of inoculating seed according to directions on the container, and planting in sterile sand moistened with a sterile nutrient solution. Great care is necessary to prevent the entrance of nodule bacteria from without and the transfer of bacteria from one pot to another. When a culture under these conditions does not produce nodules and fails to increase plant growth or produce a darker green color than the uninoculated controls, it is considered unsatisfactory.

In addition to testing commercial legume inoculants over this period of years, the United States Department of Agriculture has kept in close touch with the inoculant producers. A representative of the Department has visited the more important laboratories and offered to help the manufacturers in production problems, and thus assure better cultures for the farmer. A few of the States also have control agencies the main purpose of which is to protect their farmers from unscrupulous producers and dealers. All these agencies have had a decided effect in bringing about improvements and raising the standard and quality of the inoculants.

Commercial cultures for legumes have reached a high state of reliability and when obtained from reliable sources can be depended upon to produce satisfactory results.

**RESEARCH WITH LEGUME BACTERIA**

Despite the progress that has been made with legume inoculation, there are still a number of practical problems as well as many of a scientific nature that await solution.

In the Department's research on the improvement of legume inoculation, one phase has been concerned with obtaining and making available for experimental use a collection of highly effective strains of legume bacteria. Studies have been made on the physical, chemical and biological factors that influence the efficiency, activity, and longevity of the legume bacteria for different legumes growing under widely varying soil and climatic conditions.

A number of workers in the different
INOCULATION OF LEGUMES

experiment stations are attacking research problems, to learn more of the physiology of these microorganisms, and the mechanism of nitrogen fixation.

Some of the companies preparing inoculants maintain research departments. All are searching for more effective strains of legume bacteria that are superior to those naturally present in soils. Large acreages of lima beans, navy beans, kidney beans and peanuts are planted each year without inoculation because it has not been proved that these legumes respond to inoculation as do other legumes. Reasons for these apparent abnormalities are being investigated.

The advent of chemical seed disinfectants and their recommended use for certain legumes have created obstacles to the program of more successful legume inoculation. One or more of these seed treatments were found to be compatible with legume bacteria to a certain degree, but workers are searching for ways to successfully inoculate and chemically treat legume seeds without involving separate drilling operations.

ECONOMIC IMPORTANCE OF LEGUME INOCULATION

Good effective inoculation of legumes has been a controlling factor in increasing the yield and quality of legume crops. It makes possible greater quantities of high protein feeds so necessary in the production of livestock. Much nitrogen is added to the soil by legumes, and in addition they contribute greatly to the maintenance of organic matter in soils. Organic matter improves the physical properties of soils, increases the moisture holding capacity and the microbiological activity, and absorbs plant food elements. The activity of soil organic matter determines its real value. If it is high in nitrogen and the soil is well supplied with calcium, other soil microorganisms break it down and with necessary fertilizer additions provide a readily available supply of plant food for crop production.

The legume bacteria have, therefore, a big share in the world's food program. First, indirectly by increasing the amount of nitrogen in the soil through greater growth of legumes and organic matter, making possible greater production of other farm crops; second, by increasing the supply of high protein feeds for domestic animals; and, third, by increasing the yield of soybeans, peas and other legumes eaten for food.

Of the potential area of about 498,300,000 acres that can be put under cultivation in the United States, approximately one-fifth is planted to some legume crop—hay, seed, cover crop or pasture. Such recognition of the value of leguminous plants is well founded and shows the great importance of legumes in agriculture. Carrying out a successful inoculation program along with expanding legume acreage will make agriculture even more profitable.

HIGHLIGHTS OF LEGUME INOCULATION

1. The fixation of free nitrogen from the air by legume bacteria and the making available of such nitrogen to the host plant and to the soil in a form that can be used by either the host plant or associated plants, were discovered by Helricgel over 60 years ago.

2. The legumes are the only group of economic plants in which this symbiotic relationship between host plant and nitrogen-fixing bacteria exists, which probably accounts for the species of this group having the highest nitrogen content of any group of flowering plants.

3. The quantity of nitrogen supplied to the host plant and to the soil varies with the species of host plant, the strain of bacteria, and with soil conditions.

4. Optimum field production of legume crops is dependent on effective nitrogen-fixing bacteria since there is no other practical way of supplying such legumes in the field with the same quantity of equally available nitrogen.

5. Certain groups of leguminous plants are found to use the same general strains of bacteria, e.g., the alfalfas and sweetclovers are in the same group, and true peas and vetches are together in another group.

6. Strains of legume bacteria have been developed having a high nitrogen-fixing efficiency with certain species or varieties of legumes within a group.
7. Soil conditions, climate, moisture, fertilizers, acidity, and other factors affect the activity and efficiency of legume bacteria. Those conditions essential to the satisfactory growth of legumes or the particular legume planted must be supplied if maximum results from inoculation are to be obtained.

8. Acid soils tend to eliminate legume bacteria in accordance with the degree of acidity of the soil, and the ability of the bacteria to tolerate this condition. Some bacteria are more or less acid tolerant, while others are not.

9. The quantity of nitrogen fixed annually by many of the important cultivated forage legumes averages around 100 pounds per acre.

10. The presence of, or the number of, nodules on the roots of legumes is not an accurate measure of the value of the inoculation since certain strains are much less effective than others in their nitrogen fixation even though they form numerous nodules, and some are actually parasitic.

11. Some soils do not contain the necessary legume bacteria or may contain only relatively ineffective strains. Therefore, unless it is definitely known that the soil contains the right kind of bacteria of a highly effective strain, artificial inoculation should always be used when sowing legume seed. “When in doubt, inoculate.”

12. The effective bacteria in inoculating cultures are living organisms and should be handled accordingly. The cultures should be stored in a cool place until used and not be exposed to high temperatures. After legume seeds are inoculated they should be sown or planted as quickly as possible.

13. If inoculated legume seeds are not sown under favorable conditions for quick germination and plant development, the legume bacteria may be destroyed, in which case a supplemental inoculation may be necessary to obtain satisfactory results.

14. Most chemical seed disinfectants are injurious to legume bacteria, so care should be exercised where both kinds of treatments are desired.

15. Tests have shown that a large percentage of the commercial legume cultures on the market today put out by well known concerns can be depended upon to produce satisfactory results.

16. More effective strains of nodule bacteria and better methods of preparation and use are being developed through extensive research in Federal, State and private laboratories.

**THIS CHAPTER**

The research on nitrogen fixation by legume bacteria, upon which our present literature on this subject is based, has been done mostly by the U. S. Department of Agriculture, State experiment stations, and by private institutions and commercial concerns since 1900. The material in this chapter was taken largely from the recent bulletin by Redman (US-56) who has reviewed this manuscript.

**Chapter reference numbers:** 1 IDA-1; ILL-1; IND-12; KAN-21; NY-43, 44; WIS-38; US-55, 56.

1 The reference numbers given here refer to references which are given in full by State, U.S.D.A., and Miscellaneous, on pages 682 to 724, and which are cross-referenced by author on pages 725 to 731. Citations in the text are indicated by abbreviation and number in parentheses.
CHAPTER IV
GREEN-MANURE AND COVER CROPS

The sowing and growing of cover and green-manure crops is an imitation of Nature's method of maintaining soil fertility and holding the soil. As the natural soil-forming agencies progressed throughout the ages, Nature always protected her handiwork with a varied vegetative blanket. Man cannot disregard this plan and ignore the fundamental principles of soil building and soil holding without paying the price of accelerated soil depreciation and erosion.

Under natural conditions some type of vegetation occupies the soil throughout the growing season and leaves an organic residue to cover the ground during the winter. If agriculture is to be permanent, the soil must be managed so as to maintain its productivity. Also, the soil itself must be conserved by using cover crops in rotation or association with row crops and other crops that occupy the land for only a part of the growing season or form a partial soil cover.

The practice of using cover crops for green manure, or turning them into the soil while yet green, is almost as old as agriculture itself. It is a more or less common practice in certain parts of the United States, but it is only in recent years that we have come to a fuller understanding of the practice and the use of cover and green manure crops in the prevention of soil erosion and in soil improvement in connection with forage production.

A green manure crop improves the soil by adding organic matter and by supplying plant food for succeeding crops. It provides a ground cover which prevents erosion during its growing period, and subsequently adds fertility to the soil.

In order to utilize such crops most efficiently, special consideration must be given to many factors; but in any case, erosion or loss of soil will have been prevented during a part of the year, and if the green manure is properly utilized increased crop production will result.

Green-manure crops are grown more often in winter because summer is the season when most cash crops must be grown. Growing summer green-manure crops, however, is practical in rotations or in mixed plantings. This provides one of the most economical ways to maintain soil fertility, insure increased crop yields, and improve the soil.

The use of a legume in the rotation as one of the regular cash crops is a common practice and one of the most economical ways of maintaining soil fertility and crop production. The stubble of the legume returns to the soil considerable organic matter that is high in nitrogen and that costs practically nothing.

Any crop while serving as a solid ground cover, whether or not specifically planted for that purpose, is a cover crop. Thus, a growing grain crop, grasses in pastures, and crops planted for turning under as green manure are cover crops. General usage, however, perhaps restricts the term more definitely to crops that are planted especially for the purpose of checking soil erosion, adding organic matter to the soil, and improving soil fertility, and it is for use on lands under cultivation that cover crops need most consideration, although the vegetative cover in any situation is of first importance in soil conservation.

The advantages of cover crops ordinarily far outweigh any reasonable objection which can be made to them.
Nevertheless, some features are occasionally raised as objections to the use of a cover crop, such as cost of seed and of labor in the preparation of seedbed and sowing the seed without direct cash return, uncertainty of getting a stand, possible adverse effect on moisture condition of the soil, and possible refuge for insect pests, such as cutworms, that later attack corn or other crops.

Most of the species used as cover or green-manure crops are also useful as forage. Most of the characteristics which are essential to one are also essential to one or both of the others. Cover crops should have good root systems and form a good ground cover. Green-manure crops should develop a large growth both above and below ground in order to supply an abundance of organic matter to the soil and, in the case of legumes, also add nitrogen. Forage crops should supply an abundance of palatable, nutritious forage for animal growth, and production of animal, dairy, and poultry products. These three uses overlap each other to such an extent that a very large number of grasses and legumes are suitable for all three. Since so many forage plants are suitable also as cover and green manure crops without detracting from their forage value, it is ordinarily most feasible and profitable to use for cover or green manure those crops which can also be used for forage, since the latter use brings the most nearly direct cash returns.

VALUE OF GREEN MANURES

Among the reasons commonly advanced for the use of green-manure crops, some are based on obvious facts, but others are less apparent. In regions where soils erode badly a growing crop on the land during the season of heavy rainfall will prevent much washing. It is well known that soils containing a high percentage of organic matter will wash less than those in which it is low. Thus a green-manure crop will prevent much erosion both during the period of its growth and for the time that it increases the organic content of the soil.

The addition of organic matter usually improves the physical condition of the soil. This is noticeable in its increased moisture-holding capacity and in the ease with which it can be worked when being plowed or disked.

In addition to improving the physical condition of the soil and preventing washing, a winter green-manure crop prevents leaching of plant food during the winter season. When there is no growing crop on the land the plant-food elements that become available through decomposition or otherwise are lost. A growing crop takes up these elements, and they are again made available when it is turned into the soil. In this way a green-manure crop conserves fertilizer. It not only takes up the plant food that otherwise would leach from the soil but legume crops also add nitrogen, which they take directly from the air.

A fertile soil has a large number of micro-organisms. In order that these may flourish, organic matter must be supplied. Organic matter also has an effect on the mineral elements of the soil and aids in making them available as plant food.

It has long been recognized that legumes are beneficial to nonlegumes in the rotation. Nonlegumes in continuous culture give smaller yields than are obtained from those in rotation with legumes. This increase is due in part to the nitrogen that the legume takes from the air. In addition, other unexplained factors that persist after the fertilizing material of the plant has disappeared appear to have a beneficent effect on nonlegumes.

The net results accruing from the use of winter legumes are increased yield of the crop that immediately follows and smaller but noticeable increases in succeeding crops for several years.

INOCULATION

Under most conditions legumes need to be inoculated with nitrogen-fixing bacteria. This can be accomplished by the use of commercially available pure cultures, directions for which will be found on the package. Inoculation can be induced also by the use of soil from a field that has recently grown the crop it is de-
sired to inoculate, but this latter method is not now recommended since commercial inoculants are so generally available and so much more satisfactory.

One of the most essential things in inducing inoculation and good subsequent growth of winter legumes has to do with the use of fertilizers. Commercial fertilizer, unless it is basic slag, should not come in contact with inoculated seed, as it may injure the inoculating organism. A general application of fertilizer, however, preceding or at the time of sowing, is essential to success.

If the summer crop preceding the legume has been well fertilized, the quantity applied to the legume crop can be greatly reduced or in some cases entirely omitted.

**Fertilizers**

The successful growing of a green-manure crop on the poorer lands of the South requires the use of commercial fertilizer. Of the common fertilizer constituents phosphoric acid is usually the most needed. On the poorer lands, however, the addition of nitrogen will help materially. This should be used until a winter-legume green-manure crop has been grown successfully. The fertilizer should be applied in the fall just prior to sowing the green-manure crop or at the same time.

The quantity of fertilizer to be used varies with soil and cropping conditions. When the summer crop preceding the winter legume is heavily fertilized, little if any fertilizer will be needed on the winter legume. If the soil is poor and the summer application of fertilizer is light, it is advisable to use 200 pounds or more of superphosphate, or 300 of basic slag and 50 of sodium nitrate or ammonium sulfate or an equivalent nitrate fertilizer. When growing a winter legume for the first time on land that has been only moderately fertilized it is advisable to use as much as 400 pounds of superphosphate or 600 of basic slag per acre and 100 of a nitrate fertilizer.

Lime used occasionally at the rate of 1 to 2 tons per acre in addition to the fertilizers mentioned, sometimes increases the yields.

Whether commercial fertilizer should be used on a summer green-manure crop can generally be determined by observing the local practice with the same crop grown for immediate cash returns. Ordinarily heavy growth is desired in a green-manure crop, so when at least a fair growth cannot be attained without fertilizer, a sufficient amount should be used.

**Turning Under**

A green-manure or cover crop may be left on the surface, or it may be combined with the surface soil by diskmg or plowing. When it is mixed with the soil, care should be taken not to leave the green-manure material in bunches or layers that will not decompose readily. Large quantities of undecomposed material will tend to make the surface soil dry and result in a poor seedbed and crop growth. When ample moisture is present, a crop completely turned under ordinarily will decompose more rapidly than one left on the surface or only partially turned under. Whether a green-manure crop should be completely turned under, partially combined, or left on the surface of the soil should be considered further in connection with (1) maturity of the crop, (2) time of year, (3) length of time that will elapse before the growth period of the succeeding or cash crop, (4) nature of the succeeding or cash crop, (5) type of soil, and (6) moisture supply.

The crop should be turned down a sufficient length of time before an annual crop is planted to enable the material to pass through the first stages of decomposition in order that the plant food thus liberated may be available to the growing crop during its early development and rapid-growth period. Sowing a crop immediately after turning under a green-manure crop will sometimes result in injury to the young seedlings. In experimental planting it has been found advisable to let 2 weeks elapse before planting corn and 3 weeks before planting cotton. In
the case of such a permanent crop as trees, exact information is lacking, but it is assumed that the green-manure or cover crop should be decomposed if possible just before the rapid-growth period.

Organic matter usually can be incorporated into heavy clay soils without serious danger of loss from leaching, since leaching in such soils takes place slowly. In sandy or porous soils leaching is rapid, so it is important to have the green-manure material nearly mature and to leave it at the surface so that decomposition and leaching can be retarded.

When ample moisture is present and the temperature is sufficiently high for plant growth, decomposition goes on rather rapidly under almost any soil condition. In general, however, decomposition is retarded by leaving the green-manure material on the surface or working it in lightly or partially.

Such other factors as the effect on crops of plowing or working the soil at certain times of the year must be considered in handling the green-manure crop.

SUMMER GREEN MANURING

Under the broad definition of the term, four types of summer green manuring need consideration: (1) Using the crops exclusively for green manure, (that is, the green-manure crop occupies the land the entire season to the exclusion of any other crop), (2) growing a green-manure crop intermixed with the main crop but subsidiary to it, (3) growing a green-manure crop in midsummer or late in summer following a cash crop, and (4) using legumes in rotation with other crops and treating the stubble or aftermath of the legume as a green-manure crop.

The giving over of the entire crop season to the exclusive use of a green-manure crop is seldom profitable. This practice perhaps is justifiable only when the succeeding crop is more or less permanent and the establishment and good growth of the seedlings or young plants are of prime importance.

In the South when a summer legume is plowed under early in fall, it should be followed with rye or some other winter-growing crop to prevent the leaching of the plant food released in the decaying of the turned-under crop. When a summer green-manure crop is not followed by a winter crop, it should not be plowed under green but should be cut in the fall and allowed to remain on the surface as a mulch or should be lightly worked into
the soil so as to delay decay and prevent loss during the winter months.

In northern latitudes there is relatively little leaching during the winter period, so it is seldom profitable to grow a crop merely to prevent this relatively small loss. A legume might well be sown to occupy abandoned or worn-out lands more or less permanently, and where seed of a satisfactory legume is available at a reasonable price, such a procedure is advised. In certain parts of the South lespedeza and crotalaria can be used in this way.

When a legume, such as corn, is the main cash crop the use of a legume intermixed in the planting, or interplanted, will furnish valuable organic matter and in part have the effect of a crop rotation. Soybeans and velvetbeans are commonly planted with corn this way in the Corn Belt, and the practice is recommended.

Sometimes a green-manure crop can be planted in spring or midsummer with or following an early cash crop such as wheat, oats, or some truck crop. Whether a crop thus grown can best be used exclusively for green manure, or in part for forage and part for green manure, will have to be determined by the probable cash value to the succeeding crops and the value of the forage that might be obtained.

**Summer Crops Used for Green Manure**

The summer crops commonly used for green manure and soil improvement are such legumes as alfalfa, red clover, soybeans, cowpeas, velvetbean, sweetclover, crotalaria, and lespedeza. Other crops, both legumes and nonlegumes, are limited by special or local conditions, as indicated under the several crop headings.

Alfalfa and red clover are used in rotations as cash crops, as crops to turn under as green manure, and as permanent cover crops in orchards. Soybeans, cowpeas, and velvetbeans are used in rotations as cash crops, as crops to turn under for green manure, and as crops to grow in combination or intermixed with corn.

Sweetclover is used in rotations as a cash crop and as a crop to turn under for green manure. Lespedeza is used as a cash crop in rotations and, to a limited extent, for green manure. Crotalaria is used exclusively for green manure.

Although legumes are generally recognized as the most desirable green-manure plants, nonlegumes, under certain conditions, may be used more profitably. When the period during which the green-manure crop can occupy the land is very short, as is usually the case in truck growing, the farmer wants a crop that will make the most growth in the time available. Under such circumstances, Sudan grass, another of the sorghums, or, in certain parts of the South, pearl millet often can be used.

In improving poor or worn-out soils, a nonlegume such as buckwheat sometimes serves better than any legume. For supplying organic matter to the soil, the crop that will produce the most growth in the time available should be chosen, whether a legume or a nonlegume.

**Alfalfa:** Alfalfa, while primarily a hay crop, is valuable in crop rotation and is used effectively as a green-manure and cover crop. In the irrigated apple orchards of the Rocky Mountain and the Pacific Coast States it is being used with excellent results as a cover crop, and in the truck-crop areas of the Southwest it is popular for preceding or rotating with lettuce, cantaloup, or similar crops.

When common alfalfa is grown in orchards or elsewhere for green manure or cover, the time, rate, and method of seeding are the same as when the crop is grown for hay or other purposes.

**Buckwheat:** Buckwheat is a very old crop, used in Asiatic and European countries from very early times. In the United States it is grown mostly in the Northeast, Pennsylvania and New York having half the total acreage. It can be grown on poorer soils than most crops, does well on acid soils, and liming is seldom necessary. For these reasons, it can sometimes be used in preference to other crops for adding organic matter to the soil.

**Common sesbania:** Common sesbania is native to North America and extends as
far north as Alabama, Georgia, and Arkansas. In the southwestern part of the United States it occurs in abundance on the overflow lands of the Colorado River, and in Louisiana it is common in the rice fields.

In recent years this species has come into commercial use as a green-manure crop and is commonly known in the trade under the name of "sesbania." It is an upright annual legume attaining a height of 6 to 8 feet. In thin stands it is moderately branched, but in thick stands the lower branches either fail to develop or are shed very early and the upper branches are rather light and leafy.

The only use made of common sesbania is for green manure. It seems to be disliked by livestock and, so far as known, has no value as forage. On account of its rapid growth and the heavy tonnage produced, this crop seems well suited for green manure where the land can be given over to this purpose during the midsummer season.

Cowpeas: Cowpeas are one of the summer crops most commonly used for green manure in the Southern States. Under most conditions, cowpeas make a good yield of green manure in comparison with other crops and are also valuable as a forage and seed crop. Adapted to a wide range of soils, they apparently do as well on sandy soils as on clays. Among the best varieties for use in the South are Iron, Victor, Brabham, and Griot.

Crotalaria: Three species of Crotalaria have been used for green manure in the United States—C. spectabilis, C. intermedia, and C. striata. Crotalaria lanceolata and C. juncea have given good results in experimental plantings. Other species with similar habits have value for this purpose and are used in other parts of the world. All these species behave as annuals in the United States except under almost frostless conditions. They are upright and attain a height of 3 to 6 feet. A warm season is necessary for their best development.

Florida beggarweed: Florida beggarweed, an annual, upright, herbaceous plant, attaining a height of 4 to 7 feet, is a native of tropical and subtropical America, occurring as far north as the southern part of the United States, especially in cultivated lands. The plant is leafy above, but sparingly so below, and the main stem is sparsely branched. In thick stands the branches are greatly reduced or fail to develop.

In Florida and as far north as southern Georgia and Alabama, it has been used as a regular and volunteer crop. In more northern latitudes it can seldom compete with summer weeds.

Lespedeza: Common lespedeza is an annual spreading or upright leguminous plant well adapted to the Southeast and is found as an escape throughout the Piedmont and Coastal Plains areas, extending north to and beyond the Ohio River and west beyond the Mississippi River. It is in this general region that the crop is most valuable. For soil improvement, common lespedeza offers great possibilities. It may be used for green manure, hay, or rotating with other cash crops.

Korean lespedeza is like common lespedeza in general but differs in its range of adaptation, season of development, and minor plant characteristics. It cannot be used successfully as far south as can common lespedeza, but it has a somewhat farther northern range.

Sericea lespedeza is a hardy perennial plant similar in growth to alfalfa. It will grow on soils of greater acidity and lower fertility than most other crops and has greatly increased the yields of crops that it precedes. For controlling erosion on poor acid soils and increasing the soil fertility there is no crop superior in the region in which it is adapted.

Red clover: Red clover has long been known as a valuable crop for soil improvement. It is commonly used in crop rotations, often as a summer green manure crop, and also as a combination hay and green-manure crop. The early or first growth is cut for hay and the later or second growth used for green manure. Another way of handling it is to cut the first crop for hay, then harvest a seed crop and return the straw to the land. When only the stubble is left in the
fields the soil will benefit from the nitrogen gathered by the nodule-forming bacteria that live on the roots. The fact that red clover has upright growth and heavy yields, together with its fitting so readily into rotations with other crops, makes it one of the best crops for soil-improvement purposes.

Soybeans: While the soybean is grown primarily for seed, it is also used extensively for forage and soil improvement. When used for a green-manure crop, late-maturing varieties will usually give the largest yields. When they are used as a regular crop in rotations, varieties should be selected that will give high yields of seed or hay, as the grower may desire.

Sudangrass: Sudangrass is an easily grown nonlegume whose habit of rapid growth makes it a suitable plant for green manure when the period in which such a crop can be used is very short. The stems are upright, attaining a height of from 3 to 5 feet and a diameter equivalent to that of an ordinary lead pencil or less. Such a plant is especially serviceable in connection with truck-crop growing where the summer period between crops must usually be short.

The time of turning down should be determined with reference to the time of planting the succeeding crop and not to the stage of development of the Sudangrass. Ordinarily very succulent Sudangrass will decompose rapidly, and a short period after its turning under the soil will be in condition to receive the succeeding crop. When the plants are more mature, a longer time is required.

Sweetclover: There are two species of sweetclover that are used as summer green-manure crops in the United States — white and yellow. The first year of seeding they make a growth of 12 to 24 inches, depending on moisture and soil conditions, and in the second year reach a height of 4 to 5 feet. In the Corn Belt, white sweetclover has been especially useful as a soil-improving crop. Large increases of corn and other crops have followed its use as a green manure and hay crop in rotations. The heavy top growth and large deep-penetrating roots make both these crops excellent for green manure.

Velvetbeans: The Deering (Florida) velvetbean is a vigorous-growing leguminous annual plant that, under favorable conditions, attains a stem length of 40 feet or more. Most varieties are viny, but a bush form has been developed. It is semitropical, adapted only to the southern part of the United States. Velvetbeans are one of the best crops for sandy lands and for maintaining fertility. Because velvetbeans are hardy, yield heavily, and decay readily, they make an excellent green-manure crop.

Alyceclover: Alyceclover has only recently come into use as a cover and soil-improving crop, but it has attained some importance for this purpose in the citrus and tung groves of Florida. It is a low-spreading summer annual legume, with stems more erect in thick stands, and attaining a length of 2 to 3 feet. In addition to its use as a cover crop, alyceclover makes good hay and pasturage. According to present information alyceclover can be recommended for the extreme southern part of the Cotton Belt only.

Kudzu: Kudzu is an excellent soil-improving legume and can be used in rotations for this purpose. It is a long-lived perennial, however, and should be left for a number of years before being plowed under in the rotation. Large increases in yields of subsequent crops have followed the use of kudzu, and it can be grown to advantage in many places where other legumes do not do well. Kudzu is adapted to the same general region and conditions as lespedeza. It is recommended for gully erosion control and will prevent soil washing when used as a hay crop.

Hairy indigo: Hairy indigo, recently introduced into the United States, is an upright branching legume native to tropical Asia, Australia, and Africa. Small commercial plantings have been made in Florida, where it has proved of value both as a forage and a soil-improving crop. It is a summer annual, attaining a height of 4 to 7 feet, with moderately coarse stems becoming woody
with age and leaves that somewhat resemble vetch. Two distinct types are recognized—a large late-maturing strain and a smaller one that matures about a month earlier. The late strain matures seed in November and is adapted to the southern half of Florida. The early strain that matures in October is adapted as far north as the southern half of Georgia. 

Weeds: Weeds are usually thought of as plants that should be destroyed, but much of the vegetation that is commonly termed weeds contributes large quantities of organic matter to the soil. Whenever weeds can be utilized for green manure without sacrificing needed ground moisture and plant food, their presence can be an advantage rather than a detriment.

WINTER LEGUMES FOR GREEN MANURE

The use of winter legumes for green manure in the Cotton Belt has greatly increased in recent years, largely as a result of demonstrations by the State and Federal experiment stations and of practical experience of farmers. Research has demonstrated the value of this practice and the best crops for the purpose.

By "winter legume" is meant a legume that has the ability to survive winter temperatures ranging from 60° to 15° F. or lower and that makes more or less growth during this period. Eight winter legumes are now more or less commonly used for green manure in the Southern States. These are hairy vetch, smooth vetch, Austrian Winter pea, crimson clover, bur-clover, sourclover, Willamette vetch (a variety of common vetch), and blue lupine.

Sourclover has proved adapted to the region that includes California, Arizona, the Delta area of Louisiana and adjoining States, and the blacklands of Alabama and Mississippi. Bur-clover and Willamette vetch are most extensively

Stopping erosion and making waste land productive with Kudzu.
GREEN-MANURE AND COVER CROPS

used in the Mississippi Delta section but can be grown throughout the South, except on the very sandy lands. Austrian Winter pces and smooth and hairy vetches seem to be universally adapted and are the crops most commonly used. Lupines are grown most extensively in northern Florida, southern Georgia, and southern Alabama, but are adapted westward to Texas.

Estimates of the acreage of winter legumes used for green manure in the Cotton Belt have been made from the quantity of seed known to have been shipped into the several States, from figures compiled in a few States from reports of county agents, and from such other sources as were available. These indicate about 250,000 as the total acreage of winter legumes planted in the Cotton Belt in 1929, and about 4,000,000 in 1945. The total acreage planted for green manure would be much above these figures, as large quantities of rye and other cereals are used each year for this purpose.

According to reports of States under the Agricultural Conservation Program, over 18,000,000 acres of green manure and cover crops were grown under that program in 1946. Of this total, some 5,225,000 acres were winter legumes, 3,150,000 were summer legumes, 5,370,000 were sweetclover and the true clovers, 3,150,000 were small grains, 815,000 acres were ryegrass, and the remainder were other crops and mixtures.

Volunteering a winter legume: Winter legumes that can be satisfactorily volunteered are the least expensive. These can be divided into two classes: (1) Early-maturing, hard-seeded varieties, which set seed before time to plant a succeeding crop; and (2) late-maturing varieties with hard seeds, which do not allow a full season for a succeeding crop. In the late-maturing varieties an occasional seed crop will insure volunteering for 4 or 5 years. In the early-maturing crop an annual supply of seed would be available. No winter legume now in use matures early enough to be out of the way for cotton or early planted corn. In fields planted to these crops a hard-seeded winter legume should be allowed to mature occasionally.

Bur-clover is the one legume that is now being handled successfully on a commercial scale. A common practice in the Mississippi Delta section is to allow the bur-clover to mature seed one year in five and to follow it after that with late-planted corn. In this way enough bur-clover seed is assured for volunteering the next four years. It is also possible to leave strips of the bur-clover undisturbed at the time of planting the summer crop, with the idea of cultivating or turning down these strips after the bur-clover seed has matured, and in this manner provide seed for the succeeding volunteer crop.

Dixie crimson clover, a new hard-seeded strain, can be volunteered satisfactorily with proper management. It
can be used throughout the crimson clover area in any way that ordinary crimson clover is used. Its volunteering habit is its distinguishing characteristic.

Bigflower vetch is an excellent volunteering winter legume that, once established, will persist through a long term of years. It matures seed early and regularly, but an occasional crop should be allowed to come to full maturity in order to insure continuous full volunteer stands.

Narrowleaf vetch matures seed early and volunteers readily in waste places throughout the South. It can be successfully grown in orchards and other places where considerable organic matter has been allowed to accumulate. Its use should be extended. Regularly cultivated lands low in organic matter, however, are poorly adapted to narrowleaf vetch.

Hairy vetch under favorable conditions will mature enough seed to volunteer. It matures comparatively late, however, and is liable to damage by the corn earworm. For these reasons, when the vetch is allowed to stand late to produce seed the crop is uncertain and damage to following crops is possible.

Other volunteering legumes that make less winter growth but may serve well under some conditions are roughpea, black medic, rose clover, and Persian clover. All have a high percentage of hard seed that will carry over in the soil for several years.

Yields of green manure: The yield of any green-manure crop will vary with seasons and with different soils and other local conditions. This is especially true when it must be turned down early in order to be out of the way for a succeeding summer crop. This fact should be given first consideration in determining the time of planting and the crop to use.

The average green weight of hairy and monantha vetches and of Austrian Winter peas over a period of years as grown in connection with experimental work in Georgia, Alabama, South Carolina, Mississippi, Louisiana, and Florida, have ranged mostly from around 5,000 pounds to 18,000 pounds per acre. The green weight is about five times the dry weight. The growing periods extended from the first half of October up to sometime in March. At Tifton, Georgia, over a 17-year period, the average yields (green weight) for a growing period from October 15 to March 15 were, 17,420 pounds for hairy vetch, 22,316 pounds for monantha vetch, and 14,433 pounds for Austrian Winter peas. At St. Joseph, Louisiana, the 12-year averages for a growing period from October 9 to March 28 were, 17,394 pounds for hairy vetch, and 15,261 pounds for Austrian Winter peas. Some of the short-period average yields at other points ranged from 2,500 to 10,000 pounds. Blue lupines at Quincy, Florida, are reported to have averaged more than 25,000 pounds over a 3-year period.

Increased yields following green manure crops: Increased yields of corn and cotton have resulted from the use of a green-manure crop whenever a good yield of that crop has been obtained and handled in season. The general experience of farmers as well as experimental results indicate the value of this practice.

At Tifton, Georgia, the average increase in yields of corn and cotton for a 16-year period resulting from the use of three legumes, Austrian Winter peas, hairy vetch and monantha vetch as green manure crops preceding the corn and cotton crops, over those without green manure were 17.2 bushels per acre of corn or an increase of 58 percent, and 478 pounds of seed cotton per acre or an increase of 57 percent. No fertilizer was used with the green-manure crops. All corn plots were given 500 pounds of fertilizer, one series including nitrogen and another without. All cotton plots were given 1,000 pounds of fertilizer, one series including nitrogen and one without. The addition of nitrogen to the fertilizer increased the yields of both corn and cotton following the use of both vetches as green manure crops but did not increase the yields of either corn or cotton following Austrian Winter peas as a green-manure crop. In fact, the average yields of corn with the nitrogen were 1.6 bushels less than those without the nitrogen.
GREEN-MANURE AND COVER CROPS

In a survey of farms using winter legumes in South Carolina, Georgia, and Alabama, the writers obtained estimates from farmers of the increased yields of corn and cotton for a 5-year period following the use of these legumes. The survey covered 353 instances of corn following winter legumes and embraced 4,145 acres of that crop. The average increase in yield of corn for this acreage was 14 bushels per acre. Also, in 147 instances of cotton after winter legumes, covering 1,877 acres, the average increase due to the use of these legumes was 100 pounds of lint cotton per acre.

**Long-time effect of green manures:** Experimental data indicate that the residual effect of winter legumes continues for several years. At the Central Experimental Farm, Ottawa, Canada, a crop of clover gave an increase in corn, oats, potatoes, carrots, and sugar beets planted in successive years. In the latter year the potato increase was 20 bushels per acre, the carrots 11.16 tons per acre, and the sugar beets 13.7 tons.

At Jackson, Tennessee, a well-established stand of sericea lespedeza was turned under preceding the planting of corn. The corn yield was more than doubled the first year and the residual effect of the lespedeza continued to influence the yields through a 10-year period. If the grower merely comes out financially even on the first crop after winter legumes, he will still find their use advantageous because of their influence on the succeeding years' crops.

**INSECTS AND NEMATODES**

In the Cotton Belt little difficulty with insects has been found in growing winter legumes except in cases where the crop has been allowed to stand late in spring. Serious damage to hairy vetch by the corn earworm has resulted when the crop was allowed to stand late in the hope of getting a seed crop. No method of complete control has been discovered for the vetch weevil.

Aphids also may do serious damage to winter green-manure crops that are allowed to continue growth late in spring.

The green-manure crop is turned under for cotton or corn so early, however, that usually little, if any, damage is to be expected. When aphids appear in abundance the green-manure crop should be turned under or disked down at once.

The damage to the corn crop by the southern corn rootworm is increased when the corn follows a green-manure crop. Little or no damage, however, has resulted from plantings made on April 30 and later.

All the winter legumes commonly used in the Cotton Belt are subject to attack by nematodes, and under favorable conditions serious damage may result. All other winter legumes used in experimental planting also are hosts to nematodes, which are most active during warm weather. Serious damage to the green-manure crop can be avoided by delaying the planting until the last of September or early in October, thus bringing the growing season entirely into the cooler part of the year.

**WINTER LEGUMES ADAPTED TO THE SOUTH**

**Hairy vetch:** Hairy vetch is one of the oldest and most commonly used green-manure crops of the Cotton Belt. Being one of the most winterhardy of the vetches, it seldom suffers any winter injury. It is usually considered a winter annual, although when sown in spring it often carries over into the second year as a biennial. The stems are comparatively weak or viny, ascending only with support. The plant has a higher minimum or zero growing point than other vetches that are less winter-hardy, so that in seasons with a low mean temperature its growth may be less than that of others with a lower zero growing point. In mild winters, however, or in winters having a high mean temperature, it may yield as heavily as any less hardy variety.

**Smooth vetch:** In general, smooth vetch is like hairy vetch. It is a variety of the same species but differs in lacking the tufted growth at the ends of the stems and in having fewer hairs, or less pubescence, on stems and leaves. The flowers
are more reddish purple and somewhat smaller. Smooth vetch is winter-hardy in the Southern States and as far north as Washington, D. C., but it cannot be grown so far north as hairy vetch. It has a lower zero growing point than hairy vetch and for this reason can be expected to make winter growth in seasons and at times too cool for hairy vetch. In commercial plantings in the South it has made somewhat better growth than hairy vetch and is to be preferred to that variety.

Woollypod vetch: Woollypod vetch is of proved value for Cotton Belt conditions but it is not now found in the trade, though it was once grown commercially in small quantity. In general appearance and in cultural requirements woollypod is very much like smooth vetch. In fact, when growing in the field the two can be readily mistaken one for the other. The minimum temperature at which woollypod vetch will make growth is lower than that for hairy vetch, and in this respect it is more like smooth vetch. It is a vetch that can be widely used in the Cotton Belt when seed is available.

Monantha vetch: In general habit of growth monantha (oneflower) vetch is similar to other vetches. It has finer stems and leaves than hairy vetch and is one of the earliest maturing of the vetches. The minimum temperature at which it will make growth is lower than that for hairy or smooth vetch or Austrian Winter pea, and it is one of the best winter legumes for making growth during winter or in periods with a low mean temperature. In point of winter hardiness it is not to be compared with hairy vetch, Austrian Winter pea, or even smooth or woollypod vetch. It is comparable to common vetch, however, and will survive most winters throughout the Cotton Belt except in the extreme northern part.

Narrowleaf vetch: Found as a weed by the roadside and in waste places throughout the Cotton Belt, narrowleaf vetch is like most other vetches and is closely related to common vetch. Its season of maturity is early, and for this reason it ripens seed regularly under southern conditions. The percentage of hard seed in this species is high, and this carries over in the soil, giving a volunteer crop from year to year. When planted under field conditions and given ordinary cultural attention it has seldom succeeded.

Narrowleaf vetch can be recommended for growing in mixture with Bermudagrass or Johnsongrass for hay or for volunteering in orchards as a winter crop where a heavy grass growth is allowed to accumulate during the latter part of the summer. It will make growth under about the same temperature conditions as bur-clover or hairy vetch.

Common vetch: Common vetch is a semiviny plant having slightly larger leaves and stems than hairy vetch. Less winter-hardy than that species, it sometimes winterkills under Cotton Belt conditions. The minimum temperature at which it will make growth is lower than that for hairy vetch or Austrian Winter peas, and for this reason it is to be preferred where it is winter-hardy and adapted. This vetch is being used in commercial plantings in the lower Mississippi Delta section, where the hardier varieties have given good results. With proper cultural treatment, it seems probable that it can be grown successfully over a much wider area. Willamette vetch, a variety selected for winter hardness, is superior to common vetch for general use.

Hungarian vetch: Hungarian vetch, a comparatively new species, has become commercially established in western Oregon. It is not so well adapted to sandy lands as other vetches, but on heavy lands it has given good results. It is entirely winter-hardy throughout the Cotton Belt and as far north as Washington, D. C. The minimum temperature at which it will make growth is about the same as that for bur-clover and hairy vetch. Results up to the present time suggest that it may have value for use on the heavier lands of the northern part of the Cotton Belt and in the Mississippi Delta section.

Purple vetch: In general appearance purple vetch is similar to hairy vetch except in winter hardiness. Being one of the least winter-hardy of the vetches,
it has usually winterkilled in the Cotton Belt. The zero growing point, or minimum temperature at which it will make growth, is lower than for Austrian Winter pea, hairy vetch or smooth vetch. In this respect purple vetch is desirable, but its lack of winter hardiness precludes its general use in the Cotton Belt.

Bigflower vetch: In general habit of growth, bigflower vetch is like most other vetches. It makes good winter growth and has a high percentage of hard seed. This latter characteristic makes it possible to volunteer stands from year to year for a long period. It is somewhat more winter-hardy than common vetch, but less so than hairy vetch.

Bard vetch: The general growth habit of bard vetch is similar to that of hairy and common vetches. It does not promise to be of value under Cotton Belt conditions.

Austrian Winter peas: The variety of pea introduced to the trade several years ago under the name "Austrian Winter" seems to be identical with the gray winter variety. It is one of the most winter-hardy varieties of the pea and makes good growth under Cotton Belt conditions. It has a low minimum growing point and in this respect is about like smooth and woollypod vetches. It has a greater acreage planted than any other winter legume, with the possible exception of hairy vetch. Commercial seed production has now reached about 50,000 acres.

Tangier peas: The general habit of growth of the Tangier pea is similar to that of the common garden sweet pea. In winter hardiness it is similar to monantha vetch, being much less hardy than hairy vetch or Austrian Winter pea. The minimum temperature at which it will make growth is about the same as that of hairy vetch, or slightly lower. A rapidly growing plant at moderate temperatures, it gives a heavy yield of green manure. It will make good growth in most seasons in the southern part of the Cotton Belt but is not superior to monantha vetch and Austrian Winter peas. As its seed habits are poor and the cost of seed correspondingly high, its use no doubt will be limited.

Roughpea: Roughpea is a weak-stemmed plant similar to vetch or field pea. It makes much less winter growth than most winter cover crops, but can be used where late winter growth will serve. Its high percentage of hard seed insures volunteering. Lateness of maturity, however, makes it necessary to defer the planting of a succeeding summer crop.

Bur-clovers: Two species of bur-clover—southern and Tifton—are grown in the Cotton Belt. Tifton bur-clover is a recent introduction that has been grown and distributed from the Georgia Coastal Plain Experiment Station at Tifton, Georgia, from which place it takes its name. Although it makes a decumbent growth and in general is like the southern bur-clover, it differs in having darker green leaves and lacks the dark-purple spot in the middle of each leaflet. It also is more winter-hardy than the southern bur-clover.

California bur-clover is occasionally sown in the Cotton Belt States, but usually without success, as it is less winter-hardy than either Tifton or southern bur-clover and is often damaged severely by cold weather. The minimum temperature at which the bur-clovers will make growth is somewhat higher than that of either smooth or woollypod vetch, but about the same as that of hairy vetch.

Black medic: Black medic is closely related to the bur-clovers. It makes somewhat slower winter growth than field pea or the vetches, but in the lower South it will make a good winter cover and can be used in situations where a winter crop can be allowed to stand late and mature seed, at least every few years, in order to insure volunteering. When handled in this way, black medic can be readily volunteered and the cost of seeding reduced accordingly. In planting black medic in the South it is essential to have adapted seed. This means that the seed should be from stands that have volunteered in the South and produced a good growth.

Crimson clover: Crimson clover is recognized as a good winter legume, but it
is sometimes difficult to get a good stand. This uncertainty has prevented a much wider use of the crop for green-manuring purposes. It is best adapted to the more northern part of the Cotton Belt and is used most extensively from northern Georgia and northern Alabama northward to New Jersey. It will not make growth at as low a temperature as Austrian Winter peas and woollypod and smooth vetches, but at slightly higher temperatures it makes rapid growth. The advent of Dixie crimson clover which has a high percentage of hard seed has largely overcome the difficulty of obtaining a stand through volunteering.

Rose clover: Rose clover is a winter annual with much the same habits of growth as bur-clover. It makes less winter growth than the bur-clovers and vetches.

Persian clover: Persian clover is a winter annual. It makes somewhat more winter growth than white clover and matures earlier. Its high hard-seed content and consequent volunteering ability makes its use as a volunteering winter cover advisable in sections where it is adapted and where the cover crop can be allowed to remain until late winter or early spring before the ground must be worked for a succeeding crop. Every 4 or 5 years the crop should be allowed to mature seed fully in order to insure a supply for volunteering.

Sourclover: Sourclover, an upright-growing winter annual, has been used extensively for green manure in the Southwestern States. Its use in the Cotton Belt has been limited to the lower Mississippi Delta area and the blacklands of Mississippi and Alabama. It is not recommended for general use outside of this territory. The minimum temperature at which sourclover will make growth is higher than that for Austrian Winter peas, smooth vetch, and woollypod vetch, and it has about the same temperature-growth requirements as bur-clover.

Lupines: Lupines have been used in European countries for soil improvement and recently have come into extensive use in the southeastern United States. In Hungary and Germany they are especially valuable for green manure on sandy lands and have been grown extensively for this purpose. The white, yellow, and narrowleaf are the lupines most used.

The narrowleaf lupine, known locally in the South as blue lupine, is the one used commercially. Over half a million acres were planted to this variety in 1947. It is most extensively grown in southern Georgia and Alabama and northern Florida. Large winter growth and seed-producing ability make it an especially valuable winter green-manure and cover crop for this region.

HIGHLIGHTS OF GREEN MANURE AND COVER CROPS

1. A cover crop, generally speaking, is one sown or planted especially for the purpose of checking soil erosion, adding organic matter to the soil, and improving soil fertility.

2. Since many of the characteristics required of forage crops are those required also of cover and green-manure crops, it is usually most feasible and profitable to use for cover and green manure those crops that can also be used for forage.

3. Legumes are the most desirable green-manure crops, but under certain conditions non-legumes such as rye or buckwheat may be used more profitably.

4. Summer green-manure crops may be used either (1) exclusively for green manure, or (2) intermixed with and subsidiary to the main crop, or (3) as a midsummer or late summer crop following a cash crop, or (4) in the case of legumes, in rotation with other crops, using the stubble or aftermath of the legume for green manure.

5. Some of the most important summer green-manure crops are red clover, sweetclover, alfalfa, lespedeza, soybeans, cowpeas, velvetbeans, and crotalaria.

6. Some of the most important winter legumes used as cover and green-manure crops in the South, and the 1946 acreages reported under the Agricultural Conservation Program, are winter peas 1,900,000 acres, vetches 1,500,000 acres, crimson clover 600,000 acres, lupines 230,000 acres, and bur-clover 22,000 acres.

7. The acreage of winter legumes used for
green manure in the Cotton Belt has increased in the last twenty years from about a quarter million to about four million acres. This does not include acreage sown to rye and other cereals for this purpose.

8. Winter cover legumes such as Dixie crimson clover, bur-clover, Persian clover, certain vetches and certain other legumes, may be maintained over several years by volunteering, providing suitable practices are followed.

9. Cover crops improve the soil tilth by the addition of organic matter to the soil, and when turned under, form organic acids or other compounds which aid in the liberation of mineral plant food.

10. Green-manure crops should be turned under long enough before sowing the following crop to allow for first stages of decomposition of green material and liberation of plant food for early development of succeeding crop. Under favorable conditions two to three weeks should elapse.

11. Cover crops increase the water-absorbing capacity of the soil and the infiltration of water into the soil, reduce runoff of rain, and prevent excessive erosion.

12. Cover crops increase yields of corn, cotton, and other regular farm crops that follow, usually much more than commensurate with the expense of the cover crop.

13. Cover crops may be used to protect terraces and other mechanical soil-erosion devices.

14. Cover crops prevent the leaching of available plant food, especially nitrate nitrogen, from the soil.

15. Some of the so-called objections occasionally raised to the use of cover crops are cost of seed and cost of labor in preparing seedbed, sowing seed and other cultural practices. There is also the possible adverse effect on soil moisture supply and the danger in furnishing a refuge for insect pests.

THIS CHAPTER

The material in this chapter is largely a digest of three rather recent U.S.D.A. bulletins, Roland McKee (US-156), McKee and McNair (US-160), and McKee and Kell (US-130), which give up-to-date comprehensive information on the subject. This manuscript has been reviewed by McKee and his suggestions have been followed in its preparation.

Chapter reference numbers: 1 ALA-14; ARK-10; FLA-17; HAW-4; KY-10; LA-5, 6, 7; MICH-5, 11; OREG-16; RI-6; TEX-36, 50; US-130, 149, 150, 156, 160, 170, 201.

1 The reference numbers given here refer to references which are given in full by State, U.S.D.A., and Miscellaneous, on pages 682 to 724, and which are cross-referenced by author on pages 725 to 731. Citations in the text are indicated by abbreviation and number in parentheses.
Much emphasis in recent years has been given to the importance of the use of grasses and legumes in our agricultural programs, and to the use of as large a percentage as feasible of our farm acreage for pastures and meadows as sources of feed for livestock. This emphasis has been more or less general for all parts of the country. The techniques, however, of establishing pastures and meadows, though similar in many respects, vary in certain important ways in the different parts of the country because of variable climate, soil, elevation, and other more or less local conditions.

From the east to the west the country is divided naturally into four large regions which extend from the northern to the southern boundaries. They are (1) the Eastern or generally humid region of the eastern United States which extends westward into the eastern borders of North Dakota, South Dakota, Nebraska, Kansas, Oklahoma, and Texas, (2) the Great Plains sub-humid, semi-arid or arid region, (3) the Intermountain Region, and (4) the West Coast Region. Each of these may be divided again into a northern and a southern region. The pasture problems of the subdivisions of Region (1) are covered here by “Pastures in the Central and Northeastern States” and “Pastures in the Southeast”; those of Region (2) by “Northern Great Plains Pastures” and “Southern Great Plains Pastures.” The third region, because of its great variety of conditions is not separately treated but most of the pasture problems are covered in one or another of the other regions. The fourth region is covered by “Southwestern Irrigated Pastures,” and “North Pacific Coast Pastures.”

In all regions failure to obtain a stand of hay and pasture crops is too often accepted as an almost inevitable hazard in the culture of such crops. The extent to which farmers appreciate the importance of these crops is shown by their continuing to sow grasses, clover, and other legumes in the face of repeated failures to obtain stands. Any program of increasing the proportion of land in soil-building sod crops must, first of all, attack the problem of obtaining a stand.

Because of the vital importance of this problem, an important part of the experimental work of our State agricultural experiment stations has been in recent years, and should continue to be, devoted to a study of the basic principles involved in obtaining stands of our pasture and meadow grasses and legumes, and of ascertaining the most compatible and productive combinations for best results.

With our advanced knowledge of soils and the soil requirements of special crops, the inoculation of legume seed with strains of nitrogen-fixing bacteria developed for particular crops, the production and preparation of high-quality seed for sowing, the treatment of seed for seed-borne diseases before sowing, and the best rate, times and methods of sowing the seed, it would seem that failures to obtain stands would be becoming much less frequent, but such does not appear to be the case. One important factor among others in the continuing failure to obtain good stands is the steady depletion of the organic matter in the soil. This brings about poor physical
condition of the soil which is often fatal to success. Poor soils cause poor sods, and poor sods permit the soils to become poorer.

PASTURES OF THE CENTRAL AND NORTHEASTERN STATES

For the purpose of considering the establishment and management of pastures, the region here considered is larger than is often used in grouping States for agricultural purposes. It extends from the North Atlantic Coast west to the eastern portions of South Dakota, Nebraska, and Kansas, and south into northern Virginia and Kentucky. The entire region includes the six New England States, the six North Atlantic States of New York, New Jersey, Pennsylvania, Delaware, Maryland, and West Virginia, the eight Corn Belt and Lake States of Michigan, Wisconsin, Minnesota, Ohio, Indiana, Illinois, Iowa, and Missouri, and parts of Virginia, Kentucky, South Dakota, Nebraska, and Kansas. This takes in a lot of territory and a variety of climatic conditions, but still such as can be grouped together for the consideration of pastures and meadows.

Climatic conditions favorable: The general climatic conditions which prevail in the region indicate that rainfall conditions are generally favorable for the growth of forage grasses and legumes throughout the area. There is a marked tendency for the annual rainfall within the region to increase from the northwest to the southeast and east. The total annual precipitation ranges mostly from 25 or 30 inches in the western portion to 40 or 45 inches in the eastern, and in some small localities to as high as 50 inches.

The temperatures vary considerably. Both summer and winter average temperatures are naturally higher in the southern portion than in the northern, but the length of day is longer in the northern than in the southern. The average number of days without killing frosts varies from 80 to 180 days in the Northern States, to 140 to 210 days in the Southern States of the region.

The present agriculture of the region is devoted largely to the support of an extensive livestock enterprise. Most of the crops are used for dairy, beef, sheep, swine, and poultry production, and for the maintenance of horses and mules. Food grains, vegetables and fruits are also produced in considerable quantities in certain areas.

The New England States, the North Atlantic States, and Minnesota, Wisconsin, Michigan, and eastern Ohio are included in the hay and dairy region of the United States, whereas, Iowa, Missouri, Illinois, Indiana, western Ohio, eastern Kansas and Nebraska, and southeastern South Dakota represent a large portion of the Corn Belt.

Forages for use as hay and pastureage, and to a lesser extent for green manure, grass silage, and seed production, are integrally interwoven and vitally important in the various farm enterprises of the entire area.

Soil losses by erosion: Dairying is the most important farm enterprise in New England and the northern States of the region. With the extensive use of forages necessary for supporting this type of farming, soil losses by erosion have been reduced and depletion of fertility has been much slower than in areas where cultivated crops are grown more intensively. Nevertheless, there is widespread evidence throughout the whole area of both past and continuing soil impoverishment.

Meat production is of great commercial importance in the Corn Belt or southern portion of the region. The deep, highly fertile prairie soils characteristic of much of this area are cropped more intensively than the forest soils of the dairy region. Use of soil-improving legumes such as alfalfa, sweetclover, and medium red clover, has become increasingly important, but even when grain is largely fed to livestock, and cropping systems include forages for hay and pasture, corn frequently follows corn for two or three years in the rotations. With this
system of farming, soil losses by erosion and depletion of organic matter and fertility as a result of cropping are evident on all except the most fertile soils.

Destructive soil processes have been hastened during the period of agricultural development in both the meat and dairy-producing areas as a result of wasteful practices. It is generally recognized that restoration of the fertility that has been utilized in previous cropping and dissipated as a result of leaching and erosion, is a matter of first importance not only for successful establishment but also for the maintenance of productive forages of superior feeding value. However, other important factors of the environment may drastically curtail production and reduce quality, or if of sufficient intensity or severity, they may result in a total elimination of certain forages from sown mixtures.

Production of natural pastures low: The production of most natural or unimproved pastures in all parts of the region is low. Likewise, on cropland yields of forage harvested as hay or grass silage are often low and of poor quality. In general, the total or mass effect of all factors which cause reductions in production and quality are greater on areas utilized for grazing than on those harvested for hay or grass silage. In like manner, the total or mass effect of the factors which affect production and quality adversely are greater on the natural or permanent pastures than on pastures occurring in rotations.

The low production of natural or permanent pastures appears to be due largely to the following facts: (1) practices which increase production and quality are less easily applied to such areas, (2) they are often relegated to the poorest sites on the farm, (3) barnyard manure and commercial fertilizer are largely or entirely diverted to crop land, and (4) they are frequently used as "exercise lots" and the trampling by cattle in wet weather and rooting by hogs causes heavy damage to the forage.

Introduced forages replace native species: The important forages which occurred commonly on the upland soils of the prairie areas of the region at the time of settlement by the white man have been replaced largely by introduced forages. Lacking the aggressiveness, competitive ability and good seed habits of most introduced forages, the native grasses failed to reestablish naturally following plowing, or were eliminated as a result of grazing management procedures commonly practiced in the region.

Most of the native upland forage species can still be found in many parts of the region, but their habitats have been largely restricted. In general, they occur on infertile, abandoned sandy soils, in undisturbed waste areas, and on infertile slopes which are relatively inaccessible to livestock. In contrast to the native upland species, native lowland species have generally successfully resisted the invasion of introduced species on wet, poorly drained, uncultivated soils.

Most of the introduced species of forage plants grown in this region are grown to a greater or lesser extent throughout the entire region. None of them, however, is adapted to all of the soil and climatic conditions which prevail in the region. The use for which the sowing is intended and the local adaptation of the species or varieties serve as the basis for devising sowing mixtures. The most important of the introduced forage grasses are timothy, redtop, orchardgrass, Kentucky bluegrass, smooth brome, tall and meadow fescues, and Sudan grass. Of lesser importance are tall oatgrass, Canada bluegrass, the rye-grasses, meadow foxtail, the small grains, barnyard and foxtail millets, and the native reed canarygrass.

The principal legumes are red, alsike and white clovers, biennial sweetclover, alfalfa, soybeans for forage, and in the southern part of the region, lespezea, crimson clover, and cowpeas, all of which have come from Europe and Asia. Those of lesser importance are birdsfoot trefoil, vetches, and field peas.

Since portions of this region were the first to be settled and include the portion of the country from which most of the emigrants moved to the West, the types of farming followed in the eastern part
have influenced to a large extent the initial agricultural procedures of the West which have had to be materially modified to fit the differences in climate, soils, and water supply. However, so far as it has been possible to utilize the same species of plants and similar agricultural practices, these have been largely retained.

Because of the longer period of time in which most of the eastern part of this region has been settled, more extensive research has been conducted in this area, and more information is now available as to the general and intricate problems of pasture establishment and management, so these will be covered more fully for this region than for any other. Certain of the principles and practices which apply to this region will be more or less applicable to portions of other regions where similar conditions may prevail.

**Forage Crops Best Adapted**

The most important introduced forage species in the region during the period of early agricultural development were medium red clover, alsike clover, timothy, Kentucky bluegrass, Canada bluegrass and redtop. From various local areas into which they were introduced by early settlers, white clover and Kentucky bluegrass have spread rapidly and spontaneously to all cleared moderately fertile to fertile upland soils which are uncultivated or kept out of cultivation for a few years. At present these two species represent the most important and extensively grown forages for pasturage in almost all parts of the region. The history and development of redtop and Canada bluegrass is comparable to that of Kentucky bluegrass and white clover, but their spontaneous occurrence is more restricted and less widespread. Redtop is limited naturally to relatively infertile, acid, poorly drained soils and Canada bluegrass occurs commonly only on relatively thin, infertile, acid upland soils.

With the gradual intensification of agriculture, other valuable forages were successfully introduced into the region. In addition to Kentucky bluegrass, timothy, medium red clover, alsike clover, white clover, Canada bluegrass and redtop, smooth bromegrass, alfalfa, soybeans, and the biennial sweet clovers are now grown extensively in many parts of the region. The value of smooth bromegrass as a dependable source of highly nutritious, palatable forage was first recognized in the drier western portion of the region, but more recently it has proved valuable on fertile, well drained soils over a large part of the region. White clover and Ladino clover are of greatest value in the more humid areas.

Timothy is replaced by orchardgrass in much of New Jersey, Pennsylvania, Maryland, Virginia, West Virginia, and in Ohio, Indiana, Illinois, and Missouri. Korean and common lespedezas, crimson clover, and cowpeas are grown only in the southern portion, whereas, meadow fescue is restricted primarily to the western portion and to moist heavy soils in Indiana, Illinois, and Missouri. Reed canarygrass is grown generally on low, wet soils which may be subject to periodic overflowing, but its culture is most extensive in the Lake States. Soybeans are grown successfully in almost all parts of the region except the New England States, but the area of their most extensive culture corresponds with that of the Corn Belt. Sudangrass and sorghum are adapted to fertile soils in areas where 105-day or later-maturing varieties of corn are grown.

**Use of Grass-Legume Mixtures**

Considerable evidence is available to show that mixtures of grasses and legumes are usually more productive than grasses and legumes grown alone. For example, studies in Illinois in 1944 by Fuelleman, Burlison and Kammlade (Ill-18) have shown that bromegrass and orchardgrass sown alone produced approximately 40 percent less forage and 50 percent smaller gains in liveweight than when grown in mixtures including alfalfa. Likewise, in Wisconsin, Ahlgren and Burcalow (Wis-7) noted that timothy, smooth bromegrass, and alfalfa...
sown alone were much less productive than mixtures including one or more of these grasses and alfalfa. It is primarily for these reasons that mixtures containing grasses and legumes are commonly sown throughout the area.

The mixtures sown vary according to the purpose for which they are intended and the soil and climatic conditions prevailing in the locality in which they are to be grown. Mixtures of grasses and legumes which are recommended in the various States comprising the region are generally simple including only 2 to 4 species, but under some conditions more complex mixtures containing five or more species are used.

Regardless of the mixture used, most species which comprise the initial sowing are eventually replaced by other species, even though they are not included in the original mixture. Kentucky bluegrass eventually becomes the dominant species on fertile upland soils in almost all portions of the region, whereas, on relatively infertile, upland soils the species which are sown are often replaced by Canada bluegrass. Vegetation on impoverished soils, particularly in the eastern portion of the region, reverts eventually to broomsedge (Andropogon virginicus) and poverty grass (Danthonia spicata). Species sown on wet, poorly drained soils are gradually replaced by redtop. Well established and managed stands of reed canarygrass on lowland areas, and smooth bromegrass on fertile, upland soils are capable of resisting the encroachment of most other species if they are not overgrazed.

For the great majority of situations, mixtures are superior to any single forage, for these reasons:

1. The various hazards to which seedlings are exposed do not affect all crops equally, so that a mixture is far more certain to give a stand of forage than any pure seeding. For example, alfalfa will make a better stand in a dry season than red clover, and especially when sown in oats; in a wet season red clover will give a much better stand than alfalfa, and especially when sown in wheat.

2. Few fields have uniform soil conditions in all parts of the field. Acid and poorly drained spots may result in failures from sowing alfalfa and red clover, but if other legumes and grasses which endure these conditions are included in the mixture, there will be some forage crop on all the field.

3. The yields of forage from legume-grass mixtures are normally higher than those from any of the components grown alone.

4. Legume-grass mixtures are preferable to pure stands of grass. The legumes supply nitrogen to the grasses, so that they yield more than grasses grown alone. Frequently, just the yields of grass in such mixtures have been greater than those of the same grass grown in pure stands. Grasses in legume mixtures also contain a higher percentage of protein than grasses grown alone, half again as much in some experiments.

5. Legume-grass mixtures are more effective in reducing erosion than pure stands of legumes.

6. Legume-grass mixtures resist the encroachment of weeds better than pure stands of legumes. The fall growth of legumes does not shade out seedlings of winter annual weeds, but grasses between the legumes leave no chance for weed seedlings to start.

7. Grasses in the mixtures protect legumes from heaving on some soil types.

8. For use as pasture or silage, mixtures of legumes and grasses are more satisfactory than either grown alone. Grass mixtures probably reduce the liability of legumes to produce bloat when pastured.

9. For beekeepers, mixtures, particularly those including Ladino and alsike clovers, tend to build a larger and longer honey flow.

Alfalfa may be sown alone on land well adapted for its culture. Alfalfa-grass mixtures are proving entirely satisfactory for livestock feeders even on the best soils for alfalfa. This is particularly true in view of the present trend toward pasturing alfalfa. There is seldom any need for sowing red clover or alsike clover alone except that mammoth red clover and alsike clover intended for seed are
best sown alone. Sweetclover intended for a green-manure crop the next spring after sowing, or for seed, is best sown alone. For temporary pasture it is generally sown alone, but the sowing of orchardgrass, or some other suitable grass with sweetclover is desirable in order to furnish pasture in the fall of the second year after the sweetclover dies.

**Basic Principles of Forage Production**

A few principles are basic in developing a well-rounded and productive forage program in this region:

- **Relate land use to land characteristics:** Over a period of years farmers have tended to adjust land use to the topography and fertility of the land. More easily tilled and more fertile areas have been used for cultivated crops and hay; stony or rough areas have been used for permanent pasture or woodland. This adjustment could and should go much further. Land characteristics will determine the extent to which intensive methods will be practical. Larger quantities of labor, fertilizers, and seed can be used more profitably on some portions of crop and pasture land than on others. On easily tilled land shorter rotations may be followed; where fields are difficult to prepare, long rotations or semipermanent pastures may be most desirable.

- **Recognize growth requirements and crop limitations:** A successful forage program must recognize the requirements and limitations of the crops used.

  Alfalfa is adapted to well-drained neutral soils, on which it is very productive, but it will not persist on poorly drained or acid soils. On soils less well drained and slightly more acid, red, alsike and Ladino clovers will grow. On thin, dry hillsides and in competition with such strongly competitive grasses as Kentucky bluegrass, birdsfoot trefoil will persist under conditions where other legumes will not.

  Grasses have similar differences in adaptations. Orchardgrass grows best on well-drained soils, whereas meadow fescue, redtop and reed canarygrass will grow well under conditions of poorer drainage. The grasses and legumes that comprise most permanent pasture swards in this region do not grow well during the hot summer months.

  With these species, the production pattern is a flush period in the spring, limited growth during midsummer, and moderate growth in the fall. Lime and fertilizers will change the extent of these periods somewhat, but unless different plants are used, the same pattern persists. Species of forage plants which may be established on semipermanent pastures continue to grow during the less productive midsummer period and aid in leveling production.

  Where alfalfa cannot be grown or where losses from winterkilling are frequent, a timothy-clover combination, if handled correctly, can provide high quality hay. Since red clover usually will not maintain itself on fields for more than 2 years, frequent resowing is necessary if a mixed legume hay is desired. The addition of Ladino clover to the red clover-timothy mixture will maintain a legume over a longer period. Where timothy or other grasses in association with these clovers are used for hay, early cutting and adequate fertilization will result in good yields of high-quality hay and increased longevity of Ladino clover.

  **Develop leguminous roughage:** Larger yields of higher quality hay and pasture are obtained through the use of legumes. Red clover and alfalfa have been used most widely, but Ladino clover with a grass has proved valuable both as a pasture crop and as silage and hay. Ladino is more persistent under grazing conditions than is alfalfa and it is longer-lived than red clover. Ladino clover with a grass has the flexibility which permits the first crop of forage to be cut for silage, it is less well adapted for hay, and the aftermath provides a nutritious summer pasture.

  **Replace losses in soil fertility:** Lime and phosphorus are needed on a large proportion of farms of this region. Good management often calls for potash, and in some cases, nitrogen applications as well. These materials should be used in accord-
Forage and pasture crops—general

The maintenance of the legume in a hay or pasture sward is another major problem. Since in most cases the legume is the primary source of nitrogen for the growth of the associated grass, production of the entire sward decreases if legumes are not present in adequate amounts. The reasons for the loss of legumes are undoubtedly many, a few of which are: Unadapted soils, inadequate fertilizers, overgrazing, undergrazing, winter injury, summer injury, diseases and insects.

Any one of these causes is so general that it includes a number of separate problems. In some instances, the loss of Ladino clover has often been ascribed to winter injury, but whether the death of the clover was due to low temperatures, heaving, drying out by cold, dry winds, diseases that grow at low temperatures, previous over-grazing, or to a deficiency of some fertilizer element has not been determined. Information is now being obtained on these and many other problems affecting the survival of Ladino clover. These facts, when integrated and applied, will help maintain productive stands of Ladino clover for longer periods.

The breeding of disease- and insect-resistant plants seems to offer a promising procedure for reducing losses from these causes. Management practices may also be valuable aids when life histories and growth habits of causative organisms are better known.

Careful studies of the fundamental principles of plant growth on various soils and under different climatic conditions will provide information that can be applied to the solution of forage problems. In addition, a thorough understanding of the economics of forage production and its utilization for different farm conditions in the region is essential. By an interpretation and integration of all these facts, the farmer will be able to make the best use of his grasslands to meet the requirements of a stable and prosperous agriculture on his farm.

Preparation for sowing and protection of soil

Preparation of seedbed: The ideal seedbed for forage seeds has: (a) an abundance of moisture in the plowed layer and subsoil, (b) firm, compact soil under the seeds, (c) sufficient fine but granular soil at the top to cover the seeds, and (d) the plowed layer well connected with the subsoil with no layers of trash between them. These requirements are always important but are of maximum importance for summer and fall sowing. In the spring, in the Central and Eastern States, fairly loose seedbeds may sometimes be entirely satisfactory, since the considerable amount of rain and low evaporation at that time often settles the seedbed and prevents the failure which often follows loose, open seedbeds at other times of the year or in dry regions. If there is sufficient rainfall following seedbed preparation, loose seedbeds may be satisfactory even in the summer.

For sowing in summer and late spring, it is desirable to prepare the seedbed
sometime before sowing and to keep it worked to compact the soil and kill weeds. In the summer, disking before sowing is frequently preferable to plowing as a means of preparing the land. Late spring and summer-plowed land is difficult, and sometimes impossible to work down and firm uniformly; at best it requires considerable time and labor. As a result, the stand may be patchy. If disking is done fairly shallow, a uniform packing of the soil may be accomplished by harrowing and cultipacking. The method of cultipacking just before broadcasting is particularly adapted to obtaining firm soil under the seeds.

Mulches: It is hard to overestimate the value of mulches in obtaining good stands. Part of the value of manure is as a mulch and other materials may also be used as mulches to protect both soil and seedlings. Mulches affect the stand obtained in many ways, all favorable. In winter and early spring seedings they protect the seedlings from cold and, still more important, from freezing and thawing. The stand from almost any seed sown in a winter grain will be increased if the grain is mulched with straw in December.

Mulches conserve soil moisture near the surface and prevent puddling of surface soil, thereby permitting greater moisture infiltration. It is a common observation that soil stays moist longer under even a trace of mulch than where no mulch is used. When seedlings are struggling to establish themselves, this slight extra moisture often saves a large proportion of them.

There is little need for mulching oats with straw or similar materials to control rank growth, although it might be helpful on soils where the oats crop lodges regularly. Thin rates of sowing the oats and harvesting oats for hay are more logical control measures.

An application of some sort of mulch immediately after summer sowing will do more to insure a stand than any other one thing that can be done. In addition to saving moisture at the surface where the seedlings need it, such a mulch tends to prevent the formation of a crust, both by breaking the force of the rain and by retarding drying of the soil, thus permitting the emergence of more seedlings. It reduces the temperature of the soil and it protects the young stand against much winter heaving.

Such mulching is to be recommended on slopes and difficult situations generally, especially with seed sown for the control of erosion. However, it should often be profitable to spread some form of mulch on summer sown seed on the average farm, as insurance against failure of this vital part of the farm program.

In following this suggestion, three points are important:

1. The mulch should be put on at once after sowing. Delay may result in harm rather than good from the application.
2. The mulch must be light, about 1 to 1 1/2 tons of straw or 4 to 6 tons of manure.
3. The mulch must be evenly spread. It is almost impossible to spread either straw or manure sufficiently evenly by hand.

Fertilizers and Lime

Forages capable of producing high yields of good quality cannot be established or maintained on impoverished soils. Increasing failures of red clover following long periods of cropping and the introduction of alfalfa with its highly exacting fertility requirements were factors of major importance in focusing attention on the need for improving the soil by the use of lime and commercial fertilizer. As a result, applications of lime, phosphate, and potash on the basis of soil and plant requirements have become relatively common for the establishment and maintenance of seedings for use as rotation pasture or for hay and grass silage.

Experiments have shown that nitrogen in an available form is likely to be a limiting factor in the production of forages on almost all soils except those that support a good growth of legumes; lime and phosphate are deficient in many soils, and potash is often the limiting factor in sandy soils, peats, mucks, and many
heavy, poorly drained soils. Ample lime, phosphate, and potash produce vigorous plants which are better able to withstand drought, insect, and winter injury and competition from companion crops and weeds. They are also of utmost importance in maintaining production and quality at satisfactory levels following establishment.

Lime is often applied to advantage 6 to 12 months in advance of sowing. General recommendations regarding the use of lime, phosphate and potash for the establishment of new sowings and for the maintenance of permanent pastures, or areas utilized for rotation pasture, hay or grass silage, for the various States which comprise the region, vary in detail as to formula, quantity used, and method of application. Lime applications range from one to five tons per acre according to need, as determined by test and crops to which applied. Fertilizer applications recommended for the establishment and maintenance of meadows and pastures range mostly from 200 to 500 pounds per acre of a formula high in phosphorus, medium or low in potash, and with or without nitrogen, depending on specific need.

Methods of applying fertilizer: For establishment, the fertilizer should be drilled in deeply with a grain drill or similar equipment either before or at the time of seeding. It is generally agreed that where pastures are being established or where they are being renewed by a process of soil working and reseeding, it is desirable to make a very heavy initial application of fertilizer. A number of States report entirely satisfactory results from applying the fertilizer on the old sod and working it during preparation of the soil for the new seeding. Phosphate may be applied in quantities sufficient to meet the requirements for several years.

For maintenance, the fertilizer should be applied with a grain drill or as a broadcast top dressing in either fall or spring. Pastures in the South that are used for winter grazing should be fertilized in late summer or early fall.

It is generally agreed that when a desirable sod is already established or where it is undesirable to appreciably disturb the soil, top dressings are satisfactory. Some prefer to apply the fertilizer in bands, slightly grooving it into the soil, as with a disk drill. Placement at a depth greater than 2 inches appears to be less satisfactory than either surface or shallow treatment. Applications of potash, on soils deficient in this element, should be made annually or every two years for best results.

Broadcast or drilled applications of nitrogen on the surface of the soil in either the fall or early spring have generally given satisfactory results. There appears to be little need for incorporating the nitrogen into the soil, except where such special forms as liquid ammonia are used.

Maintenance of production with nitrogen: Grasses in fields used for pasture, hay, or silage can be kept productive after legumes have disappeared by early spring applications of such quickly available commercial nitrogen fertilizers as ammonium nitrate, ammonium sulfate, and calcium cyanamid. In addition, in certain areas, commercial fertilizers such as 8-8-8, 10-6-4, 5-10-5, and 6-10-6, are applied to advantage to increase production of forage. Treatment with all of these fertilizers should be limited to soils with a good supply of available moisture.

Broadcast applications of commercial nitrogen fertilizer are much less effective in increasing yields of forage on dry or droughty soils or on other soils during the drier times of the growing period. The usual rates of application are 125 to 175 pounds per acre for ammonium nitrate, 200 to 250 pounds for ammonium sulfate and calcium cyanamid, and 300 to 500 pounds for 8-8-8, 10-6-4, 5-10-5, and 6-10-6. Such treatments increase total production and improve quality; they also stimulate early growth so that grazing often can begin 10 to 14 days earlier.

Little commercial fertilizer is used on permanent pastures in many parts of the region, although its benefits have been widely demonstrated. Aside from increased production under conditions favoring the use of commercial nitrogen fertilizer, the greatest success in improvement of permanent pastures has been
achieved where the practices have involved the establishment and maintenance of legumes and certain superior grasses.

Manuring: Manure added at rates varying from 4 to 10 tons to the acre and worked into the soil or applied as a top dressing after sowing may be a valuable adjunct in establishing new stands, especially on infertile soils and soils low in organic matter. When it is applied as a top dressing after sowing, the benefits are due largely to the fact that the thin layer of manure not only adds nutrients but also serves as a mulch to conserve soil moisture, provides coverage for the seed, protects the young seedlings from drying and soil blowing, reduces fluctuations in soil temperature, minimizes soil losses from erosion, and protects the seedlings from excessive heaving in winter.

Reasonably weed-free barnyard manure applied as a top dressing at the rate of 4 to 8 tons an acre (during the rotation to hay fields or rotation pastures, and every 3 to 5 years to permanent pastures) is highly effective in increasing yields of forage. Fresh, rather than composted manure, reinforced with 30 to 50 pounds of 20-percent superphosphate per ton of manure and applied before the soil freezes up in the fall, usually gives the best results.

Manuring pastures in the spring and summer months has been used as a means of regulating grazing in large permanent pastures. When manure is applied to areas in overgrazed pastures, livestock tend to avoid them until the forage has had ample opportunity to recover.

COMPANION CROPS

Companion crops are often used in parts of this region for three basic reasons: first, they produce a return from the land the year the seed is sown; second, if they are not used, a more harmful companion crop of weeds may replace them; third, on sloping land they help to control erosion while the small-seeded forages are becoming established. Nevertheless, the companion crop is always a competitor of, and usually a detriment to, the young forage seedlings.

The competition of small-grain or other companion crops with legume-grass seedlings may be more or less controlled by (a) choosing the right kind and variety of companion crop, (b) clipping the early growth, (c) grazing off the early growth, (d) harvesting for hay, (e) reducing the rate of sowing of the companion crop, and (f) sowing without a companion crop.

In general, the less the growth of the small-grain companion crop under a given soil situation, the better the chance of survival of the forage seedlings. It is a common observation that stands of grass and legumes are frequently better in fields of wheat that have been thinned by winterkilling than in normal thick stands. Where wheat follows corn, better forage crop stands are usually obtained in the spots where no wheat was sown in the fall because of the presence of corn shocks. There have been repeated instances where thick stands have been obtained on unfertilized plots and at the same time thin stands have been obtained on the fertilized plots which produced a rank growth of wheat.

In a dry season the roots of the companion crops outgrow those of the forage seedlings and may rob them of moisture as to cause their deaths, especially the clovers. In a wet season the rank growth of the companion crop may shade the young seedlings so much that it will weaken or kill them. Lodging of the companion crop, common in wet seasons, is practically always detrimental to the forage seedlings.

The choice of a companion crop: There is no doubt but that spring grains are usually safer companion crops than winter grains, although good stands may often be obtained in winter wheat. Seed sown in winter wheat must compete from the very start with a well-established crop; whereas, that sown with oats or barley can grow along with the grain on fairly even terms until the grain crop starts to joint. This difference applies especially to alfalfa which is sensitive to shade but stands drought well. Red clover, which
endures shade well but is more sensitive to drought, may do as well in wheat as in oats, since wheat is harvested earlier. Wheat also often permits earlier sowing than oats.

Although exceptions exist, the usual order of value in the Central States is barley, early oats, late oats, and wheat. We have few data on rye and winter barley as companion crops, but their habit of making a rank growth early in the spring may make them unsatisfactory.

The more favorable varieties of small grains to be used as companion crops will (a) be stiff-strawed and hence lodge-resisting, (b) make a minimum of leaf growth, and (c) be early maturing.

Other crops, such as corn and soybeans may occasionally be considered as companion crops. Canning peas also make an excellent companion crop, since they are sown early and removed early. Their use is, of course, limited to the few areas in which they are a commercial crop.

Grazing off the early growth: Under some conditions grazing or clipping may be advisable. Grazing may be either light or heavy. Close grazing with dairy cattle has been favorable to obtaining good stands of the legumes and grasses. The trampling of the livestock, which firm the soil, appeared to be beneficial rather than harmful. Grazing off oats has resulted in obtaining a good stand of legumes or grass. It is best to use them entirely for pasture rather than to attempt to harvest a grain crop after grazing.

Clipping the early growth: Occasionally, a combination of favorable weather conditions and fertility causes a rank growth of wheat early in the spring, followed by excessive straw growth and lodging which kill out the legume or grass seedings. If growth of wheat has been rank and covers the ground between the drill rows, it may be clipped with a mower.

The effect of clipping is to reduce the competition of the grain crop with the developing forage plants for a period of ten days to two weeks. Apparently, this period in the life of the forage seedlings is a vital one, since stands have been saved in this way when cutting the companion crop for hay did not save them.

Clipped wheat seldom lodges, and this removes another serious hazard to the forage seedlings, but clipping has saved stands even when the unclipped wheat did not lodge.

The early clipping of oats and barley companion crops is seldom necessary, since, if properly sown, the grain crop and the legume or grass crops have an even start and strong competition does not set in until the grain crop has jointed.

Harvesting the grain crops for hay: If the grain crops start to lodge, or if the season is dry, the forage plants may sometimes be saved by cutting the grain for hay. Where the death of the forage is caused by too much shade, it will often be too late to save it by the time the grain is cut for hay in the milk or soft dough stage.

Sweet clover, however, is injured by the low cutting involved in cutting the grain for hay, and it is usually not desirable to cut for hay a companion crop in which sweet clover is sown unless the sweet clover will be killed otherwise.

Reducing rate of sowing of companion crop: In accordance with the general rule of "the less companion crop, the better the stand of forage," we find that a low rate of sowing grain favors the stand of legumes in so far as it actually makes for thinner grain stands. Wheat, however, stools out so much that unless the thin stand is winterkilled, the rate of sowing in the fall has little effect on the yield of straw. For this reason, and since winterkilling is rather more likely to occur in thin stands, it is not recommended to sow wheat thin with a view to obtaining better forage stands.

A thin rate of sowing oats may result in a better stand of forage in dry seasons; in most seasons there is no significant difference in the stands obtained at the different rates of sowing unless the oats lodge. A low rate of sowing for oats does not reduce the yield of oats as much as many imagine.

Removing straw, stubble, trash after combining: A good stand of clover or alfalfa in the fall from spring sowing with a small grain companion crop often disappears by the next spring. This is not
usually because of winterkilling but because of the large quantity of stubble, straw, weeds, and new growth of clover left in the field after harvest. Where this quantity is large, the stubble should be mowed and raked off immediately after harvest. If the quantity is not large, simply raking and removing it from the field may be sufficient. Ohio experiments show that one ton per acre of such material left on the ground was not detrimental, but that 3 tons was very injurious to the stand, and 2 tons moderately so.

**Sowing alone:** To avoid entirely the competition of companion crops, forages may be sown alone. Summer sowing should always be alone. The custom of sowing in small grain is almost universal in humid regions because of its economic advantage if stands are actually obtained. For this reason, and because of the use of the term "nurse crop" to describe these crops, many persons have the idea that forages cannot be satisfactorily sown alone in the spring. This idea is entirely erroneous. Excellent stands have been obtained from sowing alone in the spring. In favorable seasons, a small yield of hay from the newly sown forage has been obtained the year sown. The yields of hay in the next year have not been materially different from those obtained from sowing with a companion crop, when the latter method gave satisfactory stands of forage.

### Time of Sowing

The time of sowing depends on the nature of the plant and is affected by temperature relations, moisture relations, and the development of the seedlings. In most regions, except irrigated, semiarid or arid regions, there is no month in which some forage seeds may not be sown. **Spring sowing (late February to May):** Seedlings from early spring sowing are subject to greater or less freezing hazard. On the other hand, as one sows later and later in the spring, the moisture situation becomes less and less favorable, because evaporation becomes more and more rapid as the season advances. Until about April 1 to 15 in the Central States, and April 15 to 30 or later in the Northeastern States, the surface of the soil does not dry out so rapidly but that seeds sown on the surface can usually germinate and establish themselves, even without soil cover; whereas, after those approximate dates some coverage is essential to the successful establishment of seedlings, unless the season is unusually wet. Seeds sown early are usually more or less covered by freezing and thawing and by rain washing the seeds and soil into the wheat drill rows and covering them.

In order to obtain the advantages of early sowing and yet not hazard all of the seed, a method has been suggested which is now standard in some places. This consists in sowing half the seed broadcast early and the rest two or three weeks later, either broadcast or with a drill, as conditions permit. This is one of the most generally reliable methods, although, of course, when conditions are favorable for some one method of sowing at one time, that one probably will give a better stand in that year than the split seeding.

**Summer sowing (late June, July and August):** By far the most reliable hay legume for summer sowing is alfalfa. If the soil will produce alfalfa at all, it should be included in the summer sowing mixture. Red clover, alsike, and the grasses are more sensitive to summer heat and drought than alfalfa and often do not establish themselves well at this time. However, timothy will establish itself well enough that it is usually better to sow it along with the legumes later, where it is to be included in the mixture.

Summer sowing serves several purposes. On very weedy ground, it permits working the ground for two or three months before sowing and so getting rid of most of the weed seeds in the surface soil. An important advantage of summer sowing is that the large quantities of superphosphate and potash which it may be desirable to use in starting alfalfa can be applied directly for that crop; whereas, if they are applied to a small-grain companion crop, the latter may make such a rank growth as to injure the alfalfa.

The basic hazard of summer sowing is
lack of moisture. In the hot, dry summer days, especially on soils which do not furnish water readily, the soil dries rapidly below the permissible depth of growing small forage seeds. If there has not been opportunity before that time for germination and the establishment of seedlings, many of them die. The root systems of plants sown in summer are never as deep nor as well stored with food reserves before winter as are those sown in the spring in the same season, and winterkilling is more common as a consequence. In practice, summer sowing often means that there is no return from the land for one year. Also, it is usually more expensive and more difficult to prepare a suitable seedbed in the summer than in the spring.

Summer sowing of alfalfa and sweet clover in the Central and Northern States should ordinarily be done in July as soon as moisture conditions are favorable for the germination of the seed and the survival of the plants. Legume seeds sown after mid-August may not make enough growth in the fall to survive the winter. If sown after mid-August, legume-grass mixtures are more likely to survive than are legumes alone, because the grass protects the small legume seedlings to some extent against winterkilling and loss by heaving in the spring. Some timothy or other grass should ordinarily be included, in all such late sowings. If a sufficient stand of the legume fails to survive the winter, more seed can be sown in the spring.

No companion crop should ever be used with a summer sowing. The suggestion has frequently been made to sow oats with such a sowing, supposedly in order that the growth may make a mulch for the winter. At Columbus, Ohio, the yields of hay in the three cuttings the following year were 30 percent greater on the plots where the sowing was made without a companion crop than where one was used.

Sowing after small-grain harvest: When spring sowing in a small-grain crop fails, it is sometimes possible to make good the loss by sowing after grain harvest. Although the soil moisture supply is likely to be low (and this makes the practice more or less uncertain), an increasing number of Corn Belt farmers are finding sowing alfalfa at this time more certain than sowing in thick and productive stands of wheat in the spring. The soil should be prepared as soon after grain harvest as possible. Disking clean stubble land is generally preferable to plowing, since a firmer and more uniform seedbed is usually obtained. If plowing is done to destroy weed growth, it should be shallow, and the plowed land should be worked down at once with a disk and cultipacker or heavy roller in order to pack the soil and reduce the loss of moisture to a minimum.

Sowings made immediately after small-grain harvest may suffer from weeds or a volunteer crop of grain. This trouble may be greatly reduced by preparing the seedbed immediately after harvest, permitting the weeds or volunteer grain crop to sprout, and then killing the weeds or volunteer grain by cultivation.

Fall sowing (September and October): Timothy or other grasses sown with winter wheat are usually sown in the fall at the time the wheat is sown. No legumes should usually be sown after September 1, except sweet clover with a high proportion of hard seeds. On the other hand, in the Corn Belt, September 1 to October 15 is the most favorable period for sowing almost all grasses. Orchardgrass, which is sometimes winterkilled, is an exception, but even orchardgrass is frequently successful when sown in the fall. Kentucky bluegrass is so much safer when sown at this time that every possible effort should be made to sow lawns, pastures, and any other mixtures containing bluegrass in the fall. Bluegrass does not form the rootstocks which constitute a true sod until it has gone through a winter. Timothy is much more certain when fall-sown than when spring-sown. A large proportion of the mixtures used in the Central and Northeastern States contain timothy, and the sowing is made in wheat. The universal practice of sowing timothy in the fall in wheat is abundantly justified. It is possible, however, to make timothy too large a part of the mixture in the fall, and this results in a
reduction in the yield of the legume. **Winter sowing** (November to Mid-February): Sweet clover in the hull can be sown at the same time, or any time after wheat is sown. Winter sowing of red clover, and even alfalfa, is sometimes successful, but with these crops which contain a higher proportion of permeable seeds, it is much more desirable to wait until very late winter or early spring for sowing.

**Rates of Sowing**

The rate of sowing should be enough to give a satisfactory stand and, for the sake of economy in seeding, no more. Suggested rates of sowing the more important forage crops are given in pages 675 to 681. The usual rates suggested in these tables are those which experience and experiment have found to be generally satisfactory. Where sowing conditions are poor, as in a poorly prepared seedbed, or when sowing in corn where much of the seed will probably be lost, or where especially thick stands are desired, rates up to the suggested maximum may be used. Of course, soil conditions which cause the failure of seedlings, such as lack of lime or nutrients, cannot be compensated for by sowing more seed. Where sowing conditions are exceptionally favorable or seed is unusually high priced, rates down to the minimum may be used. The use of a pulverizer-packer-seeder will also lower the required rate of sowing down to or below the minimum rates indicated.

The great variety of conditions surrounding the production of meadows and pastures in the various States, portions of the same State and even parts of the same farm, make it impossible to set up fixed quantities of each grass and legume seed most desirable for sowing for meadow or pasture under all conditions. Climatic and soil conditions, quantity of moisture available when needed, the time forage is required as livestock feed, the farm management programs, the local adaptability of strains used for sowing and other conditions make it necessary for each farmer to make up his mixture according to his best knowledge of the characteristics and adaptability of each crop for the particular conditions he has in the particular field he wishes to sow it in, and the use he wishes to make of it. Anything said here can be only general and suggestive of rates of sowing or possible combinations of grasses and legumes in seed mixtures.

**Depths of Sowing**

Among the controllable factors which govern the rate of sowing of the seed of pasture and meadow crops, there is perhaps no one more important than the depth of sowing. It is probable that the practices of the past have been to sow such seeds too deep and thus prevent the optimum emergence of seedlings and in turn require too high a rate of sowing. Recommendations for depth of sowing grass and legumes in much current literature probably involve depths which are too great for maximum seedling emergence. Since a good initial stand is necessary in the establishment of meadows and pastures, and depth of sowing is a controllable factor, it becomes very important to give it careful consideration.

Moore (Ohio-25) in tests with alfalfa, red, alsike and crimson clovers, white and yellow sweetclovers, Kobe, Korean, Tenn. 76, and sericea lespedeza, timothy, orchardgrass, and Sudan grass, showed that in practically all cases, more emerged seedlings were obtained from seed sown 1/4 inch or 1/2 inch deep than from surface seedings or seed sown at depths of 1 to 2 inches.

Murphy and Amy (Minn-18) conducted experiments in Minnesota to determine optimum depth with five different soil types and with ten different species among which were five legumes and five grasses. The species used were: alfalfa, sweetclover, red clover, alsike clover, white clover, timothy, brome, crested wheat, reed canary, and Kentucky bluegrass.

Though tests were made for only one season, the field sowings were made at two different dates, one May 4, and one June 27, the former under cool temperatures and the latter under variable en-
vironmental conditions, and the sowings were made at five different depths, namely, surface, ½ inch, 1 inch, 2 inches, and 3 inches.

The total emergence from the surface and from the ½ inch plantings was satisfactory for all crops in these averaged field tests. Red clover was the only legume in these studies which averaged more than 50 percent emergence from the 1 inch depth planting.

Both of these series of experiments in Ohio and Minnesota support the conclusion that maximum seedling emergence of small seeded legumes and grasses is usually obtained by sowing at depths of ¼ to ½ inch.

Delayed emergence, weakened seedlings, and thin stands that result from deep sowings also permit weeds to get an early start and to compete successfully with the newly emerged seedlings of meadow crop plants. If deep sowings are made with a companion crop, this delayed emergence and the rapid early growth of the companion crop result in greater competition for the meadow crop seedlings.

If the depth of sowing which gives the maximum total emergence is used for a given species, it should be possible to obtain a desirable stand by sowing less seed per acre than has been practiced by farmers and often recommended by agronomists.

**Method of Sowing**

**Drilling versus broadcasting:** For sowing early, broadcasting is the only possible method. It is not possible to cover mechanically seed sown very early on wheat or other fall-prepared land, but some covering of the seed is accomplished at these times by freezing and thawing. Covering at this time is not essential except as a protection against the killing of the uncovered sprouted seeds by freezing, since the seeds can establish themselves on the moist surface. Because early sowing is so important, sowing broadcast often has an advantage over sowing with a drill.

After the soil is dry enough to work, coverage becomes increasingly important and broadcasting correspondingly unreliable. Broadcasting after the soil is workable should be used only on recently prepared seedbeds which are sufficiently loose on top that the seed will be sufficiently covered by falling into the interstices of the soil and will be brought into close contact with the soil by the next rain. The pulverizer-packer method: An excellent method of sowing on any recently prepared seedbed is to (a) pack the soil with a corrugated pulverizer-packer, (b) sow the seed broadcast, and (c) run a harrow or weeder lightly crosswise or better still, cultipack again to cover the seed. By this method most of the seed falls on the firm, moist soil at the bottom of the furrows made by the wheels of the packer, is covered uniformly at a shallow depth, and comes up in rows as though drilled. This method is especially valuable in summer sowing but may be used at any time that the soil is dry enough not to puddle or lose its granular structure under the packer.

Attempts are often made to obtain a firm seedbed by rolling or culti-packing after sowing. As just noted, it is far more important to have the soil under the seed firm. If that is accomplished, packing the earth above and around the seed after sowing is of lesser importance. If too heavy packing after sowing is followed by a dashing rain, the soil may become baked and the result will be a crust that will prevent the emergence of many seedlings.

There are several makes of corrugated pulverizer-packers in which the individual wheels which make up the rolls range from 2 to 4 inches in width. Probably all of these instruments effectively pulverize and pack the soil in preparation for sowing. However, for sowing grass seed and the seed of small-seeded legumes, alone or in mixtures, where the seed should be covered not more than ½ inch for maximum emergence of seedlings, the best implement to use to do the complete job after thorough initial preparation of seedbed is a combination pulverizer-packer-seeder. In this implement the individual wheels are not over 2 inches wide and have front and rear sections; larger wheels on
the front shaft do the pulverizing and packing before sowing and the lighter and smaller wheels on the rear shaft alternate with the front wheels (split ridges) and do the covering of the seed and firming of the soil over the seed. The seeder part of the implement sows the seed broadcast between the front and rear corrugated rolls where the seed falls into the furrows made by the front rolls and is covered and the soil firmed (not solidly packed) by the corrugated rear rolls. The seed may be sown as a grass-legume mixture or the grass and legume seed may be sown separately to obtain a more uniform distribution. With such a machine less seed is needed for a good stand and little or no seed is lost by too deep sowing. See illustration of seeder.

**Patching thin stands:** Because of the hazards of sowing, the feasibility of patching thin stands of forages is an important consideration. Two general principles may be noted: first, thin or uneven stands caused by insufficient lime or soil fertility are not likely to be repaired successfully until the condition is corrected; second, the younger the stand, the more likelihood that patching it up will be successful.

Where a partial failure is due to drought, as frequently happens to stands sown in companion crops in dry seasons, it is often possible, if good rains follow the removal of the companion crop, to repair them, unless the field is very weedy. Additional seed may be sown with a drill, if enough pressure is put on the disks to make sure that the seed is cut into the ground. With the single-disk grain drill frequently very little soil will fall back into the disk furrows, and the seeds will be left uncovered at the bottom of these shallow furrows. With this type of drill the success of this sort of sowing depends on a timely rain to wash the soil back...
into the furrows and cover the seed. When this occurs within a week or two after sowing, some excellent results have been obtained without materially injuring the stand already present. With the special grass-seed drill the furrows are narrow and steep and on loose soil types the seeds will generally be covered sufficiently to permit germination and establishment.

Sowing alfalfa seed in thin stands not successful: Attempts to reestablish alfalfa by sowing seed in old, thin alfalfa have uniformly failed, although they have been made repeatedly under very favorable conditions. The old alfalfa plants, even if there are only a few per square yard, make such a shade that the young alfalfa seedlings are smothered out and have no chance to establish themselves.

Sowing timothy in thin alfalfa: However, it is possible to sow timothy in old, thin alfalfa and so prolong the usefulness of the meadow. The sowing is made after the final cutting of alfalfa is removed. This period is very favorable for starting timothy, and alfalfa does not usually make such a growth as to kill it out. It is desirable to prepare a seedbed, preferably by use of a spring-tooth harrow, or with a disk set to cut lightly, immediately after the final harvest for the season. The timothy is then broadcast or drilled, as may be most convenient. Drilling the timothy into the otherwise unprepared alfalfa has also been quite successful, and is perhaps to be preferred where bacterial wilt of alfalfa is present in the field. Broadcasting the timothy without seedbed preparation has always failed. Five pounds of timothy per acre has been sufficient. After the timothy is established, it occupies the bare spaces between the alfalfa plants, so that the total yield of hay at the first cutting is increased and the proportion of weeds is decreased.

Orchardgrass has been successfully used in the same way, and it is possible that the other grasses can also be sown in alfalfa, but timothy has the advantages of cheap seed, being readily sown with a drill, and starting well when sown in the fall.

Summary of Sowing Suggestions

Under conditions in the Central and Northeastern States, there are four general circumstances under which seed is sown: (a) in winter wheat; (b) in spring-sown small grains; (c) in the spring without a companion crop; and, (d) in the summer or fall.

Whichever one of the four circumstances applies, there are certain general practical suggestions for obtaining a stand at any time:

1. Choose a mixture or crop adapted to the specific soil and sowing conditions. Include ½ to 1 pound of Ladino clover in every pasture mixture for sowing under conditions favorable to Ladino clover.

2. Bear in mind that a companion crop is not a "nurse crop." Its advantages are mostly economic and its disadvantages are mostly cultural; consider both before sowing.

3. If lime is needed, it should be applied in preparing for a preceding crop or as early as possible in the preparation of the seedbed.

4. On many soils, but especially on those where it is difficult to obtain a stand, a heavy application of manure to the previous crop, or far enough in advance of sowing to permit mixing with the soil and partial decay, will greatly increase the chances of success.

5. Inoculation of legumes must always be taken care of. "When in doubt, inoculate."

Causes of Failure to Obtain Stands

We have so far considered mostly the best conditions and practices for the establishment of pastures and meadows. Let us consider also the consequences of not providing suitable conditions for establishing a stand, and the specific causes of failures.

A wide variety of reasons is given for failure to obtain stands. It is common to classify these generally as "poor seed," "unfavorable season," "winterkilling," and the like, but these generalities are only slightly helpful. These failures are
for reasons which are specific and local
for each seed sown, and the stand ob-
tained is the summation of these local
effects. The more nearly we approximate
knowing the reason for the failure of each
kind of seed sown, the better. These fail-
ures may be grouped in three categories:

1. Failure of the seeds to germinate
may be because of (a) dead or weak seed,
(b) dormant or hard seed, or (c) unfavor-
able sowing conditions.

2. Early seedling hazards may be (a)
freezing, (b) too deep coverage, (c) crusts
on the soil, or (d) drying out of the seed-
bed.

3. The hazards that may endanger new
stands later are (a) lack of inoculation of
legumes, (b) unfavorable soil conditions,
(c) insects and diseases, (d) drought, (e)
competition of companion crops, (f) com-
petition of weeds, (g) poorly adapted seed,
and (h) winterkilling.

WHY SEEDS FAIL TO GERMINATE

Dead or weak seed: Good stands cannot
be obtained from seed of low germina-
tion. The labels on forage seed purchased
should always be carefully examined for
information as to germination and purity.
If there is any question as to germination,
a representative sample should be sent to
your State seed laboratory, or to a recog-
nized commercial laboratory. Seed held
a year or more after purchase or known
to be two or more years old should al-
ways be tested before sowing. "Test,
don't guess" is as important with forage
seeds as with seed corn. Old seed or seed
that has been improperly stored is likely
to be of low germination, or the sprouts
may be weak, or both. The strength of
the sprouts, as well as the percentage of
germination, should be considered in
evaluating seed.

Strong, viable seeds of most forage
crops will retain their vitality for several
years if stored in a dry, cool place where
the temperature is uniform, but under
average conditions, 1 to 3 years is about
the limit of safety.

Dormant seeds: Dormancy in seeds is
applied to any condition of the seed
which makes it resistant to germination.

In certain forage seeds it varies with (1)
species or variety, (2) stage of maturity,
and (3) conditions under which produced.
The most generally known evidence of
dormancy is exhibited in the hard seeds
of many legumes and certain other
species of plants.

In addition to "hard seeds," there are
certain physiological factors which affect
the germination of seed. These cover a
wide range of seed conditions that are
distinguished by resistance to germina-
tion of various types and degrees.

The occurrence of dormancy of seeds
in nature is more widespread than is
usually realized. Dormancy, so pro-
ounced in many of our native plants
and weeds, is of obvious advantage as an
adaptation which preserves the viability
until a season favorable for the develop-
ment of the plant, where that does not
coincide with the time of ripening of the
seed.

From various experiments and obser-
vations, it would seem probable that the
seeds of most crop plants show at least
a brief period of some degree of resist-
ance to germination.

The explanation of the hard seed prob-
lem in leguminous plants on the ground
of the impervious seed coat has appeared
so simple that we have often accepted
this as the explanation of many other
causes of dormancy which may be very
complex and which may be affected only
by specific physical influences such as
heat, water, air, chemicals, light, electric
shock and electric waves, either alone,
or in combination, or periodically.

When legume seeds are tested, a cer-
tain proportion of them will usually
remain unchanged on the blotters, while
the others either germinate or mold and
decay. These unchanged seeds have
water-resistant seed coats which keep the
interior of the seeds as dry as if they
were in storage. These "hard" seeds may
remain in a moist place under germinat-
ing conditions for months or years with-
out swelling or decaying. Finally, when
the seed coats decay or are broken by
temperature changes, the seeds germi-
nate. Red clover and alsike clover seeds,
before threshing or hulling, may contain
80 to 95 percent of hard seeds. These are responsible for many of the volunteer stands of clover on farms where ripened seeds are plowed under with the sod, or where manure from clover hay containing ripe seeds is spread. Many times these volunteer stands of clover add much to the success of the clover crop.

A considerable portion (but not necessarily all) of the hard seeds in a sample will germinate in the late winter if sown while freezing and thawing are still taking place, so that seed which contains a high proportion of hard impermeable seeds may be sown earlier than permeable seeds. This is frequently done with sweet clover.

Seed with a high proportion of hard seeds is often “scarified.” Special scarifying machines for blowing the seed at a high rate of speed over coarse sandpaper, or passing it between rapidly revolving steel disks, have been developed for this purpose. The seed coats are thus scratched sufficiently to admit water and permit germination. Scarified seed loses vitality rapidly, so that such seed more than one year old may be weak and low in germination.

Certain species of grass seeds such as Kentucky bluegrass, the fescues, timothy, and others, exhibit periods of dormancy of various durations following harvest. With such seeds the term “after-ripening” has been applied to the changes that usually take place in the seeds, making them less resistant to germination. The seed coats of these species are often thick and hard, and it is necessary to scarify the seed to obtain good germination.

Toole (US-257) has shown that with timothy the after-ripening may be slow or very rapid; more rapid in the cut head than in the threshed seed and more rapid on the plant than in the cut head; and the more mature the seed at time of harvest, the less the resistance to germination. In commercial timothy seed, dormancy disappeared one to two months after harvest. This period could be prolonged for several months by rapid drying at 105°-110° F. Prechilling, daily alterations of temperature, exposure to light, and various chemicals were shown to be aids to germination.

Kearns and Toole (US-128) have shown that seeds of the fescues tested immediately after harvest remained dormant at high temperatures, the degree of dormancy depending on stage of maturity at harvest and time intervening before testing. A constant temperature of 50° F. was best for very fresh seed of certain fescues, but somewhat higher temperatures were suitable as the seed increased in age, or following a 7-day period of chilling at about 40° F.

With buffalograss, dormancy is so pronounced that only a small percentage of the seed will grow the first year after sowing. This varies considerably with different strains and with various lots of seed, and with differences in methods of growing, harvesting, and handling. Untreated buffalograss seed ordinarily germinates less than 10 percent the first year after harvest. This may be increased to 70 or 80 percent by chilling, dehulling, and soaking in a 0.5 percent saltpetre solution.

With many other plants dormancy exhibits itself in various ways. Some of these have been studied by Crocker (Misc-18), Kearns and Toole (US-128, 129, 256-259), and other workers.

Unfavorable sowing conditions: Given seed capable of germination, a lack of any one of three things needed to induce germination may cause failure; (a) sufficient moisture, (b) favorable temperature, and (c) sufficient air. With these things in proper balance for the particular seed, viable seed will germinate.

The dominant problem in obtaining satisfactory germination of seed after sowing, is to provide sufficient moisture over a long enough period for the seeds to establish themselves. This involves the preparation of the seedbed, the date, method and depth of sowing, and the use of mulches.

Insufficient air after sowing is seldom a problem with forage seeds, which are usually sown shallow. Favorable temperatures for sowing forage seeds are largely regulated by the date of sowing. Most forage seeds will remain dormant for some time after sowing if sown when the weather is too cold for germination.
Early Hazards to Seedlings

Freezing: Sowing in late winter and early spring exposes the young plants to the hazard of freezing. Seed can be sown very early and endure even prolonged sub-zero weather if it has not germinated, but if a warm period intervenes in which the seeds start to grow, followed by low temperatures for a time, the seedlings may be killed.

Important methods of avoiding or reducing freezing injury to spring sowings are: choosing the most favorable date of sowing, staggering or splitting the sowing periods, the use of mulches, getting the seed covered by soil and, with sweet clover, the use of unscarified seed.

Too deep coverage: Most forage crop seeds are small, and the seedlings cannot force their way to the surface if covered too deeply. Critical experiments on depth sowing are lacking, but there are many experiences of poor, thin stands following too deep sowing with or in front of a drill. On the other hand, as soon as the weather is warm enough so that the surface soil dries quickly, failure to cover the seed firmly is also fatal to good stands. The method of sowing and the date of sowing are both concerned with the question of coverage. See section on “Depth of sowing.”

Soil crusts: Closely related to coverage is the problem of crusts that form on the soil and prevent seedlings from breaking through. Many soil types tend to form crusts, which are often fatal to the prospective stand. There is no possibility of breaking up a crust over small-seeded forages after it has formed, as is sometimes done over soybeans. Experiments have shown that seedlings break through a crust better if the soil under them is as firm as the crust.

Germinating seeds exert considerable force, but the difficulty is that loose seedbeds cannot resist the downward thrust, so the seedlings cannot break the crust. If the soil is firmly packed around and below the seedling, the seedling is prevented from curling under the crust, and so, it may exert greater force to break through. Mulches are extremely valuable in preventing the formation of hard crusts. Soils containing an abundance of organic matter do not crust as badly as those which are exhausted by cropping. A common experience is to obtain a perfect stand on a part of the field where a sod has recently been plowed down, although only a mediocre stand is obtained on the remainder of the field where the organic matter has been reduced by cropping.

Drying out of seedbed: This difficulty arises when a little moisture starts the seed germinating but the soil is dried out before the seedling can establish itself. When the seed is sown before April 1 to 15 in the Central States, or April 15 to 30 in northern States, the soil seldom dries out before the seedlings can establish themselves. They are progressively more subject to this hazard, until it becomes a major one in summer sowing. Early sowing, firm soil under the seed, proper coverage, mulches, and sufficient reserve moisture in the soil are the major points to be observed in avoiding loss of stands from drying. Much of the sowing of red clover and timothy seed in the Northeast is done in March on frozen ground so that freezing and thawing will cover the seed and germination occur when the temperature is high enough. The same procedure is used in renovating pastures.

Later Hazards to New Stands

Many a promising stand in the seedleaf stage has succumbed to unfavorable conditions a little later.

Lack of inoculation: In order to be successful, legumes must be provided, either naturally or artificially, with the proper bacteria on the roots. Uninoculated plants often die, or if they survive, are low in protein, and do not build up the soil. See chapter III on inoculation of legumes.

Unfavorable soil conditions: Legume seeds will germinate in strongly acid soils, but the seedlings soon begin to show the effect of the lack of lime by a slowing up of growth and a general sickly appearance. Many plants die in
a few weeks’ time, and many more are killed during the first winter. Winterkilling is less likely to occur on well-limed soils, because the plants have made good growth of both tops and roots before winter. Many a clover and alfalfa failure which is attributed to dry weather, unfavorable season, and the like, is really due to insufficient lime. All of our common legumes except sweetclover make their best growth at pH 6.8, or just below the neutral point.

Legume seeds will germinate well in a poor soil, but by weak growth and lack of vigor the seedlings soon show the effect of starvation, which makes them susceptible to disease and winter damage. Probably because of its effect in stimulating root growth, nothing helps more in establishing a legume than an abundance of available phosphorus in the soil. Applications of superphosphate, or where potash is also likely to be deficient, of 0-14-6 or a top-dressing of manure are often worth more than their cost in helping to insure a good stand of legumes.

Insects and diseases: Insects and diseases frequently cause more or less injury to the young forage seedlings, sometimes causing near-total losses. Examples are the clover leaf weevil, pea aphids, grasshoppers, and leafhoppers among insects, and anthracnose and damping-off among diseases.

Drought: Drought is a common and serious enemy of young grass and legume stands. However, when crops are sown without the competition of a companion or so-called “nurse” crop, it is usually only on very droughty soils, particularly sands, that difficulty from drought is encountered in spring sowing. Even in years of severe drought, alfalfa and clover sown alone in the spring usually survive. They will usually survive if sown in summer also, if they actually become established.

Competition of companion crops: The difficulties usually attributed to drought are largely due to the crops in which the forages are sown. These crops have been miscalled “nurse” crops for so long that many think they really have a protective effect on the forage seedlings. The cereal crops in which forages are too frequently sown are never directly beneficial to them.

Competition of weeds: Weeds may do forage crops as much or more harm than cereals, and be worth nothing. They may also appear after the companion crop has been harvested, so that means for their control are important. Clearly, the only practical control for weeds in the new stands of mixed grasses and legumes is mowing; in certain pure grass stands 2, 4-D or other chemical treatment may be effective.

Winterkilling: Winterkilling is not an infrequent hazard of seedlings. It may follow late fall sowing, poor development on account of drought, or lack of nutrients or lime, untimely clipping, or poorly adapted seed.

CONTROLLING WEEDS BY CLIPPING

In controlling weeds by clipping, two points are of importance; the size of the weeds when cut, and the height of clipping. Weeds should be allowed to make considerable growth before clipping, as much as is consistent with saving the stand of forage. The reasons for this are: first, to permit the weeds to make sufficient growth so that when they are cut they will be killed; second, to allow the forage to make top and root growth. A tall, dense growth of weeds is more likely to be killed by clipping than a young, scattered, open one, since in the former the buds on the weed stubble will have been killed by shading. Clearly, the lower the weeds are cut, the more of them will be killed. On the other hand, red clover and alfalfa recover from crown buds at ground level, whatever the height of cutting. Consequently, high clipping merely favors the weeds instead of these forages, although many directions for clipping new seedings wrongly recommend setting the mower bar high. The recommendation to cut high applies only to sweetclover, which is so seriously injured by clipping that it should not be clipped unless the stand will certainly be killed if the weeds are not clipped. Sweet-
clover recovers after clipping from buds along the stem and, like the annual weeds we have discussed, it will be seriously injured by low cutting.

**Effect of Clipping on Root Reserves**

Clipping of new seedlings has a bearing on another cause of failure of stands, the failure to form sufficient root reserves and root systems to go through the winter.

Spring-sown alfalfa has been least affected, either favorably or unfavorably, by one clipping or cutting in the summer or fall of the year sown, but it has been injured by very late clipping. Red clover was definitely injured in Ohio by clipping after September 1, but the yield the following year is usually somewhat greater following late August clipping than when it is not cut at all. There is a general opinion that allowing red clover to produce seed the first year kills it, but this is not true.

Sweetclover is most injured in Ohio by clipping September 1 to 15. Before this period, the earlier, and after this period, the later it is clipped, cut for hay or pastured, the better. This is true because sweetclover plants make no further top growth when cut after September 15, and removing the tops prevents further root storage.

As a rule, it is recommended to clip spring-sown alfalfa, red clover or alsike during August of the year sown; whereas, if first-year sweetclover is to be cut for hay, it should be cut as late as practical. The clippings may and should be removed if they are valuable for hay or are heavy enough to injure the stand.

It is not usually necessary or desirable to clip the forage in small-grain stubble more than once. Spring seedings without a companion crop are best cut or clipped twice during the year sown. The first clipping should be delayed as long as possible, and, in the latitude of Ohio may usually be left until July. One more clipping late in August will usually control weeds satisfactorily and permit the storage of reserve materials in the roots after the last clipping. However, at Wooster, Ohio, alfalfa sown alone in the spring has been clipped three times without apparent injury.

Stands obtained from summer sowing should not be clipped at all the first year (if it can possibly be avoided) since they have only a short time before winter in which to develop a strong root system. Since the growth of roots is dependent upon the growth of tops, to remove the latter seriously reduces the former. If a good job of weed control has been done previous to summer sowing, there will seldom be any weeds to contend with in the fall.

**Pasture Renovation**

Pasture renovation means the improvement of any type of pasture. More specifically—and more recently—renovation is taken to mean a general improvement and a particular kind of improvement, that of breaking up the old sod and establishing on it some of the larger species of grasses and legumes. Further, the term is usually thought of in connection with the improvement of nonplowable land. It is particularly adapted to fields where plowing would be difficult because of a rough topography or stony soils and to those where plowing would be hazardous because of erosion.

**Implements to use:** Under such conditions the use of implements like the heavy cutaway disk (bush-and-bog harrow), the field cultivator, or the spring-tooth harrow is better than plowing. The yields of forage from a renovated pasture on which the seedbed was prepared with various implements and sown to larger growing legumes and grass over a 3-year period showed little difference between those obtained from plowing or the use of a disk or field cultivator. Satisfactory results may be obtained with any of these tools.

A seedbed prepared by surface tillage, where a layer of roots and stubble from the old sod remains on or near the surface, is not so susceptible to erosion. The layer of plant residues also makes it easier to establish seedlings and increases the amount of water absorbed during beating rains.
Preparation of land: The actual preparation of the land for sowing is not difficult when one clearly understands the aims. As on plowable land that might be used for any crop, one must provide adequate lime and fertilizer to meet the needs of the plants used. The quantities required in pasture renovation are similar to those used for the initial establishment of pastures. Because the sites chosen for renovation are often on soils that had a low natural fertility or had been depleted of fertility by intensive cropping, it is wise to use liberal amounts of fertilizer at the time of establishment.

Killing existing species: Just as important is the need to subdue existing vegetation. When an old sod is broken up and lime and fertilizer applied, the grasses or weeds that have been growing there will be stimulated. These old plants compete for light and moisture with the young grass and legume seedlings, and reduce their growth. This emphasizes a primary objective with the use of surface tillage implements—that of killing a large part of the old sod.

Some plants are more difficult to kill and have a greater competitive effect on the species sown than others. Kentucky bluegrass, Canada bluegrass, and redtop sods, for example, can persist after surface tillage unless soil contact with their roots is broken, and the plants are thus made to dry out. Sods of povertygrass and broomsedge are more easily killed and, furthermore, they do not compete so severely with the new seedlings. The composition of the original sod is therefore an important factor to be considered in preparing the seedbed.

The normal periods of higher temperature and lower soil moisture in midsummer may be used to advantage in renovation procedures. When the old sod is worked during this period, the unwanted plants are more apt to be killed than if the sod were worked in the spring or fall. Even during the midsummer it will be necessary to rework the field to loosen the sods that have rooted down after a shower.

Summer preparation desirable: As a general procedure for destroying bluegrass and bentgrass sods in preparation for sowing, it is advisable to apply the necessary lime and begin working up the sod as soon as the spring or early summer flush of grass has been grazed off, about the latter part of June, and after a rain has softened the sod. A heavily weighted cutaway disk or bush-and-bog harrow is good for the purpose.

The field will probably require disking at least twice at right angles so that the roots of the sod will be broken from the soil even though it may not all be turned over. Subsequent disking with a lighter disk or a strong spring-tooth harrow will be needed if the plants root down again. This procedure will kill most of the sod by mid-August. The fertilizer can then be applied and disked or harrowed in.

A spring-tooth harrow used for this operation will help level the seedbed, although it may still appear rough.

A fairly rough seedbed is actually desirable because it halts erosion and improves the infiltration of moisture. In southern localities, where fall sowing of legumes has been successful, the field may be rolled and the sowing made in the usual way. In the central and northern parts, spring barley or spring oats may be sown in August to provide late-fall grazing. Because these plants will be killed during the winter, they will not compete with the sowing made on frozen ground the following spring. Besides providing fall pasture, the ungrazed stubble and roots will reduce erosion during the fall and winter.

Time of sowing: Over most of the region, a successful stand of legumes is more certain with a spring sowing. Better stands and larger midsummer yields are had by sowing very early in the spring. Land prepared by surface tillage in midsummer is well adapted for sowing in late February or March, as soon as the snow melts. Seed may be broadcast with a cyclone or wheel-barrow seeder on frozen ground. Alternate freezing and thawing of the soil surface covers the seed, and as soon as the temperature is warm enough to permit germination, the
SEASONAL PASTURE MANAGEMENT

Seedlings begin to grow. Also, sowing in early spring does not conflict so much with other farm operations.

In most renovations the use of a companion crop of grain does not seem warranted. If the seed is sown in March, the forage grasses and legumes make enough summer growth to reduce the growth of annual weeds, and a small hay crop can be removed in July or the new stand may be lightly grazed.

Midsummer is the best time to prepare the seedbed in most Central and Northeastern States, but not everywhere. In West Virginia and other localities where open winters make soil erosion a serious hazard and where the original sod includes such bunch-type grasses as povertygrass and broomsedge, the seedbed may be fitted in early spring. On this type of sod a spring-tooth harrow works well. Both of these species are relatively easily weakened by tillage; neither causes such severe competitive effects on a new stand as bluegrasses and bentgrasses. Lime and fertilizer may be applied, the land worked, and the desired species sown, all within a short time.

The most difficult problem to be solved in the management of grazing arises from the seasonal differences in the rate at which pasture plants grow. Summer is a period of low productivity for permanent and rotation pastures from Canada to the Gulf Coast, and eastward from western Minnesota and eastern Texas, the area to which the management practices discussed here apply, and which, although it is large and diverse in soils and climate, has several common problems of pasture management.

Early pastures most productive: Measurements of the seasonal growth of pasture grasses and mixtures in Maryland and Missouri showed that more than half of the total annual yield occurred during the first one-third, and more than two-thirds of the total occurred during the first half of the growing season.

No one crop or seed mixture yet tried in Connecticut supplies uniform grazing, and it becomes increasingly difficult to provide any pasturage there from June 15 to November 1.

In some years all of the annual gain made by beef steers on winter clover-Bermuda-grass mixtures in Arkansas had been made by July; in every year most of the annual gain had been made by that date.

Because winter legume-Bermuda-grass-Dallisgrass pastures in Mississippi have peaks of production in spring and fall, the number of animals adequately carried in spring would overgraze the same pasture in the summer period of lessened production.

The productivity of mixed grasses and winter clovers increased rapidly in the Black Belt of Alabama from late March to May, remained high through May, declined during June, remained low through July, rose to and remained at a moderate rate during August and September, and then declined to the March level by the end of October.

So, whether the grazing season is 5 months long, as it is in Maine, or 12 months long, as it might be in Florida, the problem is to provide good pasturage throughout this season.

Mature grass less nutritious: Saving part of the spring growth for summer and fall grazing is not the solution, because of the poor quality of mature grass. Chemical analyses, combined in some instances with feeding trials, have shown that some pasture grasses (such as bermudagrass) deteriorate less in quality than others but that all of them are less palatable, less digestible, and less nutritious when mature than when young, vegetative, and actively growing.

When, therefore, hay of the desired quality cannot be made from surplus growth, the size of the pasture and herd should be adjusted to herbage growth during spring, and temporary pastures should be used to supplement permanent pastures summer and fall.

Effects of heavy grazing: Heavy grazing of Kentucky bluegrass and associated legumes in Missouri from mid-April to early July, and again during September and
October, produced large acre yields of beef but weakened the grass. Close defoliation during the cool periods of spring and fall prevented the synthesis of sufficient carbohydrates to satisfy plant requirements for current growth and for the storage of organic food reserves.

The use of Korean lespedeza for supplementary pasture from July 10 to September 1 increased live-weight gains during the summer, but resting the permanent pasture at that time had little beneficial effect on the bluegrass.

Kentucky bluegrass will benefit from undergrazing or rest both during the cool period of spring, when two-thirds of the total forage is produced, and that or autumn when less than one-fifth of the total top growth occurs.

Supplementing permanent pasture: Supplemented grazing, whereby the permanent pasture was grazed to capacity from mid-April to early July and at a greatly reduced rate from early July to mid-September, and then rested from mid-September to late November, was tried in Missouri from 1941 to 1944. The pasture sward, consisting of Kentucky bluegrass, Korean lespedeza, and volunteer white clover, improved steadily under this grazing schedule and in 1944 produced 250 pounds of beef-cattle gain an acre, as compared with 199 pounds obtained from the season-long grazing of a comparable pasture. Furthermore, the September-October growth was available in the supplemented-grazing pasture for winter feed.

Grain crops as supplementary pasture: Korean lespedeza grown with wheat, winter barley, or spring oats, each harvested for grain, supplied summer pasture from July 10 to September 30. The average live-weight gain made on this supplementary pasture from 1940 to 1944 by beef steers was 103 pounds an acre.

Feed costs can be reduced and injury to permanent and rotation pastures from too early grazing can be avoided by the use of supplementary pastures in the spring. Rye provides pasture earlier than any other crop. In the middle latitudes, Missouri to Virginia, rye is ready to be pastured a month earlier than permanent or rotation pastures, but in the northern tier of States not more than 2 weeks of early grazing can be gained.

Winter oats, barley, wheat, and rye supply both winter and early-spring pasture in the Cotton Belt. Only light, intermittent grazing can be expected from them before February in the northern part of this region, but beef steers gained 159 pounds per head and 190 pounds an acre in northern Florida on winter oats pastured continuously from December 20 to April 20. Ryegrass, crimson clover, bur-clover, vetch, and roughpea, in pure stand, with one of the above cereals, or in Johnsongrass sod also are used for winter and early-spring grazing in the Southern States.

Summer is a period of low productivity for permanent and rotation pastures. North of the region within which annual lespedezas can be grown successfully, Sudangrass is the standard supplementary pasture crop from early July to late September. Japanese millet, second-growth meadow, oats or barley planted as companion crops, and reed canarygrass also can be pastured during summer. From northern Missouri and Maryland to the South, the annual lespedezas fill this gap exceedingly well. Sudangrass, pearl millet and cattail millet, Johnsongrass, kudzu, and soybeans are also used.

Building winter root reserves: Autumn is a favorable period for root growth and for the storage of carbohydrate reserves by Kentucky bluegrass and other cool-weather perennial grasses. Protection from grazing during this period increases the vigor and prolongs the life of the grass with a minimum waste of forage, for only a small fraction of the annual top growth occurs after mid-September, and this growth can be pastured off after mid-November without harm to the grass.

Annual lespedezas and Sudangrass supply grazing until the end of September. Early-sown rye, winter barley, or oats and first-year sweetclover are usually
ready to be pastured by early October. The fall growth in the permanent or rotation pastures can be pastured off after frosts in November.

Spot grazing: Farm animals never eat pasture herbage down to a uniform height unless compelled by being confined to an area so small that it is pastured out completely within a few days. Without this restriction, spot grazing occurs and the grass first refused is eaten only after livestock have failed to obtain a fill from vegetation shortened by previous grazing. Overgrazing and undergrazing within the same enclosure are the result.

Rotation grazing: Fencing the pasture into two to eight separate enclosures of equal size to be grazed alternately, known as rotation grazing, has been devised to reduce uneven grazing. If there are enough of these enclosures, the herbage can be pastured down quickly to the desired level as soon as it has grown to a height suitable for grazing. Between brief periods of intensive grazing, the sward is protected from defoliation and trampling.

During the spring period of flush growth, individual fields not needed then for pasture can be withheld from grazing and the forage in them harvested for hay or grass silage. Later these fields are pastured in turn, thereby lengthening the rest periods for all enclosures as herbage growth slows up. This practice reduces but usually does not eliminate the need for summer supplementary pasture.

Dividing herd for grazing: A further refinement of rotation grazing is to divide the dairy herd, so that producing cows have first access to new growth and dry cows and young stock finish pasturing out each enclosure after the producing cows have been moved to another field.

Each grazing period lasts from 3 to 7 days for each group of a split herd or from 1 to 2 weeks for an undivided herd or flock; and the intervening rest periods will last from 2 to 4 weeks, depending on the number of enclosures, the kind of pasture, and the weather.

Even when rotation grazing is practiced, tall grass will accumulate near droppings. If each field is mowed a day or two before the animals are to be removed, most of this previously avoided grass will be eaten after having been moved by the mower a short distance from the excrement around which it grew.

Rotation grazing has been advocated for improved permanent pastures in Maine, Connecticut, Rhode Island, New York, Ohio, Illinois, and Wisconsin, for rotation pastures of bromegrass and alfalfa or Ladino clover in Wisconsin and Indiana, and for Sudangrass in Ohio and Georgia. But in each of the experiments in which rotation grazing has been compared with uncontrolled grazing in Maryland, Michigan, Wisconsin, Missouri, and Washington, the increase in production has been too small to justify the added expense of fencing and water supply, unless these could be provided at moderate cost and unless the pasture was high in yield and quality. Rotation grazing may be necessary to maintain in pastures such crops as alfalfa and Ladino clover.

Deferred grazing: Delayed grazing for a part of the growing season to permit sufficient top growth to maintain the vigor of pasture plants is often practiced. The nutritive quality of bromegrass declines little and its carrying capacity is greatly increased by delayed grazing until the grass is 10 inches high. The destructive effect of early clipping or grazing on alfalfa, and its high nutritive quality even when in bloom, are well known. Deferred grazing is a good practice for bromegrass and alfalfa and other mixtures that have similar habits of growth.

Many other pasture grasses deteriorate in quality with advancing maturity much faster than bromegrass, and low-growing legumes, such as white clover and annual lespedezas, may be suppressed by the vigorous early growth of ungrazed grass.

Deferring the pasturing of winter clovers too long in the South, on the other hand, may reduce greatly the growth of associated Bermuda-grass or Dallisgrass. The net effect of early grazing on the pasture sward may therefore be beneficial even though the vigor of
the more aggressive early-growing component is somewhat reduced.

In Connecticut, cattle gained more than twice as much when grazing began May 5 as when it began June 10, although the yield of herbage was larger under delayed grazing. Deferring the grazing of bluegrass from 2 to 4 weeks after mid-April reduced cattle gains by 13 percent in Missouri. Although livestock should never be turned on pastures before the vegetation has made sufficient growth to permit them to obtain a full readily, a longer delay in grazing is justified only when the herbage consists of erect, tall crops that are highly sensitive to pasturing when small.

A common recommendation is that grazing begin when the vegetation is 3 to 4 inches tall. Permanent pastures in the northern tier of States are usually ready for grazing by May 15. Renovated permanent pastures or rotation pastures of bromegrass and Ladino clover or alfalfa are ready a few days earlier in Wisconsin.

Farther south, central Missouri to Maryland, livestock can be turned on permanent pastures in mid-April. From Arkansas and North Carolina to the South, pastures that contain winter legumes are ready to be grazed by late March.

**Intensive grazing:** Overgrazing should be avoided because livestock cannot obtain enough nutrients to support profitable production if the vegetation is too short, and because certain valuable pasture plants may be destroyed.

Since, however, most pastures produce two-thirds of their herbage during April to July, since this vegetation deteriorates in nutritive quality and palatability if not eaten as it grows, and since rank growth tends to suppress low-growing legumes, most pastures should be grazed during periods of lush growth to the minimum height that will permit adequate daily consumption of pasturage by the grazing animals. This is not overgrazing except for mixtures of hay-type grasses and legumes.

Pasture herbage can be consumed most rapidly and easily from a dense stand of grasses and legumes about 4 inches tall. A cow must have favorable grazing conditions in order to consume the quantity of green herbage required for maximum production during the 8 hours of each day that she is willing to spend grazing.

Beef steers averaged 287 pounds of gain per steer and 145 pounds of gain per acre on a permanent pasture at Beltsville that was stocked at the rate of one steer to 2 acres, as compared with 195 pounds of gain per steer and per acre when the rate of stocking was doubled. Both groups of steers gained equally well from April to July. The unsatisfactory gains made after June on the heavily grazed pasture is not sufficient reason for understocking during spring and early summer if land is available for the production of supplementary pastures for summer and early fall grazing.

The need to leave enough leaf surface to manufacture the carbohydrates required to sustain current and future growth of pasture plants is recognized, but the level of carbohydrates that is best for the grass may not be best for the pasture. Close grazing in May has been found to increase the growth of volunteer white clover, and later in the season the grass benefited more from this increase in clover than it had been injured by close grazing.

**Height of pasture herbage:** The specific height to which the vegetation should be eaten down depends on the crops which constitute the pasture. The opinion has been expressed that the average height of bluegrass and volunteer white clover should be one-half inch after being grazed and mowed in rotation. It is now generally believed that these and similar pasture species should not be grazed shorter than 1 to 2 inches. Two inches has been recommended as the minimum to which pastures containing Ladino clover should be grazed in Connecticut and pastures containing Bermuda-grass in Georgia.

Under skillfully managed rotation grazing, grass 3 to 4 inches tall can be quickly pastured down to a desired height. Without such management, grazing is never uniform except on a
badly overgrazed pasture. Intensity of 
grazing on the average pasture is indi­
cated by the comparative size of grazed 
and ungrazed areas. If more than 25 
percent of the total area remains un­
grazed by June, the pasture is under­
stocked, but if less than 10 percent of 
the area remains ungrazed, overgrazing 
will probably occur before supplementary 
pastures are ready in July.

Pasturing hay-type crops: Hay-type 
grasses and legumes will not withstand 
close grazing. It is recommended in Wis­
sconsin that Ladino clover be pastured 
not shorter than 4 to 5 inches. Still more 
lenient grazing is required for bromegrass 
and alfalfa, the management of which is 
governed by the requirements of alfalfa. 
In order to maintain a well-balanced mix­
ture of alfalfa and bromegrass through 
three or four seasons in Michigan, it is 
considered advisable to maintain a 
growth 8 to 10 inches tall during May 
and June, and not less than 4 inches 
high during the summer.

Efficient pasture management: Managed 
grazing is not only the means by which 
pasture herbage is used efficiently, but it 
may also be the means by which other 
 improvement practices are applied.

Most low-growing legumes are favored 
in their association with competing 
grasses by grazing practices that utilize 
most efficiently the available herbage. 
But when sweetclover, red clover, or al­
falfa is used to renovate pastures, grazing 
must be adjusted to the requirements of 
the seedlings.

Severe grazing of the grass during the 
fall preceding and the spring of sowing 
sweetclover reduces competition which 
the grass offers the clover. As sweetclover 
seedlings are more sensitive to grazing 
than to competition, pasturing ends as 
as soon as they become tall enough to be 
bitten off and is not resumed until July, 
when the clover has attained a height 
of 12 to 18 inches. Moderate grazing 
during July and August is permissible, 
but stock should be kept off from the 
first of September until freezing weather.

During the second year, pasturing be­
gins in the renovated pasture as soon as 
the sweetclover attains 6 to 8 inches, and 
until the clover begins to set seed, con­
tinues with an intensity that utilizes most 
of the grass and leaves 8 to 10 inches of 
leafy sweetclover stubble when the cattle 
are taken off in early July. After the 
sweetclover has matured seed, grazing 
is resumed and is continued throughout 
late summer and fall with an intensity 
that will not only utilize all available 
herbage but will also weaken the grass, 
thereby reducing the competition offered 
clover seedlings next spring.

Much grass is wasted and low produc­
tion often results from the grazing sched­
ule required for the establishment of 
sweetclover and similar legumes in grass 
sod. The beneficial effect of legumes 
that require inefficient grazing for their 
establishment must be great and lasting 
to justify their use.

PASTURES IN THE SOUTHEAST

Good pastures can do great good in 
the South. Every farmer knows why. 
His aim is to provide a large yield of 
nutritious forage over a long grazing sea­
son. If he does so he has a cheaper 
source of minerals and vitamins, and 
other nutrients for his stock, a tool 
against erosion, a way to revive aban­
doned land, a chance to raise more cows 
and pigs, an opportunity to stabilize his 
income by getting away from too much 
row-crop agriculture. He needs them all.

Getting a start: But to get a good pas­
ture started the farmer must remember 
two points: His pasture must include 
both grasses and legumes; he must fer­
tilize his fields.

Evidence we have from all parts of the 
South indicates that, regardless of the 
starting point for establishing and im­
proving a pasture, a legume must be 
maintained in the sod. Grasses need 
nitrogen more than any other item of 
fertilizer. Legumes add nitrogen to the 
soil, and any treatment that increases 
the growth of legumes will indirectly in­
crease the growth of the grasses. The 
increased forage that results also has a 
higher nutritional value because of the 
addition of the legume.

Soil fertility the major problem: In the
South, soil fertility is by far the most important factor and major problem in the establishment and production of pastures; almost without exception, the fertility of land available for pastures is low. The best way, and almost the only way, to start a good pasture is to use appropriate amounts of lime and fertilizers and thereby provide soil conditions that favor the growth of desirable plants.

The response of pastures to any fertilizer element depends upon the degree to which the element limits growth, the level of fertility, and the type of plants that are present in the soil.

Many levels of fertility are so low that adding one element alone will produce no effect; in some places two elements or more are necessary for substantial increases in yield. Nearly every agricultural experiment station in the South has found by test that this is true, and farmers who need information for their own land should not hesitate to ask their State experiment stations or agricultural colleges for it. Many people think that sowing and cultural practices come first. Actually, however, experimental data from all parts of the region demonstrate that if the soil is not fertile enough, no amount of seed will produce a satisfactory sod and nothing is gained by sowing poor pastures that have not been fertilized and limed.

Stands obtained on soils that have been treated with lime and mineral fertilizer will contain relatively small amounts of grasses and clovers the first year. But weeds and bare ground are markedly reduced, and yields of herbage are increased 30 to 50 percent. Desirable plants are increased 20 to 150 percent, lespedeza and low hop clover are usually doubled, and the grasses and clovers sown show some increase.

The addition of nitrogen to the lime-mineral fertilizer benefits the young grass but is often detrimental to the establishment of the legume, and does not appreciably increase the total yield if the legume stand is adequate.

*Summer legumes* a preliminary step: Idle land can be greatly improved for grazing with a minimum of expense by sowing low hop clover and lespedeza and establishing adapted grasses as time and facilities allow. Summer legumes, such as soybeans or cowpeas, have been grown for turning under, as a preliminary step in soil improvement, before sowing a legume and grass mixture, but this is not necessary because the growth of the tolerant legumes furnishes enough nitrogen for the growth of adapted grasses.

*Pasture of Louisiana white and Persian clover.*
Adequate fertilization is therefore the first step. As the phosphate level of the soil is increased, it is possible to sow clovers which are more productive and provide a longer growing season. The stimulation of clover with applications of phosphoric acid—phosphates—will tend to crowd out the lespedeza. Better seasonal distribution will be had by sowing only a part of the lespedeza-low hop clover pasture to clover under conditions of high fertility. On some alluvial soils it is better to use spring clover as a supplemental crop rather than include it in the pasture mixture.

Besides increasing yields, fertilization increases the proportion of desirable plants. The effects of continued fertilization become more noticeable as time goes on. Adapted grasses and legumes replace weeds, bare ground, and less desirable plants. So pronounced is the effect upon botanical composition that, unless seed is available at a relatively low price, we question whether sowing seed always justifies the cost in many areas.

Legumes increase feed value of forage: The increase in the percentage of desirable plants, mainly legumes, is reflected in the higher feeding value of the herbage produced. Legumes usually surpass grasses in calcium, phosphorus, and crude protein. Fertilization expands the feeding value of total herbage produced by increasing the percentage of legumes present and also the nutritive content of the plants grown. Increases in the composition of the adapted plants range from 30 to 100 percent for phosphorus, 10 to 50 percent for calcium, and 5 to 40 percent for crude protein, as compared to no fertilization. Thus, little more than half as much herbage is required per pound of animal gain for fertilized as against an unfertilized pasture.

The need for lime: Pasture soils vary considerably in their need for lime, depending upon their texture and acidity, the type of plants to be grown, and whether the lime is used for top dressing or for establishment. In general ½ to 1 ton is the proper amount to apply to light soils, and 1 to 2 tons on the heavy soils. Data from several Southern States show that the maximum response is obtained with the first 2,000 pounds applied. Other tests indicate that applications of not more than 1,000 pounds should be applied as a top dressing. Experiments indicate that lime should be applied every 8 to 10 years. Light rates should be applied oftener than heavy rates. Surface-applied applications may be repeated every 5 years. The clovers need more lime than lespedeza. Liming gives two benefits: It increases the yields of herbage and it helps fertilizers do their most good.

The need for phosphates: Phosphates are needed on pastures throughout the South. Pasture legumes vary considerably as to their response to phosphorus. The white clovers require more, and low hop clover less than any of the commonly used pasture legumes. Heavy initial applications are necessary for the establishment of clovers; smaller amounts are sufficient later to maintain the proper level of phosphorus. Heavy soils respond more readily but may require more phosphate than light soils. An application of 600 pounds of 20 percent material applied every 3 years, or 200 pounds applied annually, seems to be adequate for most sods. Ladino clover and other legumes may require more.

Response to potash: The response to potash is less general. Legumes—especially alfalfa and Ladino clover—are heavy feeders of potash, however, and, if productive stands are to be maintained, adequate quantities must be applied. The rate depends on the amount in the soil, as determined by a soil test and the particular legume. It is not advisable to delay applications of potash until deficiency symptoms occur.

Use of commercial nitrogen: Southern agronomists are not in agreement as to the use of commercial nitrogen on permanent pastures. Their different viewpoints come from an interpretation of the data, however, rather than from experimental results. The response that will be obtained is closely associated with the botanical composition. Sods in which grasses predominate respond to nitrogen. The yields
from such sods are usually lower than from sods containing both legumes and grasses, even when nitrogen is applied.

Most of the response of a grass-legume sod to nitrogen fertilization is in the early spring, and whether such a practice would be profitable depends on the value of the early spring grazing. For much of the region, it is not a sound practice, but special cases, notably on dairy farms, undoubtedly exist where it would be profitable.

We do not have all the facts we need on the response of legumes to minor elements, except boron. Light applications of boron, 5 to 10 pounds to the acre, appear desirable for legumes on some soils. In any case, adequate amounts of lime, phosphate, and potash should be supplied before treating with minor elements; a farmer will do well to consult his State experiment stations, agricultural college, or county agent before he uses any of the minor (or trace) elements.

Climatic subdivisions: Climate and elevation divide the South into three rather distinct regions: The sections of “cool” climate, or high elevation; “warm” climate, or upper Coastal Plains; and the extreme southern Coastal Plains and the Florida peninsula. Pasture plant mixtures will vary within and between sections so that no certain rule can be offered for a mixture for sowing in a specific location. The mixture and rate of sowing will depend on climate, fertility, the cost of seed, the rate at which establishment is desired, and management.

Cool-section mixtures: Recommended mixtures for cool sections will contain orchardgrass, redtop, Kentucky bluegrass, Ladino clover and white clover, and lespedeza, or a mixture of the lespedezas. Kentucky bluegrass is eliminated and the orchard and redtop grasses are increased on the less fertile soils. More recently the tall fescues, Kentucky 31 and Alta, have shown promise. Dallisgrass may be added when used in the Piedmont from Virginia southward.

Ladino clover has become an outstanding legume in the upper South. Thousands of acres have been seeded to it in Virginia, North Carolina, Tennessee, and Kentucky, and farmers have been pleased with its performance. It is being sown at the rate of 2 to 3 pounds an acre with 10 to 12 pounds of orchardgrass. This legume is more productive than common white clover in the upper South, and recovers more quickly after a dry spell.

Warm-section mixtures: Mixtures for the warm or upper Coastal Plain section will contain Dallisgrass and Bermuda-grass, Kobe or common lespedeza, and some spring clover. Additions of orchardgrass in the northern one-third of Alabama, Mississippi, and Arkansas will furnish grazing while the other grasses are becoming established. The spring clover will furnish more and longer grazing, but low hop clover will grow on a much lower level of fertility. As fertilization is increased or continued, the clovers will change from low hop to Persian to white. For high-phosphatic soils, there should be grass-clover and grass-lespedeza combinations in separate pastures. Korean lespedeza, lappa clover, sweetclover and black medic are adapted to the calcareous soils.

Mixtures for the lower Coastal Plain and for the Florida peninsula consist of Bahiagrass, Bermuda-grass, carpetgrass, Dallisgrass, Napiergrass, the clovers, and annual lespedezas. Paragrass, Bermuda-grass, Napiergrass and St. Augustinegrass are suited to the muck soils of south Florida.

Time of sowing: The exact sowing date for lespedeza will depend upon elevation and latitude, but sowing is usually begun about February 1 in the southern part of the region. Korean lespedeza is better suited to the upper half of the region than to the southern portions.

Kentucky bluegrass, orchardgrass, redtop, and the white clovers are commonly sown in the fall, although they may be sown in the spring. White clover in the lower South should be sown from August to October.

Dallisgrass, Bermuda-grass, Bahiagrass, and carpetgrass should be sown in the early spring. Dallisgrass may be sown in early fall in the lower South. Bermuda-grass and other grasses usually propagated by vegetative means should be sprigged.
PASTURES IN THE SOUTHEAST

or sodded in the spring because of more favorable moisture conditions.

Preparation of seedbed: For new seedings the seedbed should be well prepared but firm. This usually means that a thorough job of disking is enough. A rain between the time of disking and sowing should firm the seedbed satisfactorily. The seed should be covered to a depth of \( \frac{3}{4} \) to 1\( \frac{1}{2} \) inch.

There are several ways of resowing an old sod. The extent to which the sod should be broken up depends upon the species that is to be used. Lespedeza may be added to an established grass sod with little preparation. Renovation of an established carpetgrass or Kentucky bluegrass sod should be accompanied by a thorough disking. Legumes may also be successfully added to established grasses following a slicing of the old sod with a weighted disk set at a slight angle.

Management of pastures: Pasture management throughout the South fits into the same procedure pattern as for establishment. Fertilization to maintain legumes is the cardinal principle of maintenance in all sections. Maintenance fertilization can be accomplished by replacing the minerals that have been removed by plant growth. Proper management is essential to good pasture establishment, maintenance, and utilization. When the items of fertility and establishment have been attended to, maximum production of pastures depends on proper management.

A pasture that has been properly prepared, fertilized, and sown at a rate sufficient to give a satisfactory stand of desirable plants usually has fewer weeds than a poor pasture. The desirable plants compete with the weeds for soil moisture and plant food. Grazing animals find the weeds unpalatable and allow them to grow and produce seed; the desirable plants are grazed in preference and their seed production is greatly reduced. Mowing, usually twice a season, is therefore necessary to prevent the production of weed seeds. See "Seasonal Pasture Management," the preceding section, which is applicable to the entire eastern humid region.

Intensity of grazing: The rate or intensity of grazing is probably the most important management practice for pastures in the South. The principal factor in grazing management is the prevention of overgrazing, which reduces ground cover and permits erosion. Overgrazing also results in severe selective grazing with weeds replacing the desirable plants.

Erect or semi-erect plants are readily exterminated by continuous heavy grazing because all or most of the leaves are removed. When most of the leaves are continuously removed the food reserves in the plants are removed faster than they are replaced. A good practice is to manage grazing so the pasture is never grazed closer than 2 or 3 inches. Some foliage must be left on the plants at all times. Overgrazing favors one plant over another in the pasture combination, and the proper balance for maximum yields is disturbed. Summer grasses tend to be reduced, and the sod contains a greater percentage of spring clovers. The excessive growth of spring clovers further reduces the population of grass and lespedeza.

Undergrazing: Because of the loss in quality of pasturage by undergrazing, it is perhaps just as undesirable as overgrazing. New stands may be exterminated by rapidly growing native vegetation if undergrazed. The calcium, phosphorus, and crude protein content of pasture grasses drops rapidly as the plants approach maturity, and the herbage is not readily eaten because of low quality. A grain ration of higher protein content is required by cattle for meat or milk production on undergrazed pastures.

Undergrazing also favors some plants over others in the mixture and the proper balance for a good pasture is not maintained. If spring grasses, like Kentucky bluegrass and orchardgrass, are allowed to make excessive growth in the spring, they will crowd out lespedeza.

With the uneven distribution of rainfall, it is almost impossible for permanent pastures, no matter how fertile or well managed, to provide uninterrupted and sufficient nutritious forage for efficient livestock production throughout the season. Peaks of production furnish more feed than animals can consume, and pe-
periods of lessened production will result in overgrazing. It is not practical to remove animals from permanent pastures during periods of low production unless other provisions for their maintenance can be made. This means that supplementary pastures are necessary to a good farm program.

**Supplementary pastures:** Every section of the South can make use of supplementary pastures. Many such pastures can be used for hay, seed, silage, or soil improvement when not needed for emergency grazing crops. Kudzu, soybeans, lespedeza, sudangrass, millet, small grains, Italian rye-grass, and annual clovers are well adapted for the purpose. Relieving permanent pastures during periods of drought will enable them to produce efficiently later into the fall, as compared to pastures that have been either under- or over-grazed. The use of supplemental crops is often the key to good pasture management and economical livestock production.

Legumes are necessary to increase the yield, extend the grazing period, and improve the quality of permanent pastures in the South. Applications of lime, phosphate, and potash must be made if the legumes are to be maintained in the sod. Supplementary leguminous crops like kudzu, lespedeza, soybeans, and annual clovers should be fertilized in the same way. Sudangrass, millet, small grain, and Italian rye-grass are excellent supplementary grazing crops that require liberal applications of commercial nitrogen. Grazing can be had every month of the year through a combination of these crops.

**Supplementary grass crops:** Following are some of the more important crops used in the South for supplemental grazing.

Johnsongrass can be considered either a pest or a desirable forage crop. It is used primarily for forage on the Black Belt soils of Alabama and Mississippi. It can be used for hay, silage, or temporary grazing. Frequently, the first growth is cut for hay and the new growth is grazed either just before or just after the first frost in the fall.

Sudangrass is well suited to southern conditions. Its susceptibility to a leaf disease has limited its use, but plant breeders have succeeded in producing high-yielding, disease-resistant strains that should be popular for grazing and hay.

Corn is often grown in combination with velvetbeans, cowpeas, soybeans, peanuts, or some other summer legume and grazed by hogs and cattle during late summer and autumn.

Pearl millet, or cattail millet is grown in the extreme South as a grazing crop—occasionally as a silage or soil improvement crop. It is particularly adapted to a warm humid climate.

Napiergrass is grown principally in Florida and the Gulf Coast districts. It is used mostly for grazing, but it can be used for silage and as a soil improvement crop.

Orchardgrass is a short-lived perennial but is well adapted to permanent pastures, particularly in the upper South. It is primarily a pasture plant, but it can be used for hay.

Tall fescue survives longer than orchardgrass either in meadows or pastures. It is used in the same way as orchardgrass.

The small grains, when sown early in the fall and fertilized with a complete fertilizer high in nitrogen, will furnish abundant fall and winter grazing.

**Supplementary legume crops:** Alfalfa is not yet an important crop in the South, but its use is increasing. Recent research at several southern experiment stations has shown that with liberal applications of lime, phosphate, potash, and boron, alfalfa may be grown successfully on most of the fertile, well-drained soils of the South.

Sericca lespedeza is rapidly becoming an important summer grazing crop in the South. It is not entirely palatable, but cattle will eat it well enough if grazing is started when the plants are 3 or 4 inches high.

The annual lespedezas, important forage crops in the South, are used in permanent pastures, for hay, and for temporary grazing.

Kudzu is more commonly grown on rough, badly eroded areas. When it is used for hay or temporary grazing, kudzu must be handled carefully if a good stand is to be maintained.
Crimson clover, wherever it can be grown, is one of the favorite winter grazing crops. If it is planted on a well-fitted seedbed in late summer and early fall, it furnishes abundant grazing in winter and early spring.

Vetches are grown as winter forage crops for grazing or hay and, in many regions, as a cover crop that can be plowed under to improve the soil.

Roughpea, also known as wild winter-pea, Singletary pea, and Caley-pea, is an important forage crop in the Black Belt section. It is grown there as a winter crop primarily in combination with Johnsongrass. A winter legume, it is used for late-winter and early-spring grazing or for hay.

Bur-clover, an excellent winter grazing crop, grows well in combination with Johnsongrass or in rotation with grain sorghum or Sudangrass. The Manganese strain, a selection from southern bur-clover, is the most popular.

The use of sweet or nonalkaloid lupine as a forage for the lower South is still in the experimental stage. The use of the nonalkaloid strains for grazing offers the possibilities of a cheap, high-protein feed.

Hairy indigo, a native of northern Africa recently introduced into Florida as a cover crop, is used to a limited extent as a summer grazing legume in permanent pastures. Its use as a pasture plant is increasing.

Some pasture problems of the Southeast: Southern climate permits the growth of a wide variety—an embarrassingly wide variety—of pasture and forage plants. So many new ones appear and so great has been the upsurge of interest in them that it has been hard to keep up with them and their specific requirements. We need to develop facilities and methods for evaluating properly the new plants and reevaluating some of the older ones.

We do know enough about the available plants, however, to build a fairly satisfactory pasture and forage program for most southern farms and to realize that other plants are urgently needed to fill gaps in the program for certain sections.

One plant needed is a warm-weather grass, high in nutritive value, that will grow well with legumes, and at the same time allow legumes to grow—a plant, that is, to replace carpetgrass. It should be easy and rapid of establishment and disease-resistant.

Dallisgrass, with all its limitations, seems now to be the most promising candidate for this spot. Dallisgrass will require considerable remodeling before it will fill the bill because it is a poor seed producer, it is slow and expensive to establish, and its nutritive value is less than desired.

Alfalfa promises to go a long way toward solving the problem of hay production in much of the region, but elsewhere, the perennials now in use are low-yielding, unpalatable, slow to establish, or difficult to manage and harvest. As a result, most of the hay produced there is from annual crops, which have the added risk and expense of establishment each year. The plant to fill this gap should be nutritious, persistent, high-yielding, and fairly easy to establish. Such a plant is not now in sight.

Disease resistance is a prime requirement in any plant to be grown in the South, where leaf and stem diseases are intensified by the warm, humid climate. Lack of resistance to any one of them can completely eliminate a plant from certain areas and lessen its value everywhere. For example, the annual lespedeza and white clover are almost useless on some of the sandy Coastal Plain soils because of their susceptibility to nematodes. Thus, while several fairly good grasses are adapted to these soils, the lack of legumes makes good pastures scarce. The incorporation of disease resistance into plants is a major objective in breeding new or improved forage plants for the South.

Perennial pasture legumes needed: Because of the generally low nitrogen level and high rate of nitrogen losses from southern soils, the need for the nitrogen supplied by legumes is extremely vital to successful pasture production. Also, a high proportion of the grasses used are sod formers—carpetgrass, Bermuda-grass, Bahiagrass, and Kentucky bluegrass, for
example; all form tight sods and tend to make life difficult for any legumes among them.

An example: a good growth of white clover or Ladino clover will supply adequate nitrogen for the growth of a sod and (for a while at least) will convert the lowly carpetgrass into a productive and fairly nutritious plant. Such a combination, without the benefit of any applied nitrogen, actually has produced more than 600 pounds of beef an acre each year. Yet, when the summer rains come, the carpetgrass may get sufficiently out of hand to crowd out the clover. When this happens, both the early grazing and the nitrogen supplied by the legume are lost. Apparently this adverse situation may be prevented by holding back the carpetgrass by heavy grazing or mowing. Unfortunately, animals forced to graze so closely drop off in production. Frequent mowing is expensive. Another solution supposedly would be to substitute Dallisgrass for carpetgrass. Dallisgrass is more tolerant to clover growth, better able to utilize the high fertility level, and more palatable. But to survive in most areas, Dallisgrass must successfully compete with carpetgrass. Low fertility, particularly in nitrogen, and intensive grazing both tip the balance in favor of carpetgrass. Thus a management system that would encourage Dallisgrass would tend to exclude the clover. Loss of clover would lower the nitrogen level. This, in turn, would favor the carpet and cause the sod to revert to a pure carpet stand. While not impossible, the process of permanently substituting Dallisgrass for carpetgrass is one calling for astute management.

Nutritious forage cannot be produced on soils low in the essential minerals. Examples of the importance of proper soil treatment are everywhere.

Fertility studies with grassland plants in the South have never been very extensive. The recent adoption of superior species and strains, coupled with changing cultural and management practices, has made much of the previous work obsolete. More productive plants will require higher fertility levels. Improved methods of application and incorporation may require major changes in fertilizer and liming practice.

Lime a first essential: Since most southern soils are naturally low in calcium and magnesium and are rather acid, lime must be applied for the satisfactory growth of many plants. In fact, lime is the first essential for successful pasture and forage production on many soils. In order to make intelligent use of liming materials, we need to know what level of lime in the various soils is most desirable for the growth of the adapted plants and how much of what materials must be applied to reach this level. Further, we need information as to the rate of loss of lime from these soils through leaching and plant removal to enable us to maintain the proper lime level once it has been reached.

Information on time and place of application of liming materials is still sketchy for most soils and plants. Most of the natural grassland soils of the world contain free lime in the subsoil, yet most lime treatments in the South have taken into account only a few inches of surface soil. Indications are that depth and distribution of lime may be quite important for some plants on some soils. Nodulation of legume roots sometimes occurs only in the limed zone of the soil. Liming the deeper soil horizons may be of considerable value in such cases. Present practice in this field is certainly open to question and offers fruitful possibilities for investigation.

Phosphorus deficiency: Frequently a limiting factor in the growth of forage plants and in the diet of the animals that consume them is phosphorus. Most of the field crops in the region benefit from annual applications of the element. Apparently some forage plants are able to utilize available forms of phosphorus slowly.

Widespread phosphorus deficiency in the South is due to the low phosphorus content of most soils and also to the ability of the soils to fix considerable amounts of this element in unavailable or very slowly available form. The concentration of applied phosphorus in narrow zones within the soil should greatly reduce fixation. The efficiency of phos-
phorus applications for pasture and forage plants might be greatly improved in this way.

How to increase availability of soil potash: Legumes, particularly the more productive plants like alfalfa and Ladino clover, feed heavily on potassium. Some southern soils have large stores of potash minerals, but others are low in total potash. In order to use fertilizer potash intelligently, we need to know the extent to which the native potash supply of the various soils may be drawn upon. The development of methods of increasing the availability of soil potash would lower the cost of producing forage.

Some plants tend to absorb potash far in excess of need when a plentiful supply is present. Apparently about 1.25 percent of potassium in the alfalfa plant is adequate for normal growth, yet alfalfa sometimes may contain 3.50 percent. This luxury consumption of potash may result in wasteful use if the material is applied at the wrong time. For example, in a single season an acre of Ladino clover may black up potassium equivalent to that contained in 200 to 300 pounds of muriate of potash. On soils low in potash it may be necessary to split this up into more than one application in order to maintain the supply throughout the season.

Minor elements often necessary: The use of minor elements has been explored only to a limited extent. Boron, zinc, copper, manganese, and sulphur deficiencies have been found in some plants. Cobalt deficiency in livestock has developed in certain areas. The highly leached condition of some soils, plus the trend toward more productive plants and the use of heavier lime and fertilizer applications, may be expected to increase the drain on the soil supplies of the various elements. Undoubtedly it will become necessary to apply some of these more generally than has been done in the past. Plant requirements and tolerance to minor elements must be worked out.

And so, along with the numerous serious and urgent conservation problems in the South there are corresponding opportunities for correction and improvement. No other section has a larger number of useful grasses and legumes with which to build a conservation program. Proper planning of cropland, grazing land, woodland, and wildlife land, the use of necessary lime and fertilizer, and the application of vegetation according to the needs of the land and the capabilities of the plants, will give the South a sounder agriculture in which crops, livestock, and woodland products contribute to a better balanced income.

NORTHERN GREAT PLAINS PASTURES

Cultivated grasses for pastures: Pastures established from seed have many values. They can supply cheap and good feed when they are grazed in combination with the native range. They cut the amount of harvested forage or other feed that livestock needs. They can provide a long season of abundant pasturage for spring grazing to supplement native range or pasture that is ready later in the summer. They have a unique place in rotations with other crops. They help to control erosion and make the soil more absorptive of rainfall. Established near farm buildings, seeded pastures enable the farmer to keep stock under close observation. They can be restored if their stands of grasses or legumes are weakened or destroyed by overgrazing or otherwise.

The use of such pastures has been growing in the Northern Great Plains in recent years, but not enough. They differ in several respects from native range. Generally they are rather limited in area and may be located on land that could be used for other crops. Native range, on the other hand, occupies relatively large areas that would be unprofitable or impractical for crops. Pastures established from seed, even though they consist of perennial grasses and legumes, may be considered as temporary; native range is considered permanent.

Importance of hardiness: We cannot stress too strongly the importance of sowing grasses or legumes that are hardy and drought-resistant enough to withstand the severe climate of the Northern Great Plains.
Grasses that can be grown here are ordinarily classified as cool-season or warm-season grasses, depending upon their period of maximum vegetative growth. **Cool-season grasses:** Cool-season grasses make most of their growth early in the season and very little in the heat of the summer. They often make considerable growth until late in the season if autumn moisture conditions are favorable.

Among the cool-season grasses adapted to the entire Northern Great Plains region are crested wheatgrass, western wheatgrass, slender wheatgrass, Canada wild-rye, Russian wild-rye, and feather bunchgrass. Except for crested wheatgrass, western wheatgrass, and Russian wild-rye, these are used only in mixtures. Bromegrass is adapted along the eastern border and in other favorable localities. Intermediate wheatgrass is adapted only to specially favored localities in the southern portion. These are usually sown at the rate of 10 to 12 pounds per acre.

Cool-season grasses are the more important by far for cultivation in the Northern Great Plains. Only in the southwestern part are grasses of the cool-season group less well adapted. Local strains of cool-season grasses generally can be moved greater distances north and south without affecting their adaptation than can the warm-season group. Bromegrass is the most important exception to this principle; northern strains of bromegrass are not well adapted in the southern parts.

Improved strains of some of the grasses that are well adapted for use under cultivation in the Northern Great Plains are now available; among them are Nebraska 36 and 44 bromegrasses; Mandan wild-rye, an improved Canada wild-rye; and green stipagrass, an improved feather bunchgrass. Others are being developed at experiment stations.

**Warm-season grasses:** Warm-season grasses, which make most of their growth in summer, generally start growing after the last frost in the spring and stop growing by the time of the first hard frost in the fall.

Among the warm-season grasses blue grama and side-oats grama are adapted to the entire region, but the latter does better in mixtures only in the southcentral and southwestern portions. Big bluestem and switchgrass are adapted to the eastern border and in other specially favored localities. Buffalograss is adapted to dry, heavy soils of the southwestern portion. These grasses are sown at the rate of 6 to 8 pounds per acre, except buffalograss and big bluestem which require a heavier rate of 8 to 10 pounds with the former, and 10 to 12 pounds with the latter.

Warm-season perennial grasses of value in the region are all native species. In general, strains of this group should not be moved either north or south more than 200 miles from their origin; otherwise they are not sufficiently well adapted to be of value under cultivation.

**Legumes in mixtures:** Alfalfa and sweetclover are the only legumes now grown to any extent in the Northern Great Plains. Because they help to keep up production and add to the quality of the forage, at least one of them should be included in small amounts with grass in most pasture plantings.

Alfalfa is the best legume for growing in mixtures with grass toward the eastern border of the region. Under good management it may be expected to remain in the mixture for several years. One of the most important points in good management is to avoid close fall grazing because it tends to eliminate alfalfa from the mixture. In the western part, alfalfa may kill out, especially on dry, eroded sites, unless moisture conditions are unusually favorable. Ladak is one of the best varieties to use in mixtures with grass for pasture. Other hardy varieties are available, however.

Sweetclover is the best legume for use in mixtures with grass in the western part and on many dry, eroded sites in the eastern part. Madrid and Spanish are two new varieties that are excellent for use in pastures.

**Advantages of mixtures:** The use of mixtures of grasses or of grasses and legumes is generally preferable to pure seedings for pastures. A combination of species
NORTHERN GREAT PLAINS PASTURES

will often provide better grazing over a longer period than pure seedings. Cattle prefer to graze a variety of species.

There are other advantages of mixed plantings. The hazards of sowing will not affect two or more species equally, so that a mixed seeding is more likely to give a stand than is a pure seeding. Several species growing together can better accommodate themselves to a wide range of varying conditions than a single species can.

In cases where fencing and water facilities are such that several adjacent pastures can be maintained, it may be well to sow several kinds of grass in pure stands, so that the maximum use of each grass can be made during the proper season. If farmers want a seed crop, as well as pasture, pure stands are best.

Despite the recognized advantages of mixtures, the actual interrelationships of associated plants and their effect on livestock need further study.

Establishment: The sowing of high quality seed of adapted species at the correct date, a well-prepared seedbed, and proper attention after emergence will secure the successful establishment of grass in most cases. The only other difficulty is dry weather.

Four periods of sowing to be considered are late summer or early fall, late fall, early spring, and mid spring.

Late-summer sowing: Late-summer sowing is done about August 15 to September 15; the seed then has time to germinate and establish seedlings well before winter. Sowing of cool-season grasses at that time is usually the most successful, provided sufficient moisture is available for rapid germination and growth, and grasshoppers do not cause damage.

Alfalfa and sweetclover can generally be sown successfully in late summer from the southern border of North Dakota southward without danger of severe killing, except when the seedlings do not become well established before heavy frost. From that line northward, the hazards of winterkilling are generally too great for sowing these legumes at that time. If grass-legume mixtures are to be established, the grass can be sown in late summer and the legume sown the next spring. The chief advantages of late-summer sowing are that there is less competition from weeds, and the seedlings are well established by the time heat and drought become serious the following summer. Fall-established seedlings also have a better chance to escape June seedling blights.

Late-fall sowing: Late-fall sowing is done so late that germination does not occur until the following spring. Sowing in late fall has been successful, except in the southernmost parts. The greatest use of late-fall sowing has been on abandoned areas or stubbleland that were sown without seedbed preparation. An advantage of late fall sowing is that it does not depend on favorable moisture conditions at the time of sowing; late-fall sowing also may be extended over a long period and is better for sowing large acreages.

Spring-sowing: Early-spring sowing as soon as the ground can be worked is done extensively and successfully throughout the region. Early spring is a good time to sow mixtures containing alfalfa or sweetclover.

The warm-season grasses are best sown in midspring, after the soil has become warm, the first crop of weeds has germinated, and the ground has been worked to destroy weeds.

Depth of sowing: Shallow sowing is important in the establishment of grasses and legumes. The proper depth is determined by species, size of seed, soil type, and moisture conditions. Ordinarily sowing depths should be no greater than 3/4 inch—except on light, sandy soils, on which most species can be sown successfully up to 1 1/2 inches deep. Warm-season grasses should never be sown deeper than 1/2 inch.

Seedbed preparation: Poor preparation of seedbeds often causes failure. The soil must be firm in order to sow shallow and to enable the seed to be placed in close contact with the soil. A well-packed soil will also retain moisture longer and germination will be faster. Pastures are generally sown on relatively small areas that can be worked rather intensively if necessary for the preparation of a good seedbed. The additional expense of good
seedbed preparation will be repaid by the
more rapid establishment of high-yielding
pastures.

Well-prepared summer fallow is the
best seedbed preparation for late-summer
sowing. If erosion threatens, however, a
light cover crop of oats may be sown with
the grass. The reserve moisture stored in
fallow results in faster growth and strong­
er plants than those grown on any other
preparation. Successful sowing can be
made in clean grain stubble if the soil
needs a protective covering. Seedlings
that emerge in stubble have protection
against soil blowing. Besides, snow that
is caught will form a cover that greatly
lessens the danger of winterkilling. Grain
stubble also furnishes a desirable seedbed
for late-fall sowings.

Spring sowing can be done on pro­
tected fallow or corn ground. Plowed
grain stubble is somewhat less satisfac­
tory, but can be used if the soil is well
firmed before sowing. Tillage treatments
that tend to leave the soil so fine that it
is susceptible to wind erosion should be
avoided.

Method of sowing: A drill is best for
sowing because it distributes the seed
uniformly and places it more nearly at
the proper depth for good germination
and establishment. Drill spacings of 6 to
12 inches are satisfactory for pasture. The
wider spacings may be better in the drier
areas toward the west.

On well-fitted seedbeds a press drill
can be used to advantage, as it will place
the seed in closer contact with the soil
than other types of drills. Single-disk
drills are used when the farmer wants to
leave the soil surface as rough as possible.
Deep-furrow drills have been used success­
fully for sowing abandoned lands without
previous seedbed preparation. On limi­
ted acreages and on unstable soils, hay
that contains mature seed may be spread
over the surface and disked or pressed
into the soil to afford some covering.

Broadcasting the seed usually is not
satisfactory, but in localities where the
land is too rough for machinery, broad­
casting is sometimes successful. Some
method of covering the seed should be
used if possible.

Companion crops: Unless they are needed
to protect the soil, companion crops
should not be used with grasses or leg­
umes in the Northern Great Plains. If
companion crops are used, they should be
sown at very low rates; otherwise compe­
tition for moisture and shading by the
companion crop is likely to be too great
for the survival of seedlings.

Newly established stands of grass ordi­
narily should not be grazed or cut for hay
the first year. Occasionally, when seed is
sown in the late summer on fertile soil
that has a favorable moisture content,
enough growth will be made the next
year so that a light crop of hay or seed
can be harvested, or a small amount of
pasturage may be available.

Clipping weeds: Weed growth is gener­
ally rather heavy the first year, especially
where late-fall or spring plantings have
been made. Weeds should be clipped
only when they are so tall and vigorous
that the grass or legume seedlings are
seriously hampered in their growth. Clip­
ing, if it is necessary, should be done
only in cool weather, and the weeds
should be cut high to avoid injuring the
seedlings. A high stubble also will pro­
vide protection to the seedlings and
catch snow.

In early spring it is wise to mow and
remove any old heavy vegetative or weed
growth that has been allowed to remain
over winter. It is best not to burn old
growth because of the serious damage
that may be done to tender grass or leg­
ume seedlings. Stands are usually well
enough established by the second year so
that weeds cease to be a serious problem.

Management problems: The maintenance
of stands or of high production of grasses
and legumes in the Great Plains as else­
where depends greatly upon proper man­
agement. Pastures that do not have leg­
umes generally show a marked reduction
in yield the third or fourth year after es­
ablishment. This reduction is frequently
caused by a lack of available nitrogen and
may be as high as 50 to 75 percent.
Alfalfa or sweetclover planted in mixture
with grasses is the cheapest way to pro­
vide the nitrogen to maintain yield, but
it may be difficult to keep those legumes
in the mixture in dry seasons. Alfalfa may kill out because of drought. Sweetclover seedlings generally do not become established by natural means in old stands of grass.

Renovating old pasture: Yields can often be increased somewhat by tearing up thoroughly the sod of old pastures, but the beneficial effects of the practice are usually short-lived. Sowing alfalfa or sweetclover into disturbed sod offers some possibilities in favorable years. Application of commercial nitrogenous fertilizers often boosts yields sharply, but in dry periods they should be applied sparingly to guard against severe burning. Manure also will often increase yields.

The best way to get continuous high production of grass is to have the pastures in a crop-rotation system. When production falls off, the pasture can be broken and cropped for several years and then returned to grass. Old, low-producing grass stands can be broken and fallowed for a year and then resown; this method, however, may not be practical on marginal land or erosive areas.

Combining sown pastures with native range: In the Northern Great Plains the most efficient and economical method of utilizing both sown pastures and native range is to graze the sown pastures in combination with (and as a supplement to) the native range. Experiments have shown that this combination system of grazing will provide a longer grazing season and give a higher production on fewer acres.

Pastures of cool-season grasses can be grazed 2 to 3 weeks earlier than native range, and on them livestock can be grazed at a rather high intensity for 60 to 75 days in the spring. During that time grazing on the native range can be deferred. By the time the livestock have fully utilized the grass in the pasture, or after it has become too mature for good grazing, the deferred native range is in excellent condition for livestock, and because it has been deferred for approximately 45 days, the intensity of grazing on it can be greater than if it had been grazed early in the season.

Cattle grazed on sown pastures should be moved to native range while they are still making good gains. If pastures of cool-season grasses are grazed too late in the summer, the grass will mature and lose quality and livestock gains will often drop rapidly.

Native grasses remain in good condition for grazing much later in the season and greater gains can be obtained on them during this period than on cool-season grass pastures. With favorable moisture in the fall, pastures may still make considerable growth. It is generally not advisable to graze this new growth heavily, because doing so will cut production the following spring.

Rotating pastures: When cattle or sheep are grazed on a combination of native range and cool-season grass pasture, it is advisable to fence the pasture separately so that the stock can be restricted to one or the other. Proper utilization will not be made unless the cultivated grass and native range are separate. Livestock will graze the cultivated grass early in the spring, but will tend to leave it and graze the native grass as soon as it starts to grow. The cultivated grasses will then be underutilized and become coarse and stemmy. If this old growth is permitted to accumulate on the seeded pasture grazing will become patchy in later years.

Because grasses differ as to maturity and the period when they can be grazed, a series of pastures of different grasses can be established and grazed in rotation. Good results have been obtained in experiments with sheep in Wyoming by grazing them first on crested wheatgrass very early, then on Russian wild-rye, which makes somewhat later growth, and then on warm-season grasses for the rest of the summer. Gains were much higher on these pastures than on native range alone.

Temporary pastures: Temporary pastures are a possibility on farms that do not have sufficient native range or enough cultivated grass pasture for their livestock needs. The best crops for this purpose in the Northern Great Plains are winter rye, Sudangrass, and sweetclover. Individual farm needs will determine which of these...
crops can best be used for pasture purposes. Their use as supplements to native range and pastures will provide a full season of grazing.

Winter rye planted in late summer will usually provide considerable grazing later in the fall. It is very productive the following spring.

Sudangrass, if conditions are favorable, will give an abundance of pasture during the hot part of the summer. Care should be taken to use pure seed—it is generally wise to plant only certified seed in pastures.

Mixtures of cane with Sudan grass sometimes cause prussic acid poisoning. Precautions should be taken not to allow livestock to eat too much when they are first turned on the pasture even when grazing Sudangrass that is thought to be pure. Poisoning can usually be avoided by feeding hay to livestock before turning them on the pasture. Another precaution is to turn only a few head of stock on the pasture until it is determined that there is no danger from poisoning.

Sweetclover also makes an excellent temporary pasture. Sufficient growth is usually made during the first season to provide some pasture during late summer and fall. Second-year sweetclover will furnish an abundance of pasturage in midsummer. There is a danger of bloat, but it is not serious and can be avoided in most cases by feeding enough dry feed before turning the stock on sweetclover so that they will not immediately gorge themselves. Another way to avoid bloat is to have dry roughage available to stock while they are being pastured.

SOUTHERN GREAT PLAINS
PASTURES

The Southern Great Plains region represents the southern portion of the extensive belt of short-grass lands, reaching from Canada on the north to northwest Texas on the South, and from the 97th to the 100th meridian on the east to the Rocky Mountains on the west. East of this region is the tall-grass prairie which covers an area approximately as large. The line between these two general regions is not well marked. It fluctuates east and west over periods of years for a distance of 100 to 150 miles, depending on rainfall and grazing management as it affects the growth of short-grass as compared with tall grasses.

A discussion of pastures for a region such as this cannot be confined to any arbitrary territorial boundaries, but rather to a certain set of conditions which may affect plant growth, development and utilization. The discussion here relates more particularly to the strictly short-grass region, which comprises extreme western Kansas and Oklahoma, northwestern Texas, and eastern Colorado and New Mexico. Many of its crop and pasture management practices, because of its fluctuating boundary on the east, blend into those of the tall-grass prairie which are not treated separately here on a regional basis. In the main, however, the two types of prairie are rather distinct, both as to kinds of crops, production, management, and utilization practices.

In the Southern Great Plains a steadily increasing acreage of pastures is being established by sowing native or introduced grasses on cultivated and abandoned farm land. Other grazing lands include small areas of irrigated pasture and extensive native range.

Millions of acres of the more erosive and less productive lands in the region are unprofitable for cultivated crops but they can produce excellent pasture grasses if they are properly handled.

It is simple enough to get good stands of palatable and nutritious grasses on land once tilled unwisely and unprofitably, and, in doing so, to reclaim vast areas of otherwise unproductive land, make the agriculture more permanent, and achieve proper land use. More rapid expansion of grasslands may be expected when farmers more fully realize the economic returns obtainable from pastures.

Grassland most productive: Most of these fields produce more net returns in grass than in crops, and the pastures usually yield much higher net returns than adjacent native range land. Every reseeded pasture on the United States Southern Plains Experimental Range near Wood-
ward, Oklahoma, has supported many more cattle and produced much greater total live-weight gains than the native range.

A reseeded field of native sand lovegrass carried 186 steers per section of land (640 acres) throughout the year, produced 403.9 pounds of liveweight gain per head, and yielded 117.2 pounds of gain per acre. This reseeded pasteure was superior in every respect to native range. It carried 119 more steers to the square mile, produced 41.8 more pounds of gain per head, and yielded 78.6 more pounds per acre, or nearly three times that of native range.

Productive mixtures: A reseeded mixture of cool-weather and warm-weather native grasses showed similar advantages over the native range. This mixture included about 6 pounds of blue grama an acre, 4 pounds of side-oats grama, 3 pounds of western wheatgrass, and ½ pound of Texas bluegrass. This pasture combination supported 152 steers per section and produced gains that averaged 385.6 pounds per head and 92.6 per acre. The yearlong grazing advantages over native range were 90 head per section, 23.5 pounds per head, and 54.0 pounds per acre.

The mixture, therefore, produced nearly two and one-half times as much gain per acre as the virgin range.

Weeping lovegrass produced 67.6 fewer pounds of gain per head than native range, but carried 233 percent more cattle and, therefore, returned two and one-half times as much gain per acre. This vigorous-growing importation from South Africa is much more fibrous and much less palatable than the other grasses. Therefore, the cattle consumed less of this grass and produced 109.4 pounds less gain per head than on sand lovegrass and 91.1 pounds less than on the reseeded mixture.

Renovated pastures: A reseeded field of buffalograss, not yet fully established, produced about the same gain per head as native range, but supported about twice as many cattle, and returned nearly twice as much gain per acre.

The results are conservative, since the reseeded pastures had been established on some of the most highly erosive and least productive land in the Southern Great Plains. They were compared with some of the best sandy range land in the area that had been moderately grazed since 1940 and supported a good growth of blue grama, sand dropseed, sand bluestem, sand lovegrass, and numerous other grasses, weeds, and brush.

In the spring of 1943, crested wheatgrass supported 125 head of cattle on 1200 acres near Briggsdale, Colorado, for two months. It is estimated that the abandoned fields on which this grass was grown would have supported only 20 cattle for the same period if the fields had been allowed to remain in their original weedy condition.

At Amarillo, Texas, a reseeded pasture of blue grama and western wheatgrass produced 69 pounds more gain per steer in 213 days than comparable steers made on native range that included principally blue grama and buffalograss. The short native grasses had barely started growth by April 1, when the western wheatgrass was growing actively.

Most native ranges have become infested more or less with a competitive growth of weeds and other objectionable plants. Many of the more palatable grasses have been seriously reduced in vigor and replaced with less palatable ones. The result is that reseeded pastures have many natural advantages at the outset. Pure or mixed stands of the very best grasses in the region may be established over an entire field and, if properly grazed, will remain deeply rooted and persist for many years.

Abandoned farm land which had become completely regrassed by natural revegetation before the drought of 1933-36 began withstood the drought much better than adjacent range land that had never been plowed—evidence of the superiority in persistence of grass on formerly cultivated lands. From 15 to 30 or more years were required, however, for abandoned farm land to revert naturally to a good stand of native grasses. That process may be accomplished in a few seasons or years by modern reseeding methods.
Long-term rotations: Research work at Hays, Kansas, and Woodward, Oklahoma, shows that long-term grass-crop rotations may be important in the future agriculture of the region. Only about 3 years was required for a good stand of native grass to refill cultivated land with grass roots to a depth of about 4 feet and leave the soil in a condition comparable with that of virgin sod. In the absence of a legume, the grasses used in these studies had no material effect on soil fertility and caused no essential changes in the carbon or carbon-nitrogen ratio. The grasses, however, greatly improved the general physical condition of the soil and its ability to absorb water, retain moisture, and resist erosion.

It seems evident that even the more productive cultivated lands could be improved in tilth and farmed with less erosion if grasses were included in long-term rotations with other crops. Although the grasses soon restore the soil to virgin-sod conditions, it would seem advisable to leave the grass on the land for several years to justify the expense of establishment. Grasses grown on good farm land in rotation with crops can produce more forage than do pastures reseeded for permanent grazing on the less productive lands. Crops grown in rotation with the grass may not be greatly increased in actual yield, but the soil can be handled better and with fewer hazards.

Land preparation: Many methods of land preparation have been successful in regrassing cultivated and abandoned farm land when local climatic conditions were favorable. Few methods have resulted in successful stands under the adverse conditions that usually prevail.

Choice of methods depends on wind velocities and rainfall expected in a locality and the kind of grasses used. The occurrence of high winds and torrential rains in spring and early summer and the tendency of most soils to blow and bake when bare of cover were major factors in the determination of a suitable method of grass establishment.

Stubble-mulch method: A land preparation has been developed known as the stubble-mulch method, that has been consistently successful in wind-erosion districts. It is also regarded as an excellent method to use in the eastern part where water erosion, soil crusting, and rapid surface evaporation are important problems.

The method consists of drilling adapted grasses early in spring in the protective stubble left by a previous crop of close-drilled kafir, sorgo, Sudangrass, or other sorghum. Seedbeds of this kind are usually more firm than those prepared in other ways. The non-competitive mulch of stubble and hay residue helpfully controls wind and water erosion, reduces surface evaporation, and prevents crusting of the surface soil until the shallow-seeded grasses can become established.

The sorghum is sown the first year and pasture grasses the second year. The object is to drill the preparatory crop late enough in the season to prevent seed maturity, but early enough to insure adequate forage production. This is usually accomplished to best advantage by drilling the crop in late June or July, except in chinch bug areas where earlier plantings are necessary. Delayed sowing reduces or eliminates the number of mowings necessary to prevent seed maturity. Rates of sowing are the same as those ordinarily used in producing a sorghum hay crop.

Whenever the cover crop shows signs of maturing seed, it should be mowed at a stubble height of 8 to 10 inches to insure maximum protection to the seedbed the following spring. A light hay crop left on the land adds to the protective value of the mulch. The heavy hay crops may be removed without unduly lowering the quantity of stubble and aftermath required for soil protection.

A better seedbed can be prepared and the cost of preparation reduced by grazing part of the standing sorghum crop in the fall. The livestock, however, should be removed in time to leave enough stubble cover on the land to control wind and water erosion, prevent crusting, and reduce surface evaporation. The crop residue should be left evenly
distributed and sufficient to cover at least 75 percent of the ground. More of the preparatory crop may be removed by mowing or grazing in the eastern part of the region, or on special sites where soil blowing is less serious or where the slope of the land is such that severe washing is not a problem.

Many abandoned fields have a poor cover of good grasses as much as 10 years after abandonment. They are usually covered with a dense growth of weeds and poor grasses. Farmers are reluctant to plow up and establish a suitable seedbed on these lands. To do so, however, will pay dividends in rapidity of establishment, completeness of coverage of good grasses, and higher grazing returns. Seedings made in weed residues usually result in consistently poor stands or in failures.

Sowing in weed cover or small grain stubble: Cool-weather grasses, such as western wheatgrass, may be sown in weed cover with fair success under favorable conditions. They start earlier and compete better with weeds than most warm-weather grasses. Of the latter group of grasses, sand lovegrass and sand dropseed are superior in resistance to weeds and can be sown sometimes with fair success in weed cover.

Small-grain stubble may be sown to grass but is rarely satisfactory, except perhaps in the northwestern part. Volunteer cereal plants and weeds usually develop after harvest and before time for sowing grass seed the following spring. Cool-weather grasses have the best chance for success on this method of land preparation if sown in the fall or very early in the spring. Other grasses can be drilled satisfactorily in grain stubble if the land at sowing time is unusually free of volunteer plants and weeds.

Sowing in cultivated or fallow land: Clean-tilled or fallow land may be sown to grass only in protected areas or localities where soil blowing is not severe. Fine, firm, mellow seedbeds are essential in grass establishment and are difficult to obtain without danger from wind and water erosion, surface evaporation, or baking of the soil. Bare land is rather widely used in northwestern and extreme eastern districts. Sorghum stubble, with its additional protective features, however, is gaining favor there and elsewhere. That cultivated crops can withstand wind erosion on a particular field does not prove that grasses will do likewise. Seedling grasses are less able to survive the hazards that occur on clean-tilled seedbeds.

Sorghum crops usually continue growth until late in the fall and make a poor seedbed for fall-sown grasses. The hay millets have been used successfully for the purpose. Their fall growth is slower, stops sooner, and is less competitive than the sorghums. Soon after a rain in midsummer, the millets usually produce sufficient growth for soil protection. The millets are like the sorghums in that they need mowing to prevent seed maturity and competition from volunteer plants. Leaving a high stubble is likewise essential in providing adequate protection to fall-sown grasses.

When to sow: The time to sow grasses depends on the kinds used, the method of seedbed preparation, and general location in the region.

Spring sowing gives optimum results for most grasses best adapted to the area. Exceptions are the cool-weather grasses that respond about equally well to sowing in fall or very early in the spring.

Grasses adapted to fall sowing may be sown following rains late in August or September. Spring sowing in crop residues should be made directly in the undisturbed stubble. The protective value of the stubble should not be destroyed in advance by tillage operations. Hence, it is important to sow before weeds start. Satisfactory dates for sowing range from about February 15 in southern locations to April 10 in the north; the fore part of the period is preferred for sowing cool-weather grasses and hard-seeded species, such as sand paspalum and sand lovegrass.

Where it is possible to use clean-tilled seedbeds, the drilling of warm-weather grasses is delayed until the latter part of April or early May, when wind velocities are usually lower and rainfall heavier than
earlier in the season. But too much de-
lay means rapid surface evaporation and
severe crusting of the soil from heat and
heavy rains. Light surface tillage would
destroy one or two stands of weeds and
prepare a firm seedbed.

How to sow: Drilling is superior to
broadcasting. Drilling makes application
casier, distributes the seed more uni-
formly, places it more nearly at proper
depth, and requires lower rates of sowing.

Unfortunately, common methods of
harvesting and cleaning permit the sowing
of only a few adapted species with
ordinary farm drills. Common grain
drills have been used successfully for
sowing especially clean seed of buffalo-
grass, western wheatgrass, and crested
wheatgrass. New and carefully con-
structed alfalfa drills or grass-seeder at-
tachments can be used for weeping love-
grass, sand lovegrass, sand dropseed,
switchgrass and sand paspalum. These
small-seeded grasses may be sown more
satisfactorily, however, by using drills
made from garden-planting equipment.

Important native grasses usually in-
capable of being drilled properly with
ordinary farm machinery include all the
gramas, all the bluestems, Canada wild-
rye, Indiangrass, and Texas bluegrass.
Processing the light, chaffy seed of these
grasses with hammer mills and fanning
mills removes part or all of the hulls and
facilitates sowing with ordinary drills.

Most of these grasses have to be sown
in the "rough," since the processing work
is not done commercially on an extensive
scale. Special drills have been made and
used successfully in sowing all these
grasses regardless of the fluffy nature of
the seeds.

Ordinary grain drills can be used to
sow many chaffy grasses when the ma-
chines are equipped with sugar-beet
agitators or similar devices.

Depth of sowing: Shallow depths of sow-
ing of ¼ inch usually give best results
under ideal moisture conditions, but such
conditions rarely prevail long enough to
insure successful stands in dry-land areas.
Shallow-sown seed often germinates and
dies before additional moisture is re-
ceived. It is essential in dry localities to
sow the seed at or near the maximum
depth from which it can emerge. Sowing
at a regulated depth of 1 inch, followed
by heavy press wheels to give a firmed
coverage of ½ to ¾ inch, has proved
successful on many soil types with every
glass adapted to the region. Grass drills
give best results when equipped with
double-disk coulter openers and depth-
regulating bands set to prevent sowing
deeper than 1 inch. These special items
enable the operator to apply enough
lever pressure to insure proper penetra-
tion of crop residue and firm soils with­
out sowing too deep on light soils.

When drills are not available, the seed
can be broadcast by hand and covered
with a drag harrow or packer on clean-
tilled land or with an ordinary disk or
disk drill on stubble land. The seed
should be covered at depths like those
recommended for drilling. More even
distribution of broadcast seed can be had
if the seed is divided into two equal lots
and each lot used to cover the entire
field. A simple means of broadcasting is
to scatter the seed from the rear end of
a tractor, in front of the machinery used
to cover it. See pulverizer-packer method,
Chapter V.

Firmness of seedbed also is highly im-
portant in establishing grass. Heavy press
wheels should be standard equipment on
every drill. Surface rollers may be used
advantageously in packing the soil before
and after sowing. In wind-erosion areas,
the crop residue must be sufficient to
prevent soil-blowing after the packing
treatment. Loose sandy soils may be
made desirably firm before sowing by
rolling them when the ground is wet if
the stubble mulch is sufficient to prevent
clogging of the roller.

Companion crops: Small grains as com-
ppanion crops should not be sown with
the grasses; they compete too much for
moisture to justify the practice in dry-
land areas.

One has to reduce competition in seed-
ing stands of perennial grasses by mow-
ing weeds whenever they get so high they
shade the grasses or use up too much
moisture. Two mowings are usually re-
quired the first growing season; one mowing will do the second year.

Seedling stands of native grasses often seem to be failures when actually they usually develop into satisfactory stands if left undisturbed. No sowing should be destroyed without first determining definitely whether a stand failure exists.

Most perennial grasses of the region can be grazed the second fall after sowing. In some instances the growth is sufficient to warrant grazing the first fall or second summer after sowing. Grazing may start when the height and vigor of growth are comparable with moderately grazed native range.

Superiority of native grasses: The naturally high mineral content of Great Plains soils results in the production of native grasses superior in yearlong grazing value to those of most other parts of the world. The principal native grasses possess a superb combination of desirable characters. Most of them run high in calcium, phosphorus, protein, carotene, and other food essentials during the growing season. Many retain much of these values during the winter.

These grasses are also outstanding in high palatability at nearly all stages of growth. They are long-lived perennials that rarely require resowing when well established and properly managed. Many can resist heat, cold, drought, close grazing, and trampling. They have the ability to recover remarkably fast from the effects of adverse climate and abuses.

For these reasons, and because few introduced grasses are fully adapted to all parts of the Southern Great Plains, native grasses have received major attention for regrassing purposes. Most of the native grasses best adapted to the area are warm-weather species that start growth rather late in the spring, cease growth early in the fall, and remain dormant most of the winter. A few cool-weather species of native and imported grasses are adapted; they provide much green palatable and nutritious grazing early and late in the season in the northern part of the area and nearly all winter in the south.

Warm-weather native grasses: Chief among the warm-weather natives are blue grama, buffalograss, side-oats grama, sand lovegrass, sand bluestem, switchgrass, Indian grass, and little bluestem. The principal cool-weather natives include western wheatgrass, Texas bluegrass, and Canada wild-rye. The main introductions include Caucasian bluestem and Turkestan (or yellow) bluestem throughout the region, crested wheatgrass in the northern and higher locations, weeping lovegrass in the south, and Lehmann lovegrass and Boer lovegrass in the southwestern corner.

No perennial legumes have been discovered that are fully adapted for inclusion with grasses in dry-land pastures of the Southern Great Plains. Alfalfa is grown to some extent on bottom lands and other areas favored by extra moisture. Sweetclover is grown widely in all parts of the region, but is rarely suitable for use in seed mixtures with grasses. It competes too severely with the seedling grasses and usually fails to maintain itself by natural reseeding in a grass mixture. Legumes are badly needed to maintain soil fertility and add to the nutritive value of pasture mixtures.

Source of seed: The source of the seed of native grasses merits close attention. Although adaptation to local conditions may be best assured by using in a given area seed harvested in that area, the forage yield and length of growing season are greatly increased by using seed from more southern sources. The seed may be used several hundred miles or more north of its source without much danger of winterkilling. Seeds of most native grasses, when sown very far south of their harvested source, produce forage decidedly lacking in vigor, production, and period of growth. Seed of blue grama and buffalograss from sources in Colorado and Kansas, for example, produce in Oklahoma and Texas much less than half the forage yield of the same species native to the latter States. Seed of native grasses from sources in Oklahoma, New Mexico, and Texas produce higher yields throughout the region than that from northern sources.

Blue grama: Blue grama occurs naturally throughout the region and is best adapted to heavy and semishady soils but is widely
distributed on sandy land and does well when sown there. This short bunchgrass is palatable and nutritious during the growing season and retains much of these values during the winter. It can be used to excellent advantage as the basic species in most upland mixtures. The seed is comparatively easy to harvest with small combines, usually runs fairly high in purity and germination, and emerges promptly after planting.

Blue grama is not quite so resistant to close grazing as is buffalograss, but is slightly more palatable, more drought-resistant, and equally nutritious. It withstands closer grazing and heavier trampling than any other well adapted species except buffalograss. Pure sowings of blue grama at 6 to 10 pounds of combine-run material or 1 pound of dehulled seed to the acre give good stands. Mixtures of this grass with others usually give more satisfactory results.

Buffalograss: Buffalograss thrives best on the heavier soils, but has been grown successfully on land containing some sand. It occurs in about equal mixture with blue grama in native ranges on heavy soils, except in the southern areas where buffalograss predominates in association with blue grama. These two species constitute the famous short grasses of the Plains and are well known for their nutritious qualities. Nearly every mixture sown on heavy or semiheavy soils in the Southern Great Plains should contain at least 1 or 2 pounds of buffalograss seed burs or \( \frac{1}{2} \) pound of dehulled seed per acre.

It is rarely considered advisable to establish a pasture exclusively with buffalograss. The inclusion of blue grama and other grasses with buffalograss in a mixture improves the immediate and ultimate value of the pasture. These grasses add desirable qualities not possessed by buffalograss alone and provide helpful indicators of overgrazing to assist in pasture management.

Side-oats grama: Side-oats grama is not too particular in its soil requirements. It may be used as an important part of most mixtures on soils containing some sand or other previous materials. It is usually more productive than either of the short grasses but requires more moisture for maximum growth.

Side-oats grama is eaten readily by cattle, especially during the growing season, when it is often preferred to the short grasses. It is slightly less palatable and somewhat less nutritious than the short grasses during the winter, but is superior in these respects to most other grasses in the dormant stages of growth. Sand lovegrass: Sand lovegrass has proved to be one of the most valuable native grasses under trial at Woodward, and on sandy soils elsewhere in the region. Its natural occurrence is limited to very sandy soils, but it grows well on semi-heavy soils. This lush-growing, fine-stemmed, medium-tall bunchgrass, with its rich growth of soft basal leaves, is much more palatable than weeping lovegrass, which it resembles in general habit of growth and adaptability to reseeding purposes.

Sand bluestem: Sand bluestem is well adapted to deep sandy soil throughout the region, where it often occurs as the most productive if not the principal component of the native vegetation. This tall, vigorous, broad-leaved grass spreads slowly by rootstocks to form large clumps or extensive colonies. It serves equally well as an excellent summer grass for grazing purposes on sandy uplands and for hay production on bottom lands. It rates high in palatability and nutritive qualities during the spring and early summer months, but becomes coarse and stemmy in the fall and is eaten much less readily than most other grasses during the winter.

Switchgrass: Switchgrass occurs somewhat sparingly but widely distributed in favored sites on sandy upland. It is usually the principal grass on sandy lowland. It has a natural preference for sandy soils but does well on semi-heavy soils when sown there. It grows in somewhat the same manner as sand bluestem and has nearly the same grazing value. Indiangrass: Indiangrass resembles sand bluestem and switchgrass in soil requirements, grazing value, and general habit of growth. It exceeds them in seeding
vigor, and is slightly superior in palatability. The seeds are somewhat less chaffy and easier to handle than those of sand bluestem.

**Little bluestem:** Little bluestem is one of the most important prairie grasses in the subhumid area east of the Southern Great Plains, where it and big bluestem are highly regarded for beef-producing qualities during the late spring and early summer months. Little bluestem is fairly common on sandy or rocky soil throughout the region, but it usually ranks fairly low in palatability unless the previous year's growth has been removed by grazing or other means. It is eaten readily, however, when grazed reasonably close or when the old growth is mowed. This grass is more susceptible to drought injury and heavy consistent grazing than most other grasses, and is short-lived.

**Sand paspalum:** Sand paspalum, a short, semiprostrate, native bunch grass with broad, crinkly, soft, fuzzy leaves, is one of the most palatable grasses for summer grazing on sandy lands. The leaves, however, become dry, brown, and papery in the fall and have little grazing value in the winter. The grass is a fairly rapid invader and stabilizer of sand dunes and blow-out areas, where it is ultimately replaced to a large extent by more permanent species; usually, however, enough of it remains to constitute a big part of the vegetation.

**Western wheatgrass:** Western wheatgrass is one of the most valuable cool-weather natives. It is best adapted to heavy soils where its natural occurrence and greatest development is usually restricted to areas benefited by run-off water from adjacent land. It occurs generally throughout the region but becomes successively less abundant from north to south and from high to low elevations.

Western wheatgrass is less drought-resistant and less palatable than many others in summer, but it is highly palatable and extremely nutritious when growing actively in other seasons. It is a cool-season grass in the northern part of the region and a true winter grass in the south. It continues active growth through fall, winter and spring unless the weather is extremely dry or temperatures fall near or below zero for long periods. Resown stands of western wheatgrass have survived more than 10 years on upland at Woodward, and remained highly productive in the cooler months.

In grazing tests, resown pastures of western wheatgrass have supported more cattle and produced greater winter gains with much less cottonseed cake than were obtained from native range.

The rotation of cattle from western wheatgrass during the cooler months to native range during the warmer months has been clearly superior to continuous grazing of native range.

It seems advisable to establish a separate pasture of this grass for exclusive use during the cooler months, to be used in rotation with warm-weather grasses during the summer. A mixture of the two types of grass involves difficulties in establishment and management. They respond best to different times of sowing and have the greatest grazing value at different times in the year. A separate pasture of western wheatgrass would provide excellent grazing while the warm-weather grasses were being protected from use during their spring and fall growth.

**Texas bluegrass:** Texas bluegrass is more palatable than western wheatgrass, but is similar in habit of growth, nutritive qualities, and general grazing value. Limited investigations at Woodward indicate that it is less able to withstand competition from other plants than western wheatgrass. It occurs on sandy and semiheavy soils from southern Texas to southern Kansas. No seed of this extremely valuable grass is now commercially available. The fluffy seed is hard to harvest and thresh. These disadvantages have been overcome at Woodward by processing the threshed material with a hammer mill.

**Canada wild-rye:** Canada wild-rye, another cool-weather native, grows naturally on sandy soils in the region but shows a preference for roadside and lowlands favored by extra moisture. Good stands failed to survive heat and drought on semiheavy upland soils at Woodward.
for more than 3 years. The grass, however, is being used successfully on sandy soils in southwestern Kansas. The fall, winter, and spring growth of this grass is highly palatable. The mature growth is coarse, stemmy, and rarely eaten by livestock.

Crested wheatgrass: Crested wheatgrass, an introduction from Siberia, is a promising grass for resowing in the higher elevations of eastern Colorado and northeastern New Mexico. Numerous tests conducted for many years show that it suffers from intense heat and drought and grows poorly below an altitude of 4,000 feet.

On the basis of experience, sowing crested wheatgrass in these areas should be limited to fairly small trials until these later plantings have been subjected to prolonged heat and drought and have demonstrated ability to survive the adverse conditions.

Weeping lovegrass: Weeping lovegrass is much less palatable and shorter lived than most native grasses, but is usually more productive for at least a few years. It is prompt in germination, easy to establish, strong in seedling vigor, makes rapid vigorous growth on a wide range of soil types, and resists heat and moderate cold. It has survived winters in the southern half of the region and has winterkilled only to a limited extent farther north.

Weeping lovegrass compares favorably with the natives in nutritive qualities, but its high fiber content at all stages of growth and its offensive odor at flowering time reduce the palatability and quantity eaten by livestock. Cattle usually graze every other grass in preference to it, if given free choice.

Blue panicgrass: Blue or giant panicgrass has shown promise in recent years for tall, vigorous, palatable production in the far southern areas. It becomes severely injured or killed by freezing temperatures in the central districts. Native sand dropseed occurs widely throughout the region. It rapidly invades abandoned fields and depleted ranges on sandy or semihard soils. It has considerable grazing value, but is less palatable and more difficult to establish artificially than most other native grasses.

Johnsongrass: Johnsongrass has been used successfully to stabilize sandy uplands and furnish considerable seasonal grazing. Cultivation about every other year improves its forage yield and ability to withstand drought. Although its best use should be made on areas where it now occurs, it seems unwise to expand the acreage.

Other grasses: Boer lovegrass and Lehmann lovegrass are adapted to the extreme southern part, where they produce more palatable growth than weeping lovegrass and show promise for resowing. Caucasian bluestem and Turkistan bluestem are the only exotic grasses that have fully withstood cold winters and hot, dry summers from northern Colorado to southern Texas. Both are medium tall, fine stemmed, and leafy. They are equally nutritious, but the Caucasian variety is more palatable to beef cattle.

Many other perennial grasses are used to a limited extent. Big bluestem is a valuable grass on favored sites along the eastern and southeastern borders. Smooth bromegrass is grown on a limited scale under favorable conditions at high altitudes. It is more palatable but less drought-resistant than crested wheatgrass. Rhodesgrass and Dallisgrass thrive on the Gulf Coast, but usually winterkilled even in the extreme southern part of the region proper. Bermuda-grass is used to a limited extent for pasture purposes on sandy upland and moist lowland in the southeastern sections.

Slender wheatgrass is a cool-weather native perennial sometimes used at high elevations in Colorado. It is comparatively short-lived, but is strong in seedling vigor and produces fairly large yields of palatable forage.

Grass Mixtures: Mixtures of two or more species of somewhat related palatability and growth habits are usually preferred to pure stands. Sowing a mixture of well-adapted species is usually considered to have four advantages over the others—greater success in obtaining a stand, a greater variety of forage, a longer grazing
period, and more rapid and complete occupancy of the land.

Mixtures are not always desirable. Separate pasture stands of the cool-weather and warm-weather grasses offer greater possibilities than mixtures of the two types. The separate stands of these two classes of grass can be grazed in rotation with each other and when each is most nutritious. Each class can be properly managed and protected when it needs protection. Neither competes to the disadvantage of the other when planted separately.

Grama-buffalograss mixtures have been widely and successfully used in the Southern Great Plains. A suitable mixture of unprocessed seed for heavy and semi-heavy soils consists of about 6 pounds of blue grama, 3 pounds of side-oats grama, and 1 or 2 pounds of buffalograss per acre. This mixture may be improved for the extremely heavy soils by increasing the proportion of buffalograss and reducing that of side-oats grama. The combination may be modified for sandy soils by increasing the proportion of side-oats grama, reducing or eliminating the quantity of buffalograss, and adding substantial quantities of one or more of the sand-tolerant grasses. These include sand lovegrass, switchgrass, sand bluestem, and Indiangrass.

**Improved grasses:** Many improved strains of grass are being developed by plant breeders. A few of these have been released and others are being increased for further testing and general distribution in the future. Preliminary work indicates that this line of investigation will result in the development of strains greatly superior to bulk species now used. The Blackwell strain of switchgrass, selected for rust resistance, the El Reno side-oats grama, and the Hays buffalograss are examples of those already developed.

Several promising strains in the process of being increased or tested are Tucson side-oats grama, a vigorous, tall-stemmed strain of buffalograss, and a sand-tolerant strain of western wheatgrass.

**Temporary pastures:** Temporary pasture crops used extensively in the region include Sudangrass, sweetclover, and wheat. These crops, when grazed in rotation with each other and with permanent pastures or range, often provide green, succulent grazing through a greater part of the year. Wheat produces considerable grazing from early in the fall until about April 1 when moisture and temperature conditions are favorable. Second-year sweetclover usually supports heavy grazing from about April 1 to late June or early July. Sudangrass when grown on well-prepared land and favored by good rainfall distribution, can be grazed heavily from early summer to late fall. First-year sweetclover can be grazed lightly in the fall.

The Madrid and Spanish varieties of sweetclover are superior to ordinary commercial lots. The Madrid variety is about equal to Spanish in forage production and remains green much later in the fall of its first year. Most of the curly, yellow-flowered varieties of sweetclover are less productive than the white-blossom strains but are more palatable and reseed themselves better.

Wheat pastures occasionally cause severe death losses in cattle because of grass tetany, a malady locally known as wheat poisoning. The difficulty increases with an increase in the lushness of growth. The principal losses occur among pregnant cows and in cattle being transported from wheat pastures.

**Irrigated pastures on Plains:** An irrigated pasture is profitable if it yields returns equal to those from an alfalfa hay crop on similar land. A heavy carrying capacity for 5 or 6 months of the year makes an improved pasture highly useful in maintaining a dairy or breeding herd. If these goals cannot be attained, the pasture should be replaced by higher-yielding forage crops.

Methods of establishment and care of irrigated pastures are similar to those practiced for related purposes in other regions. These practices include proper attention to land leveling to conserve water and soil fertility, a firm seedbed, shallow sowing, frequent light irrigations during establishment, rotation of grazing, not grazing when the land is wet, scattering of droppings, fertilizing to maintain...
the production through the use of nitrogen for grasses and phosphates for legumes, and timely irrigations.

Grasses commonly used in irrigated pasture mixtures are smooth bromegrass, orchardgrass, timothy, Kentucky bluegrass, and meadow fescue. In the extreme southern part of the area, smooth bromegrass is replaced with perennial ryegrass. Several of these grasses are usually grown in mixtures with one or more of the following legumes: Ladino clover, White Dutch clover, alsike clover, red clover, or alfalfa. Reed canarygrass, Alta fescue, redtop, and strawberry clover are often used on very wet lands. Most of these plants are cool-weather types that produce green growth throughout the winter in the southern part of the region and from early spring to late fall when irrigated in the northern part, especially at the higher elevations.

Orchardgrass is not adapted to sandy soils, is less drought-resistant than is smooth bromegrass, and should be grazed closer to prevent accumulation of old growth. Timothy is best adapted to the higher elevations where the summers are cool. It is not suited to sandy soils. Timothy is not resistant to trampling, but its cheap seed and ease of establishment make it useful in mixtures. The stands are not permanent; the grass is medium in palatability but furnishes considerable forage throughout the season. Kentucky bluegrass is highly palatable and grows on a wide range of soils, but does not withstand hot weather in the lower and southern parts of the region.

Early spring or fall are the best times to sow these cool-weather grasses and legumes for irrigated pastures. It is advisable, however, to delay sowing until a clean, fine, firm seedbed is prepared and a continuous supply of irrigation water is available. Good, weed-free seed, properly tested and tagged in accordance with seed laws, should be used. The seeding may be done by methods we have described for dry-land pastures, except that heavier rates of sowing are used.

Regardless of the method used, from four to six light irrigations should be applied to the pasture each season. The grass should never be allowed to suffer from drought. The flooding and border methods of irrigation are used in northern Colorado. The furrow, or corrugation method, which is common in the Arkansas Valley, permits the use of a head of water ordinarily too small to apply by other methods.

Grazing irrigated pastures: Conservative grazing is the first essential in management of irrigated pastures. Grazing should be rotated by fencing the pasture into separate fields. Three fields are better than two. One can be grazed while the others are being irrigated or allowed to grow. Livestock should be withheld during the first year after planting. Mowing may be necessary to kill weeds and to cut down unpalatable growth. In some instances, a light crop of hay may be cut the second season, after which the animals can be allowed to graze. Growth should be allowed to reach a height of 5 or 6 inches before grazing is permitted in the spring. The pasture should be harrowed once each season to spread the animal droppings. When the yield or carrying capacity begins to drop the stand should be plowed. Irrigated pastures should be included in rotation with other crops.

Pastures that are used for winter grazing should be left unused during the summer. A lush growth of grass protects the soil from freezing and permits later growth in the fall. Thawing is lessened during the winter and thus trampling damage is reduced. Pasture should not be used more than 2 years at a time for winter grazing. More extended use permits the sod to thicken, and loss of grasses may result.

Manure should be applied in February or March. The application of manure should be followed by disking or treatment with an alfalfa renovator. This permits aeration of the soil and stimulates new growth. Ammonium sulfate or ammonium nitrate will produce earlier pasturage and frequently increases the yield. Phosphate will increase the yield of legumes on many soils and will produce forage with a higher phosphorus and lime content. Before the entire pasture is
SOUTHWESTERN IRRIGATED PASTURES

treated, small areas should be fertilized to see if the grasses respond.

Virgin desert lands lack most of the characteristics of productivity associated with the forest and prairie regions. The sparse plant cover varies from bunch-grasses to desert shrubs. The soil is commonly light in color and often is coated with a hard crust. Low rainfall makes the growth of even quickly maturing crops hazardous without supplemental water. But despite discouraging appearances, millions of acres of such land in the United States have become highly productive through the development of irrigation agriculture in the past 100 years.

The principal problems of soil management in this western irrigated region result, partly from the inherent characteristics of virgin desert soils, and partly from the relationships between these soils and the water applied during irrigation.

Desert soil characteristics: Because of low rainfall and limited plant growth, desert soils are naturally low in organic matter and nitrogen; sometimes they have only a tenth as much of these essential soil ingredients as a good virgin prairie soil. Because most of the rainfall on desert soils has been used by plants or evaporated, there has been little leaching of the soluble products formed from rock weathering. Consequently, desert soils usually contain large quantities of calcium, magnesium, potassium, sodium, carbonates, sulfates, and often chlorides; sometimes, in fact, the accumulations of such materials is so concentrated as to limit plant growth. But although many nutrients are present, the soils, when placed under irrigation, often lack enough phosphorus and nitrogen for maximum crop yields.

Irrigation water, which converts the soil environment from desert conditions to humid conditions, stimulates plant growth, increases the quantity of organic matter added to the soils, stimulates microbial activity, and brings many mineral constituents of the soils into solution.

Soil changes under irrigation: If the water is low in salt and drainage is good, the soil gradually changes from a desert to a humid type. In Arizona, a Red Desert soil increased in nitrogen from 0.052 percent in the virgin state to 0.076 percent after cropping under irrigation in a lysimeter for 12 years. Studies on the changes in irrigated soils in New Mexico indicate a gradual leaching of calcium carbonate from surface soils to lower horizons.

On irrigated lands, less grass has been grown in rotation systems than its value for soil fertility and immediate income justifies because farmers have not been educated to irrigated pastures and have been using unirrigated range lands and low, wet areas for grazing.

Soil management problems: The principal, special soil-management problems in pasture production under irrigation include land preparation for planting, irrigation, drainage, fertilization, and salt control.

Irrigation farming requires more thorough land preparation than other types of agriculture.

The land must be leveled to permit uniform application of water; otherwise either low spots will receive excessive water or the high soil areas will not receive enough. Leveling permits a better job of irrigation, reduces the labor required in getting water over the land, and often helps control erosion. It is usually necessary when new land is brought under irrigation. Virgin desert soils are commonly hummocky and otherwise uneven in surface topography. Land that has not been farmed for some time is also often not sufficiently level for efficient irrigation. Modern machinery has greatly lowered the cost of leveling land and has improved the quality of work done.

Water requirements of pastures: Irrigated pastures have about the same seasonal total water need as alfalfa, but require smaller, more frequent applications. Water moves over sodded land more slowly than over similar land in alfalfa or grains; it also penetrates much more rapidly. Consequently, large heads of water commonly are needed on pastures to obtain quick coverage and uniform...
distribution in the root zone. The distance between head ditches should likewise be less for pastures than for other crops.

On uniform slopes of 3 percent or less, border irrigation is usually recommended, but frequently flooding from field ditches is the accepted method because of uneven topography. Soils covered by irrigation water tend to form hard crusts under the rapid drying conditions of an arid climate. Since furrows or corrugations limit the soil surface covered with water, the use of corrugations is common in establishing pastures on heavy soils regardless of subsequent procedures. After grass is established, the corrugations fill in rather quickly unless they are frequently cleaned out.

In some areas, particularly where only supplementary irrigation is needed and where topography is rolling or the soil highly permeable, sprinkling is used for pasture irrigation. Sprinkling permits a uniform water application on rolling land and highly permeable soils, and greatly reduces runoff.

Low-lying lands in irrigated areas, which frequently are waterlogged, are commonly used for pasture. Exceptionally high water tables and water standing on the surface for long periods kill many of the more desirable species of grass and legumes. They are replaced with sedges and weeds of comparatively low palatability. Some pasture plants, as reed canarygrass and strawberry clover, endure such wet conditions, but quality and quantity of pasture are generally greatly increased by drainage. Wetlands used only for pasture often can be economically improved by short, open drains to remove excess surface water. Deeper open or tile drains are more expensive, but they increase the productivity of pastures and the number of plant species that will grow.

Fertilizers for irrigated pastures: Because the soils of arid regions are generally low in nitrogen and available phosphorus, fertilizers for pastures in irrigated regions often include one or both of these elements. Enough potassium is present in most irrigated soils to meet plant needs. Current soil management programs cause deficits in the soil-potassium balance, however, so that instances of potassium deficiencies can be increasingly expected. Some fields of Ladino clover in California have been reported to respond to potash fertilizers.

Lack of nitrogen in irrigated pastures can be handled in part by planting legumes in mixtures. Most of the soils contain lime or are neutral in reaction and are favorable for growth of legumes. In mixed pastures more economical results are often had from phosphate fertilizers than from nitrogen. Superphosphate fertilizers have generally given better results in arid regions than other types of phosphate. Ground rock phosphate, colloidal phosphate, and basic slag have low availability on alkaline calcareous soils.

Combinations of nitrogen and phosphate fertilizers or of farm manure and phosphate have generally given higher pasture yields than phosphate alone. Both nitrogen and phosphate fertilizers are usually applied to established pastures in late fall or early spring. Phosphate is commonly worked into the seedbed by plowing under, drilling, or by broadcasting and diskimg or harrowing into the soil. Farm manure is usually applied on established pastures in winter or early spring.

Large acreages of irrigated lands contain too much soluble salts for good crop growth. Grass is commonly grown on them, but often the forage produced is much lower in yield and quality than could be produced with improved plant species and improved soil-management practices.

Remedy for excess salts: The most satisfactory solution to the salt problem in soils is to establish drains and wash out the excess soluble materials by repeated heavy irrigations. In many areas the complete reclamation of salty soils is not feasible, however, because of factors like impermeable subsoils, poor drainage outlets, or inadequate or low-quality irrigation water. Salty soils are commonly divided into two groups: Saline soils that contain 0.2 percent or more of soluble salts, and alkali soils that have a pH above 8.5 and 15 percent or more of the exchange capacity occupied with absorbed
sodium. The alkali soils frequently contain caustic salts such as sodium carbonate.

Procedures for obtaining maximum plant growth on saline soils are based on the fact that plant growth decreases as the salt concentration in the soil solution increases. If salt concentration is expressed on the basis of osmotic pressure, the various neutral salts exert similar effects on numerous plants.

Injurious effects of salts: The injurious effects of the salts are caused more by a limiting of the availability of soil water to plants than by direct toxic effects. Under highly saline conditions the osmotic concentration of the soil solution may be so high that plants suffer for lack of water on soils that actually seem to have plenty of moisture.

The problem is further complicated by the rapid movement of soluble materials toward the soil surface in a drying soil, so that they are concentrated in the root zone. Frequent light irrigations encourage this type of salt accumulation and injure the plant roots. Good pasture production on saline soils requires keeping the soil moderately moist with relatively heavy irrigations rather than light irrigations at more frequent intervals.

Alkali soils are commonly highly impermeable because of the effects or absorbed sodium on clay. These soils are also frequently too alkaline in reaction for most plants. Chemical treatment with gypsum to furnish soluble calcium, or with sulfur to increase the solubility of calcium in soil lime, promotes the replacement of exchangeable sodium with calcium if drainage is provided to leach away the soluble materials. Laboratory analyses are needed as a basis for detailed recommendations for treating alkali soil.

Tolerance of plants to saline and alkaline conditions: Many grasses have a high tolerance of saline and alkaline soil conditions. They are, consequently, well adapted for planting during reclamation of salty soils and also for giving maximum returns on low-quality salty lands that cannot be reclaimed. Rhodesgrass and Bermudagrass are well adapted to irrigated saline soils in warmer regions. In the more northern States, smooth bromegrass, tall oatgrass, and western wheatgrass have all yielded well in the presence of high salt concentrations.

Mixed grass and legume pastures are admirably adapted for the improvement of desert soils for irrigation agriculture. If properly managed, they rapidly increase the content of organic matter and nitrogen. Furthermore, the distinctive effects of grass in promoting a water-stable granular structure in soils is especially important under irrigation. Soils recently plowed out of pasture are more permeable, have better aeration, and are less susceptible to crusting than similar soils that have been producing either small grain or intertilled crops. Recognition of these advantages is leading to increased use of pastures in regular crop rotations in many irrigated areas.

Irrigated Pastures in California

Both perennial and annual irrigated pastures are important feed crops in California.

The use of perennial irrigated pastures, as known today, dates from the late 1920's, when it was demonstrated that Ladino clover would produce excellent yields of forage on our shallow hardpan soil if properly watered or managed. The use of perennial irrigated pastures since that time has grown rapidly. The present acreage is estimated at about 450,000; it seems likely that within the next score of years it will become our most important forage crop. Irrigated pasture provides forage of high quality at a low cost and produces it on land unsuited to alfalfa.

Ladino clover in irrigated pastures: Ladino clover is still the leading irrigated-pasture plant, but it has limitations: It is shallow-rooted; because for continued growth it requires frequent irrigation, especially in summer, it is limited to areas having plenty of water and retentive soil; it cannot stand high temperatures. Ladino is grown on irrigated pastures in a number of districts, but most of the acreage in Ladino is located in the Sacramento and San Joaquin Valleys, where favorable conditions prevail.
Ladino clover draws heavily on the mineral nutrients, and many pastures containing it must be fertilized with phosphorus, and sometimes sulfur, for best growth.

**Birdsfoot trefoil in irrigated pastures:** Great interest has developed lately in birdsfoot trefoil as a pasture legume. It is a deep-rooted perennial; it is not adapted to the shallow hardpan land, but does well on the deeper, more porous soils. It tolerates more alkali and requires less frequent irrigation than Ladino. It tolerates more heat and is used with excellent results in the Imperial Valley in mixtures with ryegrass, Dallisgrass, Rhodesgrass, and other grasses. Elsewhere it is grown with the same mixture as Ladino is. The use of birdsfoot trefoil may greatly extend the area of irrigated pastures, but it should not be considered a substitute for Ladino clover in areas where the latter can be grown. While no direct comparisons are available, the birdsfoot trefoil does not recover so rapidly after grazing as Ladino, and observation indicates that it produces somewhat less feed.

**Irrigated pasture mixtures:** We still have much to learn about the proper mixtures for the different areas and the best management practices, but now enough experience has been gained to suggest some rather definite procedures.

To get maximum production and a better balanced feed, most of the pasture consists of clover or other legumes with various grasses. In the Sacramento Valley and in other localities in the North, a popular mixture contains Ladino clover, annual and perennial ryegrass, tall fescue, and orchardgrass. In the San Joaquin Valley the same mixture is used, although Dallisgrass is commonly added to it or substituted for the orchardgrass. Some alfalfa is sometimes added to get more legumes during the summer when heat depresses the growth of the clover.

Because the pasture must be irrigated every 10 to 14 days during the warmer months, the field is divided into four or more pastures and grazed in rotation. Opinions differ as to how close the pastures should be grazed, but observation indicates that most pastures are grazed too close so that recovery is retarded and production lowered.

One-half to two-thirds of the perennial irrigated pasture is grazed by dairy cattle, and provides succulent feed through a large part of the year. The remaining acreage is grazed by beef cattle and sheep. An important use is to finish lambs for market. The general trend appears to be to use ranges primarily to produce feeders to be finished on pastures and concentrates.

**Sudangrass pasture:** The most important annual irrigated-pasture crop, Sudangrass, is used in all of the warmer parts of the State. It is sown in April or June after a winter hay crop is removed. Sudangrass pasture will produce more feed than any other crop available during the warm summer months. Its principal use is on small dairy farms, where maximum production of feed is required. Some sweet sorghums are used in the same way, but they do not lend themselves so well to pasturing.

**Weeds in irrigated pastures:** The most serious weeds in irrigated pastures are apt to be buckhorn, dock, and various sedges. Partial control may be affected by mowing the pastures after they have been pastured to prevent the plants from seeding and to reduce spreading. Mowing also prevents some of the bunch-grasses, particularly orchardgrass and Dallisgrass, from taking over. When pastures become very weedy, the only means of eradication known is rotation with other crops.

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**NORTH PACIFIC COAST PASTURES**

**Pastures in Western Washington**

Western Washington, that area west of the summit of the Cascades between Canada and the Columbia River, was almost entirely covered with forest when the first settlers arrived. Now the agricultural land is made up of cleared river valleys, tide flats sweet enough to support crops, and a little level upland. Only small areas of potentially good agricultural land remain undeveloped. Of the 770,000 acres of cropland, two-thirds is used for hay and pasture.
NORTH PACIFIC PASTURES

Climate: Western Washington, like other Pacific Coast areas, has a maritime climate. The average January temperature varies from 32° to 40° F.; the July temperature varies from 54° to 66°. Except during July and August, the relative humidity is high.

Approximately 70 percent of the precipitation comes during the fall, winter, and early spring. The average precipitation received during the growing season, April to September, ranges from 6 inches to approximately 18 inches. Rainfall in July and August is insufficient to support grassland vegetation, except in the low subirrigated valleys. During the remainder of the growing season enough rainfall is usually received to keep grass and other forage crops growing vigorously. The average over the farming area is 35 to 45 inches.

The growing season is about 180 days in the area adjacent to the Cascade Range and more than 260 days in the area close to the Pacific Ocean.

Soils: A wide variety of types occurs, varying as to structure, texture, substrata, and conditions of drainage. The inherent fertility of the soils varies markedly and has exerted considerable influence on the crops that can be grown in western Washington.

The reaction of the soils west of the Cascade ranges from pH 4.5 to 6.5. The average value for more than 300 samples was found to be pH 5.9. These soils are of intermediate fertility. There is seldom any calcium carbonate present in the parent material and no accumulation of this material occurs in the profile.

Prairie soils occur in western Washington under a variety of rainfall conditions. Two extensive prairies are found on the Olympic Peninsula under an annual rainfall of 120 inches. Others occur in regions with only 17 inches of annual rainfall. Some of these soils, but not all, occur on extremely gravelly substrata. These areas aptly illustrate the power of the vegetative factor in a region of similar rainfall and temperature conditions, since the soils produced on the prairies are markedly different from those in the adjacent forested areas.

Adapted species: The use of subterranean clover, alta fescue, orchardgrass, perennial ryegrass, meadow foxtail, Ladino clover, and big trefoil have done much to increase the production of pastures and hay meadows in western Washington. There are still large acreages which can be sown to these species. Forage crops are much less specific with regard to their response to various soil types than they are to moisture relationships. Experimental evidence and experience of farmers demonstrate that species are distributed through the area on the basis of the water level in the soil when it is at a maximum. Thus it is more important to know the minimum depth to the water table during the year than it is to know the soil type in determining the species to be sown. The fertility level of the soil will influence the production but has little influence on choice of species.

The establishment of adapted, high-yielding species and mixtures for hay and pasture production is of primary concern in western Washington. It follows, also, that the maintenance of these stands at high levels of productivity is an essential part of the forage program.

Preparation of seedbed: A good seedbed is of primary concern in establishing forage crops. Performance of pastures or hay meadows will depend largely on careful and thorough seedbed preparation. Small-seeded crops, such as alfalfa or the perennial grasses, are best established on a firm, fine-textured, moist seedbed. Packing the seedbed will bring the soil particles into close contact with the small seeds. This will result in good germination because of rapid moisture absorption. A desirable seedbed can best be fitted on land that has been cropped to annual or intertilled crops the year before sowing. When permanent pastures or meadows must be sown, it is advisable to grow an annual or intertilled crop on the area before attempting reestablishment of the perennial crop.

The most satisfactory method of preparing a seedbed for spring sowing is to plow the area in late summer or early fall, leaving it rough over winter. Cultivation should begin as early as possible the fol-
lowing spring and the soil should be worked sufficiently to destroy any weeds on the area. Two or three cultivations usually will be needed to kill existing weeds; this will leave the seedbed in the proper condition for sowing. Additional cultivations may delay sowing to such an extent that summer drought may reduce stands.

It is recommended that the fertilizers be applied before sowing. If phosphate and potash fertilizers are needed for maximum production, 200 to 300 pounds of triple superphosphate applied before sowing time and worked into the surface of the soil will get the plant food into the root zone where it is absorbed by the plants. The application of 20 pounds of actual nitrogen before sowing is important, particularly on lands of low fertility. Only a few areas have been shown to be deficient in potash; phosphates have been found to give a good response throughout western Washington for maximum production of legume species. Nitrogen fertilizer is necessary for maximum production of the grass species.

Time of sowing: It is recommended that most of the species be sown in the spring while there is sufficient moisture in the soil to insure germination and establishment. The exception to this is on light, sandy soils where drought conditions may develop rapidly. On these soils, early fall sowing may be desirable. Subterranean clover, likewise, is an exception to the rule of spring sowing. It is a winter annual that does well on the drier sites in western Washington. The most successful stands have been obtained by sowing in September or early October, although some farmers have been successful in establishing stands very early in the spring, sowing not later than March 1.

Method of sowing: Whenever possible, a drill, should be used for sowing. Drilling insures a uniform depth of sowing, prompt emergence, and the development of a smooth, even sward. Less seed is necessary to get a good stand when a drill is used. Broadcasting is still practiced, especially in the smaller fields where the use of a drill or other large farm machinery is not possible. When seed is broadcast, every precaution should be taken to cover the seed very lightly.

New stands should be managed to reduce competition from weeds to a minimum. One or two mowings the first year are usually necessary to control the annual weeds that usually occur in new stands. It is recommended that they be mowed early in the fall to utilize the forage produced. Grazing is not recommended as the young forage plants are not well enough established by the end of the summer growing season to withstand even moderate grazing.

Fertilizers and lime: The use of fertilizer is one of the most important factors in good management of older meadows and hayfields. Phosphates are necessary for maximum legume production, while nitrogen stimulates the grasses. Yearly applications of 100 to 200 pounds of triple superphosphate and 40 to 60 pounds of actual nitrogen per acre are recommended. The nitrogen is usually applied in three equal applications—in March, May, and September. Split applications of nitrogen are particularly advisable when irrigation is practiced.

Some soils are slightly acid, and 2 to 4 tons of lime to the acre have given economic returns. Boron is necessary in most of the alfalfa-producing areas of western Washington. Applications of 50 to 60 pounds of borax an acre on heavy soils, and 30 to 40 pounds on light soils, will supply the needs of the alfalfa plants for boron.

Maintaining production: Keeping the perennial pastures in a high state of production in the years following establishment is important. Portions of perennial plants, usually the roots and crown, remain alive over winter. Even during the dormant period these living parts need some food material. The first growth in the spring must come from food stored in the roots. Unless perennial plants are given a chance to store food during the late fall, they may not survive the winter, or, at best, spring recovery will be slow. As a result, yields the following year will be low and in some cases stands may be so reduced that resowing may be necessary. It usually is necessary for perennial
plants to have a month of growing weather without grazing before the first killing frost, to store sufficient food in the roots for use during the winter period.

Grazing management: The plant is the only criterion of the time to start the grazing season. Vegetation in the pasture should be at least 5 or 6 inches tall before grazing starts in the spring. If this general rule is followed, there will be little danger of overutilizing the pasture. The date on which the plants will reach this height will depend upon the growing season each year.

The grazing load should be adjusted according to the plan of grazing and the productivity of the pasture species. During the spring, when lush, heavy growth occurs, the grazing load can be considerably heavier than during the dry period of the summer. It is desirable to vary the number of animal units according to the productivity of the pasture crop. If such adjustments are impossible, then the excess spring production should be preserved in a silo.

Rotational grazing is recommended for western Washington. The grazing load should be regulated to use the available forage during the length of time that the animals are in each division of the pasture unit. Normally it requires about 30 days from the time animals are removed from a unit before there is sufficient regrowth again to support grazing. This means that with a three-unit pasture, the animals will be on each unit 15 days and each unit will have about 30 days in which to make regrowth. In actual practice the days on each unit should be determined by growth of the herbage and the number of animals on the pasture.

Irrigation: One of the best means of increasing the production of pastures is by irrigation. July and August are dry, and, with irrigation, pasture and meadow vegetation becomes dormant during this period and normally fails to recover until late September. Experimental results and the experience of farmers indicate that forage production can be increased from 25 to 50 percent with irrigation. Sprinkler irrigation is adapted to most of the agricultural area in western Washington. It is admirably suited to the rather rough terrain and the only limiting factor is the water supply. It is necessary to obtain a permit from the department of hydraulics at Olympia to use water from any stream or well for irrigated cropland.

Weeds are a constant problem. The best control is to prevent their entrance into the pasture by using clean seed and by eradicating the weeds from the land before sowing. But if weeds are present, they can be reduced by proper fertilization of the pasture, by regulation of the grazing load to favor the forage species, and by periodic clipping to prevent weed seed production.

Pastures on cut-over timber land: There are approximately two million acres of nonrestocking timberland in western Washington. This vast area is not restocking, primarily because of continued burns and the failure to leave seed trees when the logging operation took place. A small part of the land has a suitable soil and satisfactory topography to make it feasible to develop an economic livestock unit. The places that are adjacent to existing farms can be developed for use as a supplementary pasture. Successful development of pastures on cut-over land depends upon the destruction of the existing vegetation. Fall burning to provide a seedbed, followed immediately by a broadcast sowing in the ashes with a recommended mixture has given successful establishment. Proper management of the new stand insures a supplemental pasture.

Pastures in Western Oregon

Western Oregon is part of the newest agricultural region in the United States. Farming there is less than a century old. The earliest lands to be cultivated were the open prairie or semi-open prairie areas; now the major farm activities are many and varied but still are mostly related to grassland agriculture.

Soil types: The wide range of soil types can be grouped into five. The tidelands or coastal overflow lands, limited in extent, are subject to either high-ground water level or overflow at various times.
They are relatively level and low, and are used most extensively for forage. This land is relatively expensive but, for the most part, can be most profitably used for forage for livestock.

River-bottom lands, near larger streams above tidewater, may be subject to occasional overflows. They are usually sandy, silty, or semigravelly, low and level, and considered desirable for practically every type of crop suited to the section.

First benchlands above river bottom vary in composition, fertility, drainage, and crop-producing value. They are relatively level and low, and are used mostly for general farming.

Low-elevation hill lands are generally considered as the first series of low rolling hills above the first benchlands. The soil is generally shallow and low in fertility. It washes badly unless well covered with vegetation. It is primarily pasture land.

High-elevation hilllands vary from 500 to 4,000 or more feet and are quite rough. Much is still covered with brush and timber. The soil is mostly shallow and low in fertility for cultivated crops, but reasonably good for timber growth and pasture.

Climate: Precipitation is mostly as rain—100 or more inches in the coastal area, 35 or 40 inches in the northern inner valleys, and 16 to 25 inches in the southern inner valleys. Eighty percent or more of the precipitation occurs from October 15 to June 1. The remaining period is dry, usually with only occasional light rains, except along the coast. In general, but to a lesser extent for the occurs during the season of highest pre-coastal areas, most forage-type growth cipitation, especially in late fall, late winter, spring, and early summer. Winter growth depends largely on temperature conditions. During the dry period plant growth is checked materially. In recent years the use of new and improved grassland plants has helped to equalize seasonal production where summer irrigation is not available. One grass in particular, Alta fescue, has been of primary value in that respect. Long-lived perennials are of more value for the purpose than short-lived ones or annuals.

In coastal sections and in the northern part of the area between the Coast Range and Cascade Mountains, supplemental irrigation, mostly by sprinkling, is practiced. Farther south, irrigation is mostly by furrow or flooding. Many persons find it strange that irrigation is done in sections where the precipitation is from 80 to 100 inches or more annually and still is practical. The practice is increasing in the coastal section because it supplies soil moisture during the summer when precipitation is lowest.

 Temperatures in general are mild, seldom above 100°F. Plant growth is fairly continuous, therefore, except during occasional extremes of low and high temperatures, if soil moisture is adequate. Use of field or range is possible during most of the year, although in times when the soil is filled with water the use of the fields is not considered good practice. The growing season generally varies between 150 and 265 days.

Pasture grasses: In general, grasses are considered the backbone of pastures. For most of the world, this is probably true. The northern section of the Pacific region is adapted to a wide range of grasses suitable for pasture use, among them annuals, short-lived perennials, and long-lived perennials.

The annuals are both native and introduced. Most of the native species have disappeared, largely as the result of abuse by man-controlled procedures, primarily overgrazing, burning, and land cultivation. Another factor was the introduction of new species, many of which were so aggressive that they crowded out many native species.

The introduced uncultivated annuals are, in general, of little value in comparison to the cultivated ones. The primary cultivated ones include the cereal grains, Sudangrass, and common ryegrass. These are either sown alone, used as nurse crops for longer-lived plants, or included in mixtures with longer-lived plants to reduce the period from sowing to initial utility.
Short-lived perennials may be called long-lived annuals. The native species are practically nonexistent. Introductions are few. Perennial ryegrass is the most common and most widely used. Timothy is in this category, not by choice altogether, but as the result of its life being shortened by disease infestations. Meadow fescue, while not used extensively, is in this class.

Long-lived perennial grasses are looked upon by most agriculturists as the choice of pasture grasses. They are of wide adaptability and utility. Some are classed as weeds and are recognized as such.

Sod formers are of special importance in permanent pastures. Several are available for use here. The more common ones include the bents—Seaside, Astoria, Highland, and Colonial; fescues—creeping, red, and Alta; Kentucky bluegrass, German velvetgrass, and quackgrass. Of these, the bents and fescues are most commonly used. Kentucky bluegrass is not widely adapted. German velvetgrass and quackgrass are weeds so their use is discouraged. Some persons feel that the use of Highland bent should be discouraged because of its aggressiveness. Sod formers, which usually grow rather low, are of most value for pasture. Occasionally they are cut for hay. The yields are generally low.

Bunchgrasses are extensively used for pasture purposes here. They fit in well in mixtures and are comparatively heavy hay producers. They include perennial rye, orchardgrass, tall meadow oat, Tualatin meadow oat, Chewings fescue, Hardinggrass, mountain brome, and meadow fescue. Among the grasses that may be considered as either sod formers or bunchy are Alta fescue and Chewings fescue.

Petrograsses are extensively used for pasture purposes here. They fit in well in mixtures and are comparatively heavy hay producers. They include perennial rye, orchardgrass, tall meadow oat, Tualatin meadow oat, Chewings fescue, Hardinggrass, mountain brome, and meadow fescue. Among the grasses that may be considered as either sod formers or bunchy are Alta fescue and Chewings fescue.

Few grasses of primary economic value are adapted to low wet lands in this section. Two, however, are widely used—meadow foxtail and reed canarygrass which are relatively good sod formers and good pasture producers. They grow under similar conditions, but do not grow well together. Seaside bent is used on occasion.

Pasture legumes: Legumes for pasture are always given a high rating for livestock utility. Theirs usually high palatability, nutritive value, and ability to improve make them valuable.

Legumes for pasture use in this section include annual, biennial, short-lived perennial, as well as the perennial legumes.

All the annual legumes of value for pasture are introduced. They include hop, sub, bur-, and crimson clovers; Willamette, common, hairy, woollypod, and Hungarian vetches; and winter, rough, and spring field peas. All are cultivated, except hop clover; sub and bur-clover and roughpea are considered as semicultivated or cultivated until established; thereafter they increase without being under cultivated conditions. The others are cultivated except as they volunteer for varying periods.

The main biennial legumes are sweetclover, mostly white-flowered, and alsike clover. The acreage of sweetclover is small, partly because of prejudice against it and partly because of difficulty of production due to stem rot. The development of the Willamette variety, which is highly resistant to stem rot, may result in the increased use of sweetclover for pasture and other forms of forage. Alsike clover is not commonly used for pasture when sown alone, except as supplemental pasture for short periods in the late fall of the year in which the stand was established, or early the following spring.

Red clover, being the primary one, is the leader of the few short-lived perennial legumes. It is short-lived in this section mostly because of heavy plant damage by insects, particularly root borers.

Perennial legumes used for pasture are both native and introduced. The natives are mostly several species of wild peas and vetches, commonly referred to as wild peavine. Introductions include alfalfa, common white and Ladino clover, birdsfoot trefoil, and big trefoil.

The native species have never been under cultivation. They occur most commonly in the higher hill lands in the
Coast Range Mountains. Producing areas are usually small, scattered, and materially reduced in plant population by overgrazing. Their spread is slow and largely vegetative because seed production is small and wildlife consumes a large part of the seed.

Of the cultivated legumes, alfalfa, Ladino clover, and the two trefoils are now grown largely for dual-purpose forage use, as pasture, hay and silage, and for seed. Birdsfoot trefoil is grown most extensively at present in the Rogue River Valley of southern Oregon under irrigation. Big trefoil is grown most extensively in the coastal area in Northwest Oregon and the North Willamette Valley. Both show promise of considerable expansion in production, primarily for pasture. White clover is grown primarily for pasture.

Pasture mixtures: Mixtures of plants, grasses and legumes particularly, are considered most satisfactory for pastures. In the northern part of the Pacific Region there are very few conditions or locations where combinations of grasses and legumes cannot be grown.

Because of the wide range of soil and climatic conditions, no one combination or mixture can be prescribed for this part of the Pacific Region. Each area usually requires individual attention; sometimes, even several recommendations are needed for one farm or range area.

The ideal pasture mixture is a near 50-50 combination—from the production standpoint—of grasses and legumes. But that is seldom possible, particularly with legumes, except under irrigation and other special conditions. Fertilization with phosphate is usually a factor in encouraging legumes.

Pasture types: Wild or so-called natural pastures occur in the northern part of the Pacific Region. Not often have these pastures been improved; weeds and brush are increasing, the result of factors like overgrazing and burning. The improvement that has been made consists of cleaning up brush, spot seeding, introduction of legumes (especially subterranean clover and hop clover in the area between the Cascades and the Coast Range Mountains, and birdsfoot trefoil, big trefoil, and subterranean, hop, and white clovers in the coastal region), and some introduction of good cultivated grasses, including orchardgrass, Alta, Chewings, and red creeping fescue, and Highland and Astoria bentgrasses.

Most pastures are called dry-land pastures, even though they are in relatively humid areas—this is because they are not irrigated. The more strictly dryland pastures are in southern Oregon where precipitation is relatively low. Fortunately, most pasture plants adapted to this section tolerate the rather dry soil conditions that prevail in summer and, though production is low, the plants live over and as soon as moisture conditions become more favorable renew growth satisfactorily.

Irrigated pastures are increasing. In some drier areas irrigation is just about necessary for worth-while pasture and other crops, and has been practiced for many years; in other areas, where natural soil moisture is more plentiful except in summer, supplemental irrigation is increasing, particularly on perennial pastures. Irrigation is expensive and quality and quantity must be high to bring the largest possible net returns. Utilization of irrigated pastures by dairy animals has proved most profitable. Irrigated pastures should have a high percentage of legumes in their make-up. Ladino clover is the most commonly used legume; perennial ryegrass, orchardgrass, meadow fescue, Alta fescue, and meadow foxtail are also good.

Pasture management: Good management practices, after establishment of the grass, include: Sufficient plant population of right kinds to produce maximum crops; balance of grasses and legumes; vigorous growth, perhaps encouraged by fertilization; minimum of weeds; rotation or deferred grazing; clipping where utilization is not complete and it can be done; scattering of droppings where feasible; prevention of overgrazing; elimination of poisonous plants or keeping livestock from them; allowing natural resowing at
times on rough or uncultivated lands; prevention of fires unless to burn brush; and economical use of irrigation, where practiced.

The economics of pasture production and use depends on more or less accepted premises in this area as in other parts of the world. In the past, too many farmers considered land that was worthless for anything else usable for pasture—a conclusion partly true, but usually leading to false economy. As a result, altogether too much land is below its former productivity and not enough effort is being made to improve it. Fortunately, pasture is being given increased consideration as a regular crop that should produce at a profit commensurate with the values of the land used.

PASTURE HIGHLIGHTS

1. Advancement in the management of pastures, meadows and ranges, and realization that these crops contribute to soil conservation and to efficient farming, have been salutary developments in the farm program of recent years.

2. The right use of pasture and of roughage crops is of basic importance in a national program of efficient farming, in the control of erosion, and in the building of soil fertility.

3. The programs developed under the Soil Conservation Service have more directly encouraged the planting of soil-conserving grasses and legumes, and the improvement of pastures and meadows than perhaps any other factor in recent years.

4. Farmers' experiences in recent times of severe drought have emphasized the importance of established pastures and meadows. Each farmer should examine for himself the possibility of devoting more of his land to such crops in order to reduce production costs and thereby increase the net gains from his farm.

5. Marked improvement in composition and methods of pasture management have already been made, but our pastures must be made more productive, eventually, in order to justify our going further into a grassland agriculture.

6. Pastures make for more efficient livestock production, in that they reduce the cost of feed and promote the health of the animals.

7. The more important northern pasture grasses for humid conditions are orchardgrass, Kentucky bluegrass, bromegrass, tall fescue (Alta and Ky 31), meadow fescue, timothy, cotulop, reed canarygrass, tall oatgrass, and ryegrass. To a minor extent meadow fescue, bentgrass, Canada bluegrass, red fescue, and sheep fescue are used for humid pasture.

8. The more important southern pasture grasses for humid conditions are Bermuda grass, tall fescue (Alta and Ky 31), Bahiagrass, carpetgrass, Dallisgrass, and Johnsongrass. Of lesser importance are Vaseygrass, Paragrass, Napiergrass, Pangolagrass, and St. Augustinegrass.

9. The more useful pasture grasses for the sub-humid and semi-arid conditions of the Northern Great Plains and Intermountain regions are crested wheatgrass, western wheatgrass, slender wheatgrass, intermediate wheatgrass, buffalograss, blue grama, bromegrass, wildrye, and big bluestem. Some of minor importance are switchgrass, bluebunch wheatgrass, side-oats grama, green needlegrass, Indiangrass, and Indian ricegrass.

10. The more useful pasture grasses for the subhumid and semi-arid conditions of the Southern Great Plains and Southwest Regions are buffalograss, the gramas, the bluegrasses, western wheatgrass, blue panicgrass, and the lovegrasses. Of lesser importance are vine mesquite, rescuegrass, Indiangrass, and intermediate wheatgrass.

11. The most useful pasture legumes of the United States are Ladino clover, Louisiana and common white clover, alsike clover, alfalfa, sweetclover, red clover, and the annual lespedezas. Of lesser importance are birdsfoot trefoil, big trefoil, burclover, hop clover, black medic, kudzu, and Persian clover.

12. Mixtures, especially of both grasses and legumes, are usually preferable to pure stands of either for pastures, among the reasons for which are the following:

(a) Legumes in pasture mixtures help to maintain the nitrogen content of the soil and reduce the need of nitrogen fertilizers.

(b) Mixtures of grasses and legumes provide a better-balanced ration as legumes are richer than grasses in protein and minerals.

(c) Mixtures usually result in a more uniform stand and higher production, because they are likely to
provide species adapted to a wider range of soil conditions than a single species, and several soil conditions are often represented in a pasture.

(d) Mixture provides a more uniform seasonal production because the periods of lush growth and dormancy vary in different plants.

13. As much or more care should be taken in establishing and maintaining a permanent or semi-permanent pasture as is used in the production of any other crop on the farm because it is usually the most valuable crop, gives the greatest return for intelligent care, and the cost of establishment is spread over a longer period of production.

14. Because of the difficulty of maintaining uniform all-season feed production from perennial pastures, it is desirable to have other annual or biennial crops available for pasture use to supplement them during the growing season in periods of drought or seasonal declines in production.

15. Some of the more valuable crops for supplemental pastures are crimson clover, sweetclover, vetch, velvetbean, kudzu, cowpeas, soybeans, and winter peas of the legumes; Sudan grass, millet, common ryegrass, and small grains such as oats, barley, wheat, and rye among the grasses, and dwarf Essex rape.

16. The palatability of pasturage should be considered a factor in pasture management, as well as the quantity of total nutrients. It depends on the kind of plants, their tenderness, stage of maturity, and climatic and soil conditions. Different kinds of livestock also vary in their likes and dislikes.

17. An adequate supply of vitamins and minerals is necessary for proper growth and reproduction in livestock, and to keep them thrifty and resistant to diseases. When animals are grazing on green, immature pasturage, they are better supplied with vitamins and minerals needed for growth and health than is practical by any other method.

18. Pasture grasses and legumes may be sown almost any time of year, providing temperature and moisture conditions are suitable during germination and emergence of seedlings, and there is sufficient time for the plants to make enough growth to be able to withstand winter and drought hazards.

19. Fertilization is required for good pasture. With adapted grass-legume mixtures, adequate fertilization usually consists of phosphate and lime only, instead of a complete fertilizer. It is possible, however, in many instances to use commercial nitrogen on a grass-legume mixture without reducing appreciably the increase of legumes.

20. If, for any reason, the legumes in a grass-legume mixture are not present in sufficient numbers to supply the nitrogen required by the grasses, application of commercial nitrogen is the only practical means of stimulating growth of the grasses to produce extra hay or pasture when needed.

21. With all soils, all conditions, and all kinds of pasture crops, one of the essentials in obtaining a stand is a properly prepared seedbed with a firm sub-surface soil, a finely cultivated surface and (except in rainy weather) packing after sowing. The cultipacker is the best tool to finish off the seedbed just before sowing the seed.

22. The rate of sowing pasture plants should be enough to give a satisfactory stand and no more. This varies with many factors, such as climate, soil, moisture, kind and variety, so that arbitrary figures that would generally apply cannot be given. Each set of conditions must be considered by itself.

23. Depth of sowing is very important; rates of sowing may be materially reduced from usual recommendations by sowing at optimum depth for emergence of seedlings. With most pasture grasses and legumes on most soils in the humid regions, the optimum depth is from one-fourth to one-half inch. Under dry conditions or on very light soils, somewhat deeper sowing is desirable, but even there, one inch probably should be the maximum for most seeds.

24. Mulches are valuable in obtaining good stands; if of suitable character and applied properly, they protect both soil and seedling and tend to prevent formation of a crust, thus permitting emergence of seedlings.

25. Companion grain crops sown with pasture grasses and legumes are in no sense "nurse" crops. Their use is economic and is usually detrimental to the growth of the associated forage crop. If used, they should ordinarily be sown thinly and harvested early for hay.

26. Among the causes of failure to obtain
stands of pasture grasses and legumes are (a) failure of seeds to germinate because of death or weak seedling, dormant or hard seed, and unfavorable sowing conditions; and (b) the loss of young seedlings because of freezing, too deep coverage of seed, soil crusts, and drying out of the seedbed.

27. Later hazards to new stands of pasture grasses and legumes are lack of inoculation of legumes, unfavorable soil conditions, insects and diseases, drought, competition of companion crops and weeds, poorly adapted seed, and winter-killing.

28. Much land in old unproductive pastures or nonproductive land can often be converted into production and profitable pastures through proper preparation of the land and intelligent use of lime, fertilizer, legumes and grasses.

29. Pastures can become the most conserving of soil resources and the most profitable part of the farm only through a thorough study of soil conditions, varieties of pasture crops adapted to the soils and climate of the region, and intelligent application of the principles of good pasture management.

**Chapter reference numbers:**
- Pasture establishment: CAL-3; COL-5; DEL-6; FLA-11; GA-5; KAN-27; KY-23; MD-17; MINN-18; MO-5; MONT-9; NEB-5; NEV-5; NM-1, 2, 9; NC-20; OHIO-6, 25, 34, 43; OKLA-16; OREG-19; PA-17, 19; TEX-10, 19, 43; WIS. 6; US-25, 51, 128, 223, 243, 279; MISC-18, 43, 50.
- Pasture improvement: CAL-5, 8; CONN-15; DEL-9; FLA-18; IDA-7; ILL-2, 3, 21, 31; IND-3, 5; IOWA-12, 13; LA-1, 4; ME-7; MD-13; MINN-8; MISS-19; MO-7; NJ-4, 5, 6, 28; NY-20, 21; NC-20; OHIO-12; OKLA-3; RI-9, 12; SC-11; SD-8; TEX-8, 25, 51, 57; WVA-10, 11, 12; WIS-13, 18, 19, 25; WYO-1, 2; US-67, 111, 137, 189, 225, 240.
- Pasture crops: COL-11, 12, 13; CONN-9; FLA-3, 4, 7, 16; IOWA-7; KAN-2; KY-20, 22; LA-15, 17; ME-5; MD-3; MASS-3; MICH-20, 24; MINN-5, 11; MISS-20, 22; MO-8, 10; MONT-7, 13; N.H-1, 4; NH-1; NY-6, 36, 38; NC-1, 10; ND-14; OHIO-1; OKLA-4; OREG-14; RI-14; SD-15; TENN-11, 14, 15; TEX-12, 15, 21, 30, 56; UTAH-2, 10; VT-9, 10, 20; VA-16; WIS-4, 7, 8; WYO-3; US-41, 69, 82, 89, 102, 119, 143, 145, 158, 162, 287; MISC-29, 34, 35, 36.
- Pasture programs, management, maintenance, and utilization: ALA-8, 11, 12, 19, 23, 31; ARK-7, 8; CAL-4; CONN-3, 15; DEL-7, 10; GA-1, 6; ILL-17; KAN-2, 3, 9; KY-12, 17; LA-2, 8; ME-1; MD-3, 9, 15, 19; MASS-5, 7; MICH-21; MINN-4, 12; MISS-9, 16; MO-12, 14, 21; MONT-6; NEB-5; NEV-2; NI-3; NJ-21, 23, 26, 29; NY-17, 22, 45; NC-5, 9; ND-8; OHIO-9, 10, 21; OKLA-12, 19, 23; OREG-5, 6, 7; PA-1, 3, 7, 9; SC-7, 9; SD-1; TENN-6, 16; TEX-20, 31; UTAH-9; VT-7, 11, 14; VA-1, 5; WASH-4, 19; WIS-17; WYO-6; US-21, 24, 78, 81, 90, 120, 124, 218, 253, 274.

**Pasture—soils, fertilizers, composition, and value:** ALA-24; ARIZ-2, 9; CAL-6; CONN-1, 3, 11, 12; DEL-8; FLA-1, 2, 6, 8, 9, 12; GA-16; ILL-14; IOWA-23; KY-3, 7; LA-9, 10; ME-2; MD-18; MICH-22; MINN-6; MO-2, 6, 18, 19; MONT-3; NEB-2, 8; NH-8, 10; NJ-18; NY-11, 18, 19, 22; NC-15, 18, 21; ND-13; OKLA-9, 21; PA-8, 14, 20; SC-18; TEX-13, 15, 17, 53; UTAH-8; VT-20; VA-2, 3, 11, 12, 13; WASH-24, 26; WVA-
Pastures, general: KAN-5, 7; KY-8; MD-2; MASS-2; MISS-4; MONT-12; NJ-11; PA-5; SC-3; SD-4, 14; TENN-1; UTAH-1; VT-1; WIS-2; US-3, 4, 29, 135, 142, 221, 226, 236, 238, 245, 246; MISC-29.

The reference numbers given here refer to references which are given in full by State, U.S.D.A., and Miscellaneous, on pages 682 to 724, and which are cross-referenced by author on pages 725 to 731. Citations in the text are indicated by abbreviation and number in parentheses.
For many years the total value of the hay crop of the United States ranked second only to corn. During the past 8 years (1941-48) it has ranked fourth, being exceeded in value also by wheat and cotton because the prices of these crops were inflated during and since World War II more than hay prices. The average total acreage of hay in the United States during the past 6 years (1943-48) was nearly 75 million acres, the average production from which was over 100 million tons. These figures represent a 9 percent average increase in acreage and nearly a 25 percent increase in production over an earlier 5-year period from 1928-32. The greater percentage of increase in production than in acreage probably means a shift to the use of higher-yielding hay crops and more efficient production methods.

It is a well-known fact that a large percentage of the hay produced is of poor quality. If every ton of hay could be raised one commercial grade, and this is a feasible goal to reach except possibly with wild hay, the feeding value and in turn the market value of hay would be increased two dollars or more per ton. Applied to a production of nearly 90 million tons of tame hay the additional feed or market value, by raising it one grade, would be two hundred millions of dollars or more added to the value of hay on the farms.

The two most important groups of hay in point of quantity production and feed value are (1) alfalfa, and (2) timothy-clover hay. They constitute nearly two-thirds of the total United States hay production. Both of these groups have been studied as to hay production and the preservation of quality in the hay for both farm and market use by Parker, Pollock, and Hosterman, (US-117, 210 and 211). The practices used with these two groups of hay and the principles applicable to the preservation of quality in them are generally applicable to other legume and grass hays, so these only are specifically covered here. Those principles relating to alfalfa and clover are generally applicable to other legume hays, and those relating to timothy are generally applicable to other grass hays.

TIMOTHY AND CLOVER HAY

IMPORTANCE OF CROP

Timothy and clover hay constitute one of the major groups of hay in the United States. The soil conservation programs will probably increase its importance in crop rotations. Timothy and clover hay made up about one-half of the total hay acreage of the United States in 1919, and only about 30 percent in 1948. Even with this reduction in acreage, these kinds of hay in 1948 still occupied 22,000,000 acres—about a half larger acreage than either alfalfa or wild hay, which are the second and third largest crops in hay acreage. Most of the timothy and clover hay is grown in the northeastern part of the country.

Timothy and clover continue to be the most important hay crops in the North Atlantic States, including Delaware, Maryland, Virginia, and West Virginia, but the acreage has been decreasing in the Mississippi Valley. The gradual shift from timothy, clover, and mixtures of timothy and clover in the Mississippi
Valley may be due to several factors. Among the more important are (1) the difficulty of obtaining and maintaining stands of clover in many sections, and (2) the shift to growing other legume hays such as alfalfa and lespediza.

Timothy and clover are also grown rather extensively in certain States of the Northwest—in the irrigated sections and high mountain valleys of the Intermountain States, and in the humid districts west of the Cascade Mountains.

Various mixtures of timothy and clover hay are grown in the different areas, depending on whether the meadows are nearly pure timothy, or pure clover, or a mixture of the two. In the New England States the land is left as meadow for 3 or more years. Therefore hay grown there is chiefly mixtures of timothy and other grasses, with small quantities of clover. In certain parts of New York, Pennsylvania, and Maryland the land remains as meadowland for 1 or 2 years only. There the hay is made up largely of clover the first year after sowing and of timothy thereafter. In the Mississippi Valley, particularly in the timothy-growing sections, meadows are usually left for more than 2 years, whereas clover is seldom left for more than the one crop year after the year sown. When the clover is winterkilled, which happens occasionally on certain types of soil, the hay consists largely of timothy the first year.

Statistics are not collected on the acreage of timothy, clover, and timothy and clover mixtures as separate crops. At present these three kinds of hay have been included under timothy and clover hay. It is not known definitely in which States the principal part of the clover and timothy hay acreage is timothy or in which States it is clover.

Yields of timothy and clover hay per acre vary widely in different localities. Clover or mixtures of timothy and clover usually outyield timothy under similar climatic and soil conditions. The average yield of timothy and clover hay in the United States during the past five years (1943-1947) was 1.41 tons per acre. However, yields of 2½ to 3 tons of timothy per acre are often produced around Puget Sound because of the favorable growing conditions.

**Quality in Timothy and Clover Hay**

High-grade timothy and clover hay may be defined as hay cut at the proper time, properly cured, with a large amount of natural green color, and in the case of clover, with a relatively high percentage of clinging leaves. The hay must be relatively free from foreign material, undesirable mixtures, mold and must, or other objectionable odors.

Weather conditions often prevent the making of high-grade hay but production practices are usually reflected in the quality of a lot of hay. The quality of many crops of timothy and clover hay is virtually sacrificed as a result of late cutting and improper methods of curing, handling and storing.

The quality factors employed in the United States grades for timothy hay and mixtures in which timothy predominates, are color, foreign material, and condition. For clover and mixtures of clover and timothy hay in which the clover predominates, the quality factors are leafiness, color, foreign material, and condition. The leaves of clover, like those of alfalfa, have about two and one-half times as much protein as the stems. The blossoms of the clover make up a much larger portion of the total weight of clover hay than the blossoms of alfalfa do of alfalfa hay, and since they have about the same chemical composition as leaves, they are considered as leaves in making percentage determinations. Green color in hay is the buyer’s insurance against unsoundness and his evidence of the approximate feeding value of the hay. Feeding tests have established a definite relationship between green color in hay and feeding value. More consideration is now given to green color in hay production, marketing and feeding practices, and hay producers are more and more using those haymaking and storage practices that will conserve the maximum of green color in the hay.

Experiments conducted by the United
States Bureau of Dairy Industry show that there is a correlation between the green color and the carotene content of hay. When U.S. No. 1 Timothy, which is a grade of timothy with a relatively high percentage of green color, was fed to the dairy cows as the only source of carotene or provitamin A, the cows remained in good health and produced normally. When the hay in the ration consisted of U.S. No. 3 Timothy that had lost most of its green color because it was overripe or weathered, the cows usually dropped immature, weak or dead calves if fed this quality of hay for more than 6 months.

It was also shown that butter color varies definitely with the green color and carotene content of the roughage fed. Butter from cows fed U.S. No. 1 Timothy as the sole roughage had a color value that was approximately twice that of butter from cows that were fed U.S. No. 3 Timothy as the sole roughage.

**Effect of time of cutting on quality of timothy**: Timothy should be cut for hay after it is fully headed out but before it has reached the full-bloom stage. Timothy cut from the fully-headed-out to the bloom stage has more feed value per acre than timothy cut when it has passed the bloom stage. It also can be cured with a higher percentage of green color which increases its market value as well as its feed value. As the timothy plant becomes more mature much of the protein and carbohydrates in the leaves and stems are transferred to the roots and seeds, thus increasing the percentage of crude fiber in the stems and leaves and lowering the feed value of the hay. When the leaves have ceased to function they fade and turn brown. The quality or grade of the hay is therefore reflected to a considerable extent by the presence or absence of green color.

**Relation of maturity of timothy at time of cutting to color**: Early-cut hay will retain a larger quantity of green color than late-cut hay cured under similar conditions. From the time timothy reaches the fully-headed-out stage until it reaches the full-bloom stage, there is no noticeable loss of green color due to maturity. When the plants are left standing beyond the full-bloom stage the green color fades rapidly. The leaves, beginning at the bottom, gradually turn brown and the heads and stems become greenish-yellow, then straw-colored, and finally they become distinctly brown. These brown leaves have only about one-fourth the protein content of the green leaves. Early-cut timothy may lose some green color during the curing process and still retain sufficient color for the No. 1 grade. Late-cut timothy, however, which has lost some green color before being cut cannot lose any more during the curing process without falling into No. 2 or No. 3 grade because of lack of green color.

**The stage for cutting clovers**: The clovers should be cut at or near the time of maximum yield of protein per acre because the percentage of protein in clover hay is largely a measure of its feed value. The percentage of protein in the clovers declines rapidly from the bud or heading-out stages to full bloom, and more slowly from full bloom until the seed is mature. In medium red clover the highest yield of hay per acre may be expected from the half- to the full-bloom stage. The yield of protein per acre, however, is the greatest when approximately 50 percent of the plants are in bloom, but it does not show a material decrease until after the full-bloom stage. It appears desirable, therefore, to begin cutting medium red clover when about half the plants are in bloom. Cutting should be finished by the time the plants are in full bloom.

Mammoth red clover produces the greatest number of pounds of hay per acre when cut at about the full-bloom stage, but the greatest number of pounds of protein per acre will be obtained if the cutting is done when approximately 50 percent of the plants are in bloom. The cutting of mammoth red clover should also begin when about half of the plants are in bloom and should be completed by full bloom.

Alsike clover which has a continuous growth habit, especially on moist soils, gives the greatest yields of hay per acre...
if cut when most of the flowering heads have turned brown. The greatest yields of protein per acre are obtained when the plants are cut in full bloom. Alsike clover, when grown alone, has a greater tendency to lodge as it approaches maturity than the red clovers and therefore should be cut at about the same stage of maturity as medium red and mammoth red clover.

Because of the importance of clover in the mixture, medium red or mammoth red clover containing a mixture of timothy should be cut when the clover is in the half- to the full-bloom stage. Mixtures of timothy and mammoth red clover may be sown to advantage because they reach the proper stage for cutting at about the same time. But medium red clover reaches the right stage for cutting about 10 days to 2 weeks earlier than the timothy.

Alsike clover containing enough timothy to prevent the clover from lodging may be cut for hay when the timothy is in the fully-headed-out to full-bloom stage of growth. At this stage both the clover and timothy will produce the maximum quantity of protein per acre.

When the larger part of the timothy and clover mixture is timothy, cutting should be delayed until the timothy is fully headed out, but should be finished by the time the timothy reaches the full-bloom stage. With this type of mixture it appears desirable to sacrifice the quality of the clover in order to obtain the maximum quantity of protein per acre from the timothy.

Relation of maturity of clover at time of cutting to color: More natural green color can be preserved in clover that is cut from the half- to full bloom stage than in clover cut after the heads begin to turn brown. Clover loses its bright, green color and becomes dull or greenish brown when the plants are permitted to become too mature. The stems of late-cut clover usually become coarse and woody, and most of the leaves on the lower part of the stems have died and fallen off.

Time of cutting timothy and grass mixtures: Most grasses that are sown with or occur naturally with timothy hay mature earlier than timothy. These grasses also lose their feeding value much more rapidly than timothy after they reach the bloom stage. This makes it necessary to cut timothy and grass mixtures when the grasses have reached the full-bloom stage without regard to the maturity of the timothy so that the mixture may retain its palatability. Unless timothy and grasses are cut at the right time the grass part of the mixture loses some of its feeding value and turns straw-colored which greatly detracts from the sale value of the hay.

The nutritive value of such grasses as redtop, orchardgrass, and bluegrass, if cut at the proper time, will nearly equal that of timothy.

Effect of weather damage on quality: If timothy and clover hay is cut and left in the swath or windrow for any length of time it will sun-bleach and lose some of its natural green color. Sun-bleached hay is often produced in those sections in which it is a common practice to dry the hay fully in the swath before raking. The exact effect of sun-bleach on the feeding value of hay is not definitely known. It decreases palatability, however, because the hay becomes dry and brittle, and causes a loss of vitamin A through a reduction in green color. Sun-bleaching develops a bright yellow color instead of the natural green. This lowers the grade and affects the sale value. Livestock relish green hay more than brown.

Timothy and clover hay that is partially or completely cured loses its feeding value very rapidly when rained upon. The extent of the loss depends on the dryness of the crop and the duration of the rainfall. The drier the hay, the greater the loss from leaching by rain. Severe weather damage and extensive loss of color are commonly caused by heavy rains or numerous showers when hay is in the swath, windrow or cock. Hay stacked out of doors in small or flat stacks which do not shed water is often severely damaged by rains. The evidence of severe weather damage is found in the dark-brown or faded colors or stains.

Rain usually leaches the soluble sub-
stances from hay, destroys all or part of the green color, and lowers its palatability. Weathered hay, whether from sun or rain, is usually harsh and brittle. Because of its appearance and low-feeding value, it is probably discriminated against in the market to a greater degree than hay damaged from other causes.

**Effect of fermentation on quality:** Fermentation, often referred to as sweating, is caused by baling, stacking or mowing undercured or wet hay. Sweating of newly-harvested hay may increase its palatability by softening the stems and improving the aroma. On the other hand, excessive fermentation may result in serious damage through the destruction of green color and the development of mold and must. Unless it is overcured in the field, hay sweats or ferments after it is baled, stacked or placed in the mow. The changes in the quality and condition that result from fermentation are chiefly dependent on the amount of moisture in the hay, and relative humidity and temperature of the atmosphere.

Unless fermentation is severe and the hay becomes unsound, any change in quality will be limited to destruction of green color. In most cases distinctly fermented hay ranges in color from greenish brown to brown. Fermentation may even cause tightly baled hay to "set" slightly without becoming unsound, but ordinarily set or caked hay is moldy or musty. Hay that is severely discolored from stack or mow fermentation is often referred to as stack- or mow-burnt hay. Proper curing and storing of hay will prevent reduction in quality because of fermentation.

**Foreign material in hay:** Foreign material in timothy and clover hay refers to weeds and other such plants as are coarse and not ordinarily of feed value, and to cornstalks, grain stubble, chaff and other objectionable material that occurs naturally in hay.

Separation analyses made on many representative bales of timothy and clover hay from numerous markets throughout the timothy and clover area, indicate that approximately 10 percent of the hay contains from 20 to 35 percent of foreign material which places this hay in sample grade.

Foreign material is pure waste or dockage in hay. It is usually rejected by livestock and remains uncaten in the feed manger. When hay is bought by a livestock feeder he does not get full value for his money if the hay contains much foreign material. It is recognized that a small quantity of weeds and other foreign material occurs naturally in the production of hay and that meadows that are free from weeds are uncommon. Excessive foreign material in timothy and clover hay, especially clover, is due to foul land and probably to the use of poorly cleaned and low-grade seed.

**Production of High-Quality Timothy and Clover Hay**

High-quality hay cannot be produced for either market or home use unless the producer plans ahead to have clean meadows, to cut the hay at the proper stage of maturity, to cure and store the crop as quickly as possible, and, if produced for market, to bale and load the hay according to market demands. The producer who plans to use the hay as feed for dairy cattle, stock cattle, or sheep, should store it so as to prevent spoilage in the mow or stack. This will preserve the feed value of the roughage which in turn will reduce the quantity of concentrates necessary to give maximum gains and milk production at a minimum cost. The cost of producing low-quality hay is just about the same as the cost of producing high-quality hay, and the feed value or return per dollar invested is much lower.

Good crops of high-quality hay cannot be produced from meadows with thin stands or from very old meadows where part of the stand has died out because invariably such meadows are weedy. The foundation of the business of producing high-quality hay is a good meadow, free from weeds, and sown so as to produce a thick stand.

**Curing methods to preserve leafiness and color:** Haymaking methods must necessarily vary with the kind of hay, the local
climatic conditions, the farm conditions and buildings, and the available labor and machinery. The proper curing of hay rests chiefly on the judgment, energy, and experience of the farmer.

Loss of quality from excessive swath bleaching, or fermentation in storage, or from poorly built stacks, can be controlled by proper handling. Losses from rain damage in the swath and windrow cannot usually be controlled and at best can only be minimized.

In many districts hay is allowed to dry too long in the swath. This causes excessive bleaching with loss of bright, natural green color and carotene content. Wherever the dump rake is used in haymaking, and where it is not planned to cock the hay, it is a common practice to cure the hay completely in the swath and then to rake it into windrows shortly before it is hauled. On bright, hot days this method is conducive to swath bleaching and overdrying of the leaves of clover which are shattered and lost when the dry hay is raked. Such improper handling often greatly reduces the feed value.

These methods which may lower the grade of hay, can be remedied to a considerable extent by the intelligent use of the side-delivery rake, especially when heavy mixtures of clover are being handled. The effectiveness of this rake, and the principles underlying its use, demand that the raking shall be done when the hay in the swath is somewhat sappy and not when it is well dried. When hay is rolled into somewhat cylindrical windrows with the side-delivery rake many leaves within the loose roll are protected from overdrying and will cling to the stems. Furthermore, a large part of the leaves and stems will cure without bleaching.

Storage methods to preserve quality: Timeliness is an important factor in handling hay to preserve quality. There are no simple methods of moisture determination that can be relied on in practical haymaking. But every effort should be made to haul and store at that stage of curing when the hay is no longer sappy, but before it becomes dry and brittle.

Farmers who are experienced in curing hay do not find it difficult to determine when the hay is ready for storage, providing it is cured uniformly. Hay that is stored while still slightly tough goes through a sweat in the mow or stack which usually improves the palatability of the hay.

Timothy and clover hay are often stacked by hand in low flat stacks, or tall narrow stacks, about a central pole of 2 to 4 tons in a stack. Such stacks weather badly and often become severely stained and partly rotten. It is a poor practice to store hay in small stacks because so much of it is exposed to weather. Timothy and clover hay can be stacked directly from windrows with the sweep rake and stacker. Stacks holding 10 to 15 tons can be built easily with either of several types of hay stackers. If symmetrically built and well tramped in the center, these stacks shed water so that severe weathering occurs only on the outside. In areas of heavy rainfall, a small load of straw or grass hay may be spread over the top to assist in shedding the rain.

Timothy and clover hay is often stored in barns that are used to house the livestock or used entirely for hay. Barn-stored hay will not be damaged further by weather if the barn has a good roof, but greater care must be taken regarding the moisture content because of the greater loss in case of spontaneous ignition.

Much interest is shown in the practice of chopping the hay into short lengths at the time of storage to reduce the storage space and the labor involved. The cost of using power machinery for chopping and storing hay will just about offset the saving in labor. Two to two and one-half times as much chopped hay can be stored in the same space as required for long hay, and chopped hay can be removed from the mow for feeding much easier. But the keeping qualities of the hay are influenced by the depth of the hay in the mow, its texture, and length, as by its moisture content. Fine-stemmed hay that is cut into short lengths increases the density of the mow which encourages fermentation.
Minimizing rain damage to hay: Rain damage while hay is in the swath, windrow, bunch, or cock is the hay producer’s greatest bugbear. One practice that should always be followed is to cut only the quantity of hay that can be handled with the available crew before it becomes overdried. Hay that is left in the swath or windrow after it is thoroughly cured loses quality very rapidly.

If hay has been cut and a rain is coming the hay will receive less damage in the swath than in the windrow, and less damage in the windrow than in the big bunch made by the dump rake from the windrow. If the hay is left in the cock overnight or over Sunday the cock should be built up large and high with hand-pitching, because hay in a flat, low-built cock made with the dump rake or fork will be damaged more if it should rain.

The hay-maker’s plans for holding down the rain damage must place more reliance upon the side-delivery rake, the hay loader, the sweep rake, the stacker, and the organization of his crew to provide rapid haulage and storage than upon the more expensive and tedious practice of cocking.

ALFALFA HAY

IMPORTANCE OF ALFALFA HAY CROP

The production of high-grade alfalfa hay is profitable in all major alfalfa-producing areas where freight or trucking rates to consuming districts are not prohibitive. It is also profitable in those areas where the alfalfa is to be used as feed for various types of livestock, especially dairy cattle, and it is essential in the achievement of the production goals for meat, dairy products, and wool.

Today the demand for baled alfalfa hay is from the dairy cattle feeders. Alfalfa hay, whether grown for home use or for market, must ordinarily meet the quality demands of the dairymen if the most profitable returns are to be obtained from the crop.

Dealers in alfalfa hay receive many orders from dairymen for high-grade alfalfa hay which they cannot fill because an insufficient quantity of such hay is produced. Therefore, a much greater quantity of high-grade alfalfa could be profitably produced for home use and for market.

Dairymen who do not grow alfalfa and who do not now utilize much alfalfa hay, but who depend largely on mill feeds for protein, could profitably become buyers of alfalfa hay if supplies of high-grade alfalfa hay were available at all times. Farmers who grow alfalfa for a cash crop should study market demands and then make their production and loading practices conform to the market requirements.

High-grade alfalfa hay marketed in a businesslike manner is normally a profitable cash crop in all major alfalfa-producing areas where freight or trucking rates to the consuming districts are not prohibitive. On the other hand, there is little or no profit to the producer in marketing low-grade alfalfa hay.

The top grades of alfalfa hay always have commanded premium prices. They will continue to do so because feeders are now generally recognizing the importance of green color, vitamins, and leafiness which are associated with high-grade hay.

High-grade alfalfa hay competes with mill-feed concentrates to a considerable extent in the dairy trade but there is little or no competition between high-grade alfalfa hay and low-grade hays of any kind. The dairy cattle feeder cannot make as good use of low-grade alfalfa hay as can the feeders of other livestock. The producer of high-grade alfalfa hay, therefore, has a specialized consumers’ market in which to sell his commodity to advantage.

QUALITY IN ALFALFA HAY

Soundness, purity, a high percentage of leaves, clinging foliage, green color, and pliable stems are the essential characteristics of high-grade alfalfa hay. Alfalfa hay having these desirable qualities is the type of legume forage that is always in demand with the dairy cattle feeders because of its well-recognized beneficial effect on milk flow.
The grading factors in the United States hay standards are leafiness, color, and foreign material, any one of which may cause the grade of a lot of hay to be lowered. Leafiness is considered the most important grading factor because two-thirds or more of the protein of the alfalfa plant is carried in the leaves. Thus a leafy type of alfalfa hay is relatively high in protein, and a stummy type is relatively low. Leafy types of alfalfa hay, also, commonly have relatively pliable stems.

Green color is also an important measure of quality because there is a correlation between the quantity of green color and the quantity of carotene, or provitamin A, in alfalfa hay. A high percentage of green color indicates a relatively high carotene content. Palatability, other feed nutrients, and laxative properties are also commonly associated with bright green color. For these reasons the importance of green color is emphasized especially in the grades of alfalfa hay that are used in dairy and poultry feeding.

Foreign material, such as weeds, stubble and rakings from previous cuttings are waste in hay so their presence lowers its quality and grade in proportion to the quantity present.

Good stand necessary: Good crops of high-quality alfalfa hay can be produced only from pure, dense stands. They cannot be produced on meadows with thin stands nor on very old meadows where a part of the thin stand has died out. Invariably such meadows are weedy and grassy, the stems of the alfalfa are relatively coarse and the percentage of leaves is relatively low. Under these conditions it is impossible to produce pure, leafy alfalfa hay that will have a high feed value or that will have an attractive appearance in the bale. Good policy in the production of high-grade alfalfa hay, as well as good crop-rotation practice, requires that old meadows with thin stands be broken up. The yield per acre is low on old meadows and the percentage of weeds and grasses is usually high. Weeds may lower the grade of alfalfa hay. Grass-mixed alfalfa hay, even though it be of high grade, does not sell on a parity with pure alfalfa hay of equal grade nor does it have equal feed value.

Alfalfa from pure thick stands has the fine stems and high degree of leafiness essential to the making of the high-grade type of hay that is preferred for dairy-cattle feeding.

Importance of clean meadows: Buyers and dealers discriminate against alfalfa hay containing grain stubble, corn stubs, alfalfa roots, or rakings of the previous cutting. All these materials are defined as foreign material in the United States hay standards, and alfalfa hay is graded downward in all cases in which a lot of hay meets the leafiness and color requirements of any one of the numerical grades but the percentage of foreign material exceeds the maximum quantity allowed for that grade. For this reason the producers who sell baled alfalfa hay should give careful attention to keeping the meadows clean and free from trash.

Meadows should be raked in the spring of each year to remove as much as possible of the grain stubble, corn stubs, or old alfalfa roots in newly sown fields, and to remove any spoiled hay, that may have been left on the meadow from the previous year. After each cutting the meadows should be carefully raked to clean up the loose rakings before new growth begins.

Weather damage: The lowering of the grade of alfalfa hay because of rain damage while the hay is in the swath, windrow, or cock cannot always be prevented even by the most skillful farmers. There is no escape from the unexpected rain that falls on hay before it is stored away. Damaged hay resulting from poorly built stacks, uncovered piles of bales, hauling and loading during storms, and baling rain-damp hay can be prevented by forethought and good management. Loss of grade on account of rains, heavy dews, and fogs during the curing process is minimized when alfalfa is cut at the proper stage of maturity and thereafter handled with modern machinery and by approved methods for curing hay.

Importance of leaves and green color: The retention of leaves and green color are the two things most desired by the hay producer. The time of cutting and hay-
Hay making methods practiced should be done with these in mind. There is a direct correlation between the percentage of leaves and the percentage of proteins, and the highest percentage of leaves is obtained by cutting in the early stages of bloom. On the other hand, the largest yields of hay are obtained when the alfalfa is cut between the one-tenth bloom and full-bloom stages. Also, the highest yields of protein per acre are obtained when the crop is cut somewhere between these two stages. There is a gradual decrease in the percentage of protein as the crop matures, but the yield per acre becomes larger.

For many years the impression prevailed among farmers and hay dealers that green color was not important as a feed constituent but did indicate proper curing and storage and therefore indicated soundness of the hay. For these reasons market premiums have been paid for green-colored hay. In recent years it has been found that green alfalfa hay is also a good source of carotene or provitamin A.

The Bureau of Dairy Industry has conducted feeding experiments to determine the nutritive value of the carotene content of alfalfa hay of various grades. These experiments indicate that when dairy cows are fed a liberal quantity of alfalfa hay of high grade as the only source of carotene, the cows maintain their health, milk yield, and reproductive capacity for periods ranging up to more than 7 years. Comparison of the carotene content of U.S. No. 1 Alfalfa and U.S. No. 3 Alfalfa indicate that the former has about five times the carotene content of the latter. These experiments also indicate that the carotene or provitamin A is carried over into the milk and butter produced.

Because leaf color and percentage of leaves are important in hay quality, the best method of haying will be the one that saves the most leaves and retains the green color. According to Kansas data (Kan-328), the percent of leaves in alfalfa hay varied from 41.6 to 53.4, depending on the stage of maturity at time of harvesting. Therefore, a loss of leaves is a definite loss of yield and quality.

Causes of Low-Grade Alfalfa Hay

The most common causes of low-grade in alfalfa hay are the following:

Thin stands of alfalfa in meadows in which weeds and grasses have taken the place of alfalfa. Thin stands also cause relatively coarse, hard stems, and a lower percentage of leaves is borne on coarse stems than on fine stems.

Weather damage, which causes loss of green color, leaf shattering from extra handling, stack spots in poorly built stacks, and mustiness or moldiness if stacked, baled, or loaded while wet.

Overripeness at time of cutting, which causes a relatively low degree of leafiness, hard and fibrous stems, and a weak and faded color.

Overdrying, in the swath, windrow, cock, or small stack, which causes a severe shattering of the leaves, brittle stems, and a loss of green color from sun bleaching.

Baling undercured hay from windrows or cocks followed by immediate storage or loading into cars, which causes heating, mustiness, and moldiness.

Stacking distinctly undercured hay, which causes severe fermentation often resulting in extensive mustiness and moldiness.

Baling dry hay during very hot, dry or windy weather, which shatters the leaves and causes stumpy appearing bales, or bales with a low percentage of leaves. Bales with a high percentage of shattered leaves are not wanted by dairymen because of the leaf losses incurred in handling the hay in dairy barns.

Effect of Time of Cutting on Quality

Time of cutting recommended: In most instances alfalfa should be cut at the one-tenth to one-fourth bloom stage. In those areas where alfalfa blooms sparingly because of seasonal moisture conditions, the amount of bloom is not a dependable index of the maturity. Under these conditions the growth of the basal shoots and the general appearance of the field should serve as a guide for time of cutting. If the basal shoots have made
considerable growth, or if the foliage is beginning to take on a yellow cast indicative of the slowing up or stopping of growth, the alfalfa should be harvested regardless of the percentage of bloom. Little, if any, increase of tonnage will be gained by allowing the crop to stand longer, and the yield of protein per acre will be reduced. At this stage of maturity the leaves usually constitute anywhere from 45 to 55 percent of the total weight of the plants, and the stems have not become objectionably hard and woody.

Extensive experiments in Ohio on time and number of cuttings of alfalfa have demonstrated that a system of calendar dates, carefully interpreted for seasonal weather conditions, is more satisfactory than any other system for determining when to make the various cuttings in areas where alfalfa blooms sparingly. In areas where leafhoppers are numerous the alfalfa should be cut before the leafhoppers have caused much damage, regardless of stage of maturity.

In a very comprehensive experiment in Kansas extending over a three-year period (1935-1937), to determine yield, chemical composition and feeding value for milk production of alfalfa hay cut at three stages of maturity, Dawson, Kopland and Graves (US-47) concluded their summary of results with the following statement:

"Considering all phases of this experiment, it is evident that alfalfa hay cut at the initial- or half-bloom stage is markedly superior in all respects to alfalfa cut at the full-bloom stage. While cutting at the initial-bloom stage has some advantages over cutting at the half-bloom stage, especially in yield of total digestible nutrients, the advantages are too slight to have any great significance, especially when considered from the practical standpoint. The line of demarkation, or the change that takes place in the plant between the initial-bloom and the half-bloom stage is rather indistinct; and cutting at either stage, or between the two stages, would be good practice."

Bud-stage cutting: The highest possible quality or grade of alfalfa hay is obtained when the crop is cut in the prebud or bud stage. At this growth stage the stems are soft and pliable, the leaves constitute 55 to 65 percent of the total weight of the plants, the amount of rich, natural green color is great, and the percentage of protein is exceptionally high.

It is impracticable and unprofitable, however, to cut all the various crops in the year at the prebud or bud stage of maturity. In the first place, the yearly tonnage is usually not so great as when the cutting is done at one-tenth to one-quarter bloom. In the second place, a continuous practice of bud-stage cutting usually weakens the vitality of the crowns and roots, shortens the life of the meadow, and causes an increase of grasses and weeds in the meadow. The harmful effects of bud-stage cutting can be minimized to a certain extent by allowing the alfalfa to make enough growth in the fall so that root reserves are built up for the next season. Experimental evidence on the time of cutting alfalfa indicates, however, that occasional bud-stage cuttings, such as one in three, or possibly one in two in very favorable alfalfa climates, may be made without seriously affecting the vitality and thickness of the stand.

Effect of late cutting: Large quantities of alfalfa hay are produced yearly in the United States from crops cut at full-bloom or in the early pod stage of maturity, or which have been allowed to stand for a week or ten days after growth has ceased. This type of hay is especially common in the first cutting made each season in the North Central and Mountain States. Hay is also cut at that stage in the eastern part of the United States in those areas where timothy or other similar grasses are sown with the alfalfa as an erosion-prevention measure. If the mixture is not cut until the timothy begins to bloom the alfalfa will be in the early pod stage of maturity. In the majority of cases the grade of alfalfa hay of this character is lower than No. 1 under the United States standards, irrespective of weather damage, either because of insufficient leaves or of insufficient color for the No. 1 grade, and sometimes because of both insufficient leaves and color.
Late-cut alfalfa usually has hard and relatively woody stems which may not be very objectionable to horse, mule, and stock-cattle feeders, but which are objectionable to dairy-cattle and sheep feeders. Many producers could profitably advance the cutting stage a week or so, for the first cutting. A better grade of alfalfa hay would result, and the seasonal tonnage would be increased because of the longer growing period given to later cuttings.

Time of cutting and weather damage: Cutting alfalfa not later than one-fourth bloom provides a safeguard of considerable value against losses in quality that may occur during the curing period from sun bleach, overdrying, and damage from rain or heavy dew. Early cut alfalfa, if perfectly cured, has a degree of color and leafiness above the minimum requirements for the No. 1 grade and can suffer moderate damage without having its grade lowered.

When alfalfa is cut at or near the full-bloom stage, however, it has already lost some of its leaves and color and is thus at the bottom of the No. 1 grade, or possibly in the No. 2 grade, even though the curing is perfectly accomplished. Such hay loses its grade rapidly if swath bleaching, overdrying, or rain or dew damage occurs during the curing period. The earlier cut hay enters the curing period with a surplus of quality which the late cut hay lacks.

Time of day to begin cutting: The best time of day to begin cutting varies according to local climatic conditions. In arid climates, where dews are uncommon and where the night temperatures are relatively high, many skilled alfalfa-hay producers begin cutting in the late afternoon and then begin raking and windrowing at sunrise when the hay is wilted. In areas of dews and cool nights the best time to begin cutting is usually considered to be in the early morning. External moisture like dew is not much of a factor in determining the best time of day at which cutting should be done. The additional percentage of moisture from sources of this kind will not affect materially the length of time required to cure the hay.

Curing Methods to Preserve Leafiness and Color

Haymaking methods for high-grade alfalfa hay must give first consideration always to the preservation of maximum amounts of leafiness and color. These methods will vary considerably in different parts of the country depending on climatic conditions. Methods for the rapid evaporation of moisture should be used, but such methods should not sacrifice a high degree of leafiness and color in order to save time in cutting.

Newly mown alfalfa has a moisture content of 70 percent or more, and thoroughly air-dried hay about 12 percent. Alfalfa hay is ordinarily dry enough to stack or mow safely when the moisture content has been reduced to 25 percent, and it should be somewhat drier (about 20 percent moisture) if it is to be baled from the windrow. It may be cocked safely when only wilted and when the moisture content is about 40 percent.

Moisture tests: As no accurate moisture tests are possible for the haymaker, he can only follow such general tests as are based on experience and judgment. One practical method that is used by farmers for determining when alfalfa is cured is to twist a wisp of the hay in the hands. If the twisted hay is tough and there is evidence of moisture where the stems are broken the hay is considered too sappy for safe storage.

If the stems are slightly brittle when broken and there is no evidence of moisture when the stems are twisted the hay can be stored without danger of spoilage. Another method is to scrape the outside or the stems with the finger or thumb nail. If the epidermis can be peeled from the stem the hay is considered undercured. If it does not peel off the hay is usually dry enough to stack or put in the mow.

Preservation of a high degree of leafiness and color demands that all handling of alfalfa be done when the hay is in a tough or at least slightly tough condition. Overdrying in the swath or windrow invariably results in a material shattering and loss of leaves during the raking, stacking, or windrow-baling processes, and
the loss of much green color from sun bleaching.

Because of the rainless summer weather in the irrigated sections of the Southwest, damage to the hay is not a problem except along the coast, where high humidity and fogs may prolong the curing process and cause bleaching. In the valleys, where most of the alfalfa is grown, the chief problem is to get the hay put up and baled before it becomes so dry that many of the leaves are lost by shattering. Most growers have mechanized and systematized their practices, however, so that this loss is greatly reduced. Generally hay of excellent quality is put up.

During the warmer periods, the alfalfa is usually cut in the morning, raked into windrows in the afternoon, and baled the same night. This procedure varies with temperature, humidity, and curing rate, of course. Most of the crop is cut just before the plants begin to bloom. This produces an excellent soft leafy hay with a protein content of 18 to 20 percent, but it does tend to lower the yield and contributes to the short life of the stands.

Swath curing: The rapid evaporation of moisture and the preservation of leafiness and color are jointly accomplished in the most practical way when the hay is well wilted in the swath and then either windrowed with the side-delivery rake or cocked to complete the evaporation of moisture to the degree at which the hay may be stored or baled. No definite period of time for swath curing should be assigned, as it will vary greatly according to tonnage of hay per acre, temperature, sunshine, wind, and atmospheric humidity. The rule should be rather in terms of the condition of the hay in the swath; that is, the hay should not be raked until just before the leaves are dry enough to shatter. Hay should not be left in the swath overnight in a humid climate because partly cured hay which has become wet from dews will suffer a material loss of green color while it is again drying out.

Timing operations of harvesting and curing: It is essential for the haymaker to time the operations of cutting, raking, cocking, stacking, and baling, so that the final storage or baling work can be reached with the machinery and crew available before overdrying and shattering takes place. One of the principal causes for overdry and shattered alfalfa hay is the tendency on the part of many producers to cut more hay than can be raked and stored while in good condition for handling with the machinery and crew available.

Essential points to consider are (1) facilitating rapid evaporation of a large part of the moisture in the newly mown hay by exposing it to sun and wind in the swath, where the rate of evaporation is faster than in the windrow, bunch or cock, and (2) performing the operations of raking and windroweing while the hay is tough and the leaves are not easily shattered.

Choice of machines for handling alfalfa: The choice and the proper use of machinery for handling alfalfa from the swath to the windrow or cock are subjects worthy of careful consideration in the production of high-grade hay. Some years ago the tedder or "kicker" was rather widely used to loosen heavy cuttings of alfalfa and clover in the swath, and thus facilitate the evaporation of moisture. The tedder has been largely abandoned in recent years because it tends to shatter the leaves of legume hays. The dump rake, also commonly employed for windrowing and bunching alfalfa, is fast being supplanted by the side-delivery rake. When the hay is left in the swath until all of it is completely cured and then raked into windrows with the dump rake, the leaves are usually badly shattered unless the raking is done in the morning when the hay is tough from dew.

Use of side-delivery rake: The side-delivery rake is specially adapted to making windrows of wilted and tough alfalfa that will aerate and cure uniformly with the minimum loss of leaves and color. It rolls the hay into loose, cylindrical windrows, through which there is a better circulation of air than in the flat compact windrows made with the dump rake. This facilitates evaporation. Many of the stalk butts are exposed to sun and wind, while most of the leaves are protected from...
overdrying within the roll, and will thus cling to the stalks. Furthermore, a large proportion of the leaves and stems will cure in such windrows without the bleaching that comes from direct exposure to sunlight in the swath or in the wide, flat windrows made with the dump rake. The size of the windrow can also be better controlled with the side-delivery rake. Hay will cure more rapidly in a small to medium windrow than in a large windrow.

Average crops of alfalfa hay wilted in the swath will cure almost as quickly in side-delivery-rake windrows as though fully cured in the swath, and the grade of the hay will be much superior. With very heavy cuttings, wilting in the swath, windrowing with the side-delivery rake, and finally turning the windrow with this rake, will allow the hay to cure more uniformly and rapidly than complete swath curing, and the hay will be of superior quality. The side-delivery rake is essential in the production of high-grade alfalfa hay.

Handling Alfalfa Hay from Windrow

Various methods are in use in the important alfalfa areas for the handling of windrowed hay, such as (1) stacking from the original windrows or bunched windrows with sweep rakes or hay sleds; (2) bunching and cocking, followed by stacking, with the cocks carried to the stacks by sweep rakes; (3) loading wagons from the windrows with the hay loader and hauling to barns or stacks, where unloading is done with slings or forks; (4) baling directly from windrows, using hay-loaders and wagons or sweep rakes to move the hay from the windrows to the press; (5) bunching and cocking followed by baling from the cocks with a portable baler; and (6) baling directly from the side-delivery rake windrow with pick-up windrow baler.

Direct stacking or direct baling: Direct stacking and direct baling are the methods most commonly used in handling hay from the windrow. In times of relatively high wages and scarcity of farm labor, the practice of cocking hay to cure it in the field, or to insure it against rain damage is not common. If large fields of hay are to be harvested, time and cost usually make it necessary for the farmer to place greater reliance upon the side-delivery rake, the hay loader, the sweep rake and stacker, and upon the organization of his crew to provide rapid haulage and storage or baling, than upon the more expensive and tedious practice of cocking. But the practice of cocking alfalfa hay persists and is often necessary in sections that have much rainfall, heavy fogs or dews, or continuous high temperatures and dry atmospheric conditions which cause hay to overdry and bleach quickly in the swath or windrow.

Sweating hay before baling: In the production of high-grade alfalfa hay for market, sweating the hay in cocks or stacks prior to baling is most desirable. If the hay is cocked while tough, or stacked while slightly tough and then goes through a light to moderate sweat, it develops attractive aroma, the leaves are preserved in a clinging condition, and the hay when baled can be shipped long distances with practically no risk from heating. Either of these methods, moreover, allows considerable latitude in the condition of the hay at time of cocking or stacking, whereas in baling direct from the windrow, the grade of the hay may be injured either from overdrying, which causes shattering and loss of leaves during the baling process, or from undercuring, which results in bale sweating, heating and molding, especially if the bales are pressed under heavy tension or packed tightly in piles or cars.

In the arid regions where high temperatures usually prevail during the haying season, the practice of cocking tough alfalfa hay in large cocks, curing and partial sweating in the cocks for several days, and then baling from the cocks with a portable press is to be highly recommended to producers who plan to sell high-grade hay to the dairy trade.

Stacking and baling from stacks: In the West Northcentral and Mountain States the practice of stacking alfalfa directly from the windrow while the hay is in a slightly tough condition is usually the
most satisfactory method to follow year after year. With sweep rakes and stackers, or with hay sleds, slings, and derricks, a large quantity of hay can be saved from overdrying or rain damage in a comparatively short time. Hay stacked in this way can be baled later in the season when other farm work is not pressing.

The prompt stacking of hay is a constant safeguard against rain damage or overdrying so that through a period of years the smaller losses to stacked hay, as well as the better quality resulting from sweating, offset the somewhat lower costs for windrow baling.

Some of the highest-grade alfalfa hay produced in the country comes from districts where the hay is put up in large stacks with sleds and a derrick and then allowed to sweat before being baled. Hauling the hay from the field on sleds keeps the hay free from dust and grit and preserves its leafiness to a greater extent than when it is pushed to the stacks with sweep rakes.

Baling directly from the windrows: Baling directly from windrows is a popular practice among many producers of market alfalfa hay on both arid and humid areas because it saves some extra handling of loose hay, saves storage space for loose hay in barns or sheds in humid climates, and sometimes permits the rushing of hay into an early market or an undersupplied market.

Three methods of baling hay directly from the windrows are commonly used. One is to push the hay with the sweep rake from the windrows or bunches to the press; a second is to pick it up with a hay loader and wagon from the side-delivery-rake windrows and draw it by wagonloads to the press; the third is to pick up and bale the hay from the side-delivery-rake windrows with a “pick-up windrow baler.”

The chief difficulty in producing high-grade alfalfa hay by the windrow-baling method is getting the hay to the baler in a condition ideal for baling. This difficulty is solved to a certain extent when the pick-up baler is used. Baling from the windrow is well suited to large acreages, and if care is taken, it is possible to produce high-grade alfalfa hay by this method of handling. Producers of market hay in the arid and semiarid areas could profitably adapt this method to their local conditions in many instances.

It is possible to make high-grade alfalfa hay by any of these methods if the crop is cut at the proper stage of growth and handled thereafter according to the fundamental principles that have been explained.

Storing loose hay in barns or sheds: In very humid climates the ideal method of storing loose alfalfa hay is to place it in barns or sheds that will protect it from rain damage. By means of loaders, long racks, and slings, hay can be moved into such storage from the windrow rapidly and with little hand labor. In a locality having heavy rainfall, the construction of sheds equipped with carrier tracks and tackle for handling loose hay is often advisable and profitable for the producer who plans to market high-grade alfalfa hay. Such sheds permit thorough curing and sweating without incurring rain losses during the storage period and are useful for baling operations and for the storage of baled alfalfa that is awaiting shipment.

Stack storage: In the arid and semiarid areas storage in stacks is the cheapest and most practicable method for protection against weather damage, providing the stacks are well made and of large size. Small stacks expose relatively large outside areas to weather damage, absorb much moisture from snow and rain, or may cause overdried hay in windy climates. Such stacks weather badly on the outside and often develop “stack spot” or white mold in the depressions and pockets into which the rains and snows settle.

In the stacking of alfalfa hay the possible saving in labor from the practice of throwing up numerous small stacks in a field, as compared with the practice of building a small number of large, well-made stacks, is usually more than offset by the losses in quality. The percentage of weather-damaged hay on the outside of the stack to total stack tonnage is much less in large stacks than in small stacks. The risk of damage to the center of the stack is small if the stack is drawn
out with side-wall bulges 3 to 4 feet above ground level, tramped solid in the center, and drawn to a peak at the top. In sections of considerable rainfall, a small load of wild hay or of wheat or rye straw may be used to finish the peak of the stack and to spread over the top to assist in shedding rain and snow water.

The highest-grade alfalfa hay put up in the West Northcentral and Mountain States, where stacking is common, is found in those localities where it is a common practice to build stacks of 25 to 100 tons by means of hay sleds, slings and derricks, with two or three men constantly on the stack to spread and tramp the hay into a symmetrical and weather-resistant stack.

Each cutting of alfalfa should be stacked separately as far as possible in order to provide hay of uniform class and grade at time of baling. In the stacking of alfalfa intended for market it is poor policy to put two or more cuttings in the same stack because of the variations in leafiness, color, grass mixtures, or stem texture that may exist and that would cause variations in grade.

**Baling Practice**

When hay is baled from the stack great care should be taken to remove the weathered top and sides of the stack before baling. Moldy or stack-burned hay which is occasionally found in the center or at the bottom of the stack should not be fed into the press. A relatively small percentage of such stack-injured and low-grade hay will spoil the general appearance of a baled lot of good hay and may cause a lowered price for the entire lot.

The condition of hay at time of baling is of the utmost importance. It is folly to bale hay from windrows, cocks, or stacks that are damp from rain or snow, or that are distinctly undercurled. To do so invites a shipper’s loss from hot and moldy hay. Heavy and tightly compressed bales are the cause of many severe losses in slightly tough and unsweated hay baled from windrows and cocks. Unsweated and slightly undercurled hay should be baled as loosely as is compatible with the making and tying of a bale that will stand later handling and shipment without breaking open. Loosely pressed bales of slightly undercurled hay will permit bale sweating to take place without the development of extreme heat and mold, whereas hay of the same condition, pressed into tight, heavy bales, is almost certain to develop must or mold inside the bales, and often large numbers of bales will spoil throughout.

In baling as well as in curing operations consideration must be given to the preservation of leafiness. Much attention is given to this matter in a number of western communities that specialize in the production of alfalfa hay for the dairy trade, and all baling is done in the early morning or late evening hours, when temperatures are relatively low and humidity is relatively high.

Without question, such baling methods are profitable. The bales so made are leafier, and the leaves cling better than in the case of bales made during midday hours. A local adaptation of this practice can be made to advantage in all areas that produce alfalfa hay for market, so that the baling may be done in such hours of the day or such seasons of the year as are most favorable to the preservation of leafiness.

Weather conditions permitting, the most favorable time to bale stacked hay is just at the close of the sweating period. At this time the stacks have not been subjected to much, if any, weather damage, and the hay is sufficiently tough to preserve clinging foliage in the bales, providing the baling is not done during hours of very high temperatures nor on very windy days.

**Wild or Prairie Hay**

On the basis of acreage, wild hay is the outstanding hay crop of the Northern Great Plains. More than 9 million acres of it were harvested in 1949 in the Northern Great Plains, or nearly two-thirds of the total wild hay acreage of the United
States. South Dakota, Nebraska and North Dakota lead the United States in the production of wild hay.

Grasses in prairie hay: Wild hays, made up chiefly of the tall and mid-tall grasses of the prairie regions, are the prairie hays of commerce, although their most important use is within the region. On the market they are graded as Upland Prairie or Midland Prairie hays, according to the kinds and qualities of the grasses they contain.

Prairie hays are composed of a large number of grasses and grasslike plants, with smaller admixtures of native and introduced species belonging to many different families. In any particular case, the large percentage of the grass in the hay will be of a few species.

The principal grasses found in Upland Prairie hays are the bluestems, needlegrasses, and wheatgrasses, with such grasses as Junegrass, the gramas, the dropseeds, Indiangrass, and switchgrass contributing smaller amounts in different hays. The principal species of Midland Prairie hays are those adapted to growing in wet areas; among them are sloughgrass or cordgrass, bluejoint, and switchgrass.

Wheatgrass hay is produced on the fine-textured soils largely to the north and west of the Nebraska sand hills. It is especially important along river bottoms in northeastern Montana. This hay is frequently harvested from nearly pure stands of western wheatgrass. Feeding tests have shown it to be equal or superior to alfalfa hay for wintering cattle.

In the Nebraska sand hills, meadows of the subirrigated valleys produce abundant hay crops in which the bluestems predominate. Studies of these hay meadows have shown that the relative amounts of the many kinds of grasses are closely associated with distances to the water table. The quality and yield of hay have been greatly improved by the introduction of clovers into some of these subirrigated meadows. Haymaking continues from June until September. Some of the early-cut hay of best quality is baled and shipped out of the region to terminal markets.

Yield and quality of prairie hay: The average yields of prairie hay in the Northern Great Plains is less than a ton of hay per acre. An experiment to measure the effects of time of cutting on the yields and quality of typical bluestem hay was started recently in southern Nebraska on a section of unbroken prairie given to the University of Nebraska for experimental purposes. The effects of different clipping treatments on the meadow are being measured over a period of years and the results interpreted each year in terms of the feeding value of the hay. The first experiments showed that early-cutting and aftermath harvests gave the best hay.

Studies of the different kinds of prairie hays indicate that the protein content drops as the grasses mature. There also seems to be a close association between protein and carotene content of hays. Although the early-cut hays usually contain enough protein to exceed minimum feed requirements, the later cut hays frequently are deficient. Feeding of protein supplements has become common in wintering cattle on native hay or on the range, with the result that a maximum return is had from the hays fed.

Seed of adapted strains is needed when croplands are put back into perennial grasses. Most of the commonly cultivated forage grasses have never been successfully established under the variable and severe climate of the Northern Great Plains. The native grasses provide some of the best adapted plant materials for this purpose, but until 1934, seed of these grasses was not available. Since then, much progress has been made in domesticating them, seed has been machine-harvested in large quantities from native stands and nurseries, and methods of establishment have been developed.

It is now possible to obtain seed and establish stands of such important grasses as western wheatgrass, feather bunchgrass, wild-rye, big bluestem, switchgrass, sand lovegrass, side-oats grama, blue grama, and buffalograss. A continuing problem, however, is to increase seed supplies of the adapted superior strains in order that they may become generally
available for conservation plantings and for hay and pasture production.

The hay produced from the resown range, whether with native grasses or such introduced grasses as crested wheatgrass and intermediate wheatgrass, will still be prairie hay, though not in the strictest sense wild hay. It will be graded in the market under the grades for prairie hay.

In general, cool-season grasses—which grow early in the spring and mature seed in early summer—have been shown to have a much higher content of crude protein than those of the warm-season group, which reach their greatest growth in the hot months. As such, they are important species for consideration as hay.

The cool-season group, including native western wheatgrass, wild-ryes, feather bunchgrass, and the introduced crested wheatgrass, intermediate wheatgrass, and bromegrass, offers the best possibilities for hay crops in the region. These tall grasses are suited to hay-harvesting methods, but require considerable amounts of moisture for maximum yields. However, they combine varying degrees of ability to withstand drought with the ability to produce good yields when moisture conditions are favorable. They are important for use in supplementing the warm-season group, which predominates in native hays and on the range.

**ARTIFICIAL DRYING OF HAY**

**General principles:** Freshly cut forage contains about 75 to 80 percent moisture. Under most conditions of natural drying the moisture content must be reduced from 20 to 25 percent or below for storage in the mow, in order to avoid serious deterioration in quality, loss of nutrients from fermentation, and danger of spontaneous combustion.

The permissible moisture content for safe storage without heating varies somewhat according to how the forage is stored. If it is chopped it must be drier than if it is stored long, and the finer it is cut, the drier it must be. Also, hay that is baled from the field for storage must be drier than hay stored long, and the tighter the bale the drier the hay must be. In undercured hay mold and rust might develop. 

Freshly cut forage is living material. The plant cells continue to respire, and plant enzymes continue active for some time after the crop is cut. In addition, micro-organisms naturally contained in the forage continue activity as long as air is present and there is sufficient moisture. If drying is prolonged, however, important losses in dry matter and protein may also occur. Losses amounting to 5 to 15 percent of the total crop have been found to occur from so-called field fermentation losses.

The methods of handling the forage in the field should be designed to promote the most rapid evaporation of moisture so that these losses may be kept to a minimum. The new types of equipment developed for handling forage in the field tend to keep fermentation losses low. Moisture evaporates faster from the leaves than from the stems when the crop is lying in the swath, and this condition promotes serious shattering of the leaves when the hay is handled. Besides, the color and carotene decrease more rapidly when forage is exposed in the swath. It is highly important to conserve the leaves since they contain in alfalfa about 70 percent of the protein and 90 percent of the carotene of the entire plant.

The underlying principle of drying—the evaporation of water from the surface of the forage and its removal by the surrounding air—is the same for both natural and artificial dehydration. The rate of drying depends on the amount of water in the forage, the temperature and humidity of the surrounding air, the rate the moisture-laden air is moved, and the kind of forage and texture of the plant.

Conditions that favor the most rapid removal of moisture generally produce a dried product most nearly resembling the original crop in appearance and in composition and feeding value. Thus artificial drying generally produces forage of higher feeding value than natural drying, and losses of nutrients are also somewhat smaller.
But the introduction of artificial aids to replace the natural drying generally adds to the costs. The relative advantages of such aids, therefore, must be weighed against the costs in individual situations.

In drying forage by natural or artificial means or a combination of both, the primary concern should be to conserve the maximum quantity of dry matter and of feed nutrients in the crop at the least cost.

The mere evaporation of enough moisture from forage so that it will keep in storage should not greatly change the composition of the dry matter or its feeding value.

Conditions are seldom ideal for drying when the farmer has forage ready to be harvested. Weather is uncertain and facilities are limited on farms in most of all the major hay-producing areas, so that there are important losses of dry matter and nutrients in drying the forage.

Artificial drying generally is done in the United States in one of two ways—barn finishing or dehydration.

Mow drying: In barn finishing, or mow-drying, a practice that has received a great amount of attention recently, the forage is partly dried in the field; then it is placed in a mow, and natural or heated air is forced through the forage to complete the drying.

When the barn-finishing method is used, the hay can be taken from the field when it has considerably more moisture, but drying must be continued until the forage on the top of the mow averages 20 percent or less. It is generally preferable to bring chopped hay or baled hay to the barn finisher at a lower moisture content than long hay. When barn-drying installations permit the use of heated air, however, differences in moisture content are not so important.

The moisture content at which forage should be taken in for completing the drying on the barn finisher will vary considerably. Under ideal conditions, when everything is considered, it probably is best to leave the forage in the field as long as is possible without permitting much leaf shatter. We need much more information on this point; the best recommendation now is that the moisture content of the crop should be between 35 and 40 percent when it is taken from the field.

When weather conditions do not permit leaving the forage in the field long enough to reduce the moisture content that much, it may be brought in earlier, but when this is done it will take longer to complete drying on the drier and the barn losses may be higher. The barn-finishing method makes it possible, however, to get the crop off the field, in case of threatening rain, with a moisture content at which the hay would become musty and moldy and might burn by spontaneous combustion in regular storage.

When partly dried forage is placed on a barn-hay finisher, it is still wet enough to allow rapid fermentation to take place. Air moving through the mass of hay carries with it the moisture evaporated from the forage. The temperature of the air will govern how much moisture it will pick up. Heated air will pick up more moisture than unheated air, and drying will be hastened if the air is heated before it enters the drier. The heat created by fermentation may also increase the temperature of the air and thereby increase its water-holding capacity. It is important to spread the forage evenly over the drying system and to have the same degree of packing throughout. The air will then flow evenly through the forage and the hay will dry thoroughly in all parts of the mow. The hay dries from the bottom up, and when the top layer is dry enough to prevent heating, the lower layers are even drier.

The drying should be completed as rapidly as possible to retard fermentation. The longer fermentation takes place the greater the losses of dry matter and nutrients because optimum temperature and moisture conditions are present for microbiological activity.

Tests were conducted by the Department of Agriculture with hay that contained from 40 to 45 percent of moisture when it was put in the drier. It took about 13 days to dry the hay to a point
where it would keep. During this time there was a loss of about 9.3 percent dry matter, 11.2 percent protein, and 78.2 percent carotene. These losses appear to be rather typical for this method of drying, when unheated air is used. Considerably better preservation was accomplished, however, and in a much shorter time, when heated air was used.

Other tests indicate that better preservation of dry matter and nutrients is obtained with forage stored in a chopped condition when it is dried in the field to a relatively low moisture content before it is put on the barn drier. Various workers have successfully dried baled forage on barn finishers. Here again, getting the forage as dry as possible in the field and using heated air in the barn finisher have proved advantageous.

Usually built in the haymow, the system is essentially a blower driven by an electric motor and a system of ducts. The blower forces cold air through the main duct and distributes it through lateral ducts that branch at right angles. From the laterals the air emerges through slots on the underside. The ducts usually are made of wood, although for the laterals other materials, such as sheet metal, have been used. The laterals are spaced about 5 feet on centers, and the system is so designed that about 15 cubic feet of air per square foot of mow space is delivered against a static pressure, generally about 3/4-inch water, with long hay piled to a height of about 8 feet.

A modification of the duct-type drier is the slatted floor installation developed by engineers in the Department of Agriculture and the Virginia Agricultural Experiment Station. This type, simple in design, is now generally recommended in the eastern humid regions and is gaining in popularity elsewhere. Its main feature is a tapering central air duct that is open at the bottom on each side to allow the air to flow to a slatted floor and up through the hay. Its construction cost is low because the slatted floor can be built of rough lumber and laid by inexperienced carpenters. Experimental tests showed that duct pressure losses in driers of this design, properly operated, are considerably less than in the conventional duct-type system. Air distribution is better and the flow of air through the hay is increased.

Much of the hay made by the barn-finishing method is greener, leafier, and generally of a better grade than similar hay made by field curing. This is particularly true of hay in which no mold has developed during drying.

An important advantage of the barn-finishing method is that it makes it possible to get the crop off the field sooner, in case of threatening weather, and to save large amounts of food nutrients that would be lost by field curing during extended wet spells. The best information to date is that the forage should be allowed to dry in the field as much as possible, without running the risk of damage from rain or inclement weather or excessive leaf shatter from too much drying before it is stored on the mow finisher to complete drying.

The mower-crusher: A new development that is being observed with interest by researchers is the crushing of the stems as the forage is being cut. In this operation, forage passes from the cutting bar through spring-tension-controlled rollers, which gently crush the stems. The advocates of this idea state that the moisture is evaporated from the crushed stems at about the same rate as from the leaves, and that the total drying period, therefore, is cut almost in half. The use of the mower-crusher should be of special interest in connection with mow-drying. The two together should be very effective in shortening the drying period. This device needs further testing under different conditions of hay making.

Artificial dehydration: In artificial dehydration the forage is taken from the field as soon as it is cut (in some instances it is allowed to wilt), chopped, and passed through a suitably constructed chamber where it comes in contact with heated air which rapidly evaporates the moisture in it. The length of time the forage is in contact with the hot air varies from a few minutes to a half hour, depending upon the temperature in the drier.
Forage that is to be artificially dehydrated is generally hauled to the drier immediately after it is cut. This is important in the production of high-carotene feeds, such as alfalfa leaf meal, but for drying forage for cattle feed it appears that considerable saving can be made in the cost of drying by allowing it to wilt in the field several hours before it is gathered. When forage is wilted to 75 to 60 percent moisture in the field, only about half as much water must be evaporated by artificial means for each ton of forage of 15 percent moisture content as when it is not wilted. This saving in drying costs may well outweigh the small losses in dry matter and in quality of the forage that might result from leaving it in the field a few hours after cutting. However, the rate of drying is reduced as the moisture content is lowered.

The most popular type of artificial forage dehydrator in use in this country is one that uses a high initial heat (1,200° to 1,400° F.), which is usually produced from fuel oil. The forage is usually chopped before entering the drier. The forage and heated air are in contact in the drying chamber for only a few minutes. The temperature of the air at the exhaust end of the machine is seldom over 300°.

Experimental results show that forage dried under such conditions has a normal composition and feeding value. There is no danger of affecting the feeding value as long as the forage is removed from the heated air as soon as it is dry. The appearance of burning on the leafy portions of the forage indicates that the temperature is too high or that the forage is overdried.

Experiments in drying grass showed that the digestibility of the protein and calcium was severely affected when it took 2 to 5 minutes to evaporate the moisture and the exhaust air temperature was 400°. It is not necessary to operate at such high temperatures, however, to dry forage efficiently.

Under average conditions the gross loss of dry matter from artificial dehydration varies from 5 to 7.5 percent. This loss must be charged to the costs of drying. Costs of artificial drying have been so great that its use has been limited to large-scale operations and to specialty products, such as alfalfa meal of high carotene content which are used in the feeding of poultry and swine.

Artificial dehydration produces feed of high carotene and riboflavin content, if the crop is dried soon after it is cut. Dehydrating the forage preserves the carotene effectively, although dehydrated forage, like other dried forage, undergoes carotene loss in storage during the warm weather. The dry matter and other nutrients keep very well in storage when the forage is properly dehydrated artificially.

THE HIGHLIGHTS OF HAY PRODUCTION

1. The hay crop is one of the most important crops in the United States today. In total value it ranked second only to corn in most years up to World War II, since which time it has been exceeded also by wheat and cotton.

2. The five highest hay-producing States in the order named (1934-1947) are Wisconsin, Minnesota, New York, Iowa and California, each of which averages over 5,000,000 tons of hay a year.

3. The three highest timothy and clover hay producing States in the order named are Wisconsin, New York, and Iowa, and the three highest alfalfa hay producing States are California, Minnesota and Wisconsin.

4. Timothy and clover alone and in mixtures continue to form the most important hay crop in the northeastern part of the United States because they are well adapted to the soil, climate, and farm-management practices of that region.

5. In acreage alfalfa and wild hay each have somewhat more than half the acreage of timothy and clover together.

6. In total United States production alfalfa leads all other hay crops, exceeding timothy and clover together the past 12 years by 10 percent.

7. In yield of hay per acre alfalfa leads all other important hay crops with a 12-year average of 2.13 tons per acre, while tim
othy and clover averaged 1.33 tons, sweetclover 1.21, lespediza 1.04 tons, and all hay 1.51 tons.

8. Adapted, compatible, nutritious grasses and legumes should be grown in simple combinations for highest yields of high quality hay.

9. Hay having the highest feed value can be produced only on fertile soils containing those elements necessary for both plant growth and for livestock feed.

10. High quality hay cannot be produced unless the meadows are kept clean of weeds and other trash, the hay plants are cut at the proper stage of maturity, and the crop is properly handled, cured, and stored as quickly as possible.

11. Timothy should be cut from the early-bloom to nearly full-bloom stage. If cut not later than early-bloom and properly cured, timothy hay compares favorably in protein content and feed value with all other hay grasses.

12. Clover and timothy-clover mixed should be cut when the clover is in half to nearly full-bloom stage.

13. Mixtures of timothy and grasses should be cut not later than when any of the major component grasses are in full bloom.

14. Alfalfa should be cut when in one-tenth to one-fourth bloom, or when the basal shoots have made considerable growth or the foliage takes on a yellowish cast.

15. Alfalfa yields may be larger when cutting is delayed until the plants are in full-bloom, but these increased yields are not likely to be commensurate with the loss in feeding value of late-cut hay.

16. Alfalfa hay of similar quality or grade is equal to or superior in feeding value to hay made from any other crop.

17. Legume hays should be raked as soon as they are well wilted and the curing completed in small, loose windrows as quickly as possible, to avoid loss of leaves and color.

18. The preservation of the leaves in alfalfa, clover and other legume hays is most important since the leaves contain most of the protein, minerals and vitamins in the hay.

19. Green color is an important physical characteristic of all hays. It is associated with carotene and vitamin A, and its loss through maturity or weather damage means loss of valuable protein and minerals.

20. A certain amount of sweating which is caused by fermentation always occurs in the proper curing of hay and may improve its palatability. Excessive fermentation destroys the green color and may cause the hay to become musty or moldy.

21. In a nutshell, the essential characteristics of high-quality legume hays are soundness, freedom from foreign material, a high percentage of leaves, clinging foliage, green color, and pliable stems.

22. Five types of ground alfalfa are produced from alfalfa hay—chopped alfalfa, alfalfa meal, alfalfa leaf-meal, alfalfa stem meal, and alfalfa pellets.

23. Very little ground alfalfa or alfalfa meal is fed as such, but is used mostly in mixed feeds and, to some extent, in the manufacture of alfalfa pellets.

24. Where weather conditions at harvesting time are usually unfavorable or uncertain for the drying of hay, artificial drying should be considered.

25. The most rapid removal of water from the hay produces the best dried product in appearance, feed value, and composition.

26. Artificial drying increases cost of hay, but in many localities the greater value of product more than repays for the extra cost.

27. Mow drying or barn-finishing of hay is a practical and relatively inexpensive method of drying hay that greatly lessens the danger of loss from rain.

28. Much of the barn-finished hay is greener, leafier, and generally of a better grade than field-cured hay.

29. Artificial dehydration of hay takes over the complete process of drying following cutting, and if properly done, produces feed of high carotene and riboflavin content.

This Chapter

The material for this chapter was obtained largely from Hosterman and Parker (US-117), Pollock and Hosterman (US-210 and 211), Westover and Hosterman (US-284), Woodward, et al (US-205), and Hodgson et al (US-95). The manuscript was reviewed by Hosterman.

Chapter reference numbers: 1 ARIZ-1; ARK-15; COL-4; DEL-1; ILL-24, 29; IND-4; IOWA-8, 11; LA-14; MASS-6; MICH-4, 6;
The reference numbers given here refer to references which are given in full by State, U.S.D.A., and Miscellaneous, on pages 682 to 724, and which are cross-referenced by author on pages 725 to 731. Citations in the text are indicated by abbreviation and number in parentheses.
Silage is a moist, succulent feed made by storing fresh green or slightly wilted forage crops in a silo in such a manner as to exclude the air. It occupies an important place in the feeding of livestock, either as a major source of all nutrients, or, when properly made, as a primary source of carotene or other vitamins or minerals to supplement low-grade roughage. Crops may be utilized as silage which might otherwise be a total failure, as neither drought nor excessive rains prevent the making of at least part of a crop into silage. Some crops can be more effectively preserved, and are therefore more willingly eaten as silage than as dry forage because, in the form of silage, the entire crop is edible. In all cases the same crop will retain more nutrients as silage than as dry forage. Apparently, any forage crop can be made into silage, but where corn thrives it is now the most commonly used silage crop, though perhaps not always ultimately the most economical.

Silage may be the principal forage for the winter feeding of cattle in regions where the making of good hay is uncertain and where the hay crops yield less than the silage crops. Because of its high moisture content, 2 to 3 pounds of silage is required to equal one pound of good hay in feeding value. Only rarely, however, is silage fed to the entire exclusion of hay, straw, or stover.

Silage characteristics: The outstanding characteristics of silage are its palatability, its consumption without waste, and its usually high carotene content. The quantity of carotene in properly made corn silage may be as much as in the green crop from which the silage was made, even after more than a year of storage. Grassland crops contain proportionately more leaf to stem than corn and the sorghums, and produce silage with a higher carotene content than those crops. Because of its high carotene content, along with its other valuable constituents, silage is particularly valuable to supplement grain and low-quality hay in the ration.

Silage made from corn, sorghums, small grains, or grasses contains insufficient protein and mineral matter for growth and milk production, and must be supplemented with some feed or feeds that will supply these deficiencies. Silage made from legumes, or mixed grasses and legumes, is high in protein and minerals, and can be used to replace part or all of the corn silage or hay in the ration.

Silages are most used in those regions where corn or sorghum thrives, or where the production of high quality hay is uncertain, or where dairying is an important industry. This is not because silage is considered a poor feed for other kinds of livestock but because dairy cows must have a high-quality feed and be able to get it without too much effort and without too much exposure to severe weather. In the whole economy of dairy farming silage is important because of its mechanical advantages to the operators and the nutritional advantages to the cow and to the milk produced.

Quantity produced and value: In recent years some 40 million tons of silage have been made annually in this country with a value, at a conservative estimate, of upward of 300 million dollars. At present, probably 90 percent of the silage is made
from corn or sorghums, and about 10 percent from small grains or hay crops. However, more and more land is being sown to soil-conserving grassland crops, and the use of hay and pasture crops for silage is increasing rapidly.

Advantages and disadvantages of silage:
Some of the advantages of silage are:
1. Its utilization of feed that might be inedible in the dry state or would be damaged by rains.
2. Its usually high palatability and high content of carotene and minerals.
3. The ensiling of grain crops commonly clears the ground early and completely for another crop.
4. The storing of a forage crop as silage instead of hay requires only about one-third the space, and eliminates the hazard of fire.
5. Meadow crop silage put up in May or June at the height of spring or early summer growth may be used during hot, dry summer months to supply succulent feed for maximum dairy production. The same silo may be filled again in the fall for winter feed, thus giving double use of the silo. This also keeps the silo structure in better condition than if filled only a small part of the time.

Some of the features often cited as disadvantages of silage are:
1. It requires an additional outlay for buildings, equipment, and power. As compared with mow-drying of hay, this cost may not be as great.
2. It is often difficult to regulate the moisture content of the silage, especially that made from grasses and legumes.
3. The purchase of conditioners for meadow-crop silage may involve cash outlays. The wilting process in lieu of using conditioners is ordinarily just as satisfactory, or more so, and usually can be followed with no extra cost.
4. Silage is seldom suitable for use as the sole ration unless it has the right combination of high protein legumes along with the low-protein grasses, corn, or cereal crops. This is equally true of hay as compared with meadow-crop silage.
THE MAKING OF SILAGE

determined by the duration of the feeding season.

Small trench silos are usually made wider at the top than at the bottom. This shape causes the silage to pack tightly against the sides as it settles, and is generally required to prevent the sides from caving in. The type of soil generally governs the slope of the side walls; the lighter, more friable soils require a greater slope. The depth is governed by the ground-water level and the required cross-sectional area. These silos can be made for the expense or labor of removing the soil. The soil removed from the trench is generally piled along its sides to increase its depth and provide good surface drainage away from the silo. The bottom of the trench should never be below the level of the ground water and should always slope to one end to afford good drainage. Permanent trench silos are often made by lining with concrete, cement, plaster, brick, or stone. However, such silos made “permanent” usually cost more in the long run than tower silos of the same capacity, and are rarely as satisfactory.

Size of silo and weight of silage: The size of the silo required for supplying a herd depends upon four factors: (1) the number of animals to be fed, (2) the quantity per animal per day, (3) the weight of the silage per cubic foot, and (4) the number of days in the feeding period.

The weight of the material that can be put into a silo depends upon the moisture content of the crop, the depth and diameter of the silo, the rapidity of filling, the length of cut, and the character of the crop.

For feeding 10 animals, 30 pounds of average-weight silage per day for 300 days would require a tower-type silo 10 by 22 feet; for feeding 40 animals, 50 pounds per day for 200 days would require a silo 16 by 48 feet, or 18 by 40 feet. It should be borne in mind that a silo to hold less than 10 tons of silage would be impracticable and that for summer feeding the silo size should be such that not less than three or four inches of silage can be removed daily to keep ahead of spoilage.

Care and maintenance of silo: There are several things that should be considered in the care and maintenance of a silo. Whenever a tower-type silo is empty and some time elapses before being refilled, it should be carefully examined to see if it will provide safe storage for silage for another year. It should be borne in mind that when a silo is full of silage there is considerable outward pressure exerted on the walls of the silo. If it is a wood-stave silo, all rods or bands used to hold the silo together should be examined and repaired if necessary. Every part of the silo should be examined to see whether, when it is filled, it will exclude the air from outside which is the source of much spoilage of silage. If a wood silo is left empty for any length of time, it is likely to dry out so that it cannot easily regain its original condition and provide safe storage for silage.

If the silo is of concrete and properly built on elevated solid ground, there is little danger of it going out of condition, except that the interior surface may be affected by the chemical action of the silage juices and the weather, thus making some repair or resurfacing necessary.

CROPS SUITABLE FOR SILAGE

Many crops suitable for silage: Any green forage crop that will keep in good condition without an excessive loss of food nutrients can be made into silage. Few feeds are improved, either in palatability or in nutritive value, by undergoing fermentation in the silo; on the other hand, none appear to be affected detrimentally to any marked extent. The loss of nutrients in crops properly ensiled is small and is ordinarily much less than from crops properly cured as dry forage. Very coarse or weedy crops when made into silage may be completely edible, whereas, if such feed is made into dry fodder or hay, much of it would be rejected by the cattle or other livestock. The spines or awns on some plants may be rendered harmless through ensiling. For example, in the Far West forage containing dry squirreltail or wild barley, the awns of which are injurious to animals, may be made into a safe and useful feed by con-
Forage and pasture crops: Forage and pasture crops are important in feed production. As a rule, if a forage is palatable and nutritious when it is put into the silo, and is properly ensiled, it will be palatable and nutritious when it is taken out; if it is a poor feed when it is put into the silo, it will be a poor feed when taken out.

Corn and sorghums: Corn is the most common silage crop wherever it can be grown successfully. Silage made from corn is very palatable and will keep in good condition for years. Throughout a considerable portion of the United States more food material is obtained from an acre of corn as silage than from an acre of almost any other crop. Experiments have shown that corn when ensiled loses about 4 percent of its dry matter, exclusive of top spoilage, as compared with over 15 percent when cut for fodder and cured in the field. Moreover, there is less waste in feeding silage than in feeding fodder, since good silage, properly fed, is practically all consumed. For wintering calves, one acre of corn silage has been shown to be equal to about one and two-thirds acres of dry ground fodder. Corn can be put into the silo at a cost as low as that of shocking, husking, grinding, and shredding.

The sorghums, or so-called saccharine sorghums, such as Amber, Orange and Atlas "cane," and the nonsaccharine sorghums, such as kafir, feterita, milo, hegari, and Sudan grass, are suitable for silage. Sorghums are more dependable and yield more than corn in those regions of the South and West where the rainfall is too light or irregular, or the soil or climate is not so well adapted to the growth of corn. They also outyield corn in some sections where corn is a high-yielding crop. Sorghum crops produce a characteristic silage-fermentation much like that of corn. They are also sometimes grown for silage along with soybeans.

Legumes, grasses, and cereals: Good silage can be made from the grasses or mixtures of grasses and clovers that are ordinarily used for pastureage or hay. In certain other countries, such silage is made rather extensively. Immature grasses, if wilted to reduce their moisture content slightly, will make a better quality of silage than mature grasses, just as such grasses will make a better quality of hay.

If properly made, grass silage will be palatable and nutritious and possess an agreeable odor. Furthermore, it will have a high content of carotene. Surplus spring pasturage under some conditions may be converted into silage advantageously to be fed later in the summer or the following winter. Experiments indicate that silage made from immature grasses will be eaten in as great quantities as similar grasses will be grazed; also, that the butter from cows fed grass silage high in carotene will have much the same color as the butter from cows grazing the green grass.

All forage legumes, including alfalfa, clovers, cowpeas, soybeans, lespedezas, and vetches, can be made into silage successfully. Those that are good feeds in the green state or when made into good hay, will likewise make good feeds when made into silage. Also, the stage of maturity for harvesting to make the best hay results in the best silage. If a crop is too old to make a leafy hay that will be eaten without waste, ensiling will save the remaining leaves and provide a feed that will be completely eaten. When weather conditions are likely to be unfavorable for making hay, as is generally the case over a considerable portion of the country in May and June, the conversion of the crop into silage is a satisfactory alternative.

Field peas and oats are much used in the Northwest as a silage crop in place of corn, and while there appears to be no trouble in making silage of good quality, a number of experiments show it to be less valuable, pound for pound, than corn silage. Vetch and wheat, vetch and oats, or vetch and rye are other combinations of a legume with a small grain that are used to some extent as silage.

Soybeans have been grown for silage with corn, Sudan grass, or millet primarily to increase the protein content of the silage. Corn and soybeans grown together may not yield more heavily than corn alone, but the silage is improved in protein and mineral matter. Soybeans are also grown for silage with sorghums or
THE MAKING OF SILAGE

Sudangrass interplanted. Sorghum and corn provide more carbohydrates and a better fermentation than soybeans alone.

Red clover is commonly grown along with grasses, as timothy and redtop, for hay, but the mixture may be put into the silo if the weather is unsuitable for curing hay.

The yield of silage to be obtained from a hay crop can be roughly estimated as three times as much as hay. That is to say, a crop that will yield 1½ tons of hay will make 4½ tons of silage. The yields from some of the low-growing grasses and legumes are likely to be low. If one expects to make a practice of ensiling grassland crops, he should raise some of the more productive and easily harvested kinds, such as timothy, orchardgrass, alfalfa, red clover and others in their best yielding combinations.

Wheat, barley, and oats that are to be used for silage should be harvested between the time the heads emerge and the milk stage. If harvested when the kernel is in the soft-dough stage, the stalks and leaves will be mostly yellow or brown, and the carotene less. No special treatment is necessary except to cut the material fine and pack it firmly in the silo. Rye harvested when the grain is in the milk is likely to make an unpalatable silage, just as it will make an unpalatable hay. It is better to harvest the rye earlier, say when the first heads are emerging. In those regions of the United States where small grain can be harvested for silage before the first of June, it can be followed with another silage crop, so that the silo does double duty and two crops are obtained a year from the same land.

Sunflowers: Sunflowers are used to some extent in the West and Northwest, where the weather is too cold and the season too short for the best growth of corn. There seems to be a universal agreement among investigators that in some localities sunflowers yield a much greater tonnage than corn. As high as nearly 30 tons to the acre has been reported by the experiment station at Huntley, Montana. At that station it was likewise found that when planted in rows 20 inches apart the sunflowers gave greater yields than when planted further apart. The plants were about 10 inches apart in the rows, and 15 pounds of seed was used to the acre. Unless harvested soon after they come into bloom and before the seeds are developed, the silage will be unpalatable. Sunflowers are not so easily handled as corn on account of their stiff, brittle stalks, and because the heads tend to clog the feeding rolls of the silage cutter. The spiny growth on the stalks also makes them disagreeable to handle.

A composite of all feeding experiments indicates that sunflower silage is neither so palatable nor so valuable, pound for pound, as corn silage, though it may be fully equal to some of the other kinds of silage.

Miscellaneous crops and by-products: Crops such as sugar cane, Napiergrass, Russian thistles, and other weeds, beet tops, pea vines from canning peas, corn cannery refuse, curr and surplus fruits and vegetables, pulp and trimming wastes from market vegetables and fruits, and wet brewers' and distillers' grains are all used for silage with fair to good success.

MAKING SILAGE FROM CORN AND THE SORGHUMS

Variety and thickness of planting: As there is a steady increase in all nutrients of a corn crop up to maturity, it is best to plant a variety of corn that will reach the best stage for silage before frost. Since the corn does not need to have reached maturity for silage as it does for grain, it is possible to use a later maturing variety and thus obtain a greater yield than would be obtained from the earlier maturing varieties ordinarily planted for grain. In a 5-year test made at the Ohio Agricultural Experiment Station reported in 1923, it was found that the early maturing corn yielded on an average about 10 tons of silage per acre, whereas, the late maturing corn yielded about 12 tons. Comparing varieties of corn of same maturity, the hybrids produce the highest yields of silage. Ordinarily the variety of corn that will produce the most grain to the acre is the best to use for silage. The more grain there is in the silage the more...
nutritious the silage will be, and the greater will be the saving of concentrated feed used to supplement the forage.

Thick planting results in greater tonnage and in more stalk and foliage in proportion to the ears than does thin planting. It is thought best to space the planting so as to obtain the greatest total yield of ears. The best distance between plants, therefore, is probably slightly less than for the same variety if planted to produce grain. Yield per acre: From 4 to 20 tons of silage can be obtained from an acre of corn. The average for the United States in seasons of normal rainfall is about 7 or 8 tons an acre. A 50-bushel crop of corn yields from 8 to 12 tons of silage an acre, depending on the quantity of leaves and stalks that accompany the ears, and on the stage at which it is ensiled. The quantity of silage that may be expected per acre is often roughly estimated at 1 ton for each 5 bushels of shelled corn. Southern varieties of corn as a rule have a larger proportion of stalks and leaves than northern-grown varieties.

Stage of development to cut: Ordinarily corn should be harvested for the silo about 10 days before it would be cut for shocking. The most advanced stage at which corn can be harvested and still make silage of the highest quality from it is when 90 percent of the kernels are denting and 75 percent or more of the kernels are hardened so that no milk can be squeezed out. At this time the lower leaves on the stalk are turning brown and the green corn fodder contains about 70 percent of moisture. It is generally better to harvest the corn at an earlier stage rather than one later than that described. Silage made from mature corn lacks green color, carotene, aroma, and palatability, and is more difficult to pack so as to exclude air. During drought periods, corn may be cut for silage at any stage necessary to produce a green, succulent, palatable silage.

For good sorgo or sorghum silage, it is important that the crop be harvested when the seed has become hard. If harvested earlier, a silage with a high acid content is produced. Sorghum silage is likely to have a higher content of water and less grain, and for these reasons does not ordinarily have as high feeding value as corn silage. A mixture of corn and sorghum has proved to be satisfactory in some localities where the rainfall is so variable as to make the corn crop uncertain.

Nutritive values of corn forage at different stages: The corn plant may be used as forage over a long period of growth during the season from the time of tasseling or before up to the time of ripening, or a period of about 2 months. During this period there are changes in total quantity of forage produced and in quantities of nutrients which are one measure of feed value. Weights and analyses were made in New York of corn at five stages—tassel (July 30), silk (Aug. 9), milk (Aug. 21), glaze (Sept. 7), and ripe (Sept. 23), to show these differences. These are shown in the following table and indicate that the greatest total weight and value

<table>
<thead>
<tr>
<th>Stage of growth and date</th>
<th>Yield per acre</th>
<th>Composition by weight</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pounds</td>
<td>Water</td>
</tr>
<tr>
<td>Tasseled, July 30</td>
<td>15,045</td>
<td>1,610</td>
</tr>
<tr>
<td>Silked, Aug. 9</td>
<td>22,464</td>
<td>3,025</td>
</tr>
<tr>
<td>Milk, Aug. 21</td>
<td>33,600</td>
<td>4,789</td>
</tr>
<tr>
<td>Glazed, Sept. 7</td>
<td>37,036</td>
<td>5,928</td>
</tr>
<tr>
<td>Ripe, Sept. 23</td>
<td>28,460</td>
<td>304.23</td>
</tr>
</tbody>
</table>

Chemical changes during growth of corn plant.
of palatable feed per acre is obtained from corn harvested at or near the glaze stage.

**MAKING SILAGE FROM GRASSES, LEGUMES, AND CEREALS**

**Advantages of grassland silage:** Making part of the hay and pasture crops into silage has several advantages. The grasses and legumes usually grown for hay and pasture are mostly biennial or perennial and are produced more cheaply than annual or cultivated crops. Silage can be made from them with about the same equipment (except a silage cutter) and labor that is needed for haymaking.

Because the crops are taken off the field and put into the silo soon after they are cut, there is little risk of weather damage during harvesting. About 80 to 85 percent of their value (as shown by experiments at Beltsville) is preserved for feeding; only 70 to 75 percent of the value of field-cured hay is preserved during good curing weather, and this may be reduced to 60 percent or less if the hay is badly rain-damaged. Properly made grass silage will provide much more protein and several times more carotene in the ration than field-cured hay, increase materially the carotene and Vitamin A content of winter milk, and help prevent an oxidized flavor in winter milk.

**Wilting before ensiling:** A desirable type of fermentation and a mild, good quality silage can be produced from these high protein crops by simply wilting them slightly in the field to a moisture content below 70 percent. When wilting is not possible because of unfavorable weather, the same results can be obtained by adding 5 to 15 percent of dry hay as the crop goes through the chopper.

Wilting high-moisture crops for silage not only produces a mild, palatable silage that will be consumed in normal roughage amounts; wilting also reduces the losses of nutrients (except carotene) that usually occur when the silo is filled with comparable unwilted materials.

But care should be taken not to wilt the crop too much, and the part that is wilted most should be placed in the lower part of the silo. The walls of silos used for wilted silage should be airtight and smooth. Wood-stave silos that cannot be made practically airtight by screwing up the nuts on the reinforcing bands should not be used for wilted silage because there is too little moisture in a wilted crop to swell the staves and cause them to tighten naturally.

**Use of conditioners:** A good deal of attention has been given to the possible benefits derived from the addition of other materials as conditioners (commonly, but incorrectly, called preservatives) to grass silage. Investigators have tested many materials, including phosphoric acid, cultures of lactic acid bacteria, whey, molasses, ground corn, wheat and other cereals, salt, urea, dry ice (solid carbon dioxide), hydrochloric and sulfuric acid, and other acids. Generally speaking, an acid medium (whether obtained by direct addition of an acid or by desirable acid fermentation) is the best preservative of carotene and other constituents.

Materials such as whey, molasses, and ground dry grains are used as silage conditioners because they modify the natural fermentation process, produce a more desirable type of fermentation, and increase somewhat the acidity of the silage (pH range of 4.0 to 4.5), but they are not preservatives in that they prevent spoilage, for they do not. Dry grains also lower the average moisture content slightly and reduce the seepage from high-moisture crops. The addition of 100 pounds of dry matter to each ton of silage raises the dry matter content of fresh crops by 3 percent. This may seem small, but each such addition may be highly important in changing the physical properties of the silage, and in its effect on silage formation.

Salt has little effect on the fermentation process and is of little practical value in silage making. No desirable effects and no practical value have been found from the use of urea, dry ice, or cultures of lactic acid bacteria added with or without salt.

**Kind and quantities of conditioners to use:** The conditioners most generally used in this country are phosphoric acid (68
percent or more of $P_2O_5$, cane or blackstrap molasses, and ground corn, barley, or wheat. Part of the molasses is used in the dried or granular form. The operator should be cautious in handling phosphoric acid because of its corrosive nature. It is necessary to feed ground limestone or some source of calcium or sodium carbonate to the animal at the rate of approximately 1 ounce for each 10 pounds of silage in order to neutralize the mineral acid and prevent any undesirable effects it might have.

Effects of conditioners: Conditioners are most useful with high-moisture crops and crops high in protein. They have the least value with low- or medium-protein crops and crops low in moisture; often the conditioners do little more than to make the silage more palatable. If the crop is extremely high in moisture, the silage may sometimes be of poor quality even though conditioners are added. It is therefore generally recognized that a better silage is produced when the crop is wilted slightly as well. When the crop is wilted, less of the conditioners is needed because at that moisture level the fermentation process is slowed down, a more desirable fermentation is produced, and the losses (except of carotene) are usually small.

If the crop has been wilted to below 65 percent, undesirable fermentations are seldom produced in high-protein silage, even though the acidity is relatively low, and the actual need for a conditioner has usually been eliminated. Nevertheless, some farmers prefer to use conditioners with slightly wilted crops to insure the best preservation of nutrients and carotene under such conditions, particularly if the silo is old and in not too good condition.

Another factor to be considered in using conditioners is their added cost, which is sometimes quite high, particularly the cost of ground grains. It is true that a considerable part of the nutritive value of such materials is usually retained in the silage, but if sufficient forage is available these additional nutrients are not required in the silage for their feeding value, and the farmer can use the cash they represent to better advantage elsewhere.

Experience at Beltsville, at several experiment stations, and on thousands of farms demonstrates that good silage can be produced without conditioners from almost any type of crop if the proper methods are followed. Their use, therefore, should be limited to the actual need for them.

**MAKING SILAGE FROM MISCELLANEOUS CROPS AND PRODUCTS**

Many miscellaneous crops and by-products not ordinarily utilized as forage can be made into silage of acceptable quality for livestock if properly handled. Forages such as sugar cane, Napiergrass, and miscellaneous grasses and weeds can be siloed in the same manner as corn and the sorghums. In the case of Russian thistles and other weeds, the quality of the silage would be improved by ensiling them with any available fodder or hay crop.

Products such as beet tops, wet beet pulp, apple pomace, citrus fruit residues, corn cannery refuse, and pea vines from canning peas are usually ensiled alone, sometimes in outdoor stacks or trenches. Such silages are readily consumed but are often quite odorous. These materials are usually high in moisture, and their quality would be improved by ensiling along with some forage crop.

Cull or surplus potatoes, apples, beets, pears, tomatoes, cauliflower, kale, and trimming wastes from market vegetables are usually extremely high in moisture. As a rule, they will make the best silage if chopped into the silo along with 15 to 30 percent (by weight) of good quality dry hay or fodder. If regular forage crops are being ensiled, 10 to 20 percent (by weight) of any of these products can be added to the regular silage. If the regular forage is a legume or legume-grass mixture, it should be wilted to permit absorption of the excess juice from the added material and insure a suitable fermentation. As much as 50 percent of these products can be added if the
THE MAKING OF SILAGE

Forage crop is about half dry before ensiling.

Potato silage intended for swine should be made from cooked or steamed potatoes ensiled alone in a shallow pit or silo. Spent wet grains from breweries and distilleries can be ensiled alone in small water-tight tanks or silos by sprinkling in 1 or 2 percent of salt as the filling proceeds, and compacting thoroughly.

HARVESTING THE CROP AND FILLING THE SILO

Cutting corn or sorghums: Corn or sorghums for the silo may be cut by hand, by the one-horse, two-row platform cutter, or the corn harvester and binder. Hand cutting is practiced on farms where the quantity to be cut is too small to justify the purchase of a harvester, and when the corn is down or in such position as to preclude the successful use of the platform cutter or the corn harvester. Of the three methods, all things considered, the corn harvester is the most satisfactory, although the cost per acre is likely to be the lowest when the platform cutter is used.

Ordinarily the corn is hauled to the cutter on a common, flat hayrack mounted on a low-wheeled wagon. A number of satisfactory silage cutters are on the market. The one used should be strongly made and so designed that the knives can be changed and adjusted quickly and easily. Common faults in the operation of cutters are dull knives, rounded shear plates, too much clearance between the knives and the shear plate, worn fan plates, and improperly adjusted fan-wheel housing. The cutter should be run at the speed and in the manner recommended by the manufacturer; high speeds are hazardous.

Cutting meadow crops: In handling meadow crops for silage, they should be cut at a stage when the forage has a high content of protein and carotene and when the yield of total digestible nutrients per acre is high. This stage corresponds closely with that recommended for early-cut hay from the various crops.

Hay and pasture crops and those sown in drills or broadcast are usually cut with a mower, raked into windrows with either a side-delivery or dump rake, and then loaded on the wagons by hand or with a hay loader. Green crops often are not handled satisfactorily with the ordinary farm machinery. The rakes pass over much of the material, and the loader fails to pick the windrows up clean. Hay loaders must be built for heavy duty. The use of a windrower attachment on the cutter bar of the mower saves the labor of raking and also lessens the chances of stones being elevated onto the wagon or truck along with the green material.

Machines which will pick the hay crop up out of the windrow, and field chop and blow it into the trucks or trailers, are coming into common use. Such machines may be individually owned by large operators, or, for small farms, they may be owned by rings of farmers who trade work, or custom machinery may be available. When not owned, however, the machine may not always be available when needed. The same machine can be used for field chopping corn or hay crops for silage, and for harvesting field-cured hay, or that to be dehydrated or barn-dried. Some machines will mow and field-chop hay crops in one operation.

Optimum moisture content: The moisture content of the crop at the time of ensiling is the most important factor in determining the character of the silage fermentation, the extent and character...
of the losses through seepage and fermentation, and the quality of the silage produced. An excessively high moisture content leads to large losses of liquid. Too little (under 60 percent) may result in molding and spoiling of the silage, especially if the sealing is insufficient or compaction inadequate.

When crops are ensiled with a moisture content of more than 70 percent, fermentation takes place at a rapid rate, there is considerable seepage from the silo, and losses of most feed nutrients, except carotene, are large. If no treatment other than chopping is given, the type of fermentation produced at this high-moisture level will be desirable and the silage will be of good quality, provided the crop ensiled consists principally or entirely of grasses or cereals that are cut after heading out and that contain a medium or low amount of protein. On the other hand, the type of fermentation will be undesirable and the silage will be of poor quality and have a strong, offensive odor if the ensiled crop consists principally or entirely of legumes or of grasses and cereals that are cut before heading out and that have a high protein content. These high-moisture high-protein crops, therefore, require some additional treatment. 

Cutter-set to use: Except for short and very immature crops put up under special conditions, it is necessary to chop the crop as it is ensiled. The length of cut to use will depend upon the moisture content at which the crop is ensiled. If the moisture content is 70 percent or more, the cutter should be set for a ½- to ¾-inch theoretical cut. (The actual average length of cut will be much longer than this because many of the crop stems go through the cutter crosswise). Crops with a high moisture content will pack well with this comparatively long cut and are less likely to clog up the blower pipe than when a shorter cut is used. 

Crops which are overripe or wilted when ensiled, with less than 70 percent moisture, will not pack satisfactorily in an upright silo when a long cut is used. The use of the shortest cutter set available (¼ to ½ inch) is recommended under such conditions to improve the packing of the silage and lessen the danger of molding and spoilage.”

During the silo filling, the cutter knives should be kept sharp. Knives should be changed just as soon as they fail to cut clean and begin to shred the material. The cutter bar against which the cutter knives operate should be changed or turned before its edge becomes rounded enough to allow for shredding rather than cutting. 

Packing the silage: The material should be well distributed in the silo. Many years of experience with corn show that tramping can be entirely dispensed with so far as the quality of the silage is concerned, but a silo filled rapidly without tramping does not hold quite so much. If the corn is put into the silo at the proper stage of development, distributing the silage is unnecessary for perfect preservation. If the corn is rather dry, a distributor should be used, otherwise the lighter leaves, tassels and stalks will be blown to the outside wall and the heavier corn, cobs and stalks will fall in the center or on the near side of the silo. With grassland silage, it is important that the silage be well distributed and tramped near the wall. This is especially important when the crop is slightly wilted. Of various contrivances used for distributing the cut material, a metal pipe put together loosely in sections is commonly recommended. 

The cut forage from the blower passes down the pipe into the silo, and the pipe being flexible, can be swung so as to place the material anywhere in the silo. With this contrivance, handling the material with a fork is unnecessary and one man can easily do the work of two. 

One of the products of silage formation is carbon dioxide. This gas is heavier than air and for this reason tends to displace the air in the silo above the surface of the silage. If there are no doors or other openings near the top surface of the silage to permit the carbon dioxide to flow off, it may collect on top of the silage. As this gas will not support respiration, a person entering the silo may be overcome from lack of oxygen. Before
THE MAKING OF SILAGE

Going into a partly filled silo early in the morning during silo-filling operations, it is best to run the blower for a few minutes.

Satisfactory results will be obtained only if the silo has smooth, airtight walls and tight doors. The silo should be well reinforced so that it will withstand high silage pressures. It should be provided with an adequate drain so that any excess moisture in the silage can drain off easily and quickly.

In filling the silo with corn, the most mature corn should be put in first and the greenest corn reserved for the top of the silo to provide weight and pressure. If the corn put in at the top is too dry, the last several loads should be wet with a hose, preferably as the corn is blown into the silo.

With meadow crops, only heavy, unwilted crops should be used for the last few loads so that enough weight and pressure will be provided to force the air out and keep it out. No conditioner will be needed in this top layer, even if the crop is high in protein, because the material at the top warms up sufficiently to prevent undesirable fermentations and naturally makes a mild, palatable silage.

When the silo is filled during a long dry spell or with a wilted crop, the filling should be done rapidly and with a fine cut in order to hold silo temperatures down to a desirable level. Spoilage is likely to occur on the surface of the ensiled material if more than 2 days elapse between filling periods. When such an interval occurs, the top of the material should be kept tramped thoroughly in the meantime and any spoiled silage removed before filling is resumed. Where one crop only partly fills the silo and another crop is put in some time later, the silage should be tramped, sealed and weighted down between fillings to keep silage temperatures and losses as low as possible.

After the silo is filled, the top should be thoroughly tramped once daily for 2 or 3 days, and then tramped tightly against the wall twice a week until the silage has completely settled.

The rate at which the silo is filled affects the rapidity with which the air is eliminated from the silo and, consequently, the temperature which the ensiled mass attains. If the silo is tight and is properly filled and sealed, the temperature will seldom exceed 100°F, except at the top, and may sometimes not exceed 90°F. If the ensiled material is high in moisture, or if the weather is cool, silo temperatures will be lower than when the crop is wilted or the weather is warm. When the silo is filled with a high-moisture crop, particularly in cool, moist weather, there may be an advantage in filling at a slow or moderate rate; that will allow the ensiled material to warm up slightly. That procedure also will help to prevent an undesirable type of fermentation.

Protecting top of silage in silo: In tower silos all kinds of silage tend to shrink away from the walls at the top. This admits air, and if unchecked, will lead to considerable spoilage. If the silage has been properly packed when put into the silo, this spoilage can be lessened by keeping the silage tramped tightly against the wall while the silage is settling. Unless some such precautions are taken, it will be found after a few months that the spoilage has extended down the sides 1 or 5 feet, or even more, with the loss of several tons of valuable feed.

It is a present practice to use a covering of a layer of corn from which the ears were removed before chopping. This chopped material consisting of the heavy green stalks, packs better and excludes the air more effectively than straw, even if chopped and wetted. Chopped weeds or other green materials of little or no feeding value are sometimes used.

Top losses can be reduced also by covering the top of the ensiled material with a heavy, reinforced, waterproof paper which is lapped 10 to 12 inches at the seams and against the wall, and covered with enough wet crop or wet sawdust to keep it packed tight against the wall and against the silage below. If the silage is to be stored for some time, more material should be placed on top of the paper than if the silo is to be opened soon.
The most effective and modern device for protecting the top of the silage in a tower silo from loss by spoilage is to use a special silage cap manufactured of plastic material for this purpose. Such caps are available in four sizes for use in tower silos from 10 to 16 feet in diameter. The cover consists of an impervious water and air-proof blanket which is held in place at the wall of the silo by a water-filled rubber tube which encircles the surface holding the blanket tightly against the wall and in close contact with the silage. These caps are said to save up to 3 tons of silage in a 10-foot silo at each filling and to pay for themselves usually in 2 years, in addition to the convenience and ease of handling and the almost absolute assurance of protection of surface from loss by spoilage.

**Filling trench silos:** Trench silos can be filled economically. A blower is not needed although it speeds up the operation by using less labor to distribute the chopped material evenly. In small trenches the silage should always be kept level and thoroughly tramped or packed during filling operations. Packing can be done by driving animals or some machine back and forth through the silo as the filling progresses. In completing the filling of these silos, the crop should be piled high enough so that it will be above ground level after settling, with an arch to the top. The surface should be covered immediately with a thin layer of freshly cut crop or weeds, which in turn should be covered with 6 to 12 inches or more of earth. Or, the surface can be sealed with heavy fiber-reinforced waterproof paper. If paper is used, the joints should be lapped about 12 inches and the paper weighted with enough earth to give a good seal.

If the silo is filled too rapidly and the forage is not packed sufficiently while filling, the forage may settle below ground level within a few days after filling has been completed. This would permit surface water to enter and produce a strong-smelling, unpalatable silage.

When the ground-water level is high, a modified shallow-trench type of stack silo can be used. The stack should be built up above the ground level with the sides of the chopped material straight and even with the edge of the trench. The stack can be built 4 to 6 feet above the ground level at the sides, and 8 feet at the center. When stacking is completed, the top should be well arched and covered with weedy material or reinforced paper and weighted down with 12 to 18 inches of earth to provide weight for packing and sealing. As the stack settles, earth should also be placed along the sides and ends to provide a seal.

**Labor and other costs of putting up grass and legume silage:** The cost of putting up meadow crop silage will vary with the size of the operation, the efficiency with which machinery is used, and what equipment is at hand.

If a farmer ensiles several cuttings of forage crops, including pasture clippings, he will make much more silage with the same machines than a farmer who fills silos only once or twice a season. The machinery cost therefore will be lower. Labor can be saved by using a field chopper and a silage blower for filling operations.

A tractor mower with a windrow attachment offers a way to cut labor and equipment requirements. On light crops, a side-delivery rake can be used to throw two or more swaths or windrows together; loading operations are thus speeded up and labor and equipment requirements are reduced.

Studies on the cost of making grass silage at the New Jersey Dairy Research Farm show that the lowest cost per ton of silage is closely associated with high yield per acre and high tonnage per day. These costs are also lowest for the greatest mechanization. Since labor costs have gone up proportionately more than machinery since 1940, the efficient use of machines is a major factor in keeping down the costs of silage. Work at the Agricultural Research Center at Beltsville shows that more feed value per acre can be obtained from forage crops with only slightly more labor and with about
the same equipment requirements when the crop is preserved as silage as when it is preserved as hay.

Removal of silage from silo: The silage in tower silos should be removed in even layers and the entire top should be kept level with a beveled dip at the edge, to prevent, so far as possible, the freezing of the silage to the wall. Any spoiled material or frozen silage found around the wall should be removed every day or two rather than allowed to remain, as removal of only the good silage from the middle exposes the silage around the wall more fully and further increases the spoilage. The aim should be to expose as little of the silage as possible and to feed it rapidly enough to prevent heating and spoiling.

Trench silos are emptied by removing the silage in vertical slices or sections from the end of the silage. In many cases the truck or wagon is backed into the trench for easy loading and the silage is hauled to bunks for feeding. When the quantity to be removed daily is small, or the silage is to be fed in a barn which the truck or wagon cannot enter, it may be more convenient to use a wheelbarrow, cart, or a litter carrier.

COMPOSITION AND NUTRITIVE VALUE

The chemical composition and the nutritive value of silage vary according to the crop put into the silo, the stage of growth of the crop, and other factors. In general, the composition is similar to that of the green crop from which the silage is made. Present information shows that there are no consistent or significant differences in the digestible nutrients of the dry matter of a crop, whether the crop is in the green state or whether it is made into silage, hay or fodder. See accompanying table.

Silages vary tremendously in their content of moisture, and their value cannot well be estimated without taking the moisture into consideration. The quantity of nutrients depends directly upon the content of dry matter by weight. For example, if a silage made from any certain crop contains, say, 40 percent by weight more dry matter than another sil-

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### Composition and digestible nutrients of certain forages—green, as silage, and dried.

<table>
<thead>
<tr>
<th>Forage crop</th>
<th>Moisture</th>
<th>Ash</th>
<th>Crude protein</th>
<th>Crude fiber</th>
<th>Nitrogen-free extract</th>
<th>Digestible crude protein in the forage</th>
<th>Total digestible nutrients in the forage</th>
<th>Total digestible nutrients in the dry matter</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alfalfa, in bloom, green</td>
<td>77.2</td>
<td>1.5</td>
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<td>0.6</td>
<td>7.8</td>
<td>9.4</td>
<td>2.4</td>
<td>12.9</td>
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<td>6.7</td>
<td>1.0</td>
<td>8.8</td>
<td>12.9</td>
<td>4.0</td>
<td>16.8</td>
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<tr>
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<td>8.0</td>
<td>1.4</td>
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<td>20.3</td>
<td>37.5</td>
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<td>Red clover, in bloom, green</td>
<td>70.8</td>
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<tr>
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<td>4.8</td>
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<td>22.3</td>
<td>46.6</td>
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<td>1.0</td>
<td>5.9</td>
<td>12.7</td>
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<td>1.8</td>
<td>1.0</td>
<td>6.9</td>
<td>14.4</td>
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<tr>
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<td>6.0</td>
<td>6.8</td>
<td>2.4</td>
<td>26.0</td>
<td>46.7</td>
<td>3.3</td>
<td>50.0</td>
</tr>
</tbody>
</table>

1 Compiled in the Division of Animal Nutrition, Bureau of Animal Industry.
age made from the same crop, then the digestible nutrient content will likewise be approximately 40 percent greater. One hundred tons of silage containing 25 percent dry matter may be no more valuable than 70 tons containing 35 percent dry matter. The relative feeding values of good silage and good hay made from the same crop can be estimated by comparing the amounts of dry matter contained. A high quality of hay containing 90 percent dry matter is worth approximately 3 times as much as the same weight of silage containing 30 percent dry matter.

Legume silage, if properly made, has a composition that indicates a feeding value of the dry matter comparable to the feed value of the dry matter in the green crop from which it is made. In this respect, silage and top quality hay from identical crops compare favorably with each other on a dry basis. Feeding experiments point to the same conclusion. There is still some question, however, as to how well livestock will thrive on legume silage alone. It will be better to feed some dry material, as hay or stover, along with the high-moisture legume silage, particularly since certain experiments indicate that a ration of medium-to-high-moisture legume silage is improved by the addition of either dry hay or corn silage.

CHANGES THAT TAKE PLACE IN THE SILAGE

Plant respiration—formation of carbon dioxide: The transformation of green crops into silage is brought about by the changes that take place when the green forage is stored in a silo or in any other space or enclosure in the absence of air. Plant respiration, enzymes present in plant cells, and bacteria, yeasts, and molds present on the crop when it is ensiled all may take part in this change. After the crop is ensiled, plant respiration continues until the oxygen present in the air and trapped in the forage is used up, leaving carbon dioxide and nitrogen. The respiration is accompanied by a rise in the temperature of the forage, the extent of the rise depending in part upon the amount of oxygen present.

Enzymatic action: Enzymes are also active during this time. They break down sugars into alcohol, carbonic acid, water, and acetic, lactic, and butyric acids. Enzymes also act on proteins to some extent, forming amino acids, peptides, and some ammonia.

As plant respiration and the activity of the plant enzymes slow down, the activities of the bacteria, yeasts and molds increase. Molds cease growing as soon as the air is exhausted, yeasts soon disappear, and only the bacteria remain alive thereafter. Bacteria produce additional acid from soluble carbohydrates and from alcohol, and are responsible for further breakdown products from the other constituents of silage, notably protein. They are responsible for most of the losses of dry matter and feeding constituents that occur during fermentation and storage. When the acidity of the silage increases, bacterial action diminishes, and the silage-making process proceeds toward completion.

Factors affecting chemical changes in silos: Wide variations have been found in the type of fermentation, the kinds of acids produced, the nature and extent of the losses occurring during fermentation, and the quality of the silage. Many investigators have learned that the types of fermentation and the qualities of the silages produced can be modified by suitable methods of silage making.

Among the factors influencing the type of fermentation and quality of silage produced are the stage of development and chemical composition of the crop, the ratio of soluble carbohydrates to the protein content, the percentage of moisture when stored, the rapidity and completeness with which air is excluded from the silo, and temperatures of chopped crop going into the silo.

Crops with a low content of protein and calcium, such as corn, sorghums, and small cereal grains, will develop enough acid to make good silage when ensiled alone or with not more than an equal weight of legumes. The addition of lactic acid cultures or the acid itself, or any material from which acids are formed, is
THE MAKING OF SILAGE

of no apparent value in making silage from these crops, and wilting to reduce the content of moisture is generally not practicable when all things are considered.

Crops with a high content of protein and calcium, such as the legumes and immature grasses, should be wilted slightly or should have dry, chopped hay, ground grains, or molasses added. Grasses that are harvested at the usual hay-making stage will need no special treatment, provided they are not wet with dew or rain. If they are wet, it would be safer either to add molasses, or to let the excess moisture evaporate.

Spoilage: The only actual spoilage that cannot be avoided in the silo is that which occurs at the top of the silage. In a silo 14 feet in diameter this spoilage will amount to about \( \frac{1}{2} \) to 2 tons three months after filling. With trench silos, even this spoilage is sometimes avoided. Tight sides and careful sealing around the doors of tower silos should prevent any other spoilage.

The losses through fermentation may be considerable or almost negligible, depending largely upon the effectiveness with which the air has been forced out and thereafter excluded. Over a 3-to-6-month storage period, one may reasonably expect a total loss (through spoilage and fermentation) of not less than 10 percent of the dry matter. There is evidence that the losses in summer exceed those in winter, also, that silage stored for long periods loses more dry matter than silage stored for short periods. It appears that there is no particular difference in the effectiveness with which various crops are preserved in the silo, provided proper methods have been followed in making the silage.

FEEDING SILAGE TO LIVESTOCK

The subject of feeding silage, as with all other feeding problems, is too complex and extensive for comprehensive treatment here. Only brief mention of its uses as feeds for the several kinds of livestock will be given. The reader is referred to farmers' bulletins 578, “Making and Utilization of Silage” and 1626, “Feeding Dairy Cows,” and to Morrison’s “Feeds and Feeding” (NY-30) for more extended treatment of the subject.

Silage for dairy cattle: Silage has been found to be particularly well adapted as a feed for dairy cows, and in consequence silos are more numerous on farms devoted to dairying than on any other kind of farms. In many sections, silage has come to be the dairy farmer’s main reliance for winter roughage. Dairy cows may be fed as little as 2 to 3 pounds of silage per 100 pounds liveweight, along with considerable hay; or they may be fed double that quantity with a small quantity of hay. This may be corn or sorghum silage, grass silage, or a combination of both kinds of silage.

One of the most difficult seasons of the year for dairy cows is the latter part of summer and early fall. At this season the pastures are often short or dried up. It is a common mistake of dairymen to let their cows decline in milk flow because of the shortage of feed. Later in the fall, it is impossible to restore the milk flow, no matter how well the cows are fed. On good dairy farms the milk flow of the cows is maintained at as high a level as possible, from calving to drying off. It becomes necessary, therefore, to supply some feed in addition to pasture grass, and usually the easiest way is to feed silage, which may be cheaper and more convenient than soiling crops.

Silages sometimes affect the flavor and odor of milk. The effect may be somewhat more pronounced with some silages than with others. All silages should, therefore, be fed during or after, rather than before milking. In case the silage has a rank odor, it is important that the milking barn be relatively free of these odors at milking time in order to avoid having them absorbed by the milk.

Silage for beef cattle: Beef cattle are perhaps capable of making a greater utilization of coarse roughages than most other kinds of domestic animals. Yet cattle frequently eat only the leaves and fine stems of many mature forages. In the case of some varieties of soybeans and of corn fodder made from rather mature
plants, the percentage of refused feed may vary from 25 to 50 percent. When such forages are made into silage at the right stage and fed to cattle, there will be very little waste, provided the silage is of good quality. Silage made of sorghum, sorghull, or corn from a given acreage will feed fully twice as many cattle as the fodder produced from a similar area.

Silage for beef cattle has its greatest use in wintering rations for breeding herds, feeders, and stockers. As much as 40 pounds of silage with straw and small quantities of protein concentrates are fed daily to beef cows carrying or nursing calves. For dry cows not with calf, it is a common practice to feed about 25 pounds of silage with unlimited straw or stover and a small quantity of protein concentrate.

Steers 2 years old or over, or other mature beef cattle, may be wintered almost exclusively on good quality silage with a small quantity of dry roughage such as straw or stover. Younger cattle which have to be grown out require some protein which may be supplied either in the form of a concentrate of as a legume hay, or legume-grass silage as base ration.

Silage is used in fattening rations most extensively in those areas where the supply of legume hay is more or less limited. Silage is usually used with straw, grass hay, grain, and a protein-rich meal in fattening rations rather than in those having legume hay. The requirements as regards protein, carbohydrates, minerals and vitamins for fattening cattle are somewhat different from those for cattle on maintenance and growing rations. More net energy is required in the case of the fattening animal. Hence, feeds are included which contain relatively high percentages of readily digestible starch, sugar, and fat. The use of such feeds makes it possible for the animals to store the surplus of nutrients in the form of increased muscular tissue and deposits of fat. The more rapid the resulting gains in weight, the smaller the proportion of the feed used for maintenance and the greater reduction in the cost of gains.

Silage for sheep: The use of silage in the winter ration of the flock is increasing. Heretofore, many sheepmen have been prejudiced against the use of silage, claiming that it caused abortion and losses of breeding stock. It has been proved by different experiment stations in tests with both breeding and feeder lambs that good silage is an economical as well as valuable part of the ration. Where moldy or decomposed silage is fed, losses may occur, but judicious feeding of good-quality silage improves the health and vitality of the flock.

No cheaper or better roughage can be fed the breeding flock than good grass or 
grass-legume silage, which furnishes the succulence so necessary for the maintenance of the health and vitality of the ewes.

A good quality of silage is very palatable and quantities ranging from 1 to 5 pounds per head have been fed in different feeding trials with good results. The quantity to be fed depends on the class of sheep and the character of the other feeds comprising the ration. As a rule, however, not more than 4 pounds of silage per head per day should be fed, and some hay always should be in the ration.

In fattening lambs, corn silage not only takes the place of part of the hay and grain but may reduce the cost of gains. In wintering ewe lambs, corn silage should form an important part of the ration, and when fed in conjunction with a good legume, it not only keeps the lambs in good condition, but furnishes a good growing ration.

Silage for horses and mules: Silage is not generally used in horse and mule feeding, but it is a safe feed for either if it is of good quality and is carefully fed.

Both horses and mules are peculiarly susceptible to the effects of molds, and under certain conditions varieties of molds are found in silage which are deadly poison to both of these classes of stock. If the feeder watches the silage carefully as the weather becomes warm, he can soon detect the presence of mold. When mold appears, the feeding should be stopped immediately. Similarly, care should be exercised in the winter feeding of silage so that horses or mules are not allowed
to eat frozen silage, because of the danger of colic.

Silage should not be considered as the principal roughage for horses and mules, but should serve as a partial substitute for hay in the ration. Because of its bulky nature, horses and mules doing hard work should not be fed large quantities, but, owing to its tonic, laxative, and appetizing value, it is well suited for the maintenance of idle horses and mules, brood mares, and growing stock. The value of silage is greatest in the case of horses and mules as a means to carry them through the winter cheaply or to supplement pasture during periods of drought.

Grass and legume silage for poultry: The value of green feed for poultry has long been recognized. It is only in comparatively recent years, however, that any special emphasis has been given to the use of grass and legume silage as feed for poultry. Payne and Gish (Kan-24) in their studies of grass and alfalfa silage for poultry have shown that such silage can replace green pasture and dried green forage at seasons of the year when the latter are unobtainable. The losses in nutrients in oat and alfalfa silages stored for one year were small. Straight-sided metal barrels holding 350 to 400 pounds of chopped green material were found to be convenient and practical containers for poultry silage.

Allen et al (Tenn-3) state that "when poultry are fed, in addition to a basic ration, a green succulent legume silage made from red clover, alfalfa, or sericea, and have become accustomed to its diet, they show the following advantages of silage feeding: (1) Greater zest in eating and more feed eaten per day; (2) Increase in weight over poultry not receiving such silage; and (3) Better physical condition, as determined by appearance, vitality, weight production, egg production, and post-mortem examination."

Before undertaking the feeding of silage to poultry, feeders of poultry should study carefully the methods followed and the kinds of supplementary feeds in experiments conducted in recent years, and compare the results obtained from the different methods and combinations.

SILAGE HIGHLIGHTS

1. The silo is a means of conserving quantities of forage that might otherwise be lost. Silage can be made under conditions unfavorable for the curing of dry fodder and hay, saving a larger percentage of leaves, green color, and total nutrients for feeding.

2. Silage has greater palatability, a higher carotene content, and is less wasteful in feeding than any other form of forage preserved on the farm. It occupies an important place in livestock feeding in the United States, particularly the feeding of dairy cattle. Between 40 and 50 million tons of silage are put up annually.

3. A variety of forage crops can be made into nutritious silage. Until recently, about 90 percent of all the silage produced was made from corn, about 8 percent from the sorghums, and less than 2 percent from small grains or hay crops. The percentage of silage now made from hay and pasture crops may be 10 percent or more, and the rate is gradually increasing.

4. Silage is made in permanent and temporary tower silos, and in trench and pit silos. Trench and pit silos are common in the South, Southwest, and Great Plains, and tower silos in the North and Northeast. Tower silos are made of wood, steel, concrete, and tile; temporary types of paper-lined or wood slat fencing. Trench and pit silos are sometimes lined with concrete, but are often unlined. All silos should be well constructed on well drained land, and should have bottom drains that work.

5. Silo capacity on the farm should be related to the production or availability of crops, and the potential utilization of silage by feeding. Such factors as the number of animals to be fed, quantity fed per day, weight of silage per cubic foot, and the number of days in the feeding period should all be considered.

6. Corn is the principal silage crop in the important corn producing sections of the United States. It is a carbohydrate crop, low in proteins and minerals. Yields range from 5 to 20 tons, averaging about 7 tons. Corn is usually harvested for silage about 10 days before it would be cut green to shock or no later than when 90
percent of the kernels are dented, and 75 percent are hardened so that milk cannot be squeezed out.

7. Sorghums are used for silage principally in the South and Southwest where they often outyield corn. All varieties are suitable for silage. Sorghums are usually cut for silage when the seed is in the dough stage.

8. High-yielding legume and grass hay and pasture crops are important silage crops in the North and Northeast. Legumes, or a combination of legumes and grasses make a better silage than grasses ensiled alone. These crops are higher in protein, carotene and minerals than corn or the sorghums. They produce the best silage when cut at, or slightly before, the best stage for hay. This stage is usually after heads emerge, but before bloom for grasses, and during early bloom for legumes.

9. Silage will keep almost indefinitely without molding or rotting, providing it is properly packed in the silo so that the oxygen is quickly used by fermentation and no more air gains access to it. Acids develop in silage during fermentation, the kinds produced affecting flavor and palatability.

10. The quality of the silage produced and losses occurring during storage are affected by the moisture content of the crop when it is ensiled. The quality will be best, the silage will be the most palatable and nutritious, and the losses during storage will be the lowest when the crop is ensiled with a moisture content above 60 percent but not exceeding 70 percent. In silage properly stored, packed and sealed, the loss of dry matter over a 3- to 6-month storage period may not exceed 10 percent; if this is improperly done, losses may be much higher.

11. Non-legume crops such as corn, sorghums, or the grasses cut after heading out, ensiled either alone or with an equal part or less of legumes, will produce enough of the right kind of acids to make good silage. Legume crops and immature grasses which are high in protein and low in fermentable carbohydrates should be wilted or have acid, molasses or ground dry grains added as a conditioner. Fine cutting, firm packing, and a moisture content of not more than 68 percent moisture are the requisites for the production of good wilted silage from high protein legumes and immature grasses.

12. The making of silage from a crop does not increase its inherent palatability or feeding value. The composition of silage is usually similar to that of the crop from which silage is made. The quantity of nutrients depends upon the content of dry matter. Forage that is palatable and nutritious when put in the silo will be the same when taken out. Forage which is unpalatable and low in nutritive value when ensiled will not be improved in these respects by ensiling.

THIS CHAPTER

Much of the material in this chapter was taken from Woodward et al (US-294), and Shepherd et al (US-239). The manuscript was reviewed by Shepherd of the U.S.D.A. and C. F. Rogers of the Ohio Agr. Exp. Sta., and their many valuable suggestions have been incorporated in the final text.

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The reference numbers given here refer to references which are given in full by State, U.S.D.A., and Miscellaneous, on pages 682 to 724, and which are cross-referenced by author on pages 725 to 731. Citations in the text are indicated by abbreviation and number in parentheses.
Chapter VIII

IMPROVING OUR FORAGE AND PASTURE CROPS

The ultimate objective of a forage improvement program is to produce superior varieties of each important grass and legume species that will enable the farmers to feed their livestock more adequately and more economically. Effective breeding investigations have been in progress with many other farm and garden crops for more than half a century. The remarkable improvements that have been attained stand as irrefutable evidence of the benefits of plant breeding to agriculture. Primarily because of lack of appreciation of their importance in the farm enterprise, most of the pasture and hay crops were, until recent times, largely neglected in the United States from the standpoint of development of improved types. Consequently with the exception of alfalfa, soybeans, red clover, and timothy, there are few domestic varieties of the forage species. Work at plant breeding stations in Europe, Canada, Australia, and New Zealand has resulted in improved varieties, useful in the countries in which developed. Although these varieties are, in general, not especially adapted in the United States, they serve as valuable sources of superior germ plasm and as a guide in evaluating the benefits that may result from a plant breeding program.

Most of the early research with forage plants in the United States was directed chiefly at problems of management and the correction of soil deficiencies through the application of fertilizers in various combinations and quantities at different seasons of the year. Today, with no diminution of interest in problems associated with soil fertility and management, which will always constitute vital parts of pasture improvement programs, the scope of research is extending rapidly to other fields of perhaps equal importance. It is in this connection that plant breeding has come into the program, and for the first time, plant breeders are undertaking the improvement of pasture plants with an intensity of interest approximating that which has led to notable accomplishment in the improvement of other crop plants.

The experiment stations in many of the States now have a well developed program of forage plant improvement underway. The U.S. Department of Agriculture is taking a leading part in the coordination of this program. The pasture research laboratory which has been set up at State College, Pennsylvania, with a well-trained group of research workers with specialists in plant genetics, cytology, biochemistry, and physiology to direct the work in attacking the fundamental problems, is taking a lead in the development of methods of research. The results of this research, conducted in cooperation with the State agricultural experiment stations are already being felt in a better understanding of the problems and in the development of improved varieties, not only in the Northeastern Region but in other parts of the United States.

In one respect the improvement of forage plants is much easier than the improvement of many other crops. One has an abundance of material to work with. There are numerous species of the two families of plants, grasses and legumes, which produce nearly all of our forage, and some of these are native to almost any part of the globe where conditions are comparable to the conditions in the
part of the United States in which we wish to grow the improved varieties.

The naturally adapted varieties also are likely to incorporate many of the characteristics that are desired in an improved variety. It is then left to the plant breeder to make the best possible use of this adaptation to climate and soil and these desirable characteristics in the development of greater forage and seed production, better forage quality, disease-resistance, and other qualities desired. In spite of the natural adaptation inherent in many varieties, the requirement of adaptation is still one of our foremost problems in forage crop improvement.

The success of a breeding program in helping solve forage problems is contingent upon several factors, namely, (1) ability of the plant breeder to evaluate plants and strains of the species so that superior types may be recognized and selected; (2) a knowledge of the cytogenetic behavior of the species and of the inheritance of important characters desired in a new variety; (3) the need for improvement of the important forage species by correcting in existing varieties of the species, weaknesses that hamper their usefulness in a forage program; and (4) existence in the species or in closely related species of characters desired in an improved variety.

Some of the problems beyond the field of strictly biological research fall into two major categories: (1) Those pertaining to seed supply and distribution, and (2) those pertaining to seed demand and consumption. Both categories are important, and both are of special concern to seed growers and crop improvement associations.

SOURCES OF PLANT MATERIALS

Original introductions: Up to recent years, our early-introduced species of both grasses and legumes furnished by far the larger part of our basic material for selection and improvement work in the development of new strains for a large portion of the United States. Such grasses as timothy, orchardgrass, bromegrass, and Kentucky bluegrass, and such legumes as alfalfa, red clover, lespedeza, sweetclover, vetches and soybeans, are among those utilized, and these species and other early introductions are still considered most valuable in the possible development of new strains.

Recent introductions: Some of the plants which have come into the forage crop limelight in more recent years are not necessarily very recent introductions but have come to have their real potential forage value recognized, perhaps over a larger area than formerly. Among such are sweetclover, smooth brome, Ladino clover, and birdsfoot trefoil. The writer was experimenting with birdsfoot trefoil and mixtures of various percentages of smooth brome and alfalfa in South Dakota more than 45 years ago, but it is only in comparatively recent years that these have been given favorable recognition.

Some of the more recent introductions are several grasses and legumes especially adapted to the southeastern States. Among these are the lupines, hairy indigo, the lovegrasses, and the zoysias.

With the many years of exploration into all regions of the world for new plants since before the beginning of the century, one might conclude that further exploration would not be fruitful, but such is not the case. New species of both grasses and legumes are coming to light continually, and occasionally a new strain of an old crop developed in a foreign country proves by test to be of value in the United States.

Existing varieties: The improvements that have been made in existing strains and varieties naturally furnish the best foundation for further improvement of forage plants, especially in such factors as greater forage and seed production, better quality and nutritive value of forage, leafiness, etc. Such characteristics as adaptation to climate and soil, winter-hardiness, and drought resistance, might be expected to be somewhat slowly acquired and rather difficult to introduce into strains, unless rather definitely present in one or more of the parents through a long process of adaptation brought about through elimination of unadapted strains or individuals.

Probably many more improved strains
have been produced by selection from existing naturally adapted or improved strains, or from a recombination of traits in such strains, than from any other source. Possibly one of the other fruitful sources of improvement of existing varieties in the future is the introduction into such varieties of new germ plasm of the same old variety or species from definitely foreign and unrelated or distantly related sources. Little of this has been done as yet.

The improvement of existing varieties through a study of their cytogenetic relationships and recombinations made in accord with the results of such studies, is probably one of the most promising fields of research in forage crop improvement at the present time. However, at present, the most practical improvement is not highly dependent on cytogenetics. Other aspects, as methods of varietal synthesis, testing systems, adaptability to cultural systems, and objectives, are of current promise and interest.

Native species: Because of the early introduction from Europe of such grasses as timothy, orchardgrass, Kentucky bluegrass, redtop, and the ryegrasses, all of which are, to a considerable extent, adapted to some portion or an of the northeastern quarter of the United States which was first developed by the new settlers, little attention was given to the use and improvement of native grasses and they were looked upon as of little consequence. It was not until the development of the subhumid and semiarid regions of the Great Plains forced plant breeders to consider the native species, because of the lack of adapted species from abroad, that any real attention was given to the use and improvement of native plants for forage or other agricultural use.

The search for new grasses then began on the prairies where the plants have survived centuries of drought, cold, fire, flood, insects, diseases, and heavy grazing; the American prairies are large, and combinations of soil, rain, wind, temperature, elevation, and seasons have produced many species of grass and a variety of strains of each one. Among the native species there is a wealth of good material. Up to 1930, only slender wheatgrass had been domesticated from North American grasslands, but since that time other species have come into use among which are western wheatgrass, buffalograss, the blue-stems, the graminas, wild-rye, switchgrass, and others of lesser importance. Practically no native legumes so far have lent themselves to cultural adaptation in the United States.

TESTING AND EVALUATING FORAGE PLANTS

The problems related to the testing and evaluation of forage plants, whether such plants are newly introduced species or newly developed strains, or varieties of well-known species already in cultivation, are much more acute than with most crops. One of the most perplexing problems with respect to grass and legume improvement, is to devise methods of testing new source material and new strains that may be developed therefrom. The principal reason for this difficulty is that the manner of utilization of grasses and legumes for forage may take a wide variety of forms and may vary over a wide range of conditions entirely apart from their non-forage uses for soil improvement, erosion control, and other turf uses. Class of livestock, type of management, use as pasture, use and preservation as harvested forage in the form of hay or silage, duration of the forage crop, seed production problems, and other factors all play important parts.

It is axiomatic in plant breeding that the most effective means of testing is one that simulates as nearly as possible conditions of actual use. Forage plants are grown in combination; hence, it seems essential to evaluate plants and strains of a particular species when grown in combination with another species with which it normally will be used. When this is done, the problem of interpreting results is complicated by all of the ecological factors inherent in the association of different plant species.

It is commonly known by plant breeders that varieties, to be of maximum use-
fulness, must be adapted to the specific conditions where they will be used. Variations in photoperiod, summer and winter temperatures, and other climatic and soil factors may preclude the use of a single variety of each species for an entire region. Varieties developed in one place are more likely to be adapted to that area and less likely to be adapted elsewhere. Thus it is necessary to evaluate varieties in the areas in which they are to be used and it is desirable, if possible, to conduct the breeding program in the locality in which the varieties will be used.

In a number of cases, introduced plants have been discarded or given little recognition as a result of a casual test because of a failure to recognize any desirable potentialities in such introductions. Later, these same introductions might develop great possibilities either in the form in which they were introduced or as parents of improved varieties. Such a lack of immediate recognition might be because of an inadequate trial, or because of a lack of adaptation to the new environment which had to be corrected by special methods to bring out the true merit of the species in its new home.

All factors associated with plant growth (including soil type and fertility, climate, latitude, management, and variety) are known to be active in determining adaptation. But it is not enough to test one strain or a few strains of a species. Such a lack of immediate recognition might be because of an inadequate trial, or because of a lack of adaptation to the new environment which had to be corrected by special methods to bring out the true merit of the species in its new home.

Extensive testing of strains is thus a forerunner and also a contemporary procedure of more complex breeding techniques.

Because most forage plants are biennial or perennial they cannot be evaluated in the year of sowing, the complete growth cycle required for comparisons in many cases being considerably longer than that for some other important farm crops. For example, at least three years would be needed to obtain information concerning bromegrass, timothy, alfalfa, or white clover comparable to that obtained from wheat or soybeans in one year of culture. Investigations have shown that there may be comparatively little relationship between the behavior of plants spaced in nurseries and similar plants grown together in a mass sowing typical of field conditions. In other instances, good agreement has been noted. This has caused breeders some concern as it is impossible to work with individual plants—the important breeding unit—on a mass-seeded basis. Fortunately, clonal row or mass-planting tests of selected plants may be made and a part of the difficulty avoided. A reasonably accurate evaluation of yield and other character traits often may be obtained by estimation.

The time actually required for adequate testing of an introduced species and its subsequent incorporation into use is often unaccountably long. Crested wheatgrass, for instance, was introduced into the United States from Russia in 1898 and was grown at several Northern Great Plains experiment stations in 1899. A second introduction was made in 1906 and the grass was again sown at several stations. The first favorable record of performance was made in 1909 and others followed, but the crop received little attention until the mid-1920's. Even so, the cultivation of crested wheatgrass in the United States preceded similar use in some parts of the Old World where it is native. Perhaps we are in a similar situation with reference to some of our own native species.

Though smooth bromegrass was introduced into the United States in the latter part of the last century and was in common use in the Eastern Great Plains in the early 1900's, its real value in a large part of the Corn Belt, where it is a very important hay and pasture plant, was not recognized until some twenty or more years later.

Breeders are concerned at present largely with the isolation of better plants and with possible methods of combining these plants into strains that will have superior value when compared with older types.
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In selecting plants for this purpose, the principal problem is one of determining the relative merits of a selected individual as a parent in transmitting desirable characteristics to its progeny. Various systems of testing this ability have been developed. Plants may be crossed in pairs and the progenies studied subsequently. Groups of selected plants may be allowed to intercross freely under field conditions and the progenies of each plant compared with the progenies of other plants. This type of evaluation has been referred to as polycross testing.

Occasionally in highly self-sterile species, individuals with a high degree of self-fertility may be isolated. Other things being equal, these would be desirable since inbreeding could be conducted more readily with them. If, however, relative diversity and vigor are desired in the eventual plant group which is to become a new strain, it is generally believed that a relatively high degree of self-sterility and, therefore, cross-pollination, should be present. This is thought to favor increased vigor. Other plants may be found that are male-sterile; in that case, cross-pollination is mandatory, and there is a tendency toward increased diversity in the progenies.

In the past most of the evaluation of source material had to be done by the "trial and error" method. Some of the more recently acquired knowledge of the principles of heredity and the development of new breeding techniques have shortened the time and effort required in evaluating both original material and newly developed strains.

SOME OBJECTIVES IN FORAGE CROP IMPROVEMENT

Need for improvement of our forage crops by breeding is emphasized by the fact that although many grass and legume species appear to be adapted for use in the several regions of the United States, most of them have several defects which detract from their usefulness in a forage program. Timothy is probably the most widely used hay grass, and for this purpose in the Northeast it is generally well adapted. It is not suitable for a pasture-hay program, however, because of its failure to recover following the hay cut and because of its inability to persist under grazing. Furthermore, timothy is susceptible to foliage diseases, particularly rust and leaf spots, that cause losses in yield and quality of hay.

Although bromegrass is an important hay plant in the Northcentral States and through much of the Corn Belt, its usefulness in the pasture-hay program of the Northeastern Region is limited by several factors. Bromegrass in combination with suitable legumes produces high yields of good quality hay, but frequently lodging makes harvesting difficult and tends to smother the legume. Furthermore, the more productive types of bromegrass may be so aggressive and have such a growth habit that certain legumes are crowded out and the stand becomes "sod bound." For use in the pasture-hay program, another major weakness of bromegrass is its fairly slow recovery following mowing or grazing in midsummer. In addition, several diseases take considerable toll of yield and quality in bromegrass. Difficulty has been encountered in obtaining satisfactory stands, due in part at least to a lack of sufficient seedling vigor.

One of the grasses best adapted for use as pasture and grass silage or hay, at least in the southern part of the region, is orchardgrass. This species grows fairly well as a hay crop, yet it persists under relatively severe grazing. Recovery following mowing or grazing is rapid and growth during midsummer is good, making orchardgrass particularly suited to combinations for grazing during midsummer after harvesting a late spring crop for hay or silage.

Despite the good qualities of orchardgrass, it has several serious defects. Domestic types mature too early for use with alfalfa, and often too early for good hay drying weather, produce a light hay crop that is low in quality because of lack of leafiness, and are susceptible to various types of leaf spots that further reduce yield, quality, and palatability. Later maturing, leafier varieties have been developed, particularly at the Welsh Plant
Breeding Station and in Sweden, but these varieties when grown in the North­
eastern Region start growth late in the spring, produce relatively low yields of
hay, and are subject to hazards of winter
injury.

The introduction of Ladino clover was
an important contribution to solution of
the forage problem particularly in the use
of short leys for hay, silage, and pasture.
When it was first introduced, some for­
age specialists were of the opinion that
Ladino clover was completely satisfactory
and, hence, not in need of improvement
by breeding. Subsequent experience has
revealed several weaknesses, particularly
susceptibility to certain diseases and in­
sects, lack of drought tolerance, tendency
to winterkill when in pure stands, and
under some conditions, lack of persistence
in grass mixture.

Alfalfa is probably the most important
forage legume in the United States, but
its present usefulness in some parts is
restricted because of certain limitations.
One of these is lack of wilt resistant varie­
ties adapted to soil and climatic conditions
of certain regions. Varieties available at
present are seriously damaged by a com­
p lex of leaf diseases and by leafhoppers.
For use in a pasture-hay program, alfalfa
is intolerant of frequent defoliation and
hence does not persist under heavy graz­
ing.

Similar shortcomings could be listed
for each of the other important forage
species. The benefits to the agriculture
of any region to be expected from new
varieties which correct one or more of
the weaknesses of existing varieties in such
region are great.

Stated in general terms, the character­
istics to be sought in new varieties are:
(1) higher yield and better distribution
of yield throughout the growing season,
(2) stability of production from year to
year, (3) adaptability to various systems
of management and use for which the
species is desired, (4) ability to grow satis­
factorily in association with other grasses
and legumes, (5) ease of harvesting and
management, and (6) high nutritive
value.

Some of the qualities desired in forage
plants for special purposes and special
conditions are (1) winter-hardiness, (2)
frost resistance, (3) tolerance and produc­
tive capacity with unusually small or
large total or seasonal water supply, (4)
tolerance and productive capacity under
relatively high acid or alkali soil condi­
tions, and (5) adaptation to high summer
temperatures, short or long days, high
and low humidity, etc.

High yield: High yield, particularly when
uniformly distributed throughout the
growing season, is one of the prime re­
quirements of a new variety. Evidence
already accumulated indicates that, al­
though it will probably be impossible to
breed a variety that is as productive
during midsummer as in the spring, con­
siderable improvement can be made.

The ability to recover quickly after
cutting is usually associated with the
possibility of cutting more than one crop
of hay in a season or the growth of after­
math for grazing up to the time when the
crop should be allowed to grow and
develop root reserves sufficient for win­
ter survival and maximum early spring
growth. There are few or none of the
northern grasses that produce more than
one crop of hay in one season, but there
are many legumes which produce two
or more crops. Alfalfa in the northern
States with sufficient moisture produces
two crops, while in the Southwest under
irrigation, it will produce up to seven full
crops, the number depending upon vari­
ety, water supply, and length of growing
season.

Stability of production from year to
year and throughout a season with pas­
ture plants may be more important to
the individual farmers than is total pro­
duction itself. Much can be done in
stabilizing production by the develop­
ment of varieties resistant to drought,
winter injury, diseases, and insect pests.

In order to obtain maximum produc­
tivity and usefulness of a species, it will
be necessary to develop varieties specifi­
cally adapted for various uses. Thus, it
is unlikely that the same variety of
orchardgrass will be superior both for
combination with Ladino clover and with
alfalfa. Varieties of bromegrass and of
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alfalfa that are best for hay production may not be the best for use under grazing conditions.

**High quality of forage:** The forage produced by a new variety must be nutritious. In addition to increasing the amounts of digestible nutrients, vitamins, and minerals in particular varieties, the plant breeder can make real improvement by adjusting the time of maturing. It is well known that variations in nutritive value are greater in the same plant at different periods of growth than between different plants. Hence a variety that will reach the ideal stage of growth for pasturing or for hay at the proper time is desirable.

The most important part of a forage plant which is associated with forage quality is the leaf. The proportion of leaves to stems and the retention of leaves in harvested forage are real measures of forage quality. These are important with both grasses and legumes, but particularly with legumes. Leaves contain most of the protein, vitamins and minerals, and the total quantities of each of these produced by the plant is measured largely by the percentage of leaves to stems. The importance of leaves in considering the nutritive value of any forage cannot be stressed too highly. Steminess in hay is always an indicator of low nutritive value. Leafiness is an inherent trait but may also be controlled in large measure by management.

**Adaptation to environment:** It is axiomatic that profitable forage crop production can only be obtained with crops adapted to the environment in which they are grown and to the purpose for which they are to be used. This does not mean necessarily an environment conducive to maximum longevity with a crop for a short rotation, or maximum all-season pasture production when either spring or fall pasture only is desired. It covers all those things which relate to variations of climate where the crop is grown, the soil in which grown, and all combinations of these, which are many and varied. It is sometimes desirable to have a wide adaptation because of the greater availability and facilities for handling and distributing seed supplies for all uses and conditions. Where practicable, however, with most crops maximum production for a special set of conditions will be obtained with a narrower or special adaptation for these conditions.

Because of the wide range of variation in factors affecting plant behavior from continent to continent and from one locality to another, some breeders have come to rely primarily on improvement by utilization of old, local types. These presumably are well adjusted and best capable of economical production by virtue of their continued existence following competitive growth for long periods under the particular environment. Insofar as the conditions represent those typical of the proposed area of use, there is much to be said for this viewpoint.

However, this adaptation, brought about by the natural elimination of plants not adapted to the climate and soil of the region, and of those that are poor seed producers, is only the starting point in the improvement of any species. Large production of high quality forage, rapid growth, quick recovery after cutting, and uniformity of development do not necessarily develop under natural growing conditions but require artificial selection. Having plants naturally adapted to both climate and soil to start with, however, makes improvement much easier and more rapid.

Latitude which determines length of day has come to be considered an important factor of adaptation with many of our forage crops. To what extent length of day is a factor by itself is not always easy to determine, since latitude also has an effect on temperature and possibly other factors. Studies with corn, orchardgrass, timothy, and some of the grasses of the Great Plains, have shown a definite length-of-day influence. The term "northern grown" has been overworked with many crops. Where winter hardiness is a very important consideration in any crop such as alfalfa and some other legumes, a northern locality of production of commercial seed of un-
known or indefinite variety or known genetic identity is important. With some of the native grasses of the Great Plains, tests have shown more favorable results from seed grown 200 to 300 miles south of the place of sowing than that grown more than half the distance north. **Winter survival:** Hardiness is an important problem with certain grasses and legumes. Significant differences among strains of a number of forage crops with respect to winter injury have been found. Strains of some warm-temperature species show inherited differences in ability to survive low winter temperatures. Southern strains may be more susceptible to cold in both the seedling and later stages. Orchardgrass and meadow fescue have been insufficiently hardy in breeding trials in the Northern States. As early as 1910 it was noted that the orchardgrass could withstand winter cold but that it was injured by late spring frosts. In the South, Rhodesgrass has suffered from winter injury.

One of the crops on which much research has been conducted to obtain hardiness is alfalfa. In order that seed of a satisfactory hardness may be obtained, the United States has been divided into Northern, Central, and Southern zones, and seed from the different zones is verified by State of origin. It is recommended that commercial alfalfa seed be sown, if possible, in the zone where produced. However, it is thought that seed of a definite variety, if kept free from either genetic or mechanical mixtures, can be safely reproduced, at least for a few generations in almost any locality and under almost any soil and climatic conditions without changing its genetic composition. This same principle probably holds true with all species.

**Extreme soil tolerance:** Species are known to vary in their adaptation to extreme soil conditions. Reed canarygrass and alsike clover will thrive on soils that are too wet for most other forage plants, western wheatgrass and birdsfoot trefoil on soils containing a higher concentration of alkali and salts, and big trefoil and redtop on soils with a relatively high acidity. Differences also exist within a species as, for example, strains of Kentucky bluegrass have been found to vary in their reaction to soils of different fertility levels.

**Summer growth:** One of the very difficult problems in most parts of the United States is to find ways of extending pasture growth through the summer months. Kentucky bluegrass at Columbia, Missouri, when supplied with adequate moisture, produced relatively high yields of herbage during spring and early summer at soil temperatures ranging from 50° to 70° F. but yields declined at 80°. This suggests the possibility of finding strains of Kentucky bluegrass and other grasses of similar temperature inhibitions that will continue to grow during the high summer temperatures.

On the other hand, such warm-season grasses as Bermuda-grass, the gramas and carpetgrass, and such legumes as the annual lespedezas, will produce forage at higher temperatures, and when adapted will help to tide over the difficult summer period.

**Sod-forming ability:** Ability to produce sod is often a major object. Creeping strains usually develop superior turf and serve as better protection to trampling, weed encroachment, and soil losses. In many species of both grasses and legumes, variations in type sufficient to change greatly the top and root proportions are known.

Efforts are made with certain crops to develop the creeping habit in varieties to be used especially for pasture and soil stabilization. The assumption that low creeping varieties of grasses and legumes are best adapted for pasture use is not always borne out in practice with some forage crops. Sod-forming species and varieties, however, are likely to resist trampling of livestock better than those that do not form a close, tough sod. Sod formation and an extensive root system are desirable to reduce soil erosion.

**Aggressiveness:** An unusual degree of vigor and aggressiveness is often desirable in a forage plant, especially when a combination of forage yield and erosion control is desired in the same variety or
species. Occasionally, however, a species may be so aggressive that crop rotation may be difficult—a principal fault of quackgrass, Johnsongrass, and often of smooth brome, under especially favorable conditions for spreading. A vigorously creeping grass strain may be too highly competitive for its legume partner, as, for example, bromegrass growing with alfalfa or more particularly with other legumes less vigorous than alfalfa, such as Ladino clover and red clover. Some of the bunch grasses, like orchard and tall fescue, under certain conditions are also found to be too aggressive for best results with certain desirable pasture legumes unless special management is given to protect the legume.

Seedling vigor: Some species and strains are slow in becoming established because of poor seedling vigor and subsequent slow early growth. With bromegrass this exhibits itself as a slowness in developing a strong plant early in the first season. With birdsfoot trefoil, the plants do not become well established for two or three years from seed. Under favorable conditions, there is no lack of seedling vigor in most of the legumes commonly cultivated, since this is an important characteristic in bringing about their general cultivation. However, one of the characteristics of alfalfa is that it requires a good seed bed free from aggressive competition for best establishment.

Seedling vigor is especially important in the renovation of pastures, resowing range lands, and in other situations where clean seed beds are impossible or undesirable.

Root development: Notable differences have been observed in the ability of strains to develop roots. This may be related to conservation value. The biennial white and yellow sweetclovers develop a strong root system which fixes large supplies of nitrogen, while Hubam, an annual variety, has relatively a much smaller percentage of roots to stem and leaf, which characteristic makes the biennials much better soil-improving plants if the above-ground parts are removed by grazing or cutting before plowing under.

Common alfalfa is noted for its long tap root, which accounts for its ability to draw water supplies from a great depth, and the depletion of subsoil water supplies from fields where alfalfa has been grown for a number of years. There is considerable difference in type of root development in true common alfalfa and some of the hybrids of common and yellow-flowered alfalfa, the varieties of hybrid origin or variegated alfalfas often showing a tendency to develop more fibrous roots near the surface and a less well developed tap root. This greater development of fibrous roots near the surface in some variegated alfalfas has been given as a reason for the great winter hardiness of variegated alfalfas, but this may not be an entirely adequate explanation. Alfalfas with a more extensive branched root system may also be more responsive to moderate seasonal rainfall than those with prominent tap roots and few fibrous roots, while the latter may be entirely satisfactory under irrigation.

The development of fibrous or branched rooted alfalfas in the areas of moderate rainfall, where irrigation is not practiced and where winter survival is an important factor, has been suggested as not having been given the attention it deserves in evaluating strains for these conditions. However, there is but little information on this subject.

Uniformity: Uniformity in form and structure which is highly desirable in many fiber, grain and food crops, may be less important in the forage species. It is, however, extremely desirable with all forage crops to have uniformity in certain valuable traits which are related to forage production and feed value, such as total quantity of leaves in proportion to stems, chemical composition of forage, resistance to disease, and season of maximum forage value as well as of seed maturity.

Maintenance of a highly variable variety becomes a problem for it may be more subject to change because of the operation of soil, climate, and management on the plant population. It has been suggested that strains might best be maintained, so far as possible, in a
highly uniform or pure condition. Subsequently, they may be utilized in whatever blends are desired with similar or different strains or species.

**Disease-resistance:** Good health in grasses and legumes is another virtue. In a survey of diseases and host plants in the northern part of the Great Plains and in the Western States, 221 kinds of parasitic fungi were recorded for approximately 500 kinds of grasses. As early as 1906, stem rust was reported to have destroyed some selected strains of timothy at Arlington, Virginia; other strains showed relative resistance. Losses in bluegrass due to stripe smut have been estimated at 3 to 50 percent annually in one Northeastern State. Work at the Georgia Coastal Plain Experiment Station has shown that significant differences may be obtained in Dallisgrass in resistance to anthracnose and ergot. Work of the Pasture Laboratory in Pennsylvania has indicated that snow mold of orchardgrass, stripe smut of Kentucky bluegrass, leaf spot of orchardgrass, and crown rust of meadow fescue may do serious damage and that differences in plant reaction to the disease organisms may be found.

With legumes, the disease problem has been even more serious because all of our forage legumes are attacked by one or more diseases. A large part of the breeding programs with alfalfa and red clover in the central and northeastern States has been centered on developing wilt-resistant strains of alfalfa and strains of red clover resistant to northern and southern species of anthracnose. Fortunately, these efforts have met with some success in the development of Ranger and Buffalo alfalfas and Kennel red clover. Diseases, such as the bacterial wilt of lespedeza, leaf spots, rusts, powdery mildew, stem and root rots, mosaic, and other virus diseases, all supply problems for the plant breeder to keep him occupied for some time to come.

And one unfortunate aspect is that when one disease appears to have been conquered by the development of a variety resistant to that disease, another disease which may not have been known, or which previously may have appeared to be of minor importance, is likely to step in and create an entirely new problem with that variety. It is impossible to say at the present time how far plant breeders and pathologists can go in creating general disease resistance in any single variety covering all or many kinds of diseases. However, theoretically at least, this result may be accomplished over a period of time by combining in one variety the specific resistances to the different plant diseases that have been developed separately through the plant-breeding technique.

**Insect resistance:** Comparatively little information is available about the insect resistance of special strains of grasses and legumes, but variation in reactions of strains has been noted. Harshness of tissues has been found to be related to resistance to chinch bugs in certain species native to the Great Plains. In the blue gramas, important differences in the reaction of strains to grasshopper injury may occur. Variations in the resistance of Bermuda-grass strains to root-knot nematode also have been noted. Pubescent red clover has been shown to be more resistant to leafhoppers.

**Good seed habits:** Native grasses of the United States produce very little seed. Problems of revegetation will be greatly simplified if strains of adapted grasses can be developed that will produce viable seed more abundantly than those now available, as in the case of the gramas, buffalograss, big and little bluestem, and other native species in the Great Plains. Dallisgrass is a promising grass for the Southeast but seed is always attacked by ergot. Attempts to produce ergot-free seed in the Southeast by breeding and selection have not met with much success. The possibility of producing ergot-free seed in the southwestern States is being explored.

The utilization of some species such as birdsfoot trefoil, Ladino clover, tall oatgrass, reed canarygrass, meadow foxtail, Canada wildrye, and other forage crops, is greatly discouraged by their relatively poor seed habits in one or more
respects. In birdsfoot trefoil and tall oatgrass, shattering may occur. In bluestem, for example, seeds may be light, fluffy, and densely pubescent. In some of the native prairie grasses, long, sharp awns make sowing difficult so these must be removed before sowing. In Ladino clover the number of flower heads is much smaller than with common white clover and this results in low seed yields. Variations exist in ability of certain strains of some forage crops to produce seed well under different conditions. Other factors being satisfactory, a high yield of good quality seed is desirable. This, however, may not always be accomplished through the development of potentially good seed-producing varieties since so many environmental factors often have more to do with seed yields than breeding, as is the case with alfalfa, red clover, and other small seeded legumes. Environmental factors may be so limiting that little seed is produced by any variety. With suitable environment, breeding for high seed production is successful.

There is a great variation in yields of seed among the different varieties of a single species. Since most grasses and legumes have to depend on seed for increase, it is important in making selections to work for high seed production, so long as it can be obtained without sacrificing unduly either quantity or quality of forage production. It is often difficult, if not impossible, to combine both maximum forage and maximum seed production in the same variety.

With some forage plants the type of seed production practiced commercially may have much to do with the eventual nature of a particular variety. Commercial seed production from one generation to another may tend to favor the types that produce seed most abundantly, and, while the species characteristics remain relatively constant, types that are inclined to produce less seed and more vegetative growth may be proportionately reduced and gradually eliminated. Thus, if improved forage varieties are developed, it would appear desirable to see that subsequent propagation by seed does not cause them to drift away from their original improved forage characteristics. However, there are no records of this happening with any improved varieties or strains of forage crops.

METHODS AND PROCEDURES

The growth habits of forage plants, their particular characteristics, their reproductive processes, the conditions under which they grow and are productive, their relationships with one another, and the procedures and facilities available to the plant breeder, are all involved in the improvement of forage crops by selection and breeding. These may all be considered under methods and procedures.

It is obvious that a forage breeding program that will help substantially in meeting the needs of agriculture in the United States as a whole must be developed both intensively and extensively. More information is required regarding the hereditary behavior of the individual plants involved, not only of the characteristics such as yield, leafiness, and disease resistance, but also of characteristics that are concerned with the various ecological relations—climatic, edaphic, and biologic. A forage plant grows in a fixed location, usually in association with other plants, and in pastures must withstand grazing and trampling. Another major problem involves plant evaluation. The process of passing plant breeding material through successive cycles to screen out and synthesize the desired forms involves great detail and is time consuming. This is particularly true in breeding a pasture plant because there are so many factors to consider. Further information is needed that will enable one to detect valuable germplasm earlier in the breeding program.

Laws of heredity: Without some knowledge of the laws of heredity, every plant breeder would be working in the dark by the "trial and error" method. He would have no basis for knowing the probable outcome and he might work years with few or no tangible results of his labor. The works of Darwin, Weis-
mann, De Vries, Mendel and others have been of great assistance. It was left, however, to the rediscovery of the work of Mendel in 1900 to put plant and animal breeding on a really scientific basis. His basic work on inheritance of specific characters, our knowledge of which subject has been greatly enlarged since then, has been the foundation, ever since 1900, of all plant-breeding work.

Mendel did a simple but revolutionary thing that apparently had not occurred to previous workers who had been trying to solve the secrets of inheritance. He carefully sorted the progeny of his parent plants according to their characters and counted the number that had inherited each character. By doing this, he discovered that when the things he was studying were handed on by the parents, they were distributed among the offspring in definite mathematical ratios, and in no case was there a significant variation from these ratios. For the first time, Mendel established definite laws of inheritance.

The above-mentioned men were pioneers in this field. Their work was important and served as a foundation, but relatively much more of practical use has been learned since then and we are still probing for the solution of many of our plant-breeding problems.

Mass selection: The simplest form of plant breeding applied to variable strains is called mass selection. It consists of choosing from a large number of plants those that possess desired characteristics. The selected plants or their progenies are then allowed to cross-pollinate among themselves as a means of concentrating these characteristics.

Unfortunately, plants arising by cross-pollination and reproducing by the same process frequently are not capable of transmitting to their progenies the characteristics that they themselves possess. Thus mass selection may be a rather slow and relatively inefficient method of concentrating desirable characteristics in a strain and, in fact, may not achieve a very high degree of concentration even when applied to several successive generations. Nevertheless, because mass selection is easy and sometimes yields outstanding results, it usually is made use of in early phases of a breeding program with cross-pollinated species.

Some form of mass selection is the process used so extensively by nature, and, under natural conditions, this has been effective in producing the many strains that characterize every widely distributed species. Most of the forage grasses as they exist today are the products of mass selection in nature.

Breeders of forage crops are becoming increasingly interested in the controlled hybridization of selected plants. It is a refinement of mass selection. Each selected plant is crossed with every other selected plant. By this means a considerable number of distinct progenies are obtained rather than a single progeny of restricted but indefinite parentage.

The behavior of the separate progenies indicates which combinations are superior. The parent plants may then be vegetatively increased to provide larger quantities of seed. The method offers great possibilities, but preliminary experience indicates that it should be undertaken on a rather large scale in order to increase the chances of obtaining superior combinations. No strains of range-forage grasses produced by this method have as yet reached the stage where seed is available for widespread testing.

In the earlier years of breeding forage plants, along with mass selection, considerable interest and effort were expended on cross-pollinated species in the production of selfed lines. This no doubt stemmed from the remarkable accomplishments of the corn breeders in producing hybrid corn by the recombination of inbreds. It is too early to say that the use of selfed lines for producing hybrids will not be an effective method of breeding grass, but interest in the method has lessened, and more direct methods are being pursued. It may still prove to be useful in fixing special characteristics such as disease resistance.

Most grass species are pollinated with wind-borne pollen and most legumes by pollen borne by insects. Consequently,
they are usually cross-fertilized. Many annual species of grasses, however, and some legumes, are self-pollinated. The plants that are normally self-pollinated generally produce progenies of relative uniformity, with marked resemblance between parent and progeny. In such species, strains may be separated immediately and then usually are expected to come true from seed. A number of types of such grasses may be present and usually can be selected in an old field of any self-pollinated species, but wide differences among selected strains may be found. Such selections may be perpetuated indefinitely from seed or they may be used in hybrid combinations with a fair idea of what may be expected in the hybrid.

In many perennial grasses and legumes where cross-pollination occurs, it is difficult to develop highly uniform strains without repeated selection. It is of interest to note, however, that strains of meadow fescue, timothy, and red fescue have been obtained from mass selection and subsequent propagation of superior individual plants. Some of these strains have possessed a considerable degree of uniformity. At present, however, grass varietal improvement in such open-pollinated species usually is based upon the combination of a number of desirable plants, this varying from a few to many. Natural selection in open-pollinated species is quite comparable in results, though probably not as rapid as artificial mass selection where a large number of acceptable types are propagated as improved bulk strains.

With species that are ordinarily cross-pollinated, the genetic composition of each plant is not known and cannot easily and quickly be determined. It is only by controlled progeny testing or through the polycross nursery technique that the ability of a selection to perpetuate certain desirable traits can be measured. Some progress has been made in the past by mass selection and progeny testing of open-pollinated species with and without control of pollination, but much more rapid progress is expected through the use of the polycross and other special nursery techniques.

The polycross has come to be looked upon as something new and magical. It is, in fact, only a type of progeny test very closely comparable to the top-cross test so widely used in corn. The polycross is merely a technique which makes the application of the top-cross test feasible in forage plants where full control of pollinations on a large scale is impossible.

Vegetative propagation: Most grass species, particularly the perennials, are readily propagated (clonally) from surface runners (stolons), underground stems (rhizomes), or cuttings made from portions of aerial shoots or crowns. An advantage is that an individual plant may be increased into a clone made up of any number of plants vegetatively propagated from the original selected plant, as is commonly done with many horticultural varieties of flowers and fruits, to perpetuate all the individual characteristics of the original plant. An increase of this kind is of particular value for special purposes, as with varieties of creeping bentgrasses used for golf greens, or with other species where vegetative propagation can be economically practiced. Some of the best strains of bentgrass, buffalograss, and Bermuda-grass are vegetatively propagated commercially. Stolon nursery beds for vegetative increase of desirable varieties of bentgrass are maintained by golf courses and commercial concerns.

Vegetative propagation is also possible with many legumes.

It is obvious that where vegetative propagation of improved types can be used, a much more uniform plot or field can be produced, and one doesn't have to wait to carry on individual plant selections over a number of generations to increase the genetic purity of the selected type, as would ordinarily have to be done if the increase were to be made by seed. Because of the large acreages used for forage crops, it is also obvious that vegetative propagation must have a rather limited application to restricted acreages, where the expense of establish-
ment is either a minor initial item of expense or where it can be spread over a large number of years.

For use, however, in the production of hybrid and synthetic varieties, in cross-pollinated, long-lived species of forage crops, vegetative propagation has a definitely useful place. The production of such varieties on a commercial scale might not be possible of accomplishment with open-pollinated forage crops except through the use of vegetative propagation.

Inbreeding: Because inbreeding tends to increase the resemblance between parent and progeny behavior, selection among inbred plants is relatively more effective than selection among open-pollinated individuals. As in corn, the inbreeding process, especially in species naturally cross-pollinated, also tends to result in a reduction in vigor and fertility, and progenies in earlier generations are often quite variable. Odd and weak plant types may appear. During the inbreeding period, it is desirable that selection be made for plants which possess most nearly the desired agronomic characteristics. Breeding trials may then be used to determine relative abilities of the selected plants to transmit good qualities to the offspring. It should not be assumed that all inbred strains, even with the greatest of care in selecting for desirable traits, necessarily represent the best combination of such traits or can transmit them effectively when combined with other inbreds. Many combinations have to be tried to obtain the maximum possible improvement in the resulting hybrid.

Hybrid origin: Much of the earlier hit-or-miss work on plant breeding (e.g. the work of Luther Burbank and others) prior to and since our knowledge of some of the laws of heredity, was based on hybridizing between varieties or species to create new combinations in the hope of developing something better than existed at the time. This procedure occupied a place of importance along with mass selection or individual plant selection and progeny testing. Following the creation of an initial hybrid, several or many generations of selections were made to “purify” the type or to get a strain that more nearly perpetuated the desired characteristics.

A similar procedure is often followed at the present time, except that it is done along more intelligent lines, i.e., the plant breeder through a knowledge of cytogenetic relationships of the species or variety in question, and of the known laws of heredity, knows better what to expect of any combination, can act accordingly in handling the progeny, and can make more rapid progress in arriving at the desired goal.

Many of our existing varieties today are the product of either natural or artificial hybridization. Even though the actual facts relating to the parentage and the creation of such hybrids may not in many cases be known historically, they can often be determined by cytogenetic studies and by a recreation of the variety of hybrid origin from original material. In view of the use of the term “hybrid” today as applied to hybrid vigor (e.g. hybrid corn), there is a question whether its use should be permitted as applied to varieties of hybrid origin only.

Hybrid vigor: It would perhaps be out of place here to discuss the possible explanations of hybrid vigor and the extent of its occurrence, but its use should be considered as distinct from “hybrid origin.” The most outstanding illustration of hybrid vigor today is hybrid corn. Though perhaps not so nearly “made-to-order,” in this respect so far as utilization is concerned, as in the different types of corn, a number of forage plants are amenable to the application of hybrid vigor, and it is probable that it will be used with them to a considerable extent in the future. Under “Improvement of Alfalfa” elsewhere in this chapter, the application of hybrid vigor to alfalfa is discussed.

Polycross nursery technique: In connection with the improvement of alfalfa, a method was devised for determining the combining efficiency, i.e., the ability of any one plant or clone to combine with other plants or clones and project its desirable traits into the cross, without
incurred the work of making hand pollinations and the many individual tests. This method is known as the polycross method. It is being used extensively with alfalfa.

Strain building: Atwood (NY-4) in his chapter on “Cytogenetics and Breeding of Forage Crops” in Advances in Genetics (1947) describes strain building as follows: “A method which comprises some of the features of both inbreeding and mass selection is known as strain building. It consists of selecting individuals, which conform to certain standards, and subsequently combining the chosen plants in a composite strain. The method has been employed for many years in Great Britain, particularly at Aberystwyth, where one of the most extensive breeding work with forage crops has been done, but it has found wide acceptance elsewhere, especially in Canada.

“The term strain building was defined by Jenkin to include a range of procedures from mass selection through relatively complicated progeny testing, but Kirk limited its usage to any system of mating by which a strain is built up by the crossing of carefully selected plants. The use of the term was limited even more by Stevenson, and in this form it has received its widest acceptance. It is considered as a modified method of mass selection, which, in addition to selection on the basis of type or of a certain physiological response to a particular environment, provides for thorough exploration of the genetic constitution of the provisionally selected plants and a final selection of parents on the basis of their breeding behavior. The aim is to maintain vigor by incorporating into the strain a reasonably large number of genotypes, while at the same time approaching homozygosity with respect to the genetic factors governing the particular characters which formed the basis of selecting the parent plants. Strain building allows for progressive improvement through the uncovering of superior parent plants from time to time, and the use of these new exceptional plants, possibly in place of others, in reconstituting the strain. An essential feature is the preservation, for all time, of the parent plants, which are used as stock in each additional increase. In many respects the process of selecting rigidly the type on the basis of progeny tests is the same as the approach used successfully by many livestock breeders.”

Cytogenetics: The more recent studies in cytogenetics are revolutionizing much of our work in plant breeding, but the application of this newer knowledge is not such as to be easily grasped or understood by the layman. Therefore, only a few comments will be made here to indicate the significance of cytogenetics in crop improvement.

‘To get a technical picture of the progress made in the application of cytogenetics to forage crops, one should read Atwood’s “Cytogenetics and Breeding of Forage Crops” (NY-4), and Myers’ “Cytogenetics of Forage Grasses” (US-182) from which most of the following notes are made:

With the existing knowledge of cytogenetics, it has been considered impossible to create new genes or units of inheritance, but this now is said to have been done. Practically, however, the plant breeder is limited in his quest for superior varieties to reshuffling existing genes of the same species or of closely related species into new, desirable combinations. Thus, improvement in a species is limited to the heredity variation that exists.

As is usually the case in plant material that has not been subjected to breeding, the desirable characteristics are scattered more or less at random among plants and strains of each of the forage species. Rarely are plants found occurring naturally that combine all, or even several, of the desired qualities. Plant breeding procedures are available, however, that will enable the breeder to recombine into a single strain the superior characteristics of two or more strains. By continuing this process step by step, there can be produced eventually varieties combining most or all of the desired characteristics.

This process of recombination of genes may be accomplished expeditiously only if the plant breeder is acquainted with the known laws of heredity and is
thoroughly familiar with the cytogenetic behavior of the species. Hence, extensive fundamental studies of chromosomal behavior, cytogenetic constitution, and inheritance, are essential for each of the important forage species if most effective progress is to be made in the breeding program.

Cytogenetical investigations of the grass and legume families have been initiated primarily for two reasons: (a) to serve as an adjunct to morphological data in studies of their systematic classification and evolutionary history, and (b) to provide fundamental information for the improvement of species by breeding.

One of the most important bodies within the cell is the chromosome which serves as a carrier for the genes or units of inheritance. Chromosome numbers have been recorded for 805 species in 142 genera of grasses, exclusive of species of Triticum, Aegilops, Secale, Avena, and Zea. In more than half of the species, the chromosome numbers are multiples of 7. Multiples of 5 (or 10), 6 (or 12), 8, 9, 11, 13, and 17 occur also.

Among the forage legumes, the number of chromosomes occurring most frequently are multiples of 6, 7 and 8. The numbers reported for the forage species of several genera are as follows: Glycine, 38 and 40; Lathyrus, 14; Lotus, 12 and 14; Lupinus, 40 to 50; Medicago, 16 for most non-forage species, and bur-clover, and black medic, but 32 for all three species of alfalfa (M. sativa, M. falcata, and M. media); Melilotus, 16; Phaseolus, 22; Pisum 14; Trifolium, 14 and 16; and Vicia, 12 and 14 (US-161 and 200).

Among both grasses and legumes, variations in basic number of chromosomes occur among genera within tribes, among species within some genera, and in some cases, within species. Variations in chromosome size have been reported among major groups, among genera and species, and among plants of the same species. Differences in size, shape and other characteristics occur among individual chromosomes of many species of grasses and legumes. All of these variations are considered significant in connection with plant breeding for crop improvement.

More than 200 interspecific and intergeneric hybrids have been reported in the forage grasses. An estimate of the number in forage legumes would probably be lower than this, and perhaps much lower. These can be better understood, and where desirable to recreate natural hybrids, this can be done better through an intimate knowledge of cytogenetics. The intelligent use of the science of cytogenetics in crop improvement has only just begun, and its use in the future presents many opportunities to the plant breeder.

Apomixis: A number of grasses, among which are some of the bluegrasses, are characterized by a method of reproduction known as apomixis, which offers the breeder certain opportunities for breeding work not ordinarily available.

Apomixis is reproduction without the union of gametes (sexual reproduction cells) so that apomictic progenies are genetically identical to the parent plants. The condition in species of bluegrass that makes apomixis of greatest interest to plant breeders is that it is accompanied by a variable degree of genetic reproduction. Sexual reproduction thus produces a wide range of genetic variation, and the desired types, if they are apomitic, can be perpetuated indefinitely in that manner. Certain important range-forage plants reproduce by apomixis. One of them is Tucson, an apomictic strain of side-oats grama which appears to be well adapted to the Southern Great Plains where its behavior is being studied.

ESTABLISHING IMPROVED VARIETIES

Problems to be solved: The development of improved strains and varieties of forage plants, though most essential as the initial step, will never alone solve the problem of increasing the use of superior varieties on American farms on a scale commensurate with their value. At the meeting of the International Crop Improvement Association in Chicago in
November 1938, P. V. Cardon outlined some of the problems confronting agencies dealing with forage crops. He said in part: "The problems entailed in forage crop improvement, however, will never be fully solved by research alone. Many of these problems lie beyond the province of research agencies. Some of them clearly are functions of agricultural extension agencies, others of State boards of agriculture, or of the seed growers or the seed trade, or of some other agency. If we are to improve forage crops, we must have seed supplies and be in a position to distribute them. But seed supplies will not move and distribution will therefore fail unless the demand for those seed supplies will consume them. Failure in the past fully to consider problems of demand as well as problems of supply has, in my opinion, been conducive to ineffectiveness in forage crop improvement."

Some simple form of positive identification of variety of seeds indistinguishable in appearance is necessary if the trueness of variety is to be maintained through production, processing, and distribution, if such seeds are to move freely and plentifully in commerce and become established in general culture. With forage seeds which have been produced and distributed in the past very largely by kind of seed and not by improved variety, this necessitates a complete change in production and distribution procedure.

Compared with corn and the small grains, and some other crops, relatively few new varieties of forage crops have been developed, and until recently, little has been done to distribute such new varieties and establish them in general culture. Because of several inherent factors the progress in obtaining large acreages and quantities of new varieties of forage crop seeds will likely always be slower than with grains, oilseeds, and fiber crops.

Some of the questions raised by Cardon relate to the procedures to be followed, (1) in multiplying such improved stocks and making them available commercially in regions where they are adapted, (2) in preserving the intrinsic values of superior strains while in the process of increase and distribution, (3) in obtaining accuracy in nomenclature and avoiding or minimizing the confusion in names and numbers likely to be used, (4) in demonstrating to the farmer-consumer the relative values of improved and unimproved strains or varieties and making such demonstrations effective, and last, but not least, (5) in actually getting seed supplies of improved strains and varieties produced and distributed in commercial quantities in a dependable manner in the areas where they are best adapted and most needed, whether such areas are nearby, or thousands of miles from the localities of seed production.

Not all of the above questions can be answered now, but all of them will be solved in the course of time. They are all being studied, and some of them are being solved by the seed certification program of the International Crop Improvement Association and the State crop improvement associations, in cooperation with State agricultural experiment stations and the United States Department of Agriculture.

Crop improvement associations: The first State associations organized to make effective the research work of agricultural colleges and experiment stations were started some thirty-five or more years ago. The International Crop Improvement Association, however, was not formed until 1918. Its purpose was to coordinate the work of the State associations and bring about greater uniformity in procedures and standards in seed production of improved varieties. The principal result of these unified efforts in conjunction with the United States Department of Agriculture has been the developing and perfecting of a seed certification program.

State Seed Certification

The principal objective of seed certification is to maintain and make available seed of improved crop varieties. These varieties that are superior because of their germplasm may have been in use many years, or they may have been produced
recently by the recombination of superior characteristics through scientific plant breeding. In either case, there is grave danger of their loss through careless handling without a planned method of production that is consistently carried forward.

Only those varieties that are approved by the State or provincial agricultural experiment stations and accepted by the certifying agency are eligible for certification.

While varietal purity is the first consideration in seed certification, other factors, such as weed and disease control, high germination, cleaning, and grading have also been made part of the seed certification program.

Certification standards have been established by the International Crop Improvement Association for the use of State crop improvement associations in their seed certification programs for such crops as alfalfa, red clover, white clover (including Ladino), crimson clover, sweetclover, lespedez, field pea, soybean, vetch, birdsfoot trefoil, and 20 species of grasses. These standards cover four classes of seed according to position in the multiplication process from breeder to ultimate consumer or producer of forage. They are (1) breeder's seed, (2) foundation seed, (3) registered seed, and (4) certified seed. Following are the varietal standards for the two most prominent forage legumes, alfalfa and red clover, and the general standards for grasses:

**Certification standards for alfalfa:** The certification standards of the International Crop Improvement Association for alfalfa (Misc-24) provide, among other things, the following:

1. A crop of alfalfa shall not be eligible for certification if planted on land on which alfalfa was grown or planted during the year prior to the one in which the present stand was planted. The land must also be relatively free from volunteer alfalfa plants. Roguing of off-type plants, sweetclover, and dodder is required prior to field inspection.

2. A field inspection shall be made each year that a certified seed crop is produced and at such time as is necessary to insure identity, preferably at the time the crop is in blossom.

3. Where an alfalfa variety is grown for production of certified seed outside of its region of adaptation as designated by the Bureau of Plant Industry, Soils and Agricultural Engineering, and the seed is to be labeled as "Adapted to Region, first generation increase," certification shall be limited to (1) fields planted with certified seed grown in the region of adaptation, (2) one generation increase of such seed, (3) fields not more than 6 years old, and (4) fields planted after January 1, 1943.

4. Alfalfa seed fields must be inspected annually by the seed certification agency to insure the field being relatively free from volunteer plants or additional plantings of seed from other sources.

5. All fields of alfalfa used for the production of foundation, registered and/or certified seed must have the following minimum isolation from fields of any other variety cross-pollination with which would change the adaptation of the certified seed; for foundation seed, the minimum distances are 120 rods for any size field, for registered seed they are 60 rods for fields of less than 5 acres and 30 rods for fields of 5 acres or more, and for certified seed they are 20 and 10 rods, respectively.

6. The maximum mixtures of other varieties and of sweetclover permitted are 0.1 percent of the other varieties and no sweetclover in foundation seed fields, 0.5 percent and 10 sweetclover plants per acre in registered seed fields, and 1.0 percent of other varieties and 160 sweetclover plants per acre in certified seed fields.

**Certification standards for red clover:** The certification standards of the International Crop Improvement Association for red clover (Misc-24) provide, among other things, the following:

1. Only one variety of red clover may be grown for seed production on a farm, except that a synthetic variety, and one or more of the strains used in the synthetic, may be grown.

2. When a strain or variety of red
clover is grown outside its adaptation region, as designated by the Bureau of Plant Industry, Soils and Agricultural Engineering, the production of certified seed shall be limited to three generations from foundation seed, and the production of registered seed shall be limited to the first generation from foundation.

3. The principal red clover belt of the eastern United States shall be divided into three general regions of adaptation for the purpose of certification. The general regions are as follows: Northern Region—bounded by 49° 40" on the north and the latitude of the boundary between Illinois and Wisconsin on the south and the western boundary of Minnesota on the west; Central Region—bounded by the Northern Region on the north and the 40° latitude on the south and the western boundaries of Iowa and Missouri; Southern Region—bounded by the Central Region on the north, the latitude of the southern boundary of Tennessee on the south and the western boundaries of Missouri and Arkansas on the west.

4. Certified red clover seed may not be produced on land where seed of another strain or variety has been produced within the preceding three years or where at least two cultivated crops have not intervened. These limitations do not apply if the preceding strain is one of the components of the inspected variety. No manure shall be applied during the productive period of the stand.

5. All fields of red clover used for the production of foundation, registered and/or certified seed must have the minimum isolation distance from fields of any other variety of red clover or fields of the same variety that do not meet the varietal purity requirements for certification, as follows: For foundation seed the minimum distances are 100 rods for fields of less than 5 acres, and 40 rods for fields of 5 acres or more. For registered seed, the respective minimum distances are 60 and 30 rods, and for certified seed 20 and 10 rods.

6. The maximum mixtures of other varieties permitted in each class are, none for foundation seed, 0.2 percent for registered seed and 0.5 percent for certified seed.

Certification standards for grasses: The general seed certification standards for the various species of grasses provide, among other things, the following:

1. A seed field shall be considered the unit for certification. A strip at least 5 feet in width and which is mowed, uncropped or planted to some crop other than the kind in question, shall constitute a field boundary.

2. Where foundation, registered, or certified seed is being produced, no other variety or strain of the same species shall be grown for seed production by the same grower.

3. A field to be eligible for the production of foundation seed must not have grown or been seeded to the same species during the previous five years.

4. A field should be rogued prior to blooming to remove off-type plants, and prior to harvest to remove other grasses or weeds, the seeds of which cannot be separated by mechanical means.

5. A field inspection, after heading but before harvesting, must be made each year that a registered or certified seed crop is to be harvested.

The minimum isolation distances required of fields to produce seed eligible for certification shall be 40 rods for foundation seed, 20 rods for registered seed, and 10 rods for certified seed of smooth brome and mountain brome, crested wheatgrass, meadow and tall fescues, orchardgrass, and timothy; 60 rods, 40 rods, and 40 rods, respectively, for blue and side-oats grama, big, little, and sand bluestems, feather bunchgrass, switchgrass, buffalo grass, and western wheatgrass; 60 rods, 40 rods, and 20 rods, respectively, for intermediate and Ree wheatgrass; 40 rods, 20 rods, and 20 rods for reed canarygrass; and 80 rods, 60 rods, and 40 rods, respectively, for tall oatgrass.

INCREASING PRODUCTION AND USE OF IMPROVED SEEDS

The certification of seed of improved varieties does not wholly solve the problems connected with the establishment
of improved varieties in general culture. It does a part of the work in that it furnishes the means for maintaining and certifying varietal purity in commercially produced and distributed seed. There still remain many problems of improving present seed certification procedure, and distribution and marketing of certified seeds, in addition to publicizing the merits of the improved varieties as compared with ordinary commercial seed and unadapted varieties.

Ways must be found for producing specifically adapted varieties in large quantity, and for moving the definitely identified seed to farm users. Complications develop from the fact that, in many instances, these seeds cannot be economically produced in the area of largest use. It is, therefore, a national problem. Varieties adapted to one area for use as forage must at the same time be capable of producing profitable seed yields in other areas.

Agreement and understanding are needed between seed-producing and seed-using areas, so that the interests of both are properly protected and safeguarded. All units of seed distribution that normally operate in providing American farmers with seed must understand and participate in doing the job.

Full use must be made of every area that can produce satisfactory seed stocks, and at the same time maintain inherent values.

A cooperative program between the States and the United States Department of Agriculture which provides for producing and distributing foundation seed stocks of small-seeded legumes and grasses, is intended to remove one “bottleneck” in this problem. Through this project foundation seed stocks of improved varieties will be increased. From these supplies commercial seed production can be given a quicker build-up.

It is clear that farmers’ needs for improved strains of legumes and grasses cannot be filled, or the nation’s soil resources protected, unless we have these essential seeds in large quantities.

**IMPROVEMENT OF ALFALFA**

There is probably no other forage plant on which, during the past 40 or 50 years, so much attention has been given to introducing seed from new sources, and to selection and breeding for crop improvement as alfalfa. Prior to this period the growing of alfalfa on any large scale had been confined mostly to the western and southwestern states where irrigation could be practiced, and even there very little effort was made toward improving the crop. The outstanding forage qualities of alfalfa and the possibility of obtaining or developing strains adapted to the Northcentral and Eastern States, however, were just coming to be recognized. Agronomists ever since the beginning of the century, in most of the States where alfalfa did not find an early home, have simply been on edge in their research work to not only obtain adapted varieties, but to find the best ways and means for utilizing alfalfa in their farm programs.

Among the most important characters sought for during that period in plant breeding with alfalfa were winter-hardiness, forage productivity, drought resistance, desirable habit of growth, seed productivity, leafiness, and resistance to leaf spots. In more recent years disease resistance and the ability to combine with other strains or selections certain desirable traits, in hybrids and synthetic combinations, have been added.

Some of the most serious difficulties found in breeding alfalfa are (1) difficulty of keeping strains pure, (2) maintaining a large nursery several seasons to determine survival, (3) obtaining seed, and (4) length of time required to determine the value of the progeny of any given plant.

**Early Breeding Work**

Without doubt, natural selection in alfalfa, helped here and there by the willing hand of man, has taken place for many generations. This is evident from a comparison of our vigorous-growing, sturdy cultivated alfalfas with the pros-
trate, slow-growing wild species picked up by plant explorers.

Only two examples are needed to show what apparently had been accomplished by natural selection, helped along by man. Peruvian alfalfa is not at all winter-hardy in northern latitudes. This probably has been due to many centuries of growing in warm climates. On the other hand, the original home of Grimm alfalfa in Germany has minimum temperatures less severe than those observed at Albuquerque, New Mexico. Yet, by saving seed from the plants that survived generation after generation, Wendelin Grimm produced the alfalfa that is known by his name.

The story of the development of Grimm has been variously given and the results are susceptible of several interpretations. As usually told and accepted, Mr. Grimm brought the original seed from Germany in 1857 and by continuous saving of seed, generation after generation, the less hardy plants were eliminated and a hardy alfalfa was produced. Since Grimm alfalfa is a variegated alfalfa produced as a cross between the common (M. sativa) and the yellow-flowered (M. falcata), and it has been impossible to produce a really winter-hardy alfalfa from common (M. sativa), it may be a question how much of the hardiness of Grimm is because of natural selection and how much to the hardiness of the particular strain of M. falcata that entered into its composition. As all known hardy alfalfas in general cultivation today are variegated alfalfas, it is probable that this at least has been an important factor in the hardiness of such varieties as Grimm, Baltic, Ladak, Cos-sack, Hardigan, and Ranger.

In a report of the Committee for Breeding Forage Crops, made by Piper in 1909, a very good picture is given of the alfalfa-breeding program in the entire United States at that time. "It must be borne in mind," the report states, "that alfalfa breeding is a very recent development of plant improvement, apparently no work having been conducted along this line previous to 1903." At the time of the report he said eleven workers were directly interested in alfalfa improvement: J. M. Westgate, C. J. Brand, G. W. Oliver, and A. C. Dillman, all of the United States Department of Agriculture; W. H. Olin and P. K. Blinn of Colorado; G. F. Freeman of Kansas; F. A. Spragg of Michigan; E. G. Montgomery of Nebraska; L. R. Waldron of North Dakota, and W. A. Wheeler of South Dakota.

Practically all these workers had a well-developed program, chiefly involving mass selection supplemented in some cases by progeny tests. They probably thoroughly understood the possibility of contamination by cross-fertilization, but apparently not all of them fully realized that an individual selected plant might not pass on all or many of its good characteristics to the next generation. It must be added, however, that even at this early date, many breeders knew the value of the progeny test and used it to determine which was the best parental material.

The workers of this period had a considerable number of strains to use for foundation stock. The major varieties used were Grimm, Baltic, Common and Turkistan, along with some of the more recent introductions from Asia and Africa.

The early work can be said to have begun about 1903 and ended about 1915. During this period there was considerable interest in the improvement of alfalfa, the two outstanding characters sought being winter-hardiness and ability to produce seed in the same locality where the crop was grown for forage. It may be noted that several of the varieties developed at that time came into prominence during this early period and later, notably Grimm, Baltic, Cos-sack, Ontario Variegated, and Ladak. All of these varieties have superior characteristics, such as cold resistance, and adaptation for special conditions. They are all still considered standard varieties. Introduction and selection played a part in their development.

It must be added, however, that many an alfalfa selection was "born to blush unseen" during this period. Some very promising selections made in various
nurseries never got any further. As an illustration, Tysdal and Westover (US-266) have called attention to Wheeler's Grimm No. 19A which was selected in 1906 and increased to the extent of 100 acres in South Dakota, then turned over to farmers and its identity lost. Also, some 125 acres of the same selection, the seed of which was obtained from Wheeler, was sown in rows in southern Alberta, Canada, by James D. McGregor in 1908. The seed produced from this acreage was distributed as Grimm and was reported by McGregor in 1914 as being the original source of a large part of the Grimm alfalfa grown in southern Alberta at that time and as being recognized by all who had grown it as distinctly superior to the general run of Grimm alfalfa. There is no doubt, therefore, that the worth-while characteristics in this strain and others handled in a similar manner have through the years made themselves felt in generally superior productiveness in those localities where they were grown and in other strains with which they crossed. Thus the work put into such selections may not have been entirely lost.

A specific illustration of the natural spread and influence of a superior strain is seen with Grimm alfalfa in Montana, North and South Dakota, and Minnesota. The so-called common alfalfa in these States, especially since the curbing of the shipment of seed from southern sources by the Seed Verification Service since 1927, has become so mixed with Grimm and other variegated strains as to be in many cases practically indistinguishable from them in the field.

The early work in alfalfa improvement did not reach full fruition for several reasons, among them World War I, which focused attention on food crops to the detriment of feed crops, and the widespread introduction of Grimm alfalfa, which largely solved the winter-hardiness problem, wiping out the advantage gained by selection for hardiness in common alfalfa, and also depriving breeders of a definite goal for selection. In other words, for the moment no great catastrophe seemed to threaten alfalfa, and most people, including some of the breeders, were content to let well enough alone.

**Later Breeding Work with Alfalfa**

The second period of alfalfa development and improvement began following World War I and has continued as an active program up to the present time and is gaining impetus every year. In June 1934 the first Alfalfa Improvement Conference was held at Lincoln, Nebraska. At that time an organization was formed to carry out an alfalfa improvement program as a cooperative enterprise between the States, the United States Department of Agriculture and the Canadian Department of Agriculture. Up to and including 1948, eleven conferences had been held. It is now planned to have a meeting every two years. This cooperation of all alfalfa improvement interests has brought about a coordinated program that has made much more rapid progress in alfalfa research and improvement than probably could have been attained in any other way.

During the first period (1903-1915) the improvements were largely in the direction of a search for and development of hardier and better adapted strains or varieties so as to extend the areas of general culture in the United States. The later work (1919 to date) has been directed largely towards developing disease- and insect-resistant adapted varieties, to studying the possibilities of improvement through the application of hybrid vigor, the development of hybrid and synthetic varieties, and in finding out how to increase seed production of improved strains.

Also, in this later period many new and younger workers entered the field of alfalfa breeding. A few of those formerly active remained in the picture but most of the work was done by a new generation who were better equipped with a knowledge of more recent developments in the field of plant breeding. The better knowledge of the scope and application of genetics, the more recent research in the field of cytogentic, the development of nursery techniques as a result of the
newer knowledge of these, and the results of other breeding research have played a most important part in the later improvement of alfalfa.

Some of the greatest pests of the alfalfa crop are plant diseases. Of these, bacterial wilt is at present recognized as one of the worst. Others include leaf and stem diseases which, in general, are more severe in the humid sections of the country, rots which attack the crown and roots of the alfalfa plant and cause much damage to the crop in some sections, *Fusarium* spp. which probably cause more killing over large areas of the country than is generally realized, and the viruses about which comparatively little is known as to the extent of their damage or methods of control.

Damage done to the alfalfa crop as a result of harmful insect activity is also of extreme economic concern. Leaf hoppers probably cause more damage to the alfalfa crop in the eastern half of the United States than any other one factor. Other serious insect pests are the alfalfa weevil, grasshoppers, lygus bugs, alfalfa plant bugs, and chalis fly. The lygus bugs are especially harmful and greatly reduce the seed crop where they are in abundance.

The alfalfa crop is also susceptible to several climatic hazards. The most common ones are winterkilling, droughts, and heaving. Hot, humid weather, on the other hand, is conducive to development of diseases which may destroy the crop. Heaving of the soil causes severe damage to the alfalfa crop in the eastern United States.

Plant breeders generally are agreed that the most effective means of combating practically all of these hazards is the development of resistant varieties through plant breeding. Rotations and soil amendments have been tried for bacterial wilt control without success, but varieties resistant to the disease have been developed. Ranger and Buffalo alfalfas are highly resistant to bacterial wilt and are recommended for areas where that disease is serious. Another example is Nemastan which has proved resistant to the stem nematode, a parasite for which no other practical control could be found. Atlantic, another new variety that yields well, is better adapted to the eastern States than most commercial varieties. Where wilt is not an important factor, Atlantic has given larger yields in many of the Uniform Alfalfa Nurseries than most other varieties or selections. Still another new strain, the Williamsburg, selected out of Kansas Common at the substation in Williamsburg, Virginia, has given excellent yields along the Mid-Atlantic Coast.

Through plant breeding methods, rhizomatous types of alfalfa, the crowns of which send out spreading rhizomes, are also being developed. These may be useful for both hay and pasture mixtures and in pastures they may withstand more severe grazing than ordinary alfalfa. A variety of creeping alfalfa developed at the University of British Columbia and given the name "Rhizoma" is now under trial in the United States and Canada and a small quantity of seed has been offered for sale by the University. This variety will have to be given extensive trials in various localities and under various conditions before recommendations as to its adaptability and usefulness can be made.

A breeding program has been under way for a number of years to develop a strain of California common alfalfa resistant to wilt. Considerable progress has been made, and it is expected that a healthier strain will be available in a few years. Some work also has been started on the development of strains resistant to crown rot and dwarf, but no strain has been found that shows any appreciable resistance to either disease.

Alfalfa seed production in the United States has been largely confined to the Western States primarily because conditions essential to successful seed production are found more consistently in that region. Between 1935 and 1947 an average of 81 percent of the seed was produced in the Western States. A considerable seed production may be expected in the Eastern States in certain years, but consistent production is difficult—
another reason why it is hard to develop an adequate breeding program.

Years of experimental testing show that there are varieties, such as Turkestan, that are adapted in the West but are poorly adapted in the East. On the contrary, varieties better adapted to eastern conditions, such as Hardigan and Atlantic, have done well under western conditions in approximately the same latitude.

It would be advantageous, therefore, to have a selection for disease resistance and adaptation made in the East on all strains to be increased commercially for use anywhere except in the deep Southwest. A specialized type of alfalfa for which there is no counterpart in the East is used in the Southwest for late-fall and early-spring growth.

In the coordinated alfalfa improvement program, selections are made in one region and seed produced in another region from the same plant. Vegetative propagation makes possible this attack on the problem.

Once a new improved variety of alfalfa has been developed, there is still the problem of increasing the seed in quantity so that it can be made available to growers. The increase of foundation seed has been a bottleneck for alfalfa as well as for practically all forage crops. In some cases it has taken 30 years to get a definitely superior variety into wide use. Once the foundation seed of an improved variety is increased and becomes available to growers, seed of that variety should be produced commercially and certified to insure purchasers of the identity and purity of the variety.

It is believed that improvements accomplished to date in the breeding of alfalfa are only the beginning. Resistance to various diseases and to insect depredations, as well as the promise of higher yielding, higher quality alfalfa through the utilization of hybrid vigor, and the production of rhizomatous alfalfas, all through an integrated East-West program, presents a favorable picture for continued improvements to the ultimate benefit of all growers.

Hybrid and Synthetic Alfalfas

Most recent progress in alfalfa improvement has been made in the application of hybrid vigor to the development of strains having greater productivity, longevity, and resistance to diseases and other hazards of forage and seed production than is possible in open-pollinated selected or regional strains. The first suggestion to be made publicly that the production of hybrid alfalfa commercially was a possibility was made in 1941 by Dr. H. M. Tysdal (US-265). In 1947 (US-264), he wrote that “Plant breeders can use ordinary selection methods to produce good strains of improved alfalfa, but the best strains with maximum improvement can be produced only by making use of hybrid vigor.”

In alfalfa, it is not practical to prevent self-pollination artificially. About 15 percent of the alfalfa plants, however, are self-sterile. In these self-sterile plants, pollen from a given plant will not bring about fertilization in flowers on the same plant but may be fully fertile on another plant. Hence, it is possible to obtain nearly 100 percent crossing by planting two such plants in an isolated block where the pollen of each plant readily pollinates the flowers of the other plant, but not its own. Since alfalfa can be propagated readily by cuttings, a single desirable plant can be increased to any number of plants required to plant a number of acres in a short time. Also, since alfalfa plants will live several or many years, frequent replantings or establishment of new fields will be unnecessary.

Plants selected for hybrid seed production must be relatively self-sterile and resistant to diseases, cold, and insect pests. They must also combine well with each other. The plant-breeder cannot tell by looking at a plant whether it will combine well with another plant or not. The only way to determine this point definitely is to make the cross. However, the polycross nursery has given alfalfa breeders a simple method of picking out the best combiners just as the top-cross in corn helps corn breeders choose the best inbred lines in corn.
IMPROVING OUR FORAGE CROPS

For planting in the polycross nursery, only desirable plants are used that are selected from either the better varieties of nursery-bred alfalfa or from old fields that have had natural elimination of less desirable plants. These plants will have been subjected previously to various diseases to test their resistance. Those that have shown resistance to diseases and, so far as possible, to insect pests, and other hazards, and have the other desirable characteristics, are selected. They are increased vegetatively and planted in the clonal polycross nursery. In this nursery each clone (that is, the increase of one plant by vegetative propagation) is pollinated by natural methods. Pollen from the same clone or other clones in the nursery is carried to the flowers by insects. Because these plants are relatively self-sterile, most of the seed so produced is out-crossed. The progenies resulting from seed produced in this manner are known as polycrosses.

The performance of polycross seed produced by clones in the same nursery or in other uniform nurseries gives a reliable indication of the relative combining ability of those clones. It is much easier and cheaper to produce the polycross seed than seed from single crosses or topcrosses. By vegetative propagation, the original plants can be increased for the polycross nursery as much as is necessary to produce enough seed for thorough testing under various conditions in different localities.

Besides showing the combining ability of clones, the polycross method makes it possible to obtain new superior combinations by natural crosses between selected clones in the polycross nursery. Precautions should be taken, however, to prevent the basic stocks from becoming inter-related. This can be done by separating the various types in different polycross nurseries and by introducing new, unrelated selections into the program as often as possible.

Clones that, when tested, show the best polycross performance are increased vegetatively and paired in all combinations to produce single crosses. Single crosses are made by planting the two relatively self-sterile clones in alternate rows in an isolated field where they can be naturally pollinated without being contaminated by insects carrying pollen from undesirable plants. With relatively self-sterile clones usually over 95 percent crossing is obtained in such isolated plots.

Since the possibility of commercial production of hybrid alfalfa seed was first proposed, a number of experimental hybrids have been produced in natural field crossing blocks, and tested for both forage and seed yields in comparison with the best standard varieties.

In a 2-year test of 28 hybrids and poly crosses in comparison with Grimm, Hardistan and Ladak alfalfas at the Nebraska Agricultural Experiment Station (Neb-23) the average of the top 5 hybrids in yield of green forage was 25 percent larger than the average of the 3 checks. The average seed yield of the 5 crosses highest in seed production was 105 percent higher than the average of the 3 checks. However, in this test, none of the 5 highest in forage yield correspond with any of the 5 highest in seed yield. The 5 highest crosses in forage yield averaged 60 percent of the 3 checks in seed yields and the 5 highest crosses in seed yields averaged 84 percent of the 3 checks in forage yield. Two of the 28 crosses had larger yields of both forage and seed than the 3 checks, the averages being 5 percent greater in forage and 35 percent greater in seed yield.

All results so far indicate that it may be necessary to select and test many thousands of individual plants for self-sterility and combining ability as well as for all the desirable plant characteristics before plants best adapted for the purpose are discovered, and that it may be necessary to test hundreds or thousands of crosses between these best plants before the best combinations of plants are discovered to use in making single crosses, and the best single crosses to use for the best double or final cross.

But, when the best plants and crosses have been discovered, they can be perpetuated by vegetative propagation under the technique proposed for the production of commercial hybrid alfalfa seed.
and not be subjected to the vicissitudes of going through the natural reproductive processes.

Many of the hybrids are resistant to bacterial wilt and to attacks by the potato leaf hopper and there are indications that hybrids more resistant to the leaf spot diseases may be developed. Since the leaves of alfalfa contain around 66 percent of the protein and 75 percent of the carotene of the plant, it is important that the plants be leafy and that the leaves remain healthy.

Double-cross hybrid alfalfa seed may be produced for commercial distribution by sowing seed of two high-combining single crosses either in alternate rows or blended for natural cross-pollination. Unless the single-cross parents used for the production of the double-cross have been tested for self-sterility and shown to be relatively self-sterile, the resulting double cross may not be so nearly 100 percent first generation or F₁, cross as the single cross. There is evidence, however, that self-sterility may be an inherited trait. Yield tests have shown that as much as 25-percent selfed seed planted with the hybrid reduces the yield of the mixture very little below that of the pure hybrid. No doubt this is because in any field planting there are many young plants that die from competition with more vigorous plants. In that event, the strong hybrids would crowd out the plants from selfed seed.

The same procedure outlined for the selection of high-combining clones for use in producing hybrids could be used for the development of superior synthetic varieties. A synthetic variety may be defined as a variety that is developed by crossing, compositing or planting together two or more unrelated strains or clones, the bulk seed being harvested and sown in successive generations. By natural intercrossing the unrelated strains or clones are “synthesized” into a new variety.

A synthetic variety can be increased through several successive seed generations, or so long as the productivity and other desirable traits of the initial synthetic variety are retained. The same clones used for the production of a hybrid can be utilized in the production of synthetic varieties. The original clones used for the initial single cross would be maintained or increased vegetatively to form a source of pure foundation seed. For the production of either hybrid or superior synthetic alfalfas, one of the essential features is the use of foundation plants that have high-combining value and therefore are capable of producing plants having maximum hybrid vigor, as well as possessing the many other desirable plant characteristics and resistance to disease.

Synthetic alfalfas such as Ranger, Buffalo and Atlantic have already demonstrated their superiority over other regional varieties. The cumulative evidence obtained from the Uniform Alfalfa Nurseries, conducted by the States cooperating with the United States Department of Agriculture in the alfalfa improvement program, indicates that real hybrid alfalfa may have a place in alfalfa improvement. It appears to offer the most practical solution to the problem of combining in one strain high yields of both forage and seed, resistance to wilt and other diseases, especially those affecting the leaves, greater leafiness (which is correlated with higher percentages of protein, vitamins and minerals), long life, winter hardiness, drought resistance, and special adaptation.

Whether hybrid alfalfa will ever become a practical development remains to be seen. At present it is not clear whether its superiority over the best synthetic varieties in utilizing hybrid vigor is sufficient to warrant the extra effort, time and expense that it takes to produce hybrid seed. Much experimental work must be done before this can be determined. For the time being the most superior alfalfas will be produced synthetically.

**IMPROVEMENT OF THE TRUE CLOVERS**

There are some 250 species of true clovers (Trifolium spp.), but only four of these have attained any large importance in the United States, and they are all of
European origin. They are red clover, alsike clover, white clover, and crimson clover. Others of definite forage value in the United States, but of minor importance, are Persian clover, subclover, the hop clovers, and strawberry clover. The only species on which any large amount of special breeding work has been done is red clover, which is the most important one of the genus.

Red clover: Red clover is ordinarily classified as medium (double-cut) and mammoth (single-cut, sapling or perennial) red clover, but it is so variable that one will find all gradations of characteristics in types between true medium and true mammoth. However, the commercial strains of the two are readily recognized as they occur in general culture.

Besides the usual factors of adaptation, resistance to low and fluctuating winter temperatures, potato leafhopper, and several leaf-spot diseases, northern anthracnose has recently been recognized as a serious disease in the northern and central regions of the main red clover belt. Breeders are searching for strains resistant to the disease and are meeting with some success. Another problem is one of adaptation to day-length during the growing season. Within certain limits, strains or varieties adapted to northern latitudes are lower yielding when planted farther south. On the other hand, varieties adapted to the lower latitudes give increased yields as they are moved northward until environmental factors, such as winterhardiness and diseases, limit their productivity.

The United States Department of Agriculture, in cooperation with State agricultural experiment stations, has been testing red clover seed from various foreign and domestic sources for many years. Between 1905 and 1910, and between 1920 and 1930, red clover seed from some fifty or more foreign sources was tested at various State agricultural experiment stations in cooperation with the U. S. Department of Agriculture, to determine the general adaptability, plant characters, and relative values of seed from those sources in the United States and found to be generally unadapted for growing in the United States.

In 1923 some 75 lots of seed, each of which had been grown on the same farm for ten or more years without admixture of other seed, were obtained by the U. S. Department of Agriculture from all over the red clover belt of the United States and tested at three different places in that area. From these and other tests, three general regions of adaptation were recognized (southern, central, and northern), along with groups of factors which were important in each region.

Concurrent experiments indicated that the red clover seed of the northwestern seed-producing States was not so satisfactory when used in the eastern seed-consuming States. Results of experiments also indicated that the growing of red clover varieties for successive generations in a location different from the place of origin in factors affecting adaptation, reduced the productiveness of the variety when the progeny was planted in the original location.

Procedures and regulations pertaining to the maintenance of the superior characteristics of red clover varieties and strains have been developed and are given in the annual reports of the International Crop Improvement Association.

A step toward control of these problems has been made by the development of three new red clover varieties or strains—Midland, Cumberland, and Kenland.

Midland red clover originated as a composite of equal proportions of four old strains, one each from Ohio, Indiana, Illinois, and Iowa. Thirteen years of testing it and increasing seed stocks were involved in developing Midland. Midland is winter hardy, has good growth characteristics, and has some resistance to northern anthracnose. It is adapted to the middle or central part of the Corn Belt States, and to areas with similar climatic conditions in the Eastern States.

Cumberland is a superior variety adapted to the southern part of the red clover belt. It originated as a composite of equal proportions of three identified strains, one each from Kentucky, Tennessee, and Virginia. Cumberland has good growth characteristics and is moderately resistant to southern anthracnose,
and has some resistance to crown rot as well.

Kenland, the newest of the three varieties, when sufficient seed becomes available, will probably succeed Cumberland. Its origin and adaptation are similar to Cumberland, but it is a betteryielder and more disease resistant and longer-lived than Cumberland.

But varieties even more resistant to diseases than Midland and Cumberland, such as Kenland, are in the making. A new kind highly resistant to the powdery mildew disease and more resistant to northern anthracnose than Midland, is being increased and tested to determine its range of adaptation.

One difficulty that confronts the breeder, but more particularly the distributor, of improved varieties of red clover seed, is the fact that red clover is ordinarily a biennial and not a perennial. For this reason there is likely to be more resistance to the sale of improved varieties of red clover seed, inasmuch as the extra price that has to be charged for improved seed usually falls on only one year’s production of forage or seed.

In preliminary tests at a few locations, one or more of these improved varieties have lived over into the third year or second harvest. If subsequent tests confirm the early results, this fact is of considerable significance. This is evidence that by breeding to eliminate the hazards of the environment, there are possibilities of developing superior varieties of red clover that are perennial in length of life.

White clover: There is a wide variation in growth characteristics of white clover ranging from very dwarf, as in some of the wild white pasture varieties, to very large, as in Ladino. Though there is a rather continuous gradation from small to large, for convenience they are grouped in three somewhat indefinite groups known as large, intermediate and small, in each of which there may be several varieties. They originated either through introduction or natural selection under varying climatic and soil conditions and management practices. So far as known, there are no new improved varieties of white clover selected or bred from existing stocks in the United States.

The common commercial white clover may be of the intermediate or low-growing types or mixtures of types. This clover often is called White Dutch clover, a name that is without meaning as to origin and should be discontinued.

The use of Ladino white clover, a variety of the large type introduced from Italy, has spread more widely during the past few years than any other kind of legume. Its rapid spread from the Western States, first to New England, then through the Lake and Corn Belt States, the Piedmont sections of Southern States, and throughout the irrigated regions of the West, particularly the Pacific Northwest, has been the result of excellent performance. Research work on Ladino clover is now in progress but no improved varieties have been developed for distribution.

Louisiana white clover, a regional strain, has developed under natural conditions in Louisiana and adjoining States over a large number of years. It is of the intermediate type and is adapted throughout the Southern States and as far north as the latitude of central Ohio. It also has given excellent yields in many places farther north, particularly where winter conditions are less severe, or where it is protected by a snow covering in winter.

New York Wild white and Kent Wild white are strains of the low-growing type. They are natural selections that have developed under close grazing conditions for long periods of years. They are less productive than strains of the other types but are persistent in certain regions.

Crimson clover: Two superior varieties of crimson clover are Dixie and Auburn. Both have hard seeds that facilitate the establishment of volunteer stands from shattered seed during the late spring and early summer. In preliminary tests, Auburn has been slightly less winter-hardy in the northern part of the crimson clover region. The hard-seeded characteristic of the Dixie and Auburn varieties minimizes the chances of stand failure, which frequently occurs in the fall during the
period of germination. As the seed of Dixie and Auburn cannot be distinguished from common crimson, the use of certified seed only of these varieties is recommended. Neither variety resists crown rot or sooty blotch, which occur frequently in the Southern States. Another variety, Autaga, has been brought out in Alabama, but it has not been tested sufficiently to determine whether it is worthy to be included in the Dixie synthetic or to be certified as an independent variety.

Subclover: There are many varieties of subclover, the most recent winter annual species of clover that is being extensively used in the Pacific Northwest. They are all of Australian origin and differ principally in adaptation and maturity. The early introductions were of the early maturing Dwallanup variety which is relatively worthless in Oregon. Early in the 1930's many varieties were introduced, among them Mt. Barker and Tallarook, which are, respectively, midseason and late in maturity. In the Pacific Northwest, tests indicated that they were superior and would successfully produce good volunteer stands the following fall. They also appear promising in several localities in the South.

IMPROVEMENT OF OTHER LEGUMES

Few things are more interesting than the quest for new legumes and their improvement. Locating basic material for an improvement program involves a wide search, and when promising plants are found, a program of breeding, selection, and increase of seed becomes possible.

As a group, the legumes share with grasses a position of paramount importance as forage crops. What one lacks the other seems to have, so that many compatible combinations are possible for hay, pasture, silage, or erosion control. However, the species of legumes of value for forage are fewer than the grasses and relatively little improvement work has been done except with a few of the most important species, among which are alfalfa, red clover, and sweetclover. Some of the many other species of legumes, among which may be some not now recognized as having forage value, after further study and improvement work has been done with them may exhibit forage potentialities beyond present indications.

Lespedeza: In pastures, as well as on cultivated land, the annual lespedezas are commonly maintained by volunteering. Seed that takes up moisture and germinates in the fall is killed later by cold weather or rots during the winter. Some progress has been made in the development of strains with more hard seed to insure volunteering.

Climax Korean lespedeza, a late maturing strain, is the result of selection work with the crop. It extends the range of Korean lespedeza, our best known annual species, southward and lengthens the grazing season. Early maturing strains of Korean lespedeza also have been developed which extend its range to the north. The one now available commercially is known as early Korean.

Kobe lespedeza, a large-growing superior strain of common lespedeza (another annual species), was originally selected for its size. It has proved a heavy yielding strain of superior value for both hay and pasture. It matures late and thus affords grazing at a time when green feed usually is scarce. The seed habits of Kobe, however, are inferior to Korean and for that reason the use of Korean has been more extensive in areas where both are well adapted.

Of the perennial lespedezas, sericea lespedeza is one of the most extensively used. Seed habits of this species are poor and harvesting is somewhat difficult, but with proper care and management a fair percentage of the seed crop can be saved. Selection and breeding for better seed habits is essential with Kobe and with the perennial species of lespedeza before much increase in the percentage of seed saved in harvesting can be affected.

Sweetclover: Of the many farm strains of yellow and white sweetclover, a few have proved to be superior. Madrid, an improved variety of biennial yellow sweetclover, has early seeding vigor, resists fall frosts, is slightly later in maturity, and produces greater yields than the common
biennial yellow. It is particularly adapted to the Great Plains and the Corn Belt. Erector, an improved Canadian variety, when grown under Corn Belt and Great Plains conditions, is similar to common yellow. Willamette, a variety of biennial white sweetclover, resists crown rot, matures in midseason, and is particularly adapted to the Pacific Northwest where the crown rot disease is a limiting factor in sweetclover production. Spanish, another variety of biennial white sweetclover, is midseason in maturity, has early seedling vigor, and is a high yielder. Evergreen is a variety of biennial white sweetclover that matures late and produces a rank growth. These characteristics make it valuable for grazing and green manure. Seed yields are frequently low because of shattering, since it blooms over a long period of time when weather conditions are usually unfavorable. It is adapted to the Corn Belt and the eastern edge of the Great Plains.

Hubam, an annual variety of sweetclover, blooms in the fall of the year that it is sown. Under some conditions it produces a rank growth. It is being used extensively on the black soils of Texas for seed production, forage, and green manure. It is sometimes sown in the fall but may winterkill in severe winters. Emerald is another annual variety of sweetclover that is less vigorous than Hubam, but less coarse and better for forage, having many stems of smaller size. It is adapted to southern Texas.

Vetch: Common vetch is variable both with reference to the appearance of the plant and to winter hardiness. This latter factor has determined the varieties that can be used in the United States. Selection work for more winter-hardy strains resulted in the development of the Willamette variety, which is now most commonly grown. Willamette, like the species in general, requires a mild, cool climate for good seed production. It has good seed habits and gives good yields.

A strain of hairy vetch has been developed which has little or no pubescence or hairs on the plant. It makes better winter growth in mild climates than the more hairy forms. This new strain—smooth vetch—has caused a wider use of the species. This improved variety was established in the seed-producing areas of the Pacific Northwest and most of the seed handled today under the name “hairy vetch” is of this improved form. The seed habits of smooth, or hairy vetch, are poor and the cost of production high.

Bur-clover: California bur-clover is a variable species made up of many subspecies and varieties. Because of its aggressive nature in the West and its wide distribution it would be difficult to maintain pure strains so these have not been developed. In the Southeast, the one most extensively used is spotted bur-clover. It is not so aggressive in the Southeast nor so widely spread as California bur-clover is in the West, and for this reason, it has been possible to develop and maintain improved varietal strains. Manganese and Giant spotted bur-clover have become popular and are being used in many new pasture plantings.

Birdsfoot trefoil: Naturalized plantings of birdsfoot trefoil in New York, California, and Oregon, have demonstrated the value of this legume for pasturage, and have served as centers for increase of seed for additional plantings. Birdsfoot trefoil and the regional strains that have developed show marked differences with reference to habit of growth and adaptation. Because of the slowness of establishment, it has been difficult to obtain good stands of any of the strains of birdsfoot trefoil under any but the most favorable conditions. After once established, they will all withstand hardships and make good growth where other legumes fail.

Birdsfoot trefoil also matures seed unevenly and the seed pods split open readily upon maturing, thus making the harvesting and increasing of seed difficult and the cost high. Improvement of the species depends largely on the selection of strains that will have greater seedling growth and vigor, have better seed habits, and be adapted to the different sections. The production and increase of these
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strains under sectional or regional isolation should then be undertaken in order to maintain them as selected.

In the Pacific Northwest the narrowleaf strain of birdsfoot trefoil predominates. In New York, both the broadleaf and narrowleaf are found, but the former is grown to a much greater extent. Over most of the Corn Belt, the broadleaf strain is superior to the narrowleaf. The broadleaf strain is adapted to poorer soils and will withstand drought, while the narrowleaf strain is better adapted to moist, fertile soils of heavier texture. The broadleaf strain out of New York is being distributed as Empire birdsfoot trefoil.

Roughpea: Roughpea has been used satisfactorily in the pasture program of the Black Belt of Alabama and Mississippi. Strains have become naturalized and adapted locally and volunteer from year to year. Since roughpea has a high percentage of hard seeds that carry over in the soil for a number of years, it is not difficult to maintain stands without re-sowing. In fact, once a stand has been accomplished in pasture lands, it can be maintained indefinitely with proper management.

Kudzu: Kudzu is propagated vegetatively and most of the plantings in the United States are made in that way. Because of limited facilities to carry on the breeding work, little has been done to improve the crop. Seedling kudzu plants are varied and selection should produce superior strains for forage and ground cover. The fact that the crop is propagated vegetatively will insure the maintenance of superior strains once they are established.

IMPROVEMENT OF TIMOTHY

The earliest record of an attempt to improve timothy by making selections of desirable types of timothy plants is that of Willett M. Hays at the Minnesota Agricultural Experiment Station in 1889. In 1894, A. D. Hopkins, of the West Virginia Agricultural Experiment Station, made some selections of timothy and continued his work in the development and distribution of improved varieties until 1907 or 1908, when he transferred his selections to the United States Department of Agriculture.

Hopkins (WVa-5) stated the objects of his timothy-breeding program were to develop varieties having certain desirable qualities, such as (1) prolific early varieties to mature with common red clover and the other early species of grasses, and produce a second crop; (2) prolific medium varieties to succeed the early ones and mature with other species; (3) prolific late varieties to succeed the medium ones and produce a large yield of hay of uniform quality; (4) prolific deep-rooting varieties for mixture with pasture grasses; and (5) early, medium and late varieties adapted to varying conditions of latitude, soils, and climate, and in some degree resistant to diseases and insect enemies.

In cooperation with Hopkins and some other workers, the United States Department of Agriculture conducted some timothy breeding work from 1899 to 1909, but did not enter into an aggressive effort to study and improve timothy until 1909 when a timothy-breeding station was established in Ohio in cooperation with the Ohio Agricultural Experiment Station. This was located at New London until 1915, then at North Ridgeville until 1935, and from then to date at the Ohio Station at Wooster.

The timothy breeding work at the Ohio Station was in charge of Morgan W. Evans until his retirement in 1948. He published many works on timothy which represent the largest contribution of any United States worker on this crop. Objectives: Evans (US-63) in discussing the objectives in timothy breeding said that ordinary American timothy plants vary within wide limits in season of maturity, length and degree of fineness of stems, breadth of leaves, degree of susceptibility to rust, tendency for the leaves to remain green as the seeds approach maturity, and in other ways. These numerous variations and the different ways in which they are combined in different plants result in a very wide range of variants from which selections may be made.

It is comparatively easy to develop, within a few generations, a strain of tim-
othy in which some single character, such as earliness or lateness, long stems, or yielding capacity is produced fairly well in the plants grown from seed. To produce a variety in which all of the desirable characteristics are combined is a more difficult task. Furthermore, a certain variety of timothy may be adapted only to a more or less restricted area. For instance, some of the late varieties that have produced relatively large yields of high quality hay in northern Ohio are of little value in Kentucky or farther south. It is, therefore, necessary to have varieties especially adapted to certain regions as well as for different uses, and this must be recognized in any well-formulated breeding program.

He then states that some of the objectives in the improvement of timothy are the development of (1) rust-resistant varieties, (2) early varieties suited to the southern part of the timothy-growing area, and (3) late varieties for the North, for use where timothy meadows are maintained for two or more years, (4) varieties adapted for hay production when grown in mixture with clover or alfalfa, and (5) varieties for use in pastures.

Since the primary objective in most timothy-breeding programs is increased hay production, most of the improved varieties developed to date are primarily hay varieties. Some of them are earlier than ordinary timothy. One of the characteristics of an early timothy is that it is capable of producing elongated stems with heads, and the flowers bloom and seeds form on them under shorter days than are required for late varieties. Trials in southern Ohio and at the Kentucky Agricultural Experiment Station, where the days during spring and summer are too short for the proper development of late varieties, have demonstrated the correctness of the theory that near the southern border of the timothy-producing area in the United States early varieties produce materially larger yields of hay than late varieties. It is not unlikely that some of the improved varieties of timothy, selected primarily for their usefulness in meadows, may also be superior to ordinary timothy for use in pastures.

No varieties of timothy that are primarily pasture types have yet been produced in the United States. The Welsh pasture variety, seed of which is now available to a limited extent, and others of this type are a different species or botanical variety from common timothy. They have 14 chromosomes, while common timothy has 42. This type is characterized by its short, low-growing stems and produces much smaller yields of hay than any of the hay types. Experience in this country with the European pasture varieties has shown them to be of little or no value here.

Breeding methods: Timothy is generally cross-pollinated. Experiments have demonstrated that usually only a small percentage of self-pollinated flowers produce seed. Cross-pollination results in the occurrence of many natural hybrids between plants of diverse types. This provides a wealth of forms from which selections may be made, but makes the maintaining of a new variety more difficult.

The method used in the timothy-improvement work conducted by the Department in cooperation with the Ohio Agricultural Experiment Station, and which in the same or somewhat modified form was used by some of the earlier plant breeders, is as follows:

Seed from each single plant selection is sown in a seedbed or in a small broadcast plot. The growth of the plant of different selections is observed and compared in these plots, and plants are taken from them and transplanted to cultivated row plots where each individual plant has ample space for development. Later, from the row plot of each strain, one or more new selections are made of the plants most outstanding for the desired qualities. When, as a result of repeated observations and tests, a selection of sufficient merit is finally developed, the supply of seed is increased, and it is introduced under an appropriate name as a new variety.

No provision is made during the early stages of selection to prevent the flowers of the plant or plants of one selection from becoming pollinated with the pollen produced by plants of other strains. Ex-
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Experiments conducted in this way over a number of years have shown that when selection for some particular quality or character is continued through several generations, plants may be developed that reproduce themselves through seed fairly true for this character.

At some other experiment stations or plant-breeding institutions the seed of selected plants has been produced by self-pollination. In this way, it is possible to develop selections or varieties in which the plants conform to a certain type more closely than if they grew from seed produced under open pollination. In some strains of timothy, this uniformity is attained only at the cost of much loss in vigor. This deterioration may be overcome later by cross-pollinating two established uniform strains and producing a hybrid in which some of the most desirable characteristics of both parents are combined.

When a variety of timothy is finally established and its seed is being increased and produced on a larger scale, it is essential that indiscriminate cross-pollination with ordinary timothy or other varieties be avoided, or else the peculiar characteristics by which the variety is distinguished are likely to disappear.

Improved varieties: Marietta timothy is a composite of three selected early strains, the original selections of which are vegetatively maintained in an isolated plot and harvested together for the production of foundation seed. Lorain as produced today is a composite of two late selections grown together in isolation from other strains for foundation seed production. Itasca timothy is a synthetic variety composed of six medium early inbred lines.

Some of the recognized improved varieties of timothy are Shelby, an early-maturing regional selection from southern Indiana, now largely replaced by Marietta; Itasca, a synthetic variety composed of six medium early inbred lines, developed by the Minnesota Agricultural Experiment Station; Marietta, an early synthetic variety composed of three of Evans' best early strains; Huron, a late-maturing variety developed in Ohio, but now largely superseded by Lorain; Lorain, a late variety, 10 to 17 days later than Marietta, developed at North Ridgeville, Ohio; and Hopkins, a very late (3 or 4 days later than Lorain) recent introduction by the timothy-breeding station. In spite of the increased production of better quality hay from the specially adapted varieties in trials in both northern and southern latitudes, these improved varieties have not come into very extended use in Ohio or elsewhere, largely because their superiority in field culture is not as evident as it should be to create a real demand for them among farmers.

IMPROVEMENT OF OTHER COOL-WEATHER GRASSES

Bluegrass: Whether more productive and palatable strains of bluegrass or "June-grass" can be developed is a question being studied at several of the experiment stations of the Northcentral and Northeastern States.

Although bluegrass recently in some sections has come to be regarded pretty much as a "has been" crop completely unable to match the performance of certain newer grasses, that may not be the situation if it can be shown to be possible to grow leafy, high-producing bluegrass instead of the stemmy, slow-growing material commonly seen on worn-out hillside pastures.

Some years ago there appeared to be excellent prospects that better bluegrass could be developed. A number of experimental strains looked very much better than ordinary bluegrass when grown in rows in cultivated nursery plots.

At the Wisconsin Experiment Station, it was found that the strains which were outstanding in nursery rows tended to lose much of their advantage when grown in thick broadcast seedings such as are used in pastures. Work was undertaken to evaluate the more promising experimental strains very carefully under conditions such as they would run into on farms. Comparisons were made with commercial strains of bluegrass under management ranging from moderate to heavy grazing and from no fertilizer treatments on low-fertility soil up to
heavy applications of various fertilizers. Results in Wisconsin on second-year seedings in 1945 indicated that where the fertility was high and grazing moderate, some of the experimental lines of bluegrass were superior to all the commercial strains tested. There was no evidence, however, that any of the selections had an advantage under low-fertility, close-grazing conditions.

This work showed that bluegrass can be a more productive crop than it is under the usual management, but that inherently superior bluegrass has worthwhile advantages only if given better management than is usually accorded bluegrass pasture.

In Wisconsin (Wis-11) comparisons were made between 25 selections of Kentucky bluegrass on two soil types during 1941-1943. The results showed that eight of the selections were superior to the commercial lot in the first and second years, but that only one of this group was superior in the third year on both soil types. However, the results obtained by Myers and Sprague (US-182) indicated that there was no noticeable tendency for differences among strains to disappear in the third year as compared with the first.

**Orchardgrass:** Orchardgrass is another introduction that came in with the early settlers. Only in recent years have attempts been made to develop improved strains. Field collections have been made from old fields for selection and hybridization with new improved strains from abroad.

Some of the imported types of orchardgrass have been increased or grown for several years in the United States and, no doubt, have lost part of their original characters, either through natural selection or cross-pollination with domestic types. An example is S-143, a strain imported from Aberystwyth, Wales. During its few years in the United States, it has developed into a plant that is tall-growing, a better seed producer, and of medium leafiness. A recent introduction of the same strain from Wales is low-growing, a sparse seed-producer, and leafy.

Another example is Bragg, a strain introduced from Sweden.

There are no superior new strains or varieties of orchardgrass in commercial production in the United States today. With the increased interest in orchardgrass for pasture in certain areas in recent years, and the developmental work that is now under way at the Northeast Regional Pasture Laboratory and at several State experiment stations, it is probable that one or more improved strains or varieties will be forthcoming before very long. Some recent work that has been done with orchardgrass indicates that ecological groups adapted to flood land, dry land, and mountainous areas may be segregated.

Some of the features most desired in an improved orchardgrass are: (1) late maturity, without sacrificing the good qualities of early varieties or strains, in order that the grass will not become coarse and unpalatable if not grazed or clipped early in the season, and also in order that it will reach silage or hay stage at the same time as the first cutting of alfalfa; (2) more cold or winter hardness—many of the central European, Australian, or New Zealand strains are not winter-hardy under our conditions; (3) resistance to leafspot and any foliage or leaf diseases that may occur in commercial orchardgrass and reduce the feed value; (4) good recovery after grazing or cutting—it must not be so aggressive as to crowd out the companion legume so necessary for high-quality pasture; and (5) good seed production—the consumer or farmer planting the grass must have a seed source at a reasonable price. However, if it were possible to combine all these characters into one strain with no more effort than writing about it, the grass-improvement problems would be simple.

**Bromegrass:** Smooth bromegrass exhibits a variety of types of plants varying in leafiness, height, habit of growth, rhizome production, heat and drought tolerance, disease resistance, and seed-producing qualities. Seed lots obtained from a broad geographic range produce
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plants with wide differences in these characteristics.

Considerable breeding work has been done and is still under way at several experiment stations to develop superior, uniform strains or varieties. At present, the regional strains, Lincoln, Achenbach, Fisher, and Elsberry, all representing the vigorous-growing southern type, are decidedly superior to any of the northern type in the Central States and up into southern Minnesota, Wisconsin, and Michigan. Two superior selections from the Lincoln strain, Nebraska 36 and 44, are being increased for trial outside of Nebraska. Parkland, a Canadian development of the northern type, is finer-stemmed and less creeping than the common brome but it has been less productive in the States. A superior selection of the northern type, which is being increased for further trial, has been developed by Rogler of North Dakota (Mandan 404). Martin, a Minnesota variety, and Manchar, a Washington-Idaho development, are intermediate between northern and southern types and have proved superior to either for the localities in the States for which they were developed.

Studies at the Nebraska Experiment Station show that variations in this cross-pollinated crop occur from farm to farm as well as between regions. These variations appear to have resulted from the selective effects of environmental factors operating both before and after the introduction of this grass into the United States.

Studies at the Wisconsin Experiment Station indicate that it may be possible to select strains superior to those now grown. Two or more strains will be needed there, since no single strain as yet available, appears to do best in all parts of Wisconsin.

In trials of bromegrass conducted by the Minnesota Experiment Station in southern Minnesota, the southern type varieties gave larger yields than those of the northern type, but the difference was not so great as farther south.

Tall fescue: Tall fescue (Festuca arundinacea) is often considered a natural variety of meadow fescue (F. elatior). Two destructive leaf diseases, crown rust and net blotch, are generally prevalent on meadow fescue. Tall fescue is apparently immune or highly resistant to crown rust at the Northeast Pasture Laboratory and some collections have shown resistance to net blotch. By combining these two resistances, it is expected that a variety can be obtained that will have resistance to both diseases.

Some breeding work is being done with tall fescue but the two similar varieties, Alta and Kentucky 31, are the only ones in commercial production. Alta originated from selections of tall fescue made at the Oregon Agricultural Experiment Station, and Kentucky 31 is a regional strain of 50 or more years growth on one or several farms in Kentucky. These are very similar, but in certain localities or at certain stages in their growth show minor differences. For all practical purposes, one would consider them of about the same adaptation and value. Because of the methods by which these two strains were developed, the two claims made, that Alta is the more uniform in type of growth, and that Kentucky 31 is somewhat more resistant to disease in the Southeast, may have some weight.

IMPROVEMENT OF SOUTHERN GRASSES

Hay and pasture crops merit special attention in the South, in view of the demand for a greater production of livestock and the need to adjust the uses of land.

Bermuda-grass: In the South, Bermuda-grass (Cynodon dactylon) is the most widely grown grass. Its tendency to spread to cultivated fields has given it a bad name among farmers who grow row crops like cotton and tobacco, but it grows on upland soils of various types and can control erosion.

In 1929 agronomists at the Georgia Coastal Plain Experiment Station at Tifton found a robust plant of Bermuda-grass growing in a cotton field near the station. The plant was increased vege-
tatively and distributed as Tift Bermuda-grass. Later, Department workers started an intensive breeding program at Tifton, planting tall-growing strains that had originated from common Bermuda, Tift, and an introduction from South Africa. These were allowed to cross-pollinate naturally. From these parents seed was collected in 1938, and more than 5,000 single plants were grown for careful study one by one. Of them, 147 of the most promising plants were selected. They were tested further, and among them a superior strain was found. It is now being increased and distributed under the name of Coastal Bermuda.

Coastal Bermuda-grass has larger stems, stolons, rhizomes, and longer internodes than common Bermuda. It is also leafier, more tolerant to cold, and resistant to leafspot. Because it produces little or no seed in the Coastal Plains region, it must be increased by vegetative plantings.

Another new and apparently good hybrid has been named Suwanee. It is being distributed in Florida where it has certain advantages over Coastal Bermuda. It will give a larger yield of hay, and it appears to be more productive on poor soils, but will not stand as much cold or close grazing as Coastal Bermuda.

Bahiagrass: Bahiagrass (Paspalum notatum), an early introduction from Cuba and Central America, has several good points as a pasture grass in the South. It is perennial, leafy, and deep-rooted, spreads by short stolons, and grows well on sandy soils. When it is properly managed, it produces abundant seed, an important factor because seed of most grasses has been produced outside the Southeast or imported from foreign sources. But because it is not winter hardy, its use has been limited mainly to Florida and the Gulf Coast area.

In 1936 intensive tests on Bahiagrass seed collected from different sources were started in an attempt to find more types good for controlling erosion. Collections were made by State and Federal workers in the field. Other material was obtained by introductions from plant explorers in Central and South America.

In the cooperative work at Tifton, at least six types have been found in the material so far studied. This classification is based largely on growth habits, plant and genetic characters, and winter hardiness. The strains have been identified as Common, Paraguay, Pensacola, Wilmington, Wallace, and Tampa.

Common Bahia represents the type imported from Cuba, Central America, and South America. Because it is susceptible to winterkilling, it is at home mostly in Florida and southern Georgia. It has broader and more tender leaves than the Paraguay, Wilmington, or Pensacola strains. The Paraguay strain is a smaller-growing type than common Bahia. The leaves are thicker, narrower, tougher, and darker green in color. It is more frost-resistant and can withstand lower temperatures than common Bahia. The strain was named Paraguay because it was developed from introductions made in 1937 from Paraguay. Since that time samples of Bahiagrass seed, which proved to be the same type as Paraguay, were obtained from a grower near El Campo, Texas.

Pensacola Bahia was probably introduced from ballast dumped on land near the old Perdidi Wharf at Pensacola, Florida. This strain differs from other strains in many respects, but, like Paraguay, it makes excellent pasture in the spring and early summer, although it becomes tough in late summer. It is an excellent seed producer, but the seed shatters readily and is difficult to save. Observations at Tifton indicate that Pensacola spreads more rapidly than other Bahias and tolerates frost a little better than Paraguay. The most striking genetic difference is in the number of chromosomes. The Pensacola strain has 20 pairs of chromosomes; other strains that were studied cytologically have 40 pairs.

Of the several strains collected by men in the Nursery Division of the Soil Conservation Service, Wilmington Bahia, collected near Wilmington, North Carolina, is the most winter-hardy. Other strains, but of less importance at this time, are the Wallace and Tampa Bahia.
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Sudangrass: Considerable effort is now being made to improve the forage value of Sudangrass by selection and breeding, for disease resistance, lower prussic acid content, and larger production of more nutritious forage for both hay and silage use. Several promising strains have been developed which are now becoming available for distribution. Among these are sweet Sudangrass, a hybrid of Leoti sorghum, and common Sudangrass, developed by the Texas Station, which is characterized by a sweet, juicy stem and non-shattering seed; Tift Sudangrass, a disease-resistant selection from a similar hybrid, developed at Tifton, Georgia, and Sudangrass No. 23, a very productive single-plant selection from common Sudangrass, developed in California, which has largely replaced the common in that State.

Other introductions: A number of other forage grasses on which most of the work done so far has been in testing their adaptability to southern conditions and the uses for which they were best adapted, have been introduced into the Southern States. With some of the more recent ones, there has not been sufficient time since they were received to accomplish much in the way of selection or breeding. Among the introductions that have proved of value are Dallisgrass, Vaseygrass, Rhodesgrass, the lovegrasses, blue panicgrass, Napiergrass, Paragrass, centipedegrass, St. Augustinegrass, Pangolagrass, and the Zoias.

IMPROVEMENT OF GRASSES FOR THE GREAT PLAINS AND INTER-MOUNTAIN REGIONS

The largest areas of natural grass and range lands in the United States are in the Great Plains and the Inter-mountain regions, a vast area where the soil is usually productive but where rainfall is a limiting factor. The plant breeder finds there a wealth of material that can be used in a program to improve grass. These grasses can be broadly classified as cool-temperature plants—those that make the most growth during spring and fall, and warm-temperature plants—those that grow best during the summer.

Because the number of useful grasses in this region is large, only a few examples are mentioned to illustrate the efforts to improve them.

Native grasses vary widely in their adaptation. Much of the improvement work therefore has been confined to field selections. Because of variations in winter hardiness, forage production, day length, disease resistance, and other factors, the field selections cannot be moved too far north or south from the region of their origin. Until local tests have proved otherwise, strains we now have should not be planted more than 150 to 200 miles north or south from the locality of origin.

Any attempt to evaluate the products of a grass-breeding program without placing them on the range itself is incomplete and subject to errors of unknown magnitude. The large number of grass species that are native to the range and many introduced species that require testing have imposed on the reseeder and breeder a complicated job of evaluation before the foundation material for a breeding program can be intelligently selected.

On nearly all range sites, plant growth encounters serious limiting factors, such as long, dry summers, shallow, eroded soils, or competition from aggressive species of low forage value. For these reasons, sowings frequently require several years to become established and additional time to demonstrate their adaptability to seasonal variations and management.

It is an established fact that in farm pastures a grass-legume association is more productive than grass alone. Agencies concerned with reseeding have given considerable attention to the appraisal of legumes for range lands and have found none that appears promising over extensive areas. As a result, sowing practices usually include only grasses.

Crested wheatgrass: A grass—more valuable perhaps than all other range-forage species that we now know about—is crested wheatgrass. Its merits are out-
standing. On the Northern Great Plains it has proved to be longer-lived, more productive, and more drought-resistant than slender wheatgrass; it was found to be superior to smooth bromegrass, which, although long-lived, is less drought-resistant and becomes sod-bound. It is well adapted to sagebrush lands and marginal or submarginal dry-farm lands that formerly were covered with grass or sage and are principally spring-fall range. It is probable that more acres of range land have been successfully regrassed with crested wheatgrass than with all other species combined.

It has faults, however. Except under ideal conditions, seedling development may be slow. It is sensitive in the seedling stage to competition from cheatgrass. Growth ceases during the warm part of the year even though moisture is abundant—probably the main reason that it has not spread farther southward. Its palatability becomes less satisfactory as it matures. Also, it is susceptible to foot-rot disease of wheat and this becomes a major problem when it follows wheat.

To overcome these undesirable traits, plant breeders have imported seeds of crested wheatgrass, made simple mass selections from them, and have grown them in comparative tests in several parts of the range area. They have found some that are clearly superior to others, but so far have tested no selections very extensively because of limited quantities of seed or lack of time. Their work, however, progresses.

Recent introductions that give promise in range tests of challenging crested wheatgrass under some conditions are tall wheatgrass, stiffhair wheatgrass, and intermediate wheatgrass. As reseeding work is extended into the summer and winter ranges and the all-season ranges of the South, other species will grow in importance.

Crested wheatgrass, smooth bromegrass, and many of the other promising range-forage species are naturally cross-pollinated. Such cross-pollination gives progenies in which the individual plants differ considerably. No two are exactly alike. Thus, when the available material has been compared, and the most promising strains identified, the breeder can take advantage of this variation within the strains.

**Slender wheatgrass:** A number of important species of range forage grasses are naturally self-pollinated. Like wheat and barley, they produce uniform-appearing progenies.

Slender wheatgrass, a notable example, has a wide range of adaptation, and natural selection has produced many clearly differentiated strains. Some of them differ greatly in such characteristics as yield, palatability, seed productivity, date of maturity, and earliness. Species of this type require relatively simple breeding methods because progenies generally duplicate the characteristics of the parent.

A small amount of natural crossing is believed to enhance the breeding possibilities with slender wheatgrass. Even though slender wheatgrass requires only simple breeding methods, it is not receiving a great deal of attention from plant breeders. The reason is that the species, although widespread, is not dominant on any extensive area.

**Intermediate wheatgrass:** Intermediate wheatgrass (*Agropyron intermedium*), another introduction from Russia, has shown considerable promise in the Northern Great Plains and the Intermountain Region. The original introduction was a mixture of two species, *A. intermedium* and *A. trichophorum*. As a result, it has shown considerable variation. It is less drought-resistant than crested wheatgrass, and more drought-resistant than bromegrass. The South Dakota Agricultural Experiment Station has increased one form of it under the name of Ree wheatgrass.

**Buffalograss:** Intensive work was started on buffalograss in 1935. Plant breeders want to domesticate this highly variable plant by selection and hybridization. Because of the wide variation in almost every known character in buffalograss, selection has been used most extensively. Improvement work has been under way in North Dakota, Nebraska, Kansas, Oklahoma, and Texas—most intensively...
at Hays, Kansas, and Woodward, Oklahoma.

The Hays strain is the only improved one in which seed was available for limited distribution in 1947. It was developed at the Fort Hays Agricultural Experiment Station at Hays, in cooperation with the Department of Agriculture.

The main aim of the workers who developed the Hays strain was to breed a type that bears abundant seed on stems for easier harvesting. The strain has been superior to common or field buffalograss in production of seed and forage. It is said to have more resistance to disease than common buffalograss, and has the ability to produce seed high off the ground.

Other selections of buffalograss made at the Hays Station appear to be even more promising than the Hays strain.

The Southern Great Plains Field Station at Woodward started to increase the seed of three strains of buffalograss that appeared promising in the preliminary stages of development. One of them gave evidence of being a particularly outstanding cross because it has tall, quick-spreading plants bearing seed on the stalk 6 to 8 inches above the ground. It is an aggressive strain—sprigs set out at 5-foot intervals completely filled in the space between them in about 3 months.

The gramas: Blue grama is a warm-season, short grass found growing in association with buffalograss. It forms a good sod, although it is a typical bunchgrass. Many strains of blue grama occur naturally, but southern strains generally lack winter hardiness when they are moved north, and northern strains yield less when grown in the South. Seed is hard to get, because blue grama fails to set seed consistently; the development of desirable seed-producing strains is of major importance. So far, it has been impossible to obtain lines either by selection or hybridization that are superior in seed production under irrigation or dry-land conditions. Intensive studies will have to be made to develop strains of this important range grass.

Side-oats grama is another native, perennial, warm-season grass that ranks high in palatability. It is easily established by seed and forms an important part of the mixtures recommended for range land reseedings. As with blue grama, strains from the South are subject to winter injury when moved north, and northern strains are low in production when moved southward. El Reno side-oats grama was developed from field collections made near El Reno, Oklahoma. It has ranked higher than other strains tested in Kansas and Oklahoma for leafiness, resistance to leaf disease, and seed production.

Lovegrasses: Three lovegrasses, weeping lovegrass (Eragrostis curvula), Lehmann's lovegrass (E. lehmanniana), and Boer lovegrass (E. chloromelas), all introductions from Africa, have proved to be valuable. Weeping lovegrass, well adapted to the Southern Great Plains, has been widely distributed, and is the most winter-hardy of the three. Lehmann and Boer lovegrasses are promising in semiarid parts of the Southwest, southern New Mexico, and Arizona. Sand lovegrass is a promising native palatable species of the Southern Plains.

Bluestems: Turkestan bluestem (Andropogon ischaemum) and Caucasian bluestem (A. intermedius caucasicus), introductions from Russia, show promise in the Southern Great Plains. They are vigorous, high-producing plants with fair production of seed. Both are finer-stemmed and of better texture than our native bluestems.

Wild-rye: Mandan wild-rye is an improved variety of Canada wild-rye. It was developed at the Northern Great Plains Field Station by mass selection from plants grown from seed collected on upland near Mandan, North Dakota. Several vital characters make it superior to ordinary Canada wild-rye. It is longer-lived than many strains and will withstand grazing for several years. It is leafier, finer, and the softer-textured leaves are shorter. It has more resistance to rust than other strains that have been tested. It is easy to establish, grows rapidly, and yields well in seed and forage. It can be used to good advantage in mixtures with other grasses that are
slower in becoming established. It seems to prefer sandy soils, but it also makes good growth on other soil types. Seed of Mandan wild-rye germinates more slowly than that of crested wheatgrass. It often sprouts a week later than crested wheatgrass. Establishment is relatively rapid, but it may take a year before weeds are crowded out.

Russian wild-rye (Elymus juncus) was first introduced in 1928 from the Soviet Union. It has about the same range of adaptation as crested wheatgrass and can best be compared with it. Failure to produce seed consistently has been its principal weakness. Its use is limited to the Northern Great Plains and Intermountain regions where it is best adapted.

Green stipagrass: Feather bunchgrass has given way to green stipagrass, an improved variety that was developed at the Northern Great Plains Field Station from a single plant selection which originated from a bulk seed lot collected near Mandan. It is superior to ordinary feather bunchgrass in vigor and size and excels in yields of forage and seed. In fact, it is one of the highest yielding of the cool-season grasses that have been tested at Mandan since 1942. After defoliation, it makes rapid regrowth and is useful in mixtures for pasture seedings. It is easily established in areas where weed competition is not too great. Hay cut at approximately the time the plants are in full head is nutritious and palatable. It seems to grow well on most soil types and probably can be grown successfully over most of the Northern Great Plains. Green stipagrass begins growth about a week later in the spring than crested wheatgrass. The seed ripens earlier than most species and reaches maturity about 3 weeks ahead of crested wheatgrass. It is of low germination when the seed is new, but if the seed is held in dry storage for 3 years, germination should be satisfactory.

Switchgrass: Switchgrass is a native long-season grass that grows alongside the bluestems. It resembles other native grasses in growth and adaptation, but it differs from them in that it is a good seed producer, and the seed can be easily harvested, cleaned, and stored.

One strain that is being propagated is known as Blackwell switchgrass in Kansas. It is a field selection from Blackwell, Oklahoma, developed by the Soil Conservation Service at Manhattan, Kansas. It has a fine leafy quality and considerable resistance to rust. It matures seed moderately late and yields well. The leaves remain green until frost. In Kansas, and perhaps in nearby States, it is adapted for use in mixtures. Another field selection, made from Holt County, Nebraska, is a small leafy type that is well adapted to the sandy soils north of the Platte River in Nebraska. It is susceptible to rust when grown farther South.

HIGHLIGHTS OF FORAGE CROP IMPROVEMENT

1. The ultimate objective of forage crop improvement is to work toward more efficient production and utilization of forage as feed for livestock.

2. Forage crop improvement lagged behind the improvement of grain, fiber, and vegetable crops and gained little momentum before the last 15 or 20 years. Hay and pasture were formerly the step-children of the farm, and no improvement program with the plants that compose them was initiated.

3. The slowness in taking up improvement of forage plants was due to the difficulty in properly evaluating improved varieties and the effort and expense involved in the production, distribution, and marketing of seed of improved varieties.

4. Forage plant breeding programs are now under way in many States and in Canada, and seed of some improved varieties is now becoming available.

5. The success of forage crop improvement is dependent upon many interrelated factors which separately or in combination are more difficult to evaluate than those of most cultivated single-purpose crops or varieties.

6. Few varieties of forage plants are ideally adapted for the purpose for which they were grown. All of them, however, are capable of improvement.

7. A wealth of plant materials is available to the plant breeder,—old introductions
now acclimatized, new introductions of unknown potential value, improved varieties susceptible of still greater improvement, and native species of little known adaptation to cultural procedures, though of demonstrated climate and soils adaptation.

8. Some of the outstanding objectives in the improvement of forage crops are (1) large yields of nutritious forage, (2) good seed production consistent with large forage production, (3) wide climatic and soil adaptation of varieties in which seed is largely produced some distance from where sown, (4) resistance to one or more diseases and insects injurious to forage and seed production, (5) longevity of plants to be used in permanent pastures and in waste uncultivated areas.

9. Some of the legumes in which new and superior varieties have been developed and introduced are alfalfa, red clover, crimson clover, bur-clover, and lespediza.

10. The improvement of alfalfa in the United States by introduction, selection, and breeding over a period of nearly 50 years has extended its profitable use from 15 western States into every one of the States, and into every important province of Canada.

11. Some of the grasses in which new and improved varieties have been developed and introduced are timothy, bromegrass, buffalograss, wild-rye, switchgrass, Bermuda-grass, Bahia-grass, and Sudan-grass.

12. The greatest strides in the improvement of legumes and grasses for humid areas have been made with species introduced from foreign countries; and the greatest improvement in grasses for the Great Plains has been made with native species.

13. The testing and evaluating of forage plants, whether newly introduced species and varieties, or selections in the process of development, or the final product of the plant breeder, is a complicated procedure involving trials under many conditions and for a number of uses.

14. The more recently acquired knowledge of the principles of heredity, cytogenetics, and breeding techniques, has made possible more rapid progress in forage plant improvement, in determining the direction of such improvement, and in the development of improved strains and varieties.

15. Natural or mass selection and elimination of the least fit, operating over a long period, has played a large part in the development of the old stand-by varieties or strains of forage plants and will continue to operate so long as plants survive, though playing a less conspicuous role in the future in real plant improvement, and one more dependent upon association with other processes to be effective.

16. The polycross nursery technique involving individual plant selection for superior inherent traits, vegetative propagation of clones from superior individual plants, and determination of combining quality by progeny testing of parent plants, has furnished a short cut in methods of testing, and evaluating selections for breeding purposes.

17. Cytogenetics, still a relatively little understood and less-used instrument of plant improvement, is making great strides as an aid in plant breeding and in the more intelligent development of improved varieties.

18. Since leafiness and green color are the best indicators of the percentage of protein, minerals, and vitamins, and therefore of nutritive value in forage plants, especially legumes, these characteristics are given high rank in evaluating new strains or varieties of any forage plants.

19. Total yield in dry matter is of lesser importance in the improvement of a forage crop than total yield of digestible nutrients, especially of proteins and minerals, and compatibility with associated legumes.

20. Aggressiveness, usually a desirable trait in a hay or pasture grass, or for soil control when a variety or species is grown alone, may become objectionable in a grass to be grown with one or more of our most desirable legumes.

21. Resistance to one or more plant diseases is being obtained in a number of species of forage plants, one of the most important of which is alfalfa in which bacterial wilt has been largely overcome in such resistant varieties as Buffalo and Ranger.

This chapter

Much of the material in this chapter was taken from Atwood (NY-4), Garber, Myers, and Sprague (PA-7), Hollowell (US-110, 111, 112), Keller (US-131), McKee (US-157, 158, 161), Myers (US-182), Newell (NEB-19), D. C. Smith (US-241), Tysdal (US-260, 264, 265), and Tysdal and Westover (US-266). The preliminary manuscript was
reviewed by S. S. Atwood of New York, and D. C. Smith of Wisconsin, that on alfalfa by Tysdal of the U.S.D.A., and the entire final manuscript by W. M. Myers of U.S. D.A. Many suggestions and corrections made by them were incorporated in the text.


1 The reference numbers given here refer to references which are given in full by State, U.S.D.A., and Miscellaneous, on pages 682 to 724, and which are cross-referenced by author on pages 725 to 731. Citations in the text are indicated by abbreviation and number in parentheses.
Forage crops are subject to their share of pests of various kinds, the most injurious of which are the diseases and insects infesting forage plants, and the weeds and poisonous plants of meadows, pastures, and ranges. Some of these may be wholly or in part controlled by better cultural practices, crop rotations, or by mechanical or chemical treatments. With others, no effective control measures are known. Even though no specific remedies may be known or available, a better knowledge of the life histories and characteristics of the particular injurious species often helps one to plan his cropping system and rotations so as to lessen, if not wholly alleviate, losses from these pests.

It is not feasible here to give more than brief consideration to some of the more important pests under the four headings of diseases, insects, weeds and poisonous plants, and to general practices which may reduce losses caused by them. For fuller treatment, one is referred to the publications of the State agricultural experiment stations and the United States Department of Agriculture, applicable to the particular pests in the region under consideration.

SOME DISEASES OF GRASSES AND LEGUMES

Grasses and legumes, like all other economic plants, are host to many diseases. To illustrate: In the United States, more than 45 diseases are known to attack Kentucky bluegrass, 35 timothy, 30 orchardgrass, 50 alfalfa, 30 red clover, and 25 sweetclover.

The bacteria, fungi, viruses, nematodes, and a few parasitic seed plants are among the pathogens that cause the diseases. The fungi are mostly to blame, but the others are also responsible for several economically important diseases. Non-parasitic disorders that frequently are mistaken for parasitic diseases are common to some grasses and legumes; actually, they are caused by hereditary or physiological factors.

The diseases of pathogenic origin can be classified into three major groups, according to the parts of the plant they attack: root disorders, foliage disorders, and flower and seed disorders.

Root disorders are caused by the soil-inhabiting bacteria, fungi, and nematodes. Foliage disorders are caused by bacteria, fungi, and viruses. Fungi, nematodes, and parasitic plants cause flower and seed disorders.

Of these, root disorders are the least conspicuous, but they include several of the economically important pathogens and generally are responsible for the inability to establish initial seedings of grasses and legumes or the rapid depletion of already established stands.

Foliage disorders, the most conspicuous group, include only a relatively small number of pathogens that are economically important. They destroy only the foliage, the part of the plant that is readily regenerated, especially in perennials.

Flower and seed disorders have economic importance only when crops are grown for seed. Some of this group are
highly destructive and seriously hamper seed production. One—ergot, a fungus disease—can poison livestock if infected grasses are heavily grazed.

The diseases generally are limited to certain regions. The pathogens are usually specific, attacking only a single species or species in a single genus. Accordingly, the diseases of economic importance in a given region are those that attack the dominant grasses and legumes in the region, although a few pathogens are destructive to several widely divergent species.

Environmental conditions, especially temperature and moisture, limit the range and destructiveness of diseases. These two factors limit certain diseases to geographic regions; they may be the reason why a disease becomes economically destructive one season and diminishes to one of minor consequence the following season.

A few of the diseases occur in even more limited areas; for example, the blind seed disease, especially destructive to certain grasses when grown for seed, is localized in a small area in the Pacific Northwest.

Sanitary measures, important in checking many diseases, are impractical in checking grass and legume diseases under field conditions. For one thing, waste areas into which grasses and legumes spread by natural means are inaccessible for control practices. Crop rotation, important in combating many soil-borne diseases, is not readily applied to grasses and legumes. Many are perennial and are used in permanent pastures where diseases can run an uninterrupted course. Chemical control of foliage diseases with sprays and dusts is impracticable because of the possible poisoning hazard to livestock. Seed treatment for seed-borne diseases is not commonly practiced. Many grass seeds are difficult to treat because they are so small or have awns and other parts that interfere with treatment, and bacterial inoculants necessary in establishing good stands of legumes are not compatible with the seed protectant chemicals.

The development by means of selection and hybridization of strains and varieties of grasses and legumes resistant to the diseases that attack them is the only practical control for most diseases. Disease resistance has been demonstrated for many species and breeding and improvement programs are under way in an effort to incorporate these factors into the germ plasm of improved varieties.

It would be impossible, because of the space required, to describe in detail all of the diseases which are known to attack grass and legume crops in the United States. Accordingly, only representative pathogens of economic importance are discussed.

DISEASES OF FORAGE GRASSES

Damping-off (Pythium debaryanum), is a soil-inhabiting fungus that has a wide host range including many grass species. Disease symptoms are a seed rot and decay that occur during seed germination before the seedlings emerge from the soil or for a short period following emergence. The disease is favored by wet, cool weather following sowing, which retards seed germination and allows the fungus a longer period to cause rotting. No adequate control measures for this disease are known.

Seedling blight (Pythium arrhenomanes), is a soil-inhabiting fungus destructive to many grasses and in some years causes severe losses to spring sowings of crested wheatgrass, slender wheatgrass, and smooth brome. Symptoms are a general blighting and dying of young plants a few weeks after they emerge from the soil. The fungus is favored by wet, cool weather.

Crop rotation, using crops other than grasses and cereals, is an effective control method. Fall sowing of grasses is also effective because in the fall environmental conditions are unfavorable for the development of the fungus. After stands are established the fungus is less able to attack them.

Rhizoctonia blight (Rhizoctonia solani), is a fungus present in most soils, especially acid ones, and it attacks many grasses. Disease symptoms are recognized
from the common names leaf blight, stem canker, sheath spot, and brown patch. It is most destructive in the summer months during periods of humid weather. Crop rotation is ineffective as a control method because the disease attacks so many different plants in one form or another and can thus persist in the soil indefinitely.

**Bacterial blight** (*Pseudomonas coronafaciens atropurpurea*), causes a destructive bacterial disease on smooth brome grass. Initial symptoms appear as circular to oblong water-soaked areas of uniform size on the leaf blades which turn purplish-black and frequently coalesce, involving the entire blade and sheath. Blighted leaves wither and die. The second growth of smooth brome is rarely infected, because the disease does not develop during hot, dry midsummer. The disease is favored by periods of warm, humid weather. No other bacterial disease is so destructive as this on smooth brome, and there are no known control measures.

**Powdery mildew** (*Erysiphe graminis*), causes a fungus disease common on many grasses and is widespread in its occurrence. Mildew produces conspicuous symptoms that appear to be more damaging than real. The white powdery growth visible on the surface of leaf blades is the vegetative and sporulating part of the fungus. Dried, blotched areas develop later at the points where the fungus has penetrated into the leaves. Severely infected plants become weakened and retarded in growth.

Mildew is widespread in its occurrence, but it is especially prevalent in the Northcentral States where bluegrass is a dominant grass. The disease is seasonal in development, first appearing in the spring, diminishing during the summer, and reappearing again during the fall. Resistance to mildew is known to occur in plant lines of Kentucky bluegrass.

**Brown spot** (*Pyrenophora (Helminthosporium) bromi*), causes one of the many fungus leaf spots on grasses and is a serious leaf spot on smooth brome. Initial symptoms appear as small black spots on the leaf blades in early spring. These are caused by the sexual or ascospore stage of the fungus. As lesions enlarge, a yellow halo forms around each. Severely infected leaves wither and die. The asexual spores are borne on them and this spore stage causes secondary infection. As the season advances, small black bodies develop in the withered dead leaves. These bodies are perithecia, or enclosed cups, in which the ascospores develop. The fungus is carried through the winter months in this stage. Brown spot develops most rapidly during periods of wet, cool weather and is most severe on the early spring growth of smooth brome. Resistance to brown spot is known to occur in selected lines of brome grass.

**Leaf blight** (*Helminthosporium turcicum*), causes a fungus disease destructive to Sudan grass, sorghum, and corn throughout the same geographic range. As the common name implies, symptoms are a conspicuous blighted or scalded appearance to the foliage. Within a few days an entire field of Sudan grass may develop extreme blighting and appear characteristically burned or frosted. Blight makes its appearance about midsummer and continues until plant maturity. Disease development is favored by moist, warm weather. Sudan grass is one of the few annual grasses important as a forage grass in the United States. Being an annual, destruction of its foliage by any cause reduces its forage value. Resistance to leaf blight is known to occur in commercial varieties of Sudan grass. One variety, Tift Sudan, highly resistant to leaf blight, has been in production for several years, and other varieties are in process of development.

**Anthracnose** (*Colletotrichum graminicolum*), causes a fungus disease common on many grasses but a serious pathogen to very few. Sudan grass is susceptible and often is seriously damaged by it. Initial symptoms appear on the basal leaves as small eye-spot lesions with visible black bodies in the center of each. These open structures are filled with large numbers of spores which, being readily washed and splashed by dew and rain, account for much secondary infection.
Individual lesions frequently coalesce and entire leaves wither and die. On Sudangrass anthracnose appears about midsummer and develops rapidly from that time on until plant maturity. Varietal resistance to anthracnose is known to occur among commercial varieties of Sudan grass. Plant breeders are incorporating anthracnose resistance with leafblight resistance in Sudan varieties.

Rusts: Many rust fungi attack grasses, but the important grass rusts in the United States belong to the genus *Puccinia*. The four most important are stem rust, leaf rust, stripe rust, and crown rust. Leaf rust is the most common. None of the rusts are as destructive to the forage grasses as to the cereals. Resistance to the rusts has been demonstrated for many grasses. The rusts are unique in their ability to hybridize in nature and each of the rust species is made up of many physiologic races. New races are being formed continually, and grasses resistant to known races may be completely susceptible to the new ones.

Smuts: Many smut fungi attack grasses but only a few are economically important. Stripe smut, *Ustilago striiformis*, is one that is sometimes destructive. Initial symptoms appear as chlorotic stripes on the leaf blades. When mature, stripes are filled with large numbers of smut spores. At this stage they rupture, releasing their spores, and leaf blades become shredded and torn. Severely infected plants are stunted and dwarfed. Spores cause the initial infection of plants, but after getting into its host the fungus is able to live within it from year to year. Accordingly, it is not seasonal in its development and can be found to a greater or less degree any time during the growing season.

Head smut, *Ustilago bullata*, also attacks several grasses and is sometimes very destructive. Smut-galls are formed instead of seeds on infected plants. Each smut-gall is made up of a mass of dark-colored spores. Some of the spores released under field conditions are scattered to nearby heads, but most of them remain in the galls until the seed crop is threshed. Threshing breaks up the galls and spreads the spores to the healthy seeds.

When smutted seed is planted, the spores germinate along with the seed. The growing fungus invades the developing seedling and continues to grow inside the plant until after heading when the smut-galls which have formed in place of the seeds become evident. Plants infected with head smut appear normal except for a smutted head.

Smuts can be controlled by seed treatment, but such control is not commonly practiced. Seeds of the grass species attacked by smuts are difficult to treat because of their light weight and the presence of awns and other similar seed parts. Selection and breeding for resistance is the only practical means of control.

Ergot: Two species of the ergot fungus, *Claviceps purpurea* and *C. paspali*, are of economic importance. The first is widespread and attacks a large number of grasses. The second attacks only members of the genus *Paspalum*, and accordingly is limited in its range to the Southern States. Ergot attacks only the flower and seed parts of its hosts and is of economic importance only when the grasses are grown for a seed crop or are allowed to flower and seed prior to grazing or cutting for hay.

The initial symptoms appear at flowering time when a sticky exudate, called honey-dew, is noticeable. The exudate, which contains the conidial or asexual stage of the fungus, attracts flies and insects and much secondary infection of floral parts results from insect transmission. As the disease progresses, black horny bodies called sclerotia develop in place of seeds. When mature, these bodies fall to the ground or are harvested with the seed crop. In either case, they carry the fungus over winter. When planted with the seed or carried over on the ground by natural means, they develop the perfect or sexual stage of the fungus each year. Ergot development is favored by periods of warm, moist weather. Little varietal resistance is known among the varieties of the grasses which ergot attacks.
DISEASES OF FORAGE CROPS

Thorough cleaning of seed to remove sclerotia bodies, crop rotation using crops other than grasses and cereals, and deep plowing of infected fields to bury the sclerotia are control measures. Ergot is one of the few fungus diseases that can cause livestock poisoning. Substances in the sclerotia are highly toxic, and poisoning may result if severely infected grasses are grazed or fed for hay.

Blind-seed (*Phialea temulenta*), is a fungus which was first recognized as being destructive to perennial ryegrass in New Zealand in 1938. Since then, the disease has been reported in several other countries. In the United States it is confined to a rather limited area in Oregon, and it is thought that the fungus was introduced there in infected seed.

Blind-seed disease has no recognizable symptoms and is manifested chiefly by low germination in the seed crop. The reason for the low germination is that the developing seeds infected by the fungus are in many cases non-viable. Infected or "blind" seeds are difficult to distinguish from normal seeds. When contaminated seed is sown in the fall, the fungus continues its development in the "blind" seeds to some extent and the following spring produces the spore stage of the fungus, which reinfects its host. These spores are normally produced at the same time that the grass flowers, and it is this stage of the host which is infected.

The development of the fungus and the severity of the disease are influenced by environmental conditions. High soil moisture is essential for the production of the spore stage, and wet, cool weather after infection favors secondary infection and build-up of the disease.

Crop rotation, using crops other than grasses, and deep plowing to bury "blind-seeds," are both effective control methods. Infected seed can be safely planted if such seed is at least 2 years old, because the fungus loses its viability in that time.

It was formerly thought that the rye-grasses were the only grass hosts to blind-seed in Oregon. More recently seed of Astoria bentgrass, Alta fescue, and creeping red fescue has been found infected with the disease.

Seed nematode (*Anguina agroste*) causes an important disease of Chewings fescue and bentgrasses in the Pacific Northwest where these grasses are grown for seed. The symptoms of nematode infection appear as swollen galls that replace normal seeds. These galls, when mature, may fall to the ground or be carried in threshed seed. Each gall may contain several nematodes. The disease is spread mainly through transport of the nematode galls in seeds. Sanitary measures, such as burning of infected grass fields to destroy galls which have fallen or shattered to the ground and thorough cleaning of galls from seed, are effective methods of control. Crop rotation, using crops other than susceptible grasses, is also effective in destroying nematodes in infested soil.

SEVERAL ECONOMIC GRASSES AND COMMON DISEASES

Kentucky bluegrass
- Powdery mildew—*Erysiphe graminis*
- Leaf spot—*Helminthosporium vagans*
- Stripe smut—*Ustilago strieiformis*
- Rust—*Puccinia poae-sudeticae*
- Brown patch—*Rhizoctonia solani*

Timothy
- Purple leaf spot—*Helminthosporium phlei*
- Brown stripe—*Scolecotrichum graminis*
- Stripe smut—*Ustilago strieiformis*
- Rust—*Puccinia graminis phlei-pratensis*

Orchardgrass
- Powdery mildew—*Erysiphe graminis*
- Brown stripe—*Scolecotrichum graminis*
- Anthracnose—*Colletotrichum graminicolum*
- Ergot—*Claviceps purpurea*
- Stripe smut—*Ustilago strieiformis*
- Rust—*Puccinia coronata*
- Blight—*Rhizoctonia solani*

Tall fescue
- Net blotch—*Helminthosporium dictyoides*
- Rust—*Puccinia coronata*
- Blight—*Rhizoctonia solani*

Smooth bromegrass
- Bacteria blight—*Pseudomonas coronafaciens atripurpurea*
- Brown spot—*Pyrenophora (Helminthosporium) bromi*
DISEASES OF FORAGE LEGUMES

Bacterial wilt of alfalfa (Corynebacterium insidiosum), is one of the most destructive pathogens attacking a legume species in the United States. Fortunately the wilt bacterium is specific to alfalfa. The wilt organism is known to occur in practically all areas where alfalfa is grown.

When first discovered in 1925, it was most severe in the river valleys of Nebraska and Kansas, but it is now found in considerable abundance eastward to the Atlantic seaboard. It is prevalent and destructive also in the irrigated valleys of the western United States clear to the Pacific Coast.

The first evidence of this disease in an alfalfa field is the presence of dwarfed plants with small, abnormal shaped leaves of a yellow or pale green color. The stunting and wilting are a result of the water-conducting vessels in the alfalfa roots becoming plugged with bacterial growth. The wood of such roots is yellow in color when cut open, as compared with the uniform creamy white color of a healthy root. In almost all parts of the United States, dwarfed alfalfa plants with yellow or pale green foliage associated with discolored wood in the roots indicates the presence of bacterial wilt. The disease is destructive because infected alfalfa frequently is killed outright before the third cutting season. The only known control for the disease is by selection and breeding for resistance. If growers could, through the growing of disease-resistant varieties, such as Ranger and Buffalo, maintain stands of alfalfa for even two years longer than at present, it has been estimated that they would be able to save millions of dollars.

Bacterial wilt of lespedeza (Xanthomonas lespedezae), a bacterial wilt disease somewhat similar to that of alfalfa is widely distributed in the lespedeza-growing area of the United States. It affects only the annual lespedezas and appears to be most severe on the strains of Early Korean lespedeza grown in Illinois, Iowa, and Missouri.

The first visible symptom of infection is the appearance of dark, water-soaked spots on the leaflets. The infected leaflets soon become grayish-brown, desiccated and curled, and within a few weeks entire plants of susceptible strains wilt and die.

Since the bacterium causing the disease may occur either in or on the seed, prevention of the disease requires primarily the use of disease-free seed. There seem to be no practical control measures that will check the spread of the disease once it appears in a field of annual lespedeza.

Damping-off and seedling blight (Pythium debaryanum and other Pythium spp.), are soil-inhabiting fungi which attack nearly all legume species. These pathogens are largely responsible for the inability to obtain good initial stands as they attack legume species during seed germination and in the seedling stages of growth. No adequate control methods are known.

Soft root rot (Phytophthora caactorum), is a soil-inhabiting fungus which is very
DISEASES OF FORAGE CROPS

destructive to sweetclover species. This disease is largely responsible for the inability to maintain a stand of sweetclover beyond the first year in certain areas. The fungus is favored by low temperatures and abundant moisture and accordingly is most destructive during the early spring months. No adequate control methods are known.

**Root and crown rots** (*Rhizoctonia solani* and *Fusarium spp.*), also attack many biennial and perennial legume species in the later stages of growth. These resistant varieties seem possible. An example is the selection of Williamette sweetclover that is somewhat resistant to stem rot under Oregon conditions.

**Anthracnoses** (*Colletotrichum trifolii*, *Kabatiella caulivora*, and *Glomerella cingulata*), are destructive fungus pathogens on many legumes. The first mentioned, commonly called “southern anthracnose” attacks several legumes and is especially destructive on red clover. This disease is favored by high temperature and moisture and as its name implies, is common throughout the southern area where red clover is grown. The second, commonly called “northern anthracnose” is specifically destructive to red clover. This disease is favored by moderate temperatures and moisture, and as its name implies, is common throughout the northern area where red clover is grown. The third is especially destructive to lupine and vetch species and occurs throughout the areas where these legumes are grown, and is favored by high temperatures and moisture.

**Anthracnose** occurs on red clover in early summer as small dark spots on the stems, petioles, and flower stalks. The girdling of these structures causes wilt-

Row of common alfalfa attacked by bacterial wilt disease, between two wilt-resistant strains.

pathogens are economically important as they frequently deplete a stand to the point where it is not profitable to leave fields for pasture or hay beyond the second or third year. No adequate control methods are known.

**Crown and stem rot** (*Sclerotinia trifoliorum*), is a soil-inhabiting fungus which is a destructive pathogen on many legume species. Clovers are especially susceptible, but the fungus also attacks alfalfa, lotus, lupine, and other economic legumes. The fungus is favored by moderately low temperatures and abundant moisture, and is most destructive during the late fall and early spring months.

Control through the development of throughout the southern area where red clover is grown. The second, commonly called “northern anthracnose” is specifically destructive to red clover. This disease is favored by moderate temperatures and moisture, and as its name implies, is common throughout the northern area where red clover is grown. The third is especially destructive to lupine and vetch species and occurs throughout the areas where these legumes are grown, and is favored by high temperatures and moisture.

**Anthracnose** occurs on red clover in early summer as small dark spots on the stems, petioles, and flower stalks. The girdling of these structures causes wilt-
ing and browning of the tissues above the girdles and results in breaking or bending over of the petioles and flower stalks to produce characteristic “shepherds’ crooks.” Considerable defoliation may occur in the first cutting but when anthracnose is severe during late summer, the tops are sometimes killed completely and the crown and taproot of infected plants may be invaded and rotted.

The only known control is by selection and breeding for resistance. Control by means of the development of resistant varieties offers the most promise. Three varieties developed in recent years show resistance to anthracnose. Cumberland is somewhat resistant to southern anthracnose, and Kenland, a more recent development, is highly resistant. Midland has shown some resistance to northern anthracnose.

**Powdery mildew (Erysiphe polygoni)**, is a fungus pathogen omnipresent on red clover, which is more conspicuous than destructive. It does, however, cause an appreciable reduction in hay fields. It is strictly a leaf pathogen and produces a white cottony mass composed of mycelia and spores of the fungus on the upper surface of leaves. Severe mildew infection weakens and stunts normal plant development. Progress in selection and breeding for resistance to powdery mildew is being made with red clover in the North Central region of the United States.

**Leaf spots**: Leaf spot diseases are caused by bacteria and fungi and are very common on many legume species. They only become economically important when infection is severe enough to cause leaf defoliation with subsequent reduction to the forage value of the crop. Alfalfa is host to several leaf spots, each of which is sometimes economically important, especially under humid conditions. Clover and other legume species are also commonly attacked by several different leaf spot organisms.

The common leaf spot *Pseudopeziza medicaginis*, is probably the most destructive of the foliage diseases of alfalfa. The disease is present in almost every alfalfa field, taking a small toll of the foliage under dry conditions and a large toll under more humid conditions.

Leaf-spotting and stem-blackening of alfalfa are caused by *Ascochyta imperfecta*. Infection by this fungus is favored by cool, wet weather and considerable defoliation may occur in the spring before the first cutting is made. Blackening of the stems occurs progressively from the base upward and in wet springs in some localities may result in the death of the less vigorous young shoots. Late in the season, in stands left for seed, the blackening may progress up to the racemes and even to the seed pods. Since this disease is seed-borne, seed infection probably occurs directly through the seed pods of severely-diseased plants.

Control through the development of resistant varieties seems possible. Perhaps also, strains of alfalfa resistant to both bacterial wilt and leaf spot will be developed in the future for the more humid areas.

**Viruses**: Virus diseases are common to practically every legume species of economic importance. The common mosaic type of virus characterized by stunted growth and yellow and green mottling of the leaves is omnipresent. This virus causes some loss but is not especially destructive. The dwarf virus, which attacks alfalfa, is confined to the extreme Southwest where its effects on alfalfa are similar to those of bacterial wilt. Witches’ broom, another virus attacking alfalfa, is also confined to limited geographic regions. Viruses attacking legumes are known to be insect-transmitted and also attack many nonleguminous host plants. No controls for the virus diseases are known, other than through elimination of the insect vectors.

**Nematodes**: Legumes are hosts to several destructive nematode disorders. The root knot nematode, *Heterodera marioni*, is the most common. It attacks many legumes and is common on clovers, lespezes, and lupines. *Ditylenchus dipsaci*, the stem nematode, is important on alfalfa in the Western United States. Nematode disorders are effectively controlled by using
crops which the nematode does not attack in rotation, whereby the nematode population perishes.

SEVERAL ECONOMIC LEGUMES AND COMMON DISEASES

Alfalfa
- Bacterial wilt—Corynebacterium insidiosum
- Damping-off and seedling blight—Pythium spp.
- Downy mildew—Peronospora trifoliorum
- Leaf spot—Pseudopeziza medicaginis
- Leaf blotch—Pyrenopeziza medicaginis
- Anthracnose—Colletotrichum trifolii
- Black stem—Ascochyta imperfecta
- Stem and crown rot—Sclerotinia trifoliorum
- Wilt—Fusarium oxysporum medicaginis
- Rust—Uromyces striatus
- Virus—Mosaics, witches' broom, Dwarf
- Stem nematode—Ditylenchus dipsaci
- Sooty blotch—Cymadotheca trifolii
- Stem and crown rot—Sclerotinia trifoliorum
- Southern blight—Sclerotium rolfsii
- Rust—Uromyces trifolii
- Virus—Mosaics

Crimson clover
- Damping-off and seedling blight—Pythium spp.
- Leaf spot—Cercospora zebrina
- Sooty blotch—Cymadotheca trifolii
- Stem and crown rot—Sclerotinia trifoliorum
- Rust—Uromyces trifolii
- Virus—Mosaics

Sweetclover
- Damping-off and seedling blight—Pythium spp.
- Soft root rot—Phytophthora cactorum
- Crown and stem rot—Sclerotinia trifoliorum
- Stem canker—Ascochyta caulivora
- Black stem—Mycosphaerella lethalis
- Leaf spot—Mycosphaerella daevisii
- Virus—Mosaics, mugspot, streak

Lespedeza
- Bacterial wilt—Xanthomonas lespedezae
- Powdery mildew—Microsphaera diffusa
- Anthracnose—Glomerella cingulata
- Southern blight—Sclerotium rolfsii
- Root knot—Heterodera marioni

Cowpea
- Bacterial canker—Xanthomonas vignicola
- Wilt—Fusarium oxysporum tracheiphilum
- Leaf spot—Aristastoma oeconomicum
- Target spot—Helminthosporium vignae
- Virus—Mosaics
- Root knot—Heterodera marioni

Winter pea
- Root rot—Aphanomyces euteiches
- Leaf spot—Ascochyta pinodes
- Black stem—Mycosphaerella pinodes
- Leaf blotch—Septoria pisi
- Powdery mildew—Erysiphe polygoni
- Virus—Mosaics

Vetch
- Anthracnose—Colletotrichum villosum
- False anthracnose—Kabatiella caulivora
- Leaf spot—Botrytis cinerea
- Virus—Mosaics

Lupine
- Anthracnose—Glomerella cingulata
- Brown spot—Cercophoridae setosum
- Powdery mildew—Erysiphe polygoni
- Sooty blotch—Cymadotheca trifolii
- Stem and crown rot—Sclerotinia trifoliorum
- Southern blight—Sclerotium rolfsii
- Rust—Uromyces trifolii
- Virus—Mosaics
SOME INSECT PESTS OF GRASSES AND LEGUMES

An incredible number and variety of insects live on grasses and legumes. Under favorable conditions many species compete very successfully with domestic animals as consumers of these crops, as any farmer knows who has seen an outbreak of grasshoppers or armyworms ruin a good stand of grass or grain almost overnight or a whole cutting of alfalfa lost to the pea aphid. Often running into many millions per acre, their large appetites more than make up for their small size. Hundreds of species are pests of grasses, legumes and other forage plants. Herbert Osborn has written a book about them, called “Meadow and Pasture Insects,” but only a few of the most important ones can be discussed in the present article. Since only brief mention can be made of the control methods used against them, the readers should consult their County Agricultural Agents or State Experiment Stations when specific instructions are needed.

Grasshoppers (Many species of several genera). Grasshoppers are among the most widely prevalent pests of pasture and hay crops. Some species favor the uncultivated ranges, while others prefer the cultivated grasses and legumes. In both environments their abundance and control may mean the success or failure of a year’s farm operations. Fortunately, effective means have been developed for controlling them. For many years the application of a poisoned bran mash or bran-sawdust bait broadcast thinly in the infested fields has been a standard, cheap, and under most conditions, effective method of control. When bait is properly handled and applied there is no danger to livestock, including poultry, pastured in the treated areas.

The substitution of sodium fluosilicate for the arsenical poisons formerly used in baits has practically eliminated the danger of stock poisoning as a result of carelessness. More recently, a dry flaky bran bait containing chlordane or toxaphene as the poisonous ingredient, has been widely and successfully used.

Although much bait is still spread by hand, highly efficient power equipment for spreading it from the ground and from airplanes has been developed and widely used. During the bad grasshopper year 1938, farmers spread about 136,000 tons (dry weight) of grasshopper bait supplied them by Government and State agencies on over 30,000,000 acres, and thereby saved crops valued at more than $175,000,000.

Baits are often rather ineffective in thick, succulent crops such as alfalfa. In-
vestigators have therefore been working hard to find a better method for use in the protection of such crops. Their experiments have shown that several of the new insecticides, particularly chlordane, benzene hexachloride and toxaphene, directly applied in a spray or dust, preferably as sprays, with ground equipment or airplanes, are very effective against grasshoppers.

Proper use of these insecticides is being found a practical supplement or substitute where poor control is obtained with bait. Until more is known about the residue hazards involved, however, these insecticides should be applied only to the early growth just after cutting if the crops are to be used for hay or feed, and to field margins, fencerows, roadsides and idle lands where the hoppers are congregated and which are not to be pastured or cut for hay.

The Mormon cricket. The Mormons were the first ones to lose range forage and crops to this insect, hence its common name. They encountered it soon after they first settled in Utah about 1848. In the Northern Rocky Mountain and Pacific Coast States the Mormon cricket often damages large areas of range forage severely. When very abundant it depletes the forage supply in these areas and migrates to new pastures on foot in bands sometimes miles in extent. These bands will also attack cultivated grass, grain, forage and garden crops that may lie in their path. Although they look like big, black, long-legged crickets, they are really wingless grasshoppers. A closely related species, the coulee cricket, also occurs in some northwestern areas and has similar habits.

The early Mormon settlers knew no satisfactory way of fighting the Mormon cricket but their crops are said to have been saved from destruction by an influx of seagulls that appeared in answer to their prayers and ate up the crickets. A monument to the gulls still stands near the Mormon Tabernacle in Salt Lake City. These birds continue to feed on crickets and grasshoppers in fields.

Recently, it was found that these crickets can be cheaply and quickly controlled by means of a poisoned bran or bran-sawdust bait. Although they do not like a bait containing an arsenical, investigators finally discovered that they will readily eat one containing enough sodium fluosilicate to kill them. Baits containing this poison, broadcast by hand, power spreaders and airplanes, have been widely and successfully used against them. A dry bait composed of steam-rolled wheat impregnated with one of the newer insecticides has shown promise for Mormon-cricket control.

Cutworms and armyworms (many species of several genera). In an unpublished paper on the cutworms and armyworms
of the Central Great Plains, H. H. Valken reports the observation of 54 species in cereal and forage crops, pasture grasses, and waste lands in the Middle West. Six of these are known to be of major economic importance, the pale western cutworm, army cutworm, variegated cutworm, armyworm, fall armyworm and corn earworm. Others could well be added and lawns as well as farm crops are sometimes attacked. A few of them, like the pale western cutworm, work mostly underground, while others bore within the stems of their host plants. The only methods of control yet known for these are cultural measures such as rotation of crops and properly timed summer fallowing.

Armyworms are really cutworms that occur in great numbers under favorable conditions and migrate in droves on foot in search of food as they deplete the supply in the infested fields. Most cutworms and armyworms feed on the aboveground portions of the plants and hide under the surface litter and soil during the day. Due to this habit they usually can be easily killed with poison bran or bran-sawdust bait broadcast along the infested fields late in the afternoon so that it is fresh and attractive to them as they emerge hungry in the evening. The bait may be applied by hand or with power or airplane equipment, as for grasshoppers and Mormon crickets, but should not be applied if the afternoon or evening is chilly or cold and windy.

Another method of control sometimes used against armyworms are barrier furrows plowed along the sides of the fields being invaded. In plowing a barrier furrow the dirt is thrown toward the crop to be protected. A log is then drawn back and forth in the furrow to work up a loose dust which helps prevent them from climbing out, and kills the worms as they accumulate in the furrow. Sometimes instead of using a log the furrow is left smooth and hard and postholes are dug in the bottom of it every 20 feet or so. The worms crawl along the furrow and tumble into the holes where they may be killed by crushing or by application of coal tar or crank-case oil.

Still another method is the application of an insecticidal dust or spray to the infested crop. Lead arsenate, calcium arsenate, and some of the new insecticides such as DDT have been found effective against certain species. Owing to the residue hazards involved, however, their use on forage crops or pastures is inadvisable, except perhaps where several months, much plant growth and heavy rains occur between treatment and harvest or pasturing.

Range caterpillar (Hemileuca oliviae). A large spiny larva commonly called the range caterpillar has at times caused extensive losses of range forage in eastern New Mexico. Although it feeds upon at least 40 different species of plants including cultivated grain and forage crops, it is primarily a pest of the range grasses common to that region. It injures them in two ways: first, by eating them down to the roots over large areas; second, by leaving on the plants the poisonous spines which it sheds as it crawls around or when it molts.

Control measures such as burning over the range, the use of heavy corrugated iron rollers and brush dragging have not been successful. They can be killed with a lead arsenate spray if the value of the crop to be protected would warrant the cost. It is possible that cryolite or one of the new insecticides such as DDT might also be effective, though none of these has actually been tried against them. If one of them were to be applied the same precautions concerning the attendant residue hazards should be observed as have already been mentioned in connection with the use of sprays and dusts against cutworms. Apparently poison bran baits have never been tested against the range caterpillar and might well be given a trial.

Velvetbean caterpillar (Anticarsia gemmatalis). The velvetbean caterpillar frequently invades the Southeastern States where it attacks peanuts, soybeans, velvetbeans, kudzu, and other legumes. It is believed to be unable to survive the winter in the continental United States, except perhaps in southern Florida, and apparently works north from the tropics during
the summer until by August or September after perhaps three generations, it is sometimes found as far north as Virginia. In the extensive outbreak of 1946 it was estimated to have injured legume crops to the extent of more than $5,000,000 over and above the $15,000,000 worth of crops that were saved from loss to this insect by prompt control measures.

The grayish brown moth measures about 1½ inches across its expanded wings both pairs of which bear a single dark diagonal line near their outer margin. The caterpillar is rather slender and about 1½ inches long when full grown, greenish or blackish, with several narrow light stripes along its back and sides. It is very active and will spring into the air wriggling violently when disturbed. When the larva is very abundant it rapidly produces "ragging" and defoliation of the infested plants. Susceptible crops should therefore be watched closely for it in late summer and control measures applied promptly. A single treatment with cryolite dust at 12 to 15 pounds per acre has been widely and successfully used in the control of the velvetbean caterpillar. This treatment can be used safely on crops intended for hay or pasture. Quicker control can be obtained with 15 pounds per acre of a dust containing 2 to 3 percent of DDT, but crops treated with this insecticide should not be fed to dairy animals or to meat animals that are being finished for slaughter.

**Alfalfa caterpillar** (*Colias philadice eurytheme*). Great numbers of a butterfly with bright yellow wings bordered with black and a spread of about 2 inches are a common sight in alfalfa fields of the Southwestern States. The so-called alfalfa caterpillar from which it comes is a green larva about 1½ inches long when full grown, with a fine white stripe on each side. There are several generations a year in the more southern part of its range. The larvae eat alfalfa foliage and often ruin an entire cutting. Although this insect is kept more or less under control by parasites and a wilt disease, artificial control measures are sometimes desirable.

Prompt, clean cutting of the crop and removal of the hay is often the best procedure. Cutting all fields in a neighborhood at about the same time, and keeping down the growth of weeds and volunteer alfalfa around the fields by mowing or pasturing aid in preventing serious infestations. Prompt dusting of infested fields with a heavy application of sulfur has also been found effective. Alfalfa growers in certain districts of central California have found it profitable to employ an experienced entomologist to watch their alfalfa fields during the growing season and advise them concerning the application of control measures.

**Alfalfa webworm** (*Loxostege commixtalis*). Alfalfa and clover sometimes become heavily infested by this insect. It was extremely abundant in 1947 when it was also reported attacking several other field crops. The small black-spotted, yellow or greenish to nearly black larvae web the terminal leaves together and feed on the enclosed foliage. When full grown they are about an inch long and turn into small buff-colored moths. These hide among the plants during the day but will make short flights as one walks through an infested field and often swarm about lights on warm nights. There are several generations a year. In the fall the larvae assume more of the habits of cutworms in newly-sown alfalfa and hide in silk-lined burrows in or on the ground.

Prompt, clean cutting of the alfalfa and clean-up of weeds and volunteer growth around the fields are the most practical methods of controlling the summer generations. Fields of newly seeded alfalfa infested in the early fall may be protected by dusting or spraying with calcium arsenate, lead arsenate or DDT, but crops so treated should not be used for pasture or hay the same season. The alfalfa webworm is ordinarily held in check by its insect parasites.

**Pea moth** (*Laspeyresia nigricarza*). The pea moth is found in the Great Lakes Region and the Pacific Northwest. The moth appears soon after the field pea vines begin to bloom, usually about July 14, and lays its eggs on the pods, leaves, and stems. The eggs hatch in 7 to 10 days and the larvae enter the pods and feed on the seeds. Growth is completed
in from 16 to 26 days, then they emerge from the pods and pass the winter in the soil.

The most effective remedy is to grow early varieties, sow early, thresh early, and then burn the rubbish left on the field, or plow it under deeply, preferably in the fall. Whenever possible, new crops should be planted at a distance of at least 2 miles from fields that were known to be infested during the previous season.

Green clover worm (*Plathypera scabra*). The green clover worm, which is the caterpillar of an inconspicuous, soot-colored moth, feeds on a variety of legumes, and ordinarily escapes the notice of growers. In 1919 it caused widespread injury to soybeans in the South Atlantic Coastal Plain. Many fields were so defoliated that they did not produce a crop. The following year the insects were present in smaller numbers. The green clover worm is always present in the region mentioned, however, and may at any time become numerous enough to repeat the severe injury of 1919. It is common but rarely of any importance in clover and alfalfa. In case this worm becomes abundant, its control may be accomplished by dusting with a mixture of lead arsenate (powdered), 1 pound, and hydrated lime, 8 pounds. This dust should be applied evenly but thinly at the rate of about 18 pounds to one acre. Any efficient form of hand or power duster may be used. It is possible to apply such a dust by hand, but this is a tedious process and requires considerably more of the dust than if a machine is used.

The poison should be applied as promptly as possible after the infestation is noticed. Unless the crop is cut for forage very soon after the poison is applied there is no danger of poisoning stock in feeding. Where early use of the crop as forage is intended, it may be saved by immediate cutting without applying the poison dust.

Alfalfa aphid (*Illinoia pisi*). This insect is officially known as the pea aphid. It thrives on alfalfa, clovers, vetches, Austrian peas and other legumes, and these perennial or winter crops serve as the major sources of the infestations that develop on canning and garden peas. It is a pale green, long-legged plant louse about \( \frac{1}{2} \) inch long when full grown. Although most individuals are wingless, many of them develop wings under crowded conditions and fly or are carried by winds for considerable distances.

Parasites and diseases usually hold down its numbers during warm weather but it can multiply very rapidly and often reaches extreme abundance on alfalfa, vetch and Austrian peas during late winter or early spring. At this time it bears living young which begin at once to suck sap from the newly sprouted alfalfa shoots which rapidly become solidly encrusted with aphids in all stages and soon die. As a result the entire first cutting of alfalfa is lost. This aphid is present throughout the United States and first cuttings are ruined by it somewhere in the country nearly every year.

The most practical methods of controlling the alfalfa aphid are heavy pasturing of the fields during the winter or early spring, or winter cultivation with a disk or spring-tooth harrow. These operations destroy most of the aphids that would otherwise survive the winter as eggs or adults on the fall growth and thus delay their increase until warm weather when their parasites and diseases can take over the job. Recent experiments indicate that the use of one of the new insecticides such as benzene hexachloride or hexachyl tetraphosphate on the small shoots early in the spring may be found effective and practical, but further trials of them are necessary before they can be recommended.

Alfalfa weevil (*Hypera postica*). The alfalfa weevil is an Old World insect that appeared near Salt Lake City in 1904 and has since spread to 11 western States. Little injury from it has occurred outside of Utah, Nevada, Idaho, Colorado, Oregon, Wyoming, California and Montana; however, in some areas a little wasplike parasite brought in from Europe helps to keep it down. Alfalfa is the only crop injured by it. The adult is a brown snout beetle about \( \frac{3}{4} \) inch long. They feed on alfalfa but cause little injury. The real
damage is done by the little green larvae which hatch from the eggs laid by the adults in the alfalfa stems. These larvae are about ½ inch long when full grown, with a white stripe down the middle of the back. They feed on the terminal buds and leaves, eating out the tissue and leaving only the leaf-veins. Damaged leaves take on a gray or whitish cast, giving the infested fields a frostbitten appearance. The main damage is to the first or spring crop, though the second crop may also be injured in some seasons, especially if left for seed.

Damage can usually be prevented by early cutting of the first and second crops. This means cutting before many of the alfalfa flowers have opened and before many young shoots of the next crop have started out from the plant crowns. By clean cutting and prompt removal of the hay at this time nearly all of the worms, eggs and pupae are killed by starvation or heat in the bare fields. Early cutting of the first and second crops should be practiced if possible every year, even though these crops are not actually being injured. If this practice is not followed, enough weevils may be produced to cause damage the following year.

Where early cutting is not practicable, as in the case of fields left for seed, the weevil can be controlled by one application of 2 pounds of calcium arsenate per acre, diluted with a carrier dust or spray in order to obtain proper coverage. If the dosage is limited to 2 pounds per acre, evenly applied, the treated crop can be safely fed to livestock.

A single application of a dust containing 5 or 10 percent of DDT, at the rate of 1 to 2 pounds of the active ingredient per acre, has also given excellent control of the alfalfa weevil, but crops so treated should not be fed to dairy animals or to meat animals being finished for slaughter. Recently, an early April treatment with DDT, or one of the other new insecticides, to kill the overwintered adults on the newly developing alfalfa shoots and before they have laid many eggs, has been found quite effective. If properly used, this method of control probably would avoid any material residue hazard.

Clover leaf weevil (Hypera punctata). The greenish larvae of the clover leaf weevil feed on red clover leaves early in the spring. They may be found at the
base of plants during the day, but they do most of their feeding at night. Their presence is indicated first by small holes in the leaves, and later by irregular patches eaten from the margins. During April and May a raggedness is sometimes very noticeable in the clover plants.

Seldom is an entire crop lost, but considerable injury may occur before the larvae are killed by a fungus disease to which they are very susceptible.

**Lesser clover leaf weevil (Hypera nigripennis).** The adults and larvae commonly feed on red clover but they may also attack alsike clover. The larvae will attack newly forming buds and heads of the first crop. Buds may be blasted, and new heads may fail to develop. The larvae may also eat into the stem and even partially tunnel into it. The adults feed on the leaves, riddling them. Parasitic insects attacking the larvae apparently hold this pest in check.

**Pea Weevil (Bruchus pisorum).** The pea weevil has been recorded as infesting areas wherever the crop is grown; however, the greatest damage occurs in areas where the crop is allowed to mature. In Washington, Oregon, Idaho, Utah, and northern California, where field and garden peas are grown extensively for seed, the weevil is abundant. The grower of the field-pea seed crop will therefore be more concerned with weevil control than one who grows the crop for green hay or for a cover crop.

The pea weevil is an active grayish or brownish-gray beetle about one-fifth of an inch long and marked with black and white spots. It passes the winter in the adult stage in seed pea or in any available location that affords protection from the weather. The weevils fly into the field about the time blossoms appear. The eggs are laid on the developing green pods and after hatching, the young grub enters the immature pea. The weevil is incapable of breeding in dried seed, as do the cowpea weevil and the bean weevil. As the pea grows the pea-weevil grub feeds within the pea, its presence being manifested by a small sunken area in the skin of the pea. Its development is completed a short time before the pea hardens. There is only one generation per year.

The feeding of the grubs affects germination. Therefore, weevil-infested peas are not desirable for seed purposes. Early season infestations damage early-set peas. To protect these, dusting the field early in the blossoming period with either 0.75 percent of rotenone or 5 percent of DDT has proven satisfactory. The dust is used at the rate of 20 pounds per acre per application. Later infestations are prevented from developing by fumigating peas immediately after harvest.

**CAUTION:** DDT is a poison and should not be applied to peas if the vines are to be fed to dairy animals or to animals that are being finished for slaughter.

In addition to the control measures mentioned above, certain cultural and sanitation practices help to reduce the pea weevil population from year to year. Be sure to plant weevil-free seed. Harvest peas early, to reduce the number of shattered seed, and do not allow weevils in the field to complete development. Deep, clean plowing, using jointers, immediately after harvest, destroys most of these weevils.

**Cowpea weevil (Callosobruchus maculatus).** Cowpea seed is subject to attack by several species of weevils, of which the cowpea weevil causes the most injury. This weevil is generally distributed throughout the Southern States and California. The adult lays its eggs on the cowpea pods in the field and continues to breed for successive generations in the stored seed. The food value of the crop is often entirely destroyed or its value for planting purposes seriously impaired or lost.

All small or large lots of dried beans, cowpeas, and bean or cowpea straw on farms and in warehouses serve as breeding places for cowpea weevils and as sources of infestation of the new plantings in the field. As many as possible of these sources of infestation should be eliminated prior to planting time, or at least early in the growing season. This can be done by fumigating stocks of dry beans, peas, or cowpeas, as described below, by feeding the seed stalk and bean
or cowpea straw to livestock, and by plowing the straw under deeply or burning it.

The weevils may be very easily controlled in stored seed by the application of heat or fumigation. The fumigants recommended are a 3:1 mixture of ethylene dichloride and carbon tetrachloride, or a 1:4 mixture of carbon bisulfide and carbon tetrachloride. These fumigants are sold as ready-mixed liquids under various trade names, and their preparation at home should not be attempted. Although carbon bisulfide alone is a very cheap and effective fumigant, it is no longer recommended because of its extremely high inflammability.

Vetch bruchid (Bruchus brachialis). This little weevil that came in from Europe makes a specialty of ruining the seed of hairy vetch, although it similarly attacks some other vetches. During 1941 to 1943 it greatly reduced the production of hairy vetch seed in this country. This was a serious matter, especially during wartime when no hairy vetch seed could be imported, since hairy vetch is an important cover crop in the South for which no satisfactory substitute is yet known.

Hairy vetch seed production in the Eastern States ceased to be profitable 10 years or more ago on account of this weevil and recently most of the crop has been produced in the Pacific Northwest. The vetch bruchid found its way out there just before World War II and was rapidly reducing production in that area also until entomologists found that it could be controlled by timely dusting of the crop with DDT.

The adults lay their eggs on the small newly-formed seed pods and the little maggots hatching from the eggs immediately bore through the under side of the eggs into the pods, and enter the seeds while they are still green. Infested seeds are hollowed out and ruined by the time they are mature and are eliminated in the cleaning process after the crop is threshed. A single application of about 25 pounds per acre of a dust containing 3 percent of DDT just as the pods begin to form kills off the adults as they congregate in the vetch for egg-laying. Most of the seed infestation is thus prevented and a profitable crop can be produced. The straw and chaff from vetch that has been treated with DDT should not be fed to livestock, however.

This weevil does not breed in mature, dry vetch seed, although it can survive in them for months. It was undoubtedly brought to this country in vetch seed from Europe.

Cowpea curculio (Chalcodermus aeneus). Growing cowpeas are more or less subject to attack by various insects, one of the most important of these being the cowpea curculio. This insect is distributed throughout the States east of the Mississippi River and south of Tennessee and Virginia. In the southern part of this region there are two generations annually, and the insect hibernates in the adult stage. It infests the cowpea seeds during their development in the field, but does not breed in dry seeds. According to Arant, sodium fluosilicate has proved to be one of the most satisfactory materials for control of the curculio on cowpeas being grown for human food, although it is probably impractical for use on acreages grown for hay or feed. As a dust it is applied at the rate of 8 pounds of the dry material per acre per application. The first application should be made at the time the first blossoms appear and should be followed by additional dustings in the evening, when little air is moving, at weekly intervals throughout the fruiting season. Sodium fluosilicate may be used as a spray at the rate of 6 pounds of the dry material to 100 gallons of water. Insecticidal control should be supplemented by farm practices that include the location of all new plantings in areas isolated from other cowpeas, the frequent picking of ripe pods, and the rotation of crops to prevent infestation by insects coming from hay and from other fields of cowpeas.

Clover-seed chalcid (Bruchophagus gibbus). Occasionally growers of clover or alfalfa seed harvest a small crop of especially light-weight seed when prior to the harvest they had considered that conditions were favorable for a large yield. Upon examination of the seed, it is found
to be empty and to have one or more small, circular and somewhat jagged holes in the seed coat. This is the work of a tiny wasp-like insect called the clover-seed chalcid. Soon after the female chalcid wasps insert their eggs into immature seeds, the eggs hatch into white footless larvae. These consume the contents of the seed, leaving only a thin seed coat.

Screenings accumulated during the threshing process contain many of the insects. To protect the next year’s seed crop, the screenings pile should be worked into livestock feed and utilized during the winter, or it should be burned or otherwise destroyed.

Of equal importance is the destruction of all clover and alfalfa along field margins, ditches, roadsides, and other waste places, for such plants provide a continuous source of infestation. With clover a practical aid in control is cutting or pasturing the first crop early, and also growing the seed crop early that it will be produced before there are very many insects.

Clover root borer (Hylastinus obscurus). The clover root borer is one of the most destructive enemies of red clover; this pest, however, is not equally serious in all regions where red clover is grown. Rarely does the root borer work in plants before they are a year old. Then it tunnels in the roots, where it lays its eggs. The eggs, small larvae, and even the dark-brown adults may be found in the cavities. Because of their weakened root system, affected plants are apt to break off at the ground level. Also, the damage to the roots provides entrance for fungi that may cause crown and root rots. A badly infested field should be plowed as soon as possible after the first crop of hay is removed. With the death of the plant, the larvae also die. Good control of this insect has been obtained experimentally with certain of the newer insecticides, but definite recommendation cannot be made at this writing.

Blister beetles: Blister beetles of several species (Epicauta spp.) are so injurious to soybeans and some other leguminous crops in some of the Southern and Western States as to occasion considerable alarm. The beetles usually appear very suddenly and feed so rapidly as to strip the plants completely in a short time. The young, or larvae, of these beetles devour the eggs of grasshoppers, and in this respect the insects are of considerable benefit. When the adult beetles attack crops, they may be destroyed effectively by dusting the infested plants with a mixture of equal parts of powdered sodium fluosilicate and hydrated lime at the rate of about 15 pounds to the acre. Sodium fluosilicate is a comparatively new insecticide, which is a byproduct of the manufacture of superphosphate and is poisonous to man in about the same degree as is arsenic. When applied as recommended, this insecticide kills the beetles within 24 hours and the plants suffer no appreciable injury. Arsenic in any form is not very effective for these insects. Where soybeans are being grown for hay, they may be cut immediately and thus saved from the beetles, but in this case very prompt action is necessary as blister beetles feed rapidly and may consume most of the crop before it can be cut.

Mexican bean beetle (Epilachna variestis). The Mexican bean beetle feeds upon a number of legumes. When it becomes necessary to protect a crop against attacks of this insect and the plant is not being grown for hay, it may be sprayed with cryolite (sodium fluoaluminate), either natural or synthetic, in proportion of 3 pounds in 50 gallons of water. As the Mexican bean beetle feeds on the under surfaces of the leaves, it is necessary to adjust the spray nozzles so as to apply the spray to these parts of the plants. The spray should be applied at the rate of 90 to 100 gallons to an acre. When a crop is to be used for hay and becomes infested, immediate cutting is recommended.

Chinch bugs (Blissus leucopterus). The chinch bug must be included among the most important insect pests that are native to this country. Before the planting of large acreages of small grains and corn it probably lived on native perennial grasses. It finds modern farming conditions much to its liking, however, and in
favorable seasons becomes extremely abundant in the Central and Eastern States. Chinch bugs feed only on plants of the grass family. They are most important as pests of corn and small grains, but also attack forage and lawn grasses.

Chinch bugs are little black sucking insects with white wings folded on their backs to form a sort of "X." They are about \( \frac{1}{4} \) inch long when full grown and have the typical "buggy" odor which is characteristic of many related families of insects. When newly hatched they are smaller than a pinhead, red and wingless, but the red color is gradually lost and their wings develop as they mature. When abundant the adults hibernate in great numbers hidden away in bunchgrasses and various sheltered places. With the first warm weather they emerge from hibernation and fly to the small grains and grasses. By the time small grains are ripe the first new generation of the season is nearly mature and as these grains dry up they migrate in hordes on foot in search of green food. They swarm onto corn, sorghum, sudangrass, millet, or almost any green grassy plants they can find nearby and soon kill them. When full grown they migrate by flight throughout the corn, sorghum and grass fields.

Barriers are widely used to prevent chinch bug migrations on foot from small-grain fields to immature small grains and grasses, corn and sorghums. These are made in several ways but the best of them include a narrow band of a repellent chemical such as coal tar, creosote or a poisonous dust such as di-nitro ortho cresol laid across the path of the migrating bugs. The creosote is often poured in a narrow line along the smoothly packed brow of a plow-furrow made by turning the soil toward the crop to be protected. Detailed instruction for building chinch bug barriers may be obtained from State agricultural experiment stations and this Department.

A different method must be used to control chinch bug infestations in lawns or on valuable grasses and grains being grown for seed. Under these conditions, it is necessary to make direct application of a spray or dust. Kerosene emulsion or nicotine sprays, dusts containing at least one percent of nicotine or rotenone or 10 percent of ground sabadilla seed, and a dust containing 10 percent of DDT have all been recommended. The nicotine or rotenone dust is applied at the rate of 25 pounds and the sabadilla dust at the rate of 2 to 3 pounds per 1000 square feet. The DDT dust is perhaps

Chinch bugs feeding on leaf sheaths of corn.
last previous cutting should not be fed to livestock.

Leafhoppers (Many species of several genera). Unless leafhoppers are so numerous that they fly up in swarms when disturbed, most people never see them. Some of the most injurious species, such as the potato leafhopper, are fragile, wedge-shaped, pale green insects only about $\frac{1}{8}$ inch long when full grown, but they make up in numbers for their small size. The potato leafhopper (*Empoasca fabae*) is a serious pest of alfalfa and peanuts as well as potatoes. Severe injury by other species to clover, and to range grasses being grown for seed in connection with the "Dust Bowl" regrassing program, has also been reported.

The potato leafhopper as a pest of alfalfa and peanuts may be profitably controlled by the use of a dust containing 66 percent of a fine dusting sulfur, 10 percent of pyrethrum powder, and 24 percent of an inert powder such as pyrophyllite to improve its dusting quality. A single properly-timed application of 25 pounds per acre is sufficient on any one cutting of alfalfa. On peanuts, three applications of 15 to 20 pounds each, three weeks apart, are usually necessary. On peanuts in southern Virginia, three applications of a dust containing one percent of DDT, 90 percent of sulfur, and 9 percent of an inert conditioner, at 3-week intervals beginning July 10 to 15, has been found very effective. The first application should be at 15 to 20 pounds per acre and each of the two later applications at 25 to 30 pounds per acre. Promising experimental results against various species of leafhoppers have recently been obtained with some of the other insecticides, but definite recommendations on their use on grasses and legumes cannot yet be made.

A delay of ten days or so in cutting the first crop of alfalfa, if the crop is not too much impaired thereby, often serves to keep down leafhoppers because by that time large numbers of migrating adults will have deposited their eggs in that crop. These eggs will be taken away in the hay and the young leafhoppers that hatch from them will die of starvation.

In general, the best procedure when a legume crop is being damaged by leafhoppers is prompt, clean cutting. This drives out some of them, starves others, and removes the leafhopper eggs that have been laid in the stems.

Plant bugs (*Lygus* spp. and *Adelphocoris* spp.). The damage done to alfalfa and other legumes by several species of sucking bugs of the genera *Lygus* and *Adelphocoris* was not generally recognized until recent years, although their extreme abundance in such crops had long been noticed. They greatly reduce both the vegetative growth and the seed yield of alfalfa by their feeding, and some evidence has been obtained that they do the same to clover. These insects are pale greenish to brown, flat, oval-shaped, soft-bodied insects, about $\frac{1}{4}$ inch long and winged when full grown. With their long slender beaks they suck the sap from their host plants. Many species occur in different parts of the country with corresponding variations in habitats and host plants.

The species prevalent in the irrigated alfalfa fields of the arid Southwest can be fairly well controlled by thorough winter clean-up of alfalfa and weed hosts, cutting the first crop of alfalfa at the same time in all fields throughout a whole community, and starting the seed crop in all fields on or about the same date throughout the community. This system prevents the plant bugs from moving back and forth among fields in different stages of growth, and thus starves them out. It has been successfully demonstrated in certain districts of Yuma County, Arizona.

Conditions in other regions are less favorable for the community application of uniform cultural control measures and it is thus necessary to resort to other means. Fortunately, the advent of DDT has supplied this need, at least so far as seed alfalfa is concerned. Good control of plant bugs and large increases in seed yields can be obtained by a single properly-timed application of DDT dust and this method has been widely used by alfalfa seed growers in the Western States during the last few years.
INSECT PESTS OF GRASSES AND LEGUMES

A good general recommendation is a 10 percent DDT dust at 20 pounds per acre, applied by either power duster or airplane just before the first flower-buds begin to open. The residual effect of this treatment keeps down the bugs enough for a good crop of seed to develop beyond the stage where they can hurt it. When thus applied, there is no danger of killing the wild and domestic bees that are essential to the pollination and seed-setting of alfalfa, since they are not attracted into the treated fields until the blossoms open and for one reason or another are not killed by the DDT residues. Recent experimental trials indicate that sprays may be better than dusts and that some of the other new insecticides may also be satisfactory. Incidentally, the much more abundant bloom following the control of plant bugs makes excellent bee pasture.

The one bad feature of this method of control is the uncertainty relative to the hazard of feeding the threshings of seed alfalfa, or the hay if a treated field should be cut for hay, to livestock. Although there is no danger of acute poisoning, enough DDT may remain in the threshings or hay so that it will be secreted in the fatty tissues and milk of animals to which they are fed. Therefore, alfalfa that has been treated with DDT should not be fed to dairy animals or to meat animals that are being finished for slaughter.

Spittle bugs (Philaenus spp.). Spittle bugs are little sucking insects with the queer habit of living in small masses of white froth or spittle which they excrete around themselves during their immature stages as a protection against their natural enemies. They were unusually abundant on grasses, clovers, alfalfa and weeds in the Eastern and Lake States during 1946, 1947, and 1948. These insects look like leafhoppers and cause a withering of the infested stems and blasting of the seed heads. Suggested methods of control are early mowing, burning the dead grass in the infested fields during the dormant season, and frequent rotation from grass and clover to some other crop. Toxaphene, chlordane and benzene hexachloride sprays, applied early in the season, have been found quite effective in experimental trials. Where these are used, however, the precaution against feeding treated forage to dairy animals or to meat animals being finished for slaughter should be observed.

White grubs: Pasture and lawn grasses in the Eastern and Central States are subject to severe and extensive injury by white grubs of which 20 to 50 species are involved. These are the thick little grubs or grub-worms about an inch long when full grown, with bodies curled in a half-circle and brown heads and legs, that are often numerous in the soil under and around the roots of grasses. They feed on the underground portions of the plants and when very abundant sever the roots of large patches of grass so that the sod can be easily rolled up like a carpet. Certain species are among the worst pests of permanent bluegrass pastures and lawns. White grubs also attack cultivated crops that are planted on plowed-up sod. Undisturbed sodlands are particularly favorable to them because most species require two or three years to mature. The Japanese beetle completes its life cycle in one year, the wheat white grub in two years, and the common grass-feeding species require three years.

When full grown the grubs turn into the well-known large brown to black May beetles or "June bugs." The adult beetles fly mainly to trees and feed on the foliage, returning to the soil during the day to hide and lay their eggs. Grasslands are their favorite places for egg-laying. Long-time records have shown that in certain areas heavy flights of the injurious species occur in only one out of every three years. Where the years when these flights may be expected are known, it is recommended that as much of the farm as possible be put into cultivated crops and legumes during those years. The beetles do not lay many eggs in such crops and grub infestations are thus avoided. A rotation of oats or barley, clover, and corn has proved satisfactory in some sections. This should be timed so that the maximum acreage will be in clover and a minimum in grass or small grain during the years of beetle flight.

Late summer or early fall plowing of
infested lands, and heavy pasturing of such lands with hogs and poultry help to reduce infestations where these practices can be followed. Hogs like white grubs and will root for them vigorously. Fields should not be hog-pastured oftener than once in three years, however, because these animals may become infested with the thorn-headed worm, a parasite of swine which passes the early part of its life in white grubs.

A system of renewing badly infested hillside pastures has been developed in Wisconsin, based on the knowledge that both the adult beetles and the grubs are partial to grasses but do not like legumes. The sod is thoroughly torn up with a disk, spring-tooth harrow or field cultivator during late fall and early spring, treated with lime and fertilizer in accordance with need as shown by soil tests, and sown in the spring with a seed mixture consisting mainly of legumes. These soon provide good pasture and are gradually replaced by the original bluegrass. A more detailed description of this system cannot be given here but may be obtained from the Wisconsin Agricultural Experiment Station at Madison.

No insecticidal treatment for white grubs has yet been found practical on pasture and crop lands, but lead arsenate has been widely and successfully used on lawns and golf links for control of the grubs of the Japanese beetle. This treatment is also effective against other white grubs, and is applied to the turf at the rate of 10 pounds per 1000 square feet. To obtain an even distribution the lead arsenate is mixed with sand or dry soil at the rate of 1 pound of lead arsenate to 1 peck of the carrier. In establishing new turf on ruined lawns the treatment should be applied at the time the seed bed is prepared.

DDT and chlordane have recently been found effective against Japanese beetle grubs. They are applied to the infested turf at the rate of 6 pounds of a 10 percent powder, or 2½ pounds of a 10-percent chlordane dust, per 1000 square feet. Whether these treatments will control other species of grubs has not yet been determined. After application of DDT, lead arsenate, or chlordane, the grass should be well watered to wash the poison into the soil.

When lead arsenate, DDT or chlordane is properly handled, spread, and washed down, there is no danger of poisoning wildlife or domestic animals. It must be remembered, however, that these materials are poisonous and should be handled accordingly.

Certain species of wingless May beetles are sometimes prevalent and injure field crops in the Southcentral States. A poisoned bran bait similar to that used for cutworms and grasshoppers has been used successfully against the adult beetles. The bait is broadcast thinly in the infested fields at the time the adults are abundant. These wingless beetles have also been trapped successfully where they are migrating from one field to another by the use of steep-sided furrows containing postholes as already described for use against armyworms.

Sod webworms (Crambus spp.). Grasslands, especially lawns and golf greens, are sometimes seriously injured by sod webworms, mainly in dry seasons. These are lively little grayish, blackish or spotted larvae ⅛ to ⅜ inch long that web particles of soil and litter together to make small tubes at or just under the surface of the soil at the bases of the plants. They hide in these tubes and come out at night to cut off leaves or stems which they often pull back into their tunnels to eat. When full grown they change into small whitish or buff-colored moths with long snouts and narrow wings. The moths fold their wings closely against their bodies and hide in the grass during the day. When very abundant they fly up almost in swarms and quickly light again as one walks through the grass.

The damage to lawns and golf greens is not usually noticed until the worms are nearly mature and it is almost too late to apply control measures. Hence, a close watch should be kept for them in dry seasons and treatment applied promptly. Various insecticides are effective against them, one of the most practical being a lead arsenate spray. The application of 2 pounds of lead arsenate in 10 gallons of
water per 100 square yards, left on the grass for 48 hours without watering, is recommended. This treatment will also control cutworms. Another spray that has given good results is composed of \( \frac{1}{2} \) ounce of dichloroethyl ether per 1 gallon of water, applied at the rate of 1 gallon per square yard.

Sorghum midge (*Contarinia sorghicola*). The sorghum midge is abundant in the Southern States from central Texas eastward. In that region it has often prevented the production of sorghum seed to such an extent that the growing of grain sorghum is unprofitable.

The sorghum midge is a very small fly with a red body. It lays its eggs within the hulls or glumes of the sorghum flower during blossoming time. The egg produces a small white larva, or grub, which takes its position alongside the developing ovary and absorbs the juices, thus preventing the development of the seed. This larva soon attains its growth and changes into a pupa, from which the adult fly, or midge, emerges in a few days and starts a new generation by depositing eggs on other sorghum heads. Under favorable conditions of temperature and moisture this whole process requires only 14 days, the average time being 14 to 20 days. The adults do not feed on the developing seed; only the larvae do injury in this way.

The midge appears first in the spring on Johnsongrass and breeds there sufficiently to infest cultivated sorghums in considerable numbers as soon as the crops come into head. All sorghums are subject to its attacks, and it has been found also on foxtail and certain other wild grasses. Absence of the cultivated sorghums from any community throughout an entire year is therefore not disastrous to the midge. It lives over winter in the larval state in heads of the sorghums and Johnsongrass that remain as trash on the fields or along fence rows. Parasites become numerous usually late in the season and destroy large numbers of the midge, but too late to prevent the greater part of their injury to the sorghums. Damage to sorghums from midge appears to be much less than in former years, possibly because of an increase in parasites of the midge.

Injury by the sorghum midge may be reduced by using varieties and cultural methods that will produce a uniformly blooming and maturing crop, planting at the optimum time for the variety selected, preventing Johnsongrass from producing bloom or heads near the sorghum fields, cultivating or burning over fields of Johnsongrass early in the spring to destroy hibernating midges, and plowing under, burning or feeding all sorghum refuse before the spring emergence of midges.

Clover seed midge (*Dasyneura leguminicola*). This insect does much damage to the red clover seed crop. It is a small fly that lays its eggs in the blossoms. The tiny larvae injure the blossoms so that seeds are not formed. This pest can be controlled to a large extent by cutting the first crop before the larvae are mature. They will then die from lack of food. Early cutting of the first crop hastens the development of the seed crop, so that the flowering heads will be too far advanced for the second brood to cause much damage.

Leaf-cutting and harvester ants: Several species of ants that are common in the Southwestern and Southcentral States cut off the foliage or seeds of almost any plants available including grasses and legumes, and carry these materials into their nests in the ground. The Texas leaf-cutting ant is especially interesting because it does not eat the bits of leaves and stems which it harvests but uses them as the medium on which to grow “fungus gardens” in certain galleries of its nests. This ant feeds only on a certain white fungus which it grows in these galleries. Both the red harvester ant and the mound-building prairie ant make a specialty of harvesting seeds which they store in their nests and use for food. The two last-mentioned species have the disagreeable ability to sting severely as well as bite.

Single colonies of these ants may be many feet across. Some nests of the Texas leaf-cutting ant cover as much as 4500 square feet and extend to a depth of 15 to 18 feet. Aerial photographs of Arizona
alfalfa fields badly infested by the red harvester ant showed that the circular bare spots around their nests occupied \( \frac{3}{4} \) or more of the area. Over 33 colonies have been counted on a single acre. Successful control of the leaf-cutting ant is especially difficult because of the many scattered entrances to their extensive nests, and because each colony may have several queens laying eggs in different parts of the nest. By thorough treatment at the right time of the year, however, colonies can be completely killed. The red harvester and mound-building prairie ant nests are easier to kill out because each one has only one opening and one queen.

One of the best methods of control is fumigation of the nests with carbon disulfide. The best time of year to apply it is early in the spring as soon as the ants have become active. The procedures followed in applying the fumigant depend on various factors including the species involved. For this reason, they cannot be described in this brief article. Anyone interested should write to his State agricultural experiment station or to this Department for details.

Another method of control found successful against the red harvester ant and mound-building prairie ant is the use of a thin ring of London purple about 4 inches in inner diameter and 1 1/2 inches wide on the ground around the opening of each nest. The results of this treatment do not become apparent for several days. Though a less certain method than fumigation with carbon disulfide, it is much cheaper and easier to apply. At least three treatments 10 to 12 days apart, and sometimes more, are usually necessary. Paris green may be used instead of London purple with fair success but has not proved so satisfactory. Dusts containing DDT or chlordane are also reported to be effective when applied in the same way. Details on the best strength of it to use are not yet available.

Any of these insecticides must be handled with care. Carbon disulfide is highly inflammable, even explosive, and London purple, Paris green, DDT and chlordane are all poisonous. Stocks of these, as well as the empty cartons which contained them must not be kept or left where children or livestock have access to them.

Other insects: Many other insect pests of grasses and legumes could be mentioned which injure one or another of these crops in one area or another every year. Then there are the special problems caused by alien insects that become established in this country, such as the alfalfa snout beetle in western New York, white-fringed beetle in the Southeastern States, and Rhodesgrass scale in Texas. But space will not permit a discussion of all these. In general, one or more of the control measures already described may be found useful against them, depending on the insect and its habits. Something can usually be done to reduce the losses caused by most of them if infestations are discovered in time and the grower is willing to make the effort.

FORAGE INSECT HIGHLIGHTS

1. An incredibly large number and variety of insects feed on grasses and legumes. Many millions of insects may be present and feed on an acre of meadow.
2. Some insects (grasshoppers, armyworms, etc.) consume the above-ground parts of the plants as effectively as though the field was pastured or cut for forage.
3. Insects of one kind or another may attack any or all parts of the plant—root, stem, leaf, flower, or fruit—and render either partial or complete destruction.
4. A mixture of several species of grasses and legumes in a meadow will usually withstand attacks of certain insects better than a pure stand, because of their liking for certain kinds of plants and not for others.
5. Insect depredations are affected by many factors—geographical, biological, physical, and environmental. One of the most important factors with many insects is weather.
6. The meadow often serves as a center of propagation of insects that prey on other crops, either by migration during the growing season, or by following the grassland in the rotation.
7. Control methods have been developed or discovered for many kinds of insects but there are many times this number for
which no efficacious treatment is known.
8. For effective control of the depredations
of any particular insect, a knowledge of
its life history and habits is nearly always
essential.
9. A large number of materials, a variety of
equipment, many adjustments of farm
operations, and both private and Gov-
ernment agencies, perform a part in in-
ssect control.
10. Control measures may involve rotation of
crops, burning of field, use of mechanical
devices such as hopper-dozers and trap
lights, use of poison bait, dusting or
spraying, and natural enemies.
11. Effective control of insect raids is de-
pendent upon the cooperation of both
the individual and the community in
planning preventive measures and effect-
ning ultimate destruction of the pests.
12. New chemical insecticides and new meth-
ods of treatment are being developed or
discovered so rapidly that only up-to-date
advice from a county agent or other re-
liable source should be followed in the
application of control measures.

WEED CONTROL IN GRASSLANDS

Weeds occur in all grasslands, and
since they are less palatable and less
nutritious than grass and clover, their
presence reduces the feed-producing value
of the land almost in proportion to their
abundance. Weeds have no medicinal or
therapeutic value and they are not needed
in a meadow or pasture to maintain
"tone" in animals. Some weeds, chiefly
western species, are definitely poisonous
and a dozen or more impart bad flavor to
meat and milk. From every point of
view, weeds are undesirable in grassland
and should be discouraged by every rea-
sonable means. Just how far one may
economically go in achieving this end is
sometimes a difficult question.
Importance of grassland management:
There is little doubt that the cheapest,
and usually the best way to reduce weeds
in grassland is to follow the practices of
good grassland management as discussed
elsewhere in this book. This is not a
spectacular method. Months may pass
before an appreciable reduction in weeds
will be observed following the beginning
of a program of controlled grazing, pe-
riodic mowing, and the use of fertilizer.
Sometimes the weeds are so destructive
that direct action and a quick result are
needed. In such case the use of chemical
weed-killers may be desirable. On the
whole, however, an intelligent and stead-
ily maintained program of general pasture
or meadow improvement will be found to
yield all the weed control really needed.
Probably no one practice is so helpful
in improving the appearance and the pro-
ductivity of grassland as the use of ferti-
izer. Very few species of weeds respond
to fertilizer as well as do Kentucky blue-
grass and other good forage crops, and
the latter soon crowd out the less desira-
ble plants. Even weeds like hawk-weed
and catsear, which are turf formers them-
selves, are unable to compete in fertile
soil with strong-growing forage plants.
The very presence of such weeds indicates
impoverished soil. They are there because
the soil is too poor to support the better
species. A simple application of super-
phosphate and nitrogen is often all that
is needed to cause weeds almost to disap-
ppear. Provided there is a fair stand of
good plants to begin with, the character
of grassland can be changed within a few
months by this one practice.
Mowing to prevent seed production: All
annual weeds, and most biennials and
perennials, reproduce chiefly by seeds,
and it is axiomatic that the prevention of
seed production is the first step toward
eliminating those species. Use of a mow-
ing machine and if necessary, a scythe,
twice a year in June and in August, is a
simple and inexpensive practice that yields
very large returns. Objection is some-
times made that pasture land is too
rough, stony or full of stumps to permit
the use of a mowing machine. Good pas-
ture is too valuable to let that stand in
the way. A few dollars an acre spent on
leveling uneven ground, piling rocks, or
pulling or dynamiting stumps and ledges
is often an excellent investment, if for no other reason than that it permits a mowing machine to be used.

Mowing is a preventative rather than a cure. It prevents the weeds from spreading but may not kill them. Perennial weeds such as Canada thistle, broom-sedge, and ironweed, are not killed by mowing any more than is alfalfa. Depending on the species, mowing must be accompanied by fertilizing, and in some cases, by the use of chemical weed-killers. Nevertheless, mowing is the primary weapon in weed control and should be regularly employed regardless of other circumstances.

Many annual and biennial weeds, notably wild carrot, bitterweed and ragweed tend to send out new shoots from the base of mowed plants, especially in wet seasons. Frequently these shoots form so close to the ground that a second mowing does not get under and destroy them. To avoid this the first mowing should be high enough to leave at least a 6-inch stubble. The new shoots then grow high enough that the second mowing destroys them.

Control of the rate of grazing affects the weeds in a pasture quite as much as the grass, but in the opposite way. Both overgrazing and undergrazing tend to depress the grass and improve the weeds. During the process the species of weeds may change, but the total quantity is likely to become greater. Changing the rate of grazing in an effort to find the correct rate may or may not change the weediness of the field. It may merely change the species. Consequently, change of the grazing rate is not always in itself a guarantee that weeds will become less abundant. But a change in the grazing rate plus the use of fertilizer, mowing, and other good practices all taken together, usually results in better grass and fewer weeds.

Chemical weed control: Next to mowing the best direct-action method of killing weeds in grassland is spraying with a chemical weed-killer. The most generally useful is 2,4-D. More than 90 percent of all annual weeds and most tap-rooted perennial weeds are easily killed by a single spraying with this herbicide. Plants not killed are likely to be severely injured. Perennials like Canada thistle and horse nettle with running root systems are only moderate affected. The chemical does not remove weedy grasses. Most serious objection to the use of 2,4-D is the adverse effect on legumes. Lespedeza is almost totally destroyed, as are red clover and alfalfa. White clover is injured more or less severely but from stem sprouts or seeds it usually recovers and after some months is as abundant as ever. Ladino clover is more sensitive than white clover and because of its high value is rarely treated with 2,4-D. When annual weedy grasses are the chief menace in Ladino, they may be removed without harm to the clover by treating with TCA.

Perhaps the most difficult kind of weed control in grassland is in young seedings. Fall-seeded grass is often smothered by a dense growth of chickweed, Mayweed, or other fall-germinating sorts. Spring seedings of clover are frequently overcome by ragweed, pigweed, and other summer-growing species. The weed-killer 2,4-D cannot be used on new seedings without serious danger of destroying the tender plants. The best recourse seems to be to mow the stand as close as possible with a mowing machine when the new grass is about 2 inches high.

Nearly three thousand species of plants are known to cause trouble as weeds and more than half of these occur in grassland. About one hundred are capable of causing extensive damage to grass. Chief of these, classified by groups according to their characteristics and methods of control, are:

**TYPES OF GRASSLAND WEEDS**

Weedy annual grasses, represented by crabgrass, pigeon grass and downy brome grass. Even in strong turf these ubiquitous, weedy annuals can establish themselves, and although they furnish brief, early grazing, they are for the most part useless. No adequate method of control is known, although new selective herbicides may eventually be an answer.

Annual broad-leaved weeds, represented
by ragweed, lambsquarter, pigweed, and smartweed. Most of these can be controlled by spraying with 2,4-D, although the economy of this is doubtful, especially where clover exists. The cost of spraying an acre is about $2.50 which must be weighed against the cost of mowing. The best preventative of such weeds is to plant grass on well-prepared land which has been freed of the bulk of the weeds by several years of cultivated crops. Virtually none of these plants have forage value.

Weedy perennial grasses. Broomsedge is the outstanding example, but numerous others cause trouble from time to time. Mowing is of little value except to check seed production. Generous use of fertilizer in early spring and again in early autumn has resulted in almost complete disappearance of these perennial clump grasses in areas where fertilizers are employed. In semi-arid regions, the best remedy for infestations of this kind of weed has been the introduction of better types of forage grasses. Few grasses of the turf-forming type become weeds among other grasses.

Perennial broad-leaved weeds, represented by dandelion, thistles, goldenrod and ironweed. Spudding with a spade if the weeds are not too numerous, with the addition of a spoonful of salt on the end of the cut root is a long-established remedy. A few drops of kerosene or fuel oil in the heart of each plant is quicker. Some species, as dandelion, are killed by spraying with 2,4-D, but many others are not sensitive to the chemical. Mowing, if in a meadow, should be early, perhaps too early for the best quality forage. Ferns of all species are difficult to destroy, although spraying with 2,4,5-T may help.

Bulbous plants, as represented by wild onion, wild garlic and Star of Bethlehem. In very early spring, usually not later than the first of April, these pests can be killed or severely checked by spraying with 2,4-D, preferably the ester form. A simpler procedure, where it can be followed, is to turn young stock and dry cows onto the infested pasture in early spring before the grass has begun to grow. At that time the animals are hungry for green material and eat the wild garlic sprouts to the ground. When the grass begins growth the milking cows are placed on the pasture, and since the grass provides a good bite, they ignore the aromatic weed and no flavor results in the milk. This does not destroy the weed but does enable the dairyman to live with it.

Broad-leaved turf-forming weeds, as represented by the hawkweeds, everlasting, and heal-all. While 2,4-D is deadly to some of these and would be feasible to use on a large infestation, a better plan in most instances is reliance on fertilizer to strengthen the grass and crowd out the weeds. Harrowing, an old remedy, is likely to spread the weed rather than otherwise. Lime is usually indicated as a soil amendment, and improvement of the drainage may be necessary.

Woody plants as weeds. Innumerable shrubby plants invade grasslands and sometimes become a major pest, as for example, mesquite in the Southwest, buckbrush in the Midwest, and hawthorne in the northeastern States. Until recently, no control practice was known that was economically feasible. Experience with 2,4,5-T, and in some instances 2,4-D or ammonium sulphamate, has shown that a moderate spray treatment with one of these herbicides defoliates most species and often kills the root. The dead bushes remain standing but grazing animals gradually push them over and in three years or so they disappear. Failing success with chemicals, resort may be had to bulldozers or other up-rooting machines. These dig the soil badly and destroy much grass and leave the ground too rough for subsequent mowing.

An alternative method of using herbicides on brush is to cut the plants at the ground level with an axe or bush-hook and immediately paint the top of the freshly cut stump with strong 2,4-D solution, ammonium sulphamate or sodium arsenite. The last named is a deadly poison and must not be used where animals are grazing. The treated stumps are killed below the ground line and, in most cases, do not send up new sprouts.
POISONOUS PLANTS

Practical knowledge of the identity and actions of poisonous plants has been the possession of primitive peoples since time immemorial. Published references to poisonous plants are of great antiquity. Both Biblical and secular literature bear evidence to the knowledge of poisonous plants among ancient peoples. However, there is still much to learn about poisonous plants and their effects on livestock at different stages of growth and under different conditions.

Poisonous plants are an important consideration in livestock management, especially on range and native pastures. Annual losses in Colorado alone from this source are reported to average about a million dollars, and losses in the range country as a whole from poisonous plants average about 4 percent annually.

A conservative estimate of the plants in this country known to poison domestic livestock or man is 62 families, 182 genera, and about 525 species. This list would easily run into four figures if every plant were considered about which some suspicion has been raised or which somebody somewhere has questioned.

The families with the greatest number of genera involved are, in order: Composites (daisy family), Liliaceae (lily family), legumes, spurges, heaths, crowfoot (buttercup family), umbellifers (parsnip family), milkweeds, grasses, and figworts. The four families with the greatest number of species involved are, in order: Legumes (easily first, with 102 species), crowfoots, composites, and spurges. Some families, such as the dogbane, milkweed, and spurge families, are notorious for their general possession of toxic properties, which are largely, in the families named, resident in their milky juices. In the case of some families, such as the lily and legume families, the poisonous properties are especially characteristic of certain tribes or other groups, as, for example, the asphodel, bunchflower, no-lina and scilla tribes of the lily family, and the andromeda and rhododendron tribes of the heath family.

Some plants, harmless elsewhere, may become poisonous when growing on soils containing selenium because of their ability to substitute this toxic element for a harmless substance, such as sulfur, in their metabolism. In this category are the woody asters (Aster, sec. Xylorrhiza) crucifers of the genus Stanleya, timber poison-vetch (Astragalus convallarius), cultivated wheat, etc.

Aside from those plants, such as poison-ivy and nettles, which cause irritation or inflammation of the skin (dermatitis), probably the most poisonous compounds in plants are (1) alkaloids, such as andromedotoxin, cicutin, cocaine, morphine, nicotine, and quinine—these contain nitrogen, are the so-called “active principles” of plant compounds, and in general include the most virulent poisons; (2) glucosides, such as esculin (in the bark of horsechestnuts), and amygdalin (in the kernels of cherries and plums), which, under the action of an enzyme, acid, or other catalyst, are broken down into sugars, alcohols, etc.

It is well known, of course, that hydrocyanic (prussic) acid is widely distributed in the vegetable kingdom, and is perhaps particularly familiar in the species of the plum-cherry-choke-cherry-peach genus (Prunus), in many legumes, and in certain grasses of the sorghum alliance. This very dangerous, toxic liquid occurs in plants in a “locked-up” condition and needs an enzyme or ferment of some kind as a “key” to unlock it—otherwise the plant, from the HCN standpoint at least, is harmless. In the digestion of proteins these complex nitrogenous compounds are broken down in the alimentary tract by various enzymes, such as pepsin in the stomach and trypsin and crepsin in the small intestine, into simpler, soluble substances principally amino acids.

A curious case of extensive poisoning of sheep and cattle was reported from Australia, resultant from dual use by sheep and cattle of two shrubs or small trees, “Georgina gidgee” (Acacia georg-
POISONOUS PLANTS

In this case it was found that the acacia pods, (which the stockmen at first thought were poisonous), are harmless but contain an enzyme which liberates prussic acid from a glucoside in the “berrigan” browse. In other words, both plants can be grazed separately with impunity but are poisonous when browsed together. This raises a question as to whether or not, among the obscure and unexplained cases of range stock-poisoning in this country, a toxic twosome may occasionally be responsible.

Some plants seldom give trouble except in wild hay, familiar examples being brackens (Pteridium spp.) and horsetails (Equisetum spp.). In some species as, for example, corncockle, flax, and horsechestnut, the seeds or fruits are the source of poisoning. Some plants cause photosensitivation, affecting white-faced or lightly pigmented animals; among these, some are buckwheat (Fagopyrum), flax (Linum spp.), the lechuguilla (Agave spp.), and St. Johns-wort (Hypericum spp.).

As a general rule, poisonous plants are not eaten extensively by livestock when other and more palatable and harmless plants are available. There are, however, important exceptions. At least one case is on record where cattle went out of their way to eat waterhemlock which had been grubbed out of a “poison” area and hung on a rack to dry prior to burning. Poisoning is particularly likely to occur on overgrazed areas, along streams and in meadows where stock like to congregate, in the spring (when plants like low larkspur and deathcamas make their appearance) and, when snow is on the ground, and leaves of evergreen poisonous plants (such as mountain-laurel and rhododendron) are in evidence and tempt hungry animals. Some plants, such as lupines, are particularly toxic to sheep, and other plants, such as larkspur, are especially dangerous to cattle. Rhododendron, dangerous for domestic livestock, is an important deer browse.

SOME POISONOUS PLANTS OF THE RANGE

Perhaps the most important range stock-poisoning plants of this country are species of the following genera: pingue (Actinea), burroweed and jimmyweed (Apolopappus), locos and poisonvetches (Astragalus), waterhemlocks (Cicuta), larkspurs (Delphinium), sneezeweeds (Helenium), lupines (Lupinus), crazy-weeds (Oxytropis), podgrasses and arrowgrasses (Triglochin), and deathcamas (Zigadenus).

Pingue (Actinea richardsonii), occurs on dry, sandy or gravelly soils, from sagebrush to the spruce types, from Saskatchewan and Alberta to Texas, Arizona, eastern California, and eastern Oregon. Losses usually occur in early spring or late summer or on heavily overgrazed range, as its palatability, under normal conditions, is zero to poor. It is definitely poisonous to sheep, losses occurring chiefly in the Southwest. It is known also as “Colorado rubberweed” and at one time it received much publicity as a possible source of commercial rubber. A related species, bitterweed, or bitter rubberweed (Actinea odorata) has caused heavy sheep losses in the Edwards Plateau region of western Texas.

Douglas waterhemlock (Cicuta douglasii, syn. C. occidentalis), a marsh herb, perennial from a cluster of elongated fleshy roots, and ranging from Alaska to California, New Mexico, and South Dakota, belongs to a genus of what are probably the most virulently poisonous flowering plants in North America. All parts of the plant, but especially the roots, are toxic. A small piece of the root, which is easily pulled out of moist ground by a cow, horse, or sheep, is likely, if eaten, to prove speedily fatal.

Menzies larkspur (Delphinium menziesii), perhaps the commonest and most widely distributed of the low, or “spring” larkspur, ranges from British Columbia to northern California, New Mexico, and Montana. This species is especially characteristic of open grass-weed-brush areas, at altitudes from about 1,000 feet
in northwestern California up to as high as 10,500 feet in the southern portions of the Rocky Mountains. It is readily grazed and causes heavy losses of cattle on spring and early-summer ranges. Later, the above-ground portions dry up and blow away.

Tailcup lupine (*Lupinus caudatus*), named from the backward prolongation of the floral cup (calyx), is distributed from Washington and Oregon (east of the Cascades) to California (east of the Sierra Nevada), Nevada, Colorado, and Idaho, chiefly between 3,000 and 8,500 feet. It is one of the common lupines in the ponderosa pine type and is often locally abundant. Unfortunately, it is one of the more palatable lupines and is particularly poisonous to cattle and horses, and somewhat so to sheep. This makes it remarkable among native range lupines, which are commonly poisonous only to sheep and, as a rule, only the pods and seeds are notably toxic.

Crazyweed (*Oxytropis lambertii*), is representative of a group related to the locoweeds (*Astragalus* spp.) that cause locoism. Because of its confusion in poisonous plant literature with other related species, its precise status is somewhat uncertain, but there is no doubt that it is one of the important sources of locoism in domestic livestock. It has a wide altitudinal variation, from plains to the Engelmann spruce-lodgepole pine belt, and occurs from Minnesota to Montana and southward to Arizona and Texas. Attempts to isolate and determine the chemical identity of the toxic principles of crazyweed have thus far failed.

Grassy deathcamas (*Zigadenus gramineus*), belongs to the bunchflower tribe of the lily family and ranges from South Dakota to Saskatchewan, Idaho, Utah, and Colorado, occurring on hills and meadows between about 4,000 and 7,000 feet, usually in sandy or gravelly loams. It is the most toxic member of this poisonous genus—all parts are injurious—and is especially dangerous in early spring (when other feed is relatively scarce) and at fruiting time, the seed being especially virulent. It affects all classes of livestock.

**SOME POISONOUS PLANTS OF THE EASTERN STATES**

Though the poisonous plants that are likely to be eaten by livestock are more prevalent in the western ranges than in the East, there are certain rather well-known species of plants in the Eastern States which are not usually thought of as poisonous but which constitute a hazard when grown where livestock may browse them at will. Not all of these constitute an important part of pastures; some are trees and shrubs located where cattle may browse the young foliage or chew the stems or roots and be poisoned as a result.

Recently W. A. Dayton of the Forest Service made an inquiry covering 15 States along the Eastern Seaboard to ascertain the extent of losses of livestock because of poisonous plants and the kinds of plants causing such losses. From this inquiry it was observed: (1) That data on stock losses from poisonous plants in the Eastern States are very meager; (2) that Virginia appears to be the only State in this group which is contemplating correcting this condition; (3) that stock losses from this cause do occur and are occasionally rather heavy; (4) losses or illness from bracken, cherry, cocklebur, dogbane, kalmia ("laurel" and "wicky"), nightshade, rhododendron, waterhemlock, while snakeroot, and yew are specifically mentioned. It might be of interest to add that Forest Service Region 8, which covers 26 National Forests in ten southeastern States (of which four are Atlantic States) reported 87 head of cuttle and horses killed by poisonous plants in 1947.

Bracken (*Pteridium aquilinum*). The species grows almost throughout North America; eastern bracken (var. *latiusculum*) grows cast of the Great Plains beyond which it is supplanted by western bracken (var. *pubescens*); tailed eastern bracken (var. *pseudocaudatum*) occurs from Massachusetts southward. This is our commonest and most widespread fern. The palatability is usually very poor except after frost when it is sometimes
POISONOUS PLANTS

caten by all classes of stock, particularly horses, which sometimes acquire a taste for it. Losses to cattle and horses, especially horses, are usually due to hay which contains a third or more of bracken and are greatest in dry seasons and especially following the haying period. All parts of the plant are somewhat toxic (but the young fronds are often cooked for greens) and affected animals have what is called “fern stagers”; the toxic principles are reported to be two acids, pteritannic and filicic.

Sticky tofieldia (Tofieldia racemosa). The asphodel, bunchflower, nolina, and scilla tribes of the lily family (on the whole a rather innocuous family) are, in all likelihood, all more or less poisonous. We have time to consider only three of these plants. In our Atlantic Seaboard States are a number of these plants, e.g., turkeybeard (Xerophyllum asphodeloides), swamp pink (Helonias bullata), Atlantic deathcamas (Zigadenus glaberrimus), fairywand (Chamaelirium luteum), featherfleece (Stellanthium spp.), and New Jersey bog asphodel (Narthecium americanum). Sticky tofieldia, also called “bog-asphodel,” grows in bogs from Newfoundland to the southern Alleghanies and west to Minnesota and Michigan. The stem has black glands and is up to about 20 inches tall; the greenish-white flowers, often in 3’s, are in an erect spike-like panicle. The seeds are tailed. The genus is widely distributed and has often been suspected in obscure losses, but apparently no research has been done on it.

Crowpoison (Amianthium muscaetoxicum). This is a perennial herb from a bulb which is sometimes 1 inch in diameter. It occurs mostly in the sandy coastal plain from Long Island south to Florida, and west to Tennessee, Missouri, and Arkansas. The stem is 18 inches to 4 feet high. The flowers are white, glandless in a terminal raceme. It is often called “fly-poison,” from household use of the bulb. The plant is often abundant locally, growing in patches, and is very toxic—even more so than the related deathcamas. Salivation, nausea, and staggering are the usual symptoms (whence the name “staggergrass”). All classes of livestock are affected by it except swine. The bulbs do not often seem to be pulled up by stock. Reported losses are chiefly from cattle, sheep, and occasionally horses and mules. The plant contains alkaloids of the veratrin group. In fatal cases death often takes place within an hour after eating.

Bunchflower (Melanthium virginicum), is a perennial herb which ranges in marshes and wet woods from southern New England to Minnesota and south to Texas and Florida. The erect stems are 2½ to 5 feet high bearing panicles of greenish-yellow flowers; the perianth segments have 2 dark glands at the base. All parts of the plant are poisonous. It sometimes causes trouble in wild hay. The symptoms in livestock, chiefly horses and cattle, are similar toaconite poisoning, the animals acting as if “crazed.” The heart action is often greatly accelerated.

American false-hellebore (Veratrum viride), is a familiar and locally abundant coarse herb, 2 to 8 feet tall, growing in swamps and wet woods, from New Brunswick, Quebec, and Ontario south to Tennessee and Georgia, extending westward to Illinois, and Minnesota. There are large panicles of yellow-green flowers. All parts of the plant are more or less poisonous, but especially the seeds. The dried rootstocks are in commerce, being used after reduction to powder, as an insecticide. The plant is often grazed with impunity after frost, but the fresh herbage, in quantity, is toxic to horses and cattle. It contains toxic alkaloids, including veratrin and-cevadirin.

Black cherry (Prunus serotina). This and the hardly distinguishable P. virginiana are best known, perhaps, as one of our most highly prized native furniture woods. It is well known that wilted cherry trees are poisonous to grazing animals, developing prussic acid.

Yellow buckeye (Aesculus octandra) is perhaps the largest of our native buckeves. In the best sites a stature of 100 feet is attained. The tree ranges from southwestern Pennsylvania and southern Illinois south to Tennessee and northern
Georgia. It contains toxic alkaloids, including esculin. The fresh leaves and sweet flowers are sometimes attractive to cattle in spring and, if so, are a source of danger. The seeds are particularly poisonous. Apparently the properties need further study. Twitching paralysis and labored breathing are among the chief symptoms of affected cattle. It is thought that horses are seldom, if ever, affected.

Lambkill kalmia, "sheep laurel" or "wicky" (Kalmia angustifolia), ranges from the Hudson Bay region and Newfoundland south to Georgia and west to Tennessee and Michigan. It is a small shrub of wet acid sites, 1 to 3 feet tall. The leaves and flowers are very toxic. Most of the reported trouble is in flowering time (late spring and early summer; about June-July). Sheep, especially lambs, are affected. The poisonous properties and symptoms are about the same as those of mountain-laurel.

Mountain-laurel (Kalmia latifolia), a shrub to small tree, ranges from New Brunswick, Quebec and Ontario to Indiana, south to Louisiana and Florida. It is very poisonous, losses usually occurring in winter when other food is scarce. The plant contains the highly poisonous alkaloids andromedotoxin and arbutin. Affected animals exhibit frothing or drooling at the mouth, watering of eyes and nose, nausea, convulsions, paralysis, and internal hemorrhage.

Staggerbush (Lyonia mariana), ranges, chiefly in the coastal plain and on sandy soils, from Rhode Island to Florida and west to Tennessee and Arkansas. It is a shrub up to 4 feet high, with smooth slender black-dotted stems; the leaves are black-dotted beneath. The stamen filaments have 2 bristlelike appendages below the anther. This plant is known to be a source of poison honey, to contain the toxic alkaloid andromedotoxin, and to poison livestock which occasionally eat it. It evidently needs further study.

The andromeda and rhododendron tribes of the heath family are well represented in the Atlantic States and there is reason to believe that all the members are more or less poisonous. Among these genera are Andromeda, Cassiope, Ledum, Leucothoe, Menziesia, and Rhododendron (including Azalea). Many of these plants are important as cultivated ornamentals; some are definitely involved in livestock losses. Strange to say, however, some are rather important deer browse.

Carolina-jessamine (Gelsemium sempervirens), is a climbing or trailing woody vine of the Loganiaceae (to which strychnine belongs), ranging mostly in woods and near the coast from Virginia to Florida and Texas and south through Mexico to Guatemala. The opposite leaves are evergreen and the yellow, very fragrant flowers are large and showy. It is often grown as an ornamental. All classes of livestock are affected but the plant ordinarily is not browsed except when other feed is scarce or animals are exceptionally hungry.

Hemp dogbane (Apocynum cannabinum), often called "Indian hemp," is widely distributed in both Canada and the United States, ranging from New Brunswick and Ontario to British Columbia and south to California, Texas, and Florida. It is a perennial, milky-juiced herb, 2 to 4 feet tall; the flowers are greenish-white to flesh-color. The plant, which contains the glycoside apoconein, is often an aggressive, troublesome weed, and is distinctly poisonous to animals which occasionally are tempted to graze it.

White snakeroot (Eupatorium rugosum), is a perennial herb up to 6 feet high, ranging from New Brunswick, Quebec, and Ontario south to Florida and Louisiana, and extending as far west as eastern Nebraska. The opposite leaves are distinctly stalked; flower-heads are white in large showy spreading cymelike panicles. The plant causes "milksickness" and one of the stock diseases called "trembles." All classes of stock, but especially cattle and sheep, are affected, weakness and trembling being characteristic symptoms of affected animals. Through the milk of affected dairy cattle the disease can be transmitted to man. It will be recalled that Abraham Lincoln's mother died in a "milksick" epidemic in Ohio. There is some
controversy as to the cause of the toxicity but general agreement that aluminum phosphate occurs in the plant and is at least partly responsible. The plant loses much of its toxicity in drying.

THIS CHAPTER

The material in this chapter was prepared by four specialists of the U.S. Department of Agriculture; that on diseases of grasses and legumes by J. L. Allison, Senior Pathologist of the Division of Forage Crops and Diseases, B.P.I.S. & A.E.; that on insect pests of grasses and legumes by C. M. Packard, Chief of the Division of Cereal and Forage Insect Investigations, E. & P.Q.; that on weed control in grasslands by L. W. Kephart, in charge of Weed Investigations, B.P.I.S. & A.E.; and that on poisonous plants by W. A. Dayton, in charge of Division of Dendrology and Range Forage Investigations of the Forest Service. The preliminary manuscript on insect pests was reviewed by Roger C. Smith and G. A. Dean of Kansas.

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The reference numbers given here refer to references which are given in full by State, U.S.D.A., and Miscellaneous, on pages 682 to 724, and which are cross-referenced by author on pages 725 to 731. Citations in the text are indicated by abbreviation and number in parentheses.
PART II

SPECIAL CROPS—LEGUMES
The agricultural importance of alfalfa cannot be over-estimated. It is undoubtedly the most outstanding forage plant in the United States today. It has played the role of balancing crop production in two ways: by building soil fertility and by furnishing large yields of high quality feed for livestock. Alfalfa is the highest in feed value of all commonly grown hay crops; it is high in protein and minerals, and is an excellent source of vitamin A.

In returns per acre, alfalfa has a record perhaps second to none over so large an area of the United States. Morrison (NY-30) gives the average feed returns per acre from alfalfa hay as exceeding those of timothy and timothy-clover mixtures by 66 percent in yield of hay per acre, by 70 percent in dry matter, and by 76 percent in total digestible nutrients. However, it is in digestible protein where alfalfa hay is particularly outstanding, having nearly five times the quantity of digestible protein found in timothy and timothy-clover mixed hay.

When we consider the fact that alfalfa is high in minerals and carotene, its comparison to other roughage feed is highly favorable. As a supplier of calcium, it is far superior to any other forage crop. Alfalfa hay also contains an average of 14 to 15 percent protein which is around 2½ times as much as sorghum fodder or corn fodder. This makes alfalfa hay a desirable supplement to other carbonaceous forage and grain.

The liberal feeding of alfalfa hay to dairy cattle results in material savings in the cost of grain feeds and concentrates without material loss in milk production. This fact is illustrated by feeding experiments with dairy cattle conducted by the United States Department of Agriculture, in which cows were fed all the high-grade alfalfa hay they would eat together with either a full-grain ration, half of a full-grain ration, or without any grain ration. The milk production obtained from the feeding of hay only was about 70 percent of that obtained from feeding hay and the full-grain ration, and the milk production obtained from the feeding of hay and one-half of the full-grain ration was approximately 90 percent of that obtained from feeding the hay plus the full-grain ration.

These experiments indicate that those dairymen who have home-grown high-grade alfalfa hay available for feeding purposes can reduce materially the quantity of grain concentrates necessary to maintain good milk production, thus effecting savings in the total feed cost, although the milk production may not be as high as when a full-grain ration is fed.

**ORIGIN AND HISTORY**

Asiatic origin: The best authorities agree that the original home of alfalfa was in southwestern Asia, from Mesopotamia northward across Persia and Turkistan to Siberia. More recently, Department of Agriculture explorers have found many so-called “wild alfalfas” in the region of Turkistan, so there can be no doubt that alfalfa got its start in this general region. Alfalfa was probably planted in this region by half-civilized man ages before any history was written. The earliest records indicate that by that time man had
discovered the superior feeding value and soil-building properties of alfalfa.

Alfalfa was thus developed in dry regions and was usually found in river valleys with soils rich in lime and of alkaline reaction. The earliest records alluding to alfalfa were discovered in Babylonian text written in 700 B.C.

**Introduction into Europe:** From this point on the story of alfalfa becomes history. Pliny and Strabo, both early Roman writers, record that when the Medes and Persians invaded Greece in 490 B.C., they introduced alfalfa into that country for the sustenance of their chariot horses, camels and domestic animals. This is believed to be the first introduction of alfalfa into Europe. From there, it spread to Italy and during the next centuries to other European countries, including Spain. Thus the queen of forage plants, as it has been called, followed the path of historic civilizations and conquering armies from East to West.

**Introduction into America:** The first introduction of alfalfa into the Americas was through the Spanish explorers. When Cortez and Pizarro had completed their conquest, the natives had alfalfa in lieu of their gold. This was the beginning of the sixteenth century, and alfalfa soon became distributed over Peru and Chile. It is probable, though not certain, that some of the Catholic missionaries brought alfalfa from Mexico into southern California, New Mexico and Arizona. Be that as it may, there was no decided spread of alfalfa growing in North America at that time.

The English, French, and Germans introduced alfalfa into the colonies of the Atlantic seaboard under the name of lucerne. There was some success in growing it in Virginia, North Carolina, Pennsylvania, and New York, but there were also some disappointments. General Washington tried alfalfa at Mount Vernon with enough success to warrant planting a field of it in 1794. Thomas Jefferson took considerable pride in his lucerne field, which was in production prior to 1793.

From the beginning alfalfa produced remarkably good crops in the fertile irrigated valleys of California, and it is not strange that its gradual spread was across the country from the West rather than from the East, because, although it had been grown continuously in New York for over a century, and the first recorded attempt to grow alfalfa in the United States was in Georgia in 1736, it received its main impetus from the success it had attained in the West. From California it was soon taken to Utah, where the Mormons found it extremely satisfactory. It was then introduced into Colorado, Kansas and Nebraska.

In the 1890's alfalfa had become an important crop in Kansas and spread into Nebraska, where it was also successful. By 1900 it had crossed the Missouri River and become important on the well-drained and alluvial soils of Iowa and Missouri. Then it spread across the Mississippi into Illinois. Wing had previously carried the crop from a ranch in eastern Utah to Champaign County, Ohio, where he established one of the first really successful alfalfa projects in the State.

Considering the historical background of alfalfa production in this country, it is probably safe to assume that the so-called common alfalfa now being extensively grown originated from the early introductions of Chilean alfalfa.

**Origin of Grimm alfalfa:** The first recorded introduction of a variegated alfalfa into the United States was that of Wendelin Grimm from the Grand Duchy of Baden, Germany, into Carver County, Minnesota, in 1857. The Grimm alfalfa of today is supposed to have descended from that original introduction. It was more than forty years after it was originally introduced, however, before it was recognized as a superior hardy strain. During that time much elimination and acclimatization probably took place, so that Grimm alfalfa today undoubtedly is quite different from the original introduction, especially in its resistance to cold. It was during the period from 1897 to 1910 that the intensive search for hardy alfalfas was under way and that importations of common, yellow-
ALFALFA

flowered, and variegated alfalfas from Europe, Turkistan and other parts of the Old World were being brought into the United States by the U.S. Department of Agriculture, and crop improvement work was begun in an effort to find or develop strains that were more winter-hardy and drought-resistant than those that were being grown here.

DESCRIPTION

Common alfalfa (Medicago sativa), is an herbaceous perennial legume. Its flowers are borne in loose bunches, or racemes, and are of a purplish color. The pods in which the seed is produced are twisted spirally in one or two turns, similar to the shell of a snail. Each pod contains several small kidney-shaped seeds. The stems which are usually not more than one-eighth of an inch in diameter, are erect and commonly reach a height of about 2½ feet. They arise from a semi-woody base known as the crown. The root system is characterized by a distinct taproot, which in permeable soils extends to a considerable depth. The tap root has few to many branch roots. The leaflets are in threes, like clover, and are arranged alternately on the stem. This species includes the three commercial groups of alfalfa known as common, Turkistan, and non-hardy.

Yellow-flowered alfalfa (Medicago falcata), is a variable species differing rather consistently in a number of characteristics from common alfalfa, among which are the following: The flowers are smaller, and range in color from light to deep yellow; the seed pods are straight or slightly curved or twisted; the seeds are more variable in size but usually smaller; the plants are usually many-stemmed and bushy with a strong tendency in many forms to be decumbent or prostrate; the roots are largely fibrous and branched with little or no tendency to the development of a taproot, and the plant does not recover readily after a first cutting like common alfalfa. The yellow-flowered alfalfa is not of great economic importance in the United States. Its greatest value has been in its contribution of hardiness to the most important group of variegated alfalfas. It may, however, have some value for pasture in the most northern part of the Great Plains.

Variegated alfalfas (Medicago media), are hybrids between common and yellow-flowered alfalfas and represent many different combinations of plant characteristics of the two parent species, exhibiting more largely, however, the traits of common alfalfa. Even though the yellow-flowered parent species of these alfalfas is known to be indigenous to large areas of Europe and Asia, representing both severe and mild climates, most of the variegated strains known in the United States are more winter-hardy than common alfalfa. Typical of these are Grimm, Baltic, Ladak, Ranger, Hardigan and Canadian Variegated. So far, no variety or strain of true common alfalfa has been developed equal in winter-hardiness to some of the variegated strains.

ADAPTATIONS

Climate: The wide distribution of alfalfa in the world indicates a remarkable adaptability to climate and soil. Although the crop requires considerable moisture to produce profitable yields of hay or pasture, it does best in a relatively dry atmosphere where water is available for irrigation. It is not so well adapted to humid conditions. In the United States it succeeds at altitudes ranging from below sea level in the Imperial Valley, California, to 8,000 feet in the mountains of Colorado. It will grow and produce hay in every state of the United States, in every province of Canada, and throughout Mexico, and Central and South America. In some states, however, it cannot compete in area or yields with some other forage crops.

It withstands hot weather well but is seriously affected by the cold weather of winter and early spring. To what extent extremely low temperatures alone are responsible for the death of alfalfa plants during the winter is not known, but this, together with other winter conditions, may result in high mortality in
the Northern States. On poorly drained clay soils alternate freezing and thawing, such as occur in many sections, frequently do much damage to alfalfa by heaving the plants out of the soil and incidentally breaking the roots 6 or more inches from the crown.

Soils and moisture: Deep loams with open porous subsoils are undoubtedly best for alfalfa, but where other conditions are favorable the plant has a very wide range of adaptation insofar as soils are concerned. On account of the deep, penetrating character of its root system, alfalfa does not thrive on a soil that has an impervious subsoil, hardpan, or bedrock near the surface. Instances have been observed, however, where it made satisfactory growth on soils underlain at 18 inches by limestone ledges.

In the eastern part of the United States rich river bottoms and soils of limestone origin are best suited to alfalfa, provided they are well drained, although with proper soil amendments the crop is grown successfully on a wide variety of soils. It tolerates alkali and salt concentrations better than most other farm crops, but on strongly alkali soils, such as are frequently found in the West, alfalfa makes little or no growth. Sweetclover is more tolerant than alfalfa in this respect. Alfalfa is especially sensitive to soil acidity and rarely grows to advantage at pH levels below 6.

The characteristics of practically all soils developed under conditions of low rainfall are both chemically and physically favorable to alfalfa, with the exception of those which are strongly alkaline, salty, or excessively sandy.

Some of the important alfalfa-producing soil series in various sections are the Hagerstown of Pennsylvania, Virginia and Indiana; the Honcroye and Ontario of New York; the Kewaunee, Miami, and Fox of Wisconsin, Michigan, Indiana and Ohio; the Waukesha, Hall, and Moody of Nebraska; the Summit of Kansas and Missouri; the Bearden of the Red River Valley; the Miller, Yahola, and Reinach of Texas and Oklahoma; the Fort Collins and Prowers of Colorado; the Ralston of the Big Horn Basin, Wyo.; the Gila and Mohave of Arizona; the Hanford and Yolo of California; the Portneuf of Idaho; and the Ritzville of Idaho, Washington, and Oregon. The Davidson clay loam of the Piedmont section is locally very important, although its contribution to national production is small.

SELECTING AND PREPARING LAND FOR ALFALFA

Selecting the land: In selecting land for alfalfa careful consideration should be given to the texture of the soil, its productivity, and drainage. Where possible, very sandy or very compact soils should be avoided. The character of the subsoil requires special attention. The soil auger is of considerable assistance in determining the character of the soil and subsoil and should be used freely.

The most productive soils on the farm should be selected for alfalfa. It is practically useless to attempt to grow the crop on lands that are non-productive with the idea of building them up, as is often done. Where good drainage does not exist naturally, it must be supplied by artificial means before alfalfa can be expected to succeed. Tile drains placed 3 feet below the surface will ordinarily lower the water table sufficiently to insure the satisfactory growth of alfalfa, other conditions being favorable. Complaints are occasionally received of tile drains that carry water continuously being clogged by alfalfa roots, but this occurs so seldom that it need be given little consideration.

During the growing season complete submergence for 24 to 48 hours may do considerable injury, but when the plants of certain strains are dormant they may remain under water several days with no serious damage. The formation of ice sheets on alfalfa fields during the winter months may result disastrously. Alfalfa seldom succeeds if the water table comes close to the surface, especially if the level of the water table fluctuates considerably. The preceding crop: Alfalfa may be successfully grown after almost any crop provided proper attention is given to the
preparation of the soil after the preceding crop has been removed. In deciding upon the preceding crop, however, one should be chosen that fits best into the particular system of farming and at the same time leaves the land in good condition for alfalfa. Due consideration also should be given to the time available for preparing the seedbed for alfalfa after the preceding crop has been harvested.

As the young alfalfa plants are very tender and are likely to be killed by weeds during their early stages of growth, it is best to precede the alfalfa for 1 or 2 years with some cultivated crop. Corn or potatoes in the North, and corn, tobacco, or cotton in the South serve this purpose admirably. In the Southern States crimson clover or rye and vetch may be sown after the removal of any one of these cultivated crops. The cover crop should be plowed under or cut for hay the following season and the land prepared for alfalfa.

Preparing unirrigated land: Where late summer or early fall sowing is practiced, canning peas, early potatoes, and early sweet corn leave the land in excellent shape, and little further preparation is required. The heavy application of fertilizers that these crops require in many parts of the country will usually suffice for alfalfa. Except in the extreme North, small-grain stubble may usually be worked up in time for late-summer sowing provided the land has been treated previously so as to destroy the weeds. The chief objection to such a practice is the possible lack of moisture in the soil, because of the demands of the grain crop and the hot weather of summer. Crops that smother the weeds, such as cowpeas, may be used to precede alfalfa to good advantage. In the East it is not usually advisable to sow alfalfa on sod land, but in the Great Plains area this is done with a considerable degree of success.

Preparing irrigated land: In preparing irrigated land for alfalfa the first step is to break it deeply and then level it if necessary. Plowing should be done several weeks in advance of sowing so that the soil may be properly compacted by the use of a heavily loaded disk, a roller, or some other suitable implement. Ordinarily it is best to irrigate the land just prior to sowing the seed; and, as soon as it has dried out sufficiently, the surface should be worked up into a fine mellow seedbed. If possible, further irrigation should be avoided until the plants have developed three or four leaves.

Good stands are sometimes obtained where the seed is "irrigated up," but the practice is not recommended, particularly on heavy soils, as the surface often becomes so crusted that the young plants are unable to break through.

Methods used for obtaining the desirable seedbed will vary in different sections because of weather, soil differences, and cultural practices, but if the objectives are kept in mind during the two or more months of preparation, the failures in obtaining a stand of alfalfa will be few.

Preparing the seedbed: A good seedbed for alfalfa is one with a compact, finely pulverized, and mellow soil to the depth of sowing. This condition can best be obtained by starting the seedbed preparation early. If following a small grain crop, plow as soon after harvest as possible, and if following a fall crop with an intervening fallow, the plowing should be done shortly after weed growth has started in the spring. In both instances, further operations in the seedbed preparation will depend on weather conditions. In either case, the ground should be handled so as to be kept free of weeds, store and conserve moisture, liberate plant food materials, and prevent soil erosion by wind and water.

Shallow plowing is preferable to deep plowing, as a firm seedbed is more easily obtained. The ground should be worked to kill weeds, volunteer grain, and to settle the seedbed. Other methods of seedbed preparation are sometimes used, particularly where soil moisture is not a factor, such as disking wheat, oats, or barley stubble immediately following harvest, with additional cultivations to kill weeds and volunteer grain. These practices are not generally recommended. The successful operator will have a crop rotation plan that calls for the more
Methods used for obtaining the desirable seedbed will vary in different sections of the country because of weather and soil conditions, but if the objectives are kept in mind during the two or more months of preparation, the failures in obtaining a stand of alfalfa will be few.

**Lime requirements**: Before sowing alfalfa it is important to know what the soil needs. Soil requirements for lime will vary and it is advisable to make a lime requirement test if there is any doubt. The application of three to four tons of ground limestone per acre is not uncommon in central and eastern States, while less than one ton is seldom used. Agricultural limestone with a purity of 90 to 95 percent calcium carbonate or its equivalent, that is ground fine enough for 100 percent to pass through a 10-mesh sieve and 40 percent through a 100-mesh sieve is satisfactory and should be applied to the land shortly after plowing. When coarsely ground limestone is used, the rate of application must be materially increased. Other forms of lime are sometimes available, such as caustic lime, hydrated lime, and air-slacked lime, but these are not generally used because of the greater expense involved.

The necessity of using lime on acid soils is well illustrated in certain Kansas experiments where the use of lime alone more than doubled the average yield for the 37 crop years, and where superfosphate was added to the lime, the yield was nearly three times greater.

Alfalfa stands will be maintained longer by the use of lime. An experiment conducted in Allen County, Kansas, over a period of nine years showed that lime prolonged the life of the stand to the close of the experiment; whereas, where lime was not used, the stand was completely killed out in five years. The application of manure did not overcome the deficiency of lime.

The lime should be applied early in the period of seedbed preparation and at a rate predetermined by tests made by the county agent or the experiment station. Alfalfa rarely grows satisfactorily at pH levels below 6. The rate of application will depend on the acidity of the soil and the purity and fineness of the limestone. Limestone can be spread either with a lime spreader, manure spreader, or by any other method that will apply the limestone evenly and at the desired rate.

**Fertilizer requirements**: Alfalfa should be grown only on soils abundantly supplied with phosphorus. Phosphorus may be profitably used on most soils of the Eastern and Central States. Experiments conducted at the Southeast Kansas experiment fields where the soils are deficient in both lime and phosphorus showed the following: The response to lime and phosphate was good. The combination of lime and superphosphate increased the hay yield 1.57 tons per acre over the no-treatment. Manure added to lime and superphosphate gave an additional increase in yield of 0.47 ton per acre. Where potassium was added, no response was obtained.

Results obtained from the Southcentral Kansas experiment fields indicated that phosphate may be used profitably in central Kansas. Increased yields of alfalfa hay averaged 0.20 ton per acre over the no-treatment from the use of superphosphate. At the Manhattan station in north central Kansas an average increase of 0.33 ton per acre was obtained from the use of superphosphate. On some central Kansas soils alfalfa can be grown without phosphorus, but generally it will increase the yields profitably, improve the quality of the crop, and aid in maintaining stands. The need for continuing applications of phosphatic fertilizers to alfalfa is increasing and the soils which formerly did not respond to phosphorus are now showing economic returns.

When soils are low in nitrogen, and manure is not available, the application before sowing of a mixed fertilizer containing some nitrogen along with the phosphorus would be advisable. A light application of nitrogen will give the small seedlings added vigor and aid them to come through the first winter.

The rate of application of phosphatic fertilizer will depend on the form used, whether the application is being made at
sowing time or later, and will also depend on the \( \text{P}_2\text{O}_5 \) content. The most common form now used is superphosphate. Others, such as bone meal or raw rock phosphate, are rarely used. Superphosphate is available in varying contents of \( \text{P}_2\text{O}_5 \) ranging from 16 to 48 percent. The 20- and 45-percent materials are more common than others. They should be applied at the rate of 225 pounds of 20-percent or 100 pounds of 45-percent superphosphate at sowing time and every second year thereafter, or the application may be made annually at one-half of these rates.

For new stands, superphosphate should be applied with the combination drill at sowing time or it can be applied just before sowing. In the latter case the fertilizer should be worked into the surface soil. On established stands, the superphosphate may be applied as a surface dressing in the early spring.

Woodhouse (NC-19) says: "Alfalfa seems to be quite responsive to heavy applications of phosphate, made prior to seeding, with the effect of carrying over for several years. For example, phosphate applications have produced 30 to 40 percent increases in yield the third year after application. On the other hand, excessive potash uptake on the part of alfalfa without an increase in yield.

"The potash content of a normal alfalfa plant can be doubled just by piling on more potash. This is a wasteful use of this fertilizer and means that it isn't feasible to apply several years' supply at once. That makes it all the more important to keep up the supply of this element by annual topdressings. It usually is not necessary to topdress the first year after sowing, but every year thereafter apply 400 to 600 pounds of 0-9-27 (or 0-12-12) plus borax. Right after the first cutting seems to be the most satisfactory time to put it on."

Boron is quite generally needed for alfalfa especially on soils of the eastern and southeastern States, so don't be deceived by the small amount required. Be sure it goes on at sowing, and it is good insurance to reapply it in each annual topdressing.

Barnyard manure is beneficial to alfalfa, and preferably should be applied on the crop preceding the alfalfa. This will allow the manure to decompose and also give time for weed seed spread with the manure to germinate and be destroyed. Manure may also be used as a top dressing on established stands. It should be applied in the late fall or winter to prevent interference with haying. Methods of applying fertilizer: For establishment, the preferred method is to drill the fertilizer, particularly the phosphate, into the soil at a depth of 3 or more inches, through a grain drill attachment or similar equipment, prior to or at the time of sowing the alfalfa. Where heavy applications are made, broadcasting of about half of the fertilizer before plowing has been used with considerable success, particularly on heavy or stony soil where the drill frequently fails to place the fertilizer uniformly as deep as desired. Drilling the fertilizer with the small grain crop when the alfalfa is sown with the grain is generally regarded as satisfactory. The most effective fertilizer application is that made either during seedbed preparation or at time of sowing.

For maintenance, when alfalfa stands are continued for more than two years, application of phosphate and potash in early fall, late winter, or early spring as a top dressing, which may be accomplished with grain drill equipment, is generally regarded as desirable and profitable. The evidence from a number of stations indicates, however, that supplemental top dressing with phosphate is much less effective than the initial application.

**SOWING THE SEED**

**Time of sowing:** Late summer or early fall sowing is desirable for the larger part of the United States when conditions are favorable. Sowing at this time eliminates the weed hazard often encountered with spring sowing and in addition, a profitable crop can be obtained the first year. Sowing should be done only when weather and seedbed conditions are favorable. If seedbed preparations are started early and continued so as to conserve moisture and
control weeds, the weather will be the controlling factor at sowing time. The earliest date at which weather and soil moisture conditions are most likely to become favorable for late summer sowing is about August 15. If the sowing is done earlier than this date, a period of hot dry weather may occur before the small plants are well rooted into the moist subsoil and cause them to die. When moisture has been conserved during seedbed preparation, the first good rain after August 15 will wet the surface soil down to the subsoil moisture. If the seedbed is ready and the sowing is done immediately following the rain, quick germination will occur and the roots will reach the subsoil moisture before much drying has occurred. The important factor is to have the seedbed ready. The less the ground is worked after the rain and before sowing, the better the chances are of a successful stand.

The latest date that alfalfa may be successfully sown in the early fall will again depend on the weather and seedbed. Generally the first week in September is considered the latest safe date for the latitude of Nebraska and Ohio, and the last week in September for the latitude of southern Kansas and Kentucky. The chance of success diminishes rapidly if sowing is done later than these dates.

Spring sowing should not be resorted to in the Central and Southern States except when late summer or early fall sowing is not practical. In the Dakotas, Minnesota, Wisconsin, and other Northern States, alfalfa is usually sown in April or May. It is sometimes sown in early or midsummer if moisture conditions of seedbed are suitable, but this is not considered so favorable as spring sowing in the North. Again, soil moisture and weather conditions will be the determining factor. With spring sowing, the hazards of maintaining a stand the first summer are greater than from late summer or early fall sowing, largely because of weeds. Usually this would not be true on summer-fallowed land. Spring-sown alfalfa seldom produces a profitable crop the first year.

Under conditions such as exist in most of the Central States, a companion crop, such as oats, sown with alfalfa at one-half the usual rate is sometimes successful but ordinarily should be avoided if possible. It will not be necessary if the seedbed has been prepared properly and the sowing is done on clean ground. A companion crop will help control weeds in the spring but will also use soil moisture and plant food needed by the alfalfa.

In the Eastern States where there is plenty of moisture, and alfalfa is usually sown in early spring, a companion crop is nearly always used. The advantages from the use of a companion crop generally outweigh the disadvantages.

Rate of sowing: Since there are approximately 220,000 alfalfa seeds in a pound, sowing at the rate of one pound per acre is sufficient to make five plants per square foot if all seeds germinate and grow. However, the present sowing equipment makes it impossible to obtain an even distribution of seed and this number of plants per square foot when sown at this small rate. The hazards encountered in establishing stands of alfalfa make it necessary to recommend that 8 to 15 pounds of seed be used per acre. The lower rates are usually recommended for low moisture, and the higher rates for high moisture conditions. In some of the eastern and southern States, and in California as high as 25 or 30 pounds of seed per acre have been recommended under certain conditions, but it seems that with proper preparation of seedbed and favorable sowing conditions, such high rates of sowing are unwarranted for any locality suited for the growing of alfalfa.

Manner of sowing: It is always more difficult to obtain good stands of small-seeded crops like alfalfa than of the larger-seeded crops. It is necessary to get the small seed in close contact with the soil particles to hasten germination and make possible a rapid early growth of the seedlings. That is why it is so important to have a seedbed packed well both before and after sowing.

The pulverizer-packer-seeder described in chapter V is probably the best machine for sowing all small-seeded legumes and grasses. If only regular equipment
is available, drilling is the best method of placing the seed in the ground. It assures a uniform distribution of seed at a uniform depth. If the row spacing of the grain drill is over six inches, it would be advisable to drill both ways, sowing one-half of the seed at a time. The seed should be sown at a depth of approximately one-half inch. If the seedbed has been reasonably well prepared and is packed by a cultipacker before and after drilling, the seed will be in close contact with the soil and immediate germination will follow.

Broadcasting is not a good method but, if used, the seedbed preparation should be the same as for drilling. The seed should be covered by a drag harrow followed by a packer. It is usually necessary to sow more seed per acre when broadcasting. The manner of sowing and equipment used are the same as for the clovers and other small-seeded legumes.

ALFALFA IN ROTATIONS

Alfalfa in the rotation has a marked effect on the fertility of the soil, influencing the yields of the crops that follow. Experiments have demonstrated the value of alfalfa in the rotation with grain crops in comparison to other rotations.

Grain crops are heavy users of soil fertility, and alfalfa in the rotation will maintain the nitrates and organic matter in the soil for increased yields. It must be recognized, however, that alfalfa is a heavy user of the soil's calcium, phosphorus and potassium. In the subhumid areas of the Midwest and West, the yield of crops immediately following unirrigated alfalfa may be decreased the first year in seasons of low rainfall, but this should not discourage the use of alfalfa in the rotation, as over long periods the gains more than offset the losses. Under the humid conditions of the Eastern States the yields following alfalfa are usually increased. The successful farmer operates on a long-time basis and will use alfalfa because of the superior value of the crop itself, as well as its influence on the productivity of other crops grown in the rotation.

It is a well-known fact that alfalfa is a deep rooted crop. Instances have been reported of alfalfa roots penetrating the soil to a depth of 35 to 40 feet.

Certain experiments have shown that unirrigated alfalfa will deplete the subsoil moisture to a depth of 23 feet within 2 years after sowing, and 35 feet six years after sowing. Also, that after all reserve subsoil moisture had been removed by alfalfa, it took many years of fallow to restore that moisture under relatively low rainfall conditions. Other experiments have shown that following alfalfa with other crops will permit the restoration of only a part of the subsoil moisture over a period of years. This, however, should not interfere with the satisfactory production of shallow rooted crops such as the cereals. It is evident from these experiments that after alfalfa has been on the ground for two years or more without irrigation the yield of the hay crop will depend on current rainfall. This is illustrated by data of Tysdal and Kiesslbach (Ncb-21). The average yield for the first three years was more than three tons higher than the average yields for the last five years. The difference in the precipitation during the two periods was a little over an inch.

CULTIVATING ALFALFA

Cultivation of solid alfalfa stands is not recommended. Generally it does not pay. It may be desirable in some instances to cultivate in order to reduce weed growth, so as to produce clean hay or a clean seed crop but usually if the stand is so thin that the meadow becomes weedy, it should be plowed up. Cultivation may be effective in eradicating winter grasses as cheat and downy brome. When these grasses are present, the cultivating should be done in the late fall and again in the spring.

The best implement to use for cultivating alfalfa is the alfalfa renovator or the spring-tooth harrow. The disk should never be used on alfalfa as it is apt to split the crowns and bring about infections of wilt and other vascular diseases.

It is not practical to try to thicken old
stands by sowing or cultivating, either generally over the field, or in small patches. If the patches are large, the field should be plowed up. Cultivation alone will never thicken a stand. The new seedlings from seed sown in an old stand cannot compete with the older plants. If the stand is so thin that the new plants can survive, then the stand is so thin that it should be plowed up and the acreage sown after a seedbed has been prepared. The only place where resowing might be successful would be in patches in a field or border killed by grasshoppers the first spring following a fall sowing. In that case the seedbed may be prepared by disking and the sowing may be done in the usual manner.

PLOWING UP ALFALFA

Farmers often complain of the difficulty of breaking up and destroying a stand of alfalfa, but under most conditions this need not offer any serious objection to the crop provided the necessary equipment is at hand, that is, strong horses or a tractor and a sharp plow. The plow should be kept in good condition during the entire operation.

The furrow slice should be 2 inches less in width than the plow will turn. This is to prevent any of the large roots from slipping by uncut. Sometimes the plows are provided with a knife attachment to the landslide to cut the roots near the outer edge of the next furrow. The most successful practice is to plow shallow in the fall and deep the following spring. If only one plowing is practicable, this should be rather shallow. If plowed too deeply the roots frequently retain enough life to start again. Ordinarily, it is better to leave the furrow slice to dry out some time before cultivating, as this assists in killing the roots.

REGIONAL ALFALFA CULTURE

Growing Alfalfa in Michigan, Wisconsin, Minnesota, New York, and the New England States

In Michigan, Wisconsin, Minnesota, New York, and the New England States the following practices are observed in the growing of alfalfa:

Attention is given to the need for lime, fertilizer, and inoculation. Land that is intended for alfalfa should be in some cultivated crop, such as corn or potatoes, for 1 or 2 years prior to being sown in alfalfa. The ideal seedbed is obtained by plowing in the fall and completing preparation in the spring. On some soils that have been in a clean-cultivated crop the previous season, a good seedbed can be prepared by disking and harrowing in the spring without the necessity of fall plowing. Under favorable conditions the practice of sowing alfalfa seed in the spring with a small-grain companion crop results in good stands. In the Eastern States, when spring or late winter sowings are made, alfalfa is usually sown with spring oats, spring barley or winter wheat. An early-maturing variety of grain is preferable and should be sown at the rate of about 1 bushel per acre. In order to conserve moisture it is sometimes advisable to cut the grain for hay just after it has headed. If the grain lodges it should be removed early; otherwise it may smother the alfalfa. Canning peas make an excellent companion crop, as they are harvested early.

Successful stands are also obtained from sowing the seed alone in June or early July, but when this is done no return is obtained from the land the first year. For this reason most farmers prefer to chance sowing later, after some such crop as early potatoes or an early truck vegetable has been removed, as the land requires little preparation for alfalfa provided the vegetable crop has been well cultivated, and kept free from weeds. It is seldom safe to sow alfalfa after a crop of small grain has been removed as there is barely time for the alfalfa to become thoroughly established before cold weather, and the moisture supply may be limited owing to the demands of the preceding crop. Sowing later than the middle of August is not dependable, as the alfalfa may not make sufficient growth to withstand the winter.

On land that is well adapted to alfalfa 10 to 15 pounds per acre of clean seed
that germinates 90 percent is sufficient, although several New England States recommend 15 to 20 pounds.

**Growing Alfalfa in Ohio, Indiana, Illinois, Iowa, Missouri, Kentucky, Pennsylvania, Northern New Jersey and West Virginia**

On most of the soils in Ohio, Indiana, Illinois, Iowa, Missouri, Kentucky, Pennsylvania, northern New Jersey, and West Virginia, lime, inoculation, and some sort of fertilizer treatment are essential for the best growth of alfalfa.

Where the land is well suited to alfalfa the seed is commonly sown in the early spring with a small grain sown at about one-half the normal rate, or occasionally in barley, winter wheat or rye. Better stands are assured under the former practice. If the companion crop gives evidence of injuring the alfalfa seedlings, it should be cut for hay. Early canning peas have also been successfully used as a companion crop. Good results are often obtained if the seed is sown after an early crop of sweet corn, potatoes, or truck vegetable. Such land requires little preparation for alfalfa, provided it has been well cultivated. Small-grain crops usually mature early enough for late-summer sowing of alfalfa, but there is very likely to be a deficiency in the soil moisture at this time, owing to the demands of the previous crop. An early crop of red clover may also be taken off soon enough to get the land into shape for alfalfa the same year. Such land will require considerable preparation, as it needs to be plowed and thoroughly worked before alfalfa can be safely sown.

The quantity of seed required varies with the condition of the seedbed, the character of the soil, and the condition of the weather at sowing time. Under favorable conditions about 10 to 12 pounds per acre has proved sufficient, although some of the experiment stations in these States recommend a somewhat higher rate.

If the weather is favorable and the soil in good condition and free from weeds, it does not seem to make much difference when alfalfa seed is sown so long as there is sufficient time for the plants to become well established before winter starts in. During midsummer, however, the weather is usually too hot and the soil too dry to insure successful germination and growth of seedlings. It is not advisable to sow much later than the first of September. In the Eastern States early spring sowing is usually most favorable for obtaining a good stand.

**Growing Alfalfa in the Middle Atlantic and Southeastern States and the Gulf Coast**

The soils in the Middle Atlantic and Southeastern States and the Gulf coast region, with few exceptions, are not naturally well suited to the production of alfalfa, and careful attention must be given to preparing the land for the crop. Consideration should be given to liming, inoculation, and fertilizing. In addition to the usual fertilizer constituents, boron should be included in alfalfa fertilizers for this region. Weeds are especially troublesome in this region, and for this reason alfalfa should be preceded for 1 or 2 years with crops that are cleanly cultivated or with such a crop as cowpeas, which chokes out weeds. Corn and cotton are good preparatory crops. Early truck and potato crops furnish excellent opportunities for destroying weeds and may generally be taken off the land in time for sowing alfalfa. These crops leave the land in such shape that plowing is not necessary. Red or crimson clover or rye and vetch can be cut up with a disk, then turned under, and the land prepared for the late-summer or early-fall sowing of alfalfa. A common practice in the southern part of the region is to sow winter grain after a crop of corn or cotton has been removed. The grain is harvested in the spring and the land plowed and sowed to cowpeas as soon as possible. In the latter part of the summer the cowpeas are cut up with a disk, and the land is prepared for sowing the alfalfa by the latter part of September or early October.
It is not advisable to plow under cowpeas as far north as Virginia, as there is not time for them to decompose and the land to settle before alfalfa is sown. In sections where considerable silage corn is produced, successful stands are sometimes obtained from sowing after the corn is removed.

In this region it is generally recommended that alfalfa be sown without a companion crop at the rate of 15 to 25 pounds per acre. In the Piedmont sections of the Mississippi Delta, and on the prairie limestone soils of Alabama and Mississippi, good stands are secured with 15 to 20 pounds, but on the Coastal Plains, where the soils are sandy and weeds troublesome, 25 pounds per acre are usually sown.

In the northern part of the region under consideration sowing about the middle of August has given the best results on an average. In the South Atlantic and Gulf States the date of sowing may be delayed with safety until the middle of October, and when weather conditions are especially favorable successful stands are sometimes obtained from sowing as late as the first of November, although this is not recommended. March sowing is sometimes successful in the extreme South.

Growing Alfalfa under Semiarid Conditions

Alfalfa is grown extensively in the Great Plains and other parts of the West where rainfall is limited and where water is not available for irrigation. In this region soil-moisture conditions are usually most favorable in the spring, and in the North it has generally been considered the best practice to sow as early in the spring as the ground can be put in shape; but recent experiments indicate that, in some sections at least, weeds are less troublesome if sowing is delayed until the 1st to the 15th of May. This gives opportunity to work up the seedbed two or three times, thus destroying many of the weeds. If sowing is delayed until the weather is hot and dry, the plants may not become well enough established to survive the winter. From Nebraska southward seed may be sown either in the spring, late summer or early fall. Moisture conditions usually are most favorable in the spring, but weeds are likely to prove more troublesome when seed is sown at this time. For this reason many growers prefer to keep the land cleanly cultivated during the summer and sow the seed in the late summer or early fall.

Preparation for alfalfa should begin somewhat in advance, to insure sufficient moisture for the young seedlings. If the seed is to be sown in the spring the land should be summer-fallowed the previous year or devoted to some cultivated crop, such as corn, to assist in freeing it of weeds and to conserve moisture. Except on heavy soils, it will not be necessary to plow again, but where plowing seems advisable it should be done in the fall and the land disked and harrowed as soon as it is in condition to be worked the following spring. Land to be sown in late summer or early fall should be plowed the previous fall and kept cultivated throughout the spring and early summer.

The use of a companion crop is not recommended under dry-land conditions, as it draws too heavily on the rather limited moisture supply. However, good stands are frequently obtained with one-third or one-half the normal rate of sowing of some small grain crop, particularly where it is cut early for hay. Good results have also been obtained from the use of flax as a nurse crop.

Over most of the dry-farming area less seed is required than is advised under humid conditions or under irrigation, partly owing to the fact that weeds are less troublesome. Ordinarily, from 8 to 12 pounds of seed per acre is ample. Good stands have been obtained with 2 to 4 pounds, but such light rates cannot be recommended for general practice, except in rows for seed production.

Growing Alfalfa under Irrigation

Experience in the growing of alfalfa shows that it thrives best in the soil and climate of the arid and semiarid regions, provided water is supplied by irrigation.
ALFALFA

It prefers a deep, well-drained loam soil, abundant sunshine, and a dry atmosphere. Certain varieties do well in Imperial Valley, California, below sea level, while other varieties thrive in the San Luis Valley of Colorado, 7,500 feet higher. More than one-third of the acreage devoted to alfalfa in the United States is under irrigation in the 17 Western States.

The topsoil should be moist enough from recent rains or an irrigation at time of sowing to supply the water needed by the plant until a number of true leaves appear and the taproot attains a depth of about 2 feet. The long slender tap-root of the young plant has a number of tiny branches throughout its length; for them moisture must be available if a satisfactory crop is to be produced. Hence an adequate soil-moisture content should be maintained, if possible, in all parts of the root zone.

Water requirements: Alfalfa requires more water than most crops. It is estimated that 750 tons of water are used in the production of one ton of cured alfalfa hay. This is accounted for readily by the character of the plant, the rapidity with which it grows, the number of crops produced in a season, and the heavy seasonal tonnage obtained. Its roots are not only deep but well-distributed to draw plant food from the most fertile layers of soil, and moisture from the wettest layers, while that part which is above ground is well provided with leaves from which water is transpired in large quantities. The rate of growth varies with the soil, temperature, and other factors, but under favorable conditions a crop matures for hay in about 35 days. In some localities killing frosts shorten the growing period to such an extent that only one or two cuttings can be made in a season. Ordinarily, however, when the deficiency in rainfall is made up by irrigation and the period of growth is long enough, three to six crops are harvested, yielding a seasonal total of 3 to 7 tons of hay per acre.

There is a wide variation in the seasonal quantity of irrigation water required by alfalfa. Two of the most influential factors are climate and soils. Temperature determines the length of the growing period and the number of crops that can be grown yearly, while precipitation, if it is effective, lessens the quantity of irrigation water needed. Soils cause a variation in that more water is wasted in irrigating pervious than impervious soils.

The results from experiments made to determine the water requirement of alfalfa seem to establish the following facts: (1) For the first few months the energies of the plant are devoted more to the establishment of a root system than to the production of stems and foliage; (2) the least demands for water occur in early spring, by reason of low temperatures and other unfavorable conditions, and immediately after a crop is harvested; (3) the demand for water is fairly constant during growth but tends to increase slightly up to the blooming stage; and, (4) within a narrow range the water consumed by the alfalfa, per ton of hay produced is fairly constant regardless of the quantity applied during the season or at each irrigation.

Frequency of irrigations: Except during its dormant stages, alfalfa should be furnished with sufficient water to enable it to grow continuously at a maximum rate. After cutting and removal of a crop, less water is needed until the foliage of the subsequent crop again demands its quota of water. Except during this interval, however, about the same quantity of water is needed during the entire period of growth.

There is no question that yields of alfalfa and the life of the stand might be increased considerably if more care were used in finding out when to apply water. In each kind of soil and under any given set of climatic conditions there is a certain range of soil moisture which will give the best results, and a practice should be adopted to keep the soil moisture within these limits at all times. Under the present unskilled practice, the soil is likely to receive too much or too little water, or else it is deluged with cold water at a time when it needs only heat and air.

The number of irrigations required depends upon the depth and nature of the soil, the depth to ground water, the
number of cuttings, and the rainfall, temperature and wind movement. More frequent waterings are required in the warm sections of the Southwest than in the cooler portions of the North. The number of irrigations per year for alfalfa ranges from 3 in Montana and Wyoming to as many as 12 in parts of California and Arizona.

Methods of applying water: There are several methods of applying water to alfalfa, their suitability depending on the character of soil and subsoil, climate, water supply, size of farm, and other factors. The most common are (a) the flooding method which can be used on rather steep slopes and is adapted for use with small streams, (b) the border method which can be used best with large streams, and (c) the check method, the most favorable conditions for which are light sandy soils with moderate, even slopes, or heavy soils on which water may be held long enough to percolate to desired depth.

A careful study of local conditions should be made before one decides on the need for irrigation and the methods to use in applying water under irrigation. A description of irrigation practices and methods is given in Farmers' Bulletin No. 1630, “Irrigation Practices in Growing Alfalfa” (US-68).

GROWING ALFALFA ON SANDY SOILS

In the Eastern States alfalfa usually does not survive long on very sandy soils, although fairly good yields may be obtained for 2 or 3 years where liberal applications of stable manure are made prior to sowing the seed. West of the Mississippi River such soils, if not too sandy, usually will grow alfalfa successfully after the plants are once well established. However, it is often difficult to start the crop on soils that are so light in texture that they drift badly, as the young plants are likely to be cut off by the sand unless special precautions are taken. This may be avoided by applying a light top dressing of straw or coarse manure just after sowing. Another method that has proved satisfactory is to scatter a thin layer of wild hay or straw from an old stack bottom over the land immediately after the seed has been sown. The field is then gone over with a weighted disk set straight. This cuts the hay into the ground and leaves it standing over the field, much like stubble. Good results are also obtained if the alfalfa is drilled into high-cut stubble of sorghum or millet. Where cornland is used and the field is in good shape, it may be prepared by disking down the stalks early in the spring and leaving the soil rough until time for sowing. Alfalfa seed may also be sown with about a peck per acre of rye, barley, or some other small-grain crop that will make rapid growth and protect the young alfalfa seedlings. Unless there is danger of injury from drifting soil the companion crop should be avoided, as it is likely to draw so heavily on the soil moisture as to injure the alfalfa.

WEEDS IN ALFALFA

In most of the United States weeds constitute the worst enemy of alfalfa. Dodder, a threadlike yellow twining plant, which lives as a parasite on plants, is very objectionable in seed-producing districts, as there is little market for alfalfa seed that carries with it seeds of dodder. The seeds of some species are difficult to separate from alfalfa seed. Highly specialized machines have been developed which are now used by processors to remove dodder from alfalfa seed. Dodder seldom gives much trouble in fields that are devoted entirely to the production of hay.

Other troublesome weeds are Kentucky bluegrass and quackgrass in the northeastern one-fourth of the United States; crabgrass and Bermuda-grass in the Central and Southern States; cheat (Bromus tectorum) and foxtail, or wild millet, in the Middle West and the Great Plains; and whitetop, field peppergrass, chickweed, and yellow rocket in the Middle West and the East. In the irrigated sections of the West the wild barley, also known as foxtail and squirreltail grass (Hordeum spp.), are decidedly troublesome, as the beards ruin the first crop of
Alfalfa hay for feeding unless it is cut very early. Where weeds are troublesome in the West, wheat is sometimes drilled in the alfalfa in the fall, and as it comes on early, the growth of the weeds is checked. The first cutting of hay the following spring consists of a mixture of alfalfa and wheat. Cultivation of established stands of alfalfa may help to hold the weeds in check, but unless done with considerable care the alfalfa may be injured. The most satisfactory way to control weeds is to make the conditions so favorable for alfalfa that they are smothered out. When they become abundant, it is better to plow the field than attempt to get rid of them by cultivation.

Alfalfa hay as grown in the West under irrigation is usually quite clean and free from grasses and weeds, except for the first spring cutting, which often may be so full of weeds as to be practically worthless. Recent experiments in California have demonstrated that a late-winter spraying, before the alfalfa starts rapid growth, with a mixture of oil and a selective weed spray, may eliminate the weedy grasses and weeds.

Diseases and insects are important factors in the production of alfalfa in that they affect both the yield and quality of hay produced. It is impossible to estimate accurately how much damage they actually cause. The crop is subject to many diseases and insects of which only those of greatest economic importance are mentioned here. More information on this subject is given in chapter IX.

Diseases: The most serious threat to alfalfa growing in the United States is the bacterial wilt disease that kills out stands of susceptible alfalfas in from two to four years. It is most prevalent and destructive in the Central and Midwestern States, but does much damage in the irrigated valleys of the western United States, and appears also to be extending both eastward and southward. The losses due to this disease include not only the crop destroyed, but also the cost of sowing and the loss of production from the land until a new crop is established. If growers could, through the growing of disease-resistant varieties, maintain stands of alfalfa for even two years longer than at present, it has been estimated that they would be able to save millions of dollars.

Black stem is a serious disease of alfalfa in the Southeast and the West. During cool, wet spring seasons this disease occasionally causes death of the stems and serious defoliation. The disease is most severe on the first crop of alfalfa in the spring which is produced during the wettest and coolest period of the growing season. It is negligible on the second and third cuttings, but increases considerably on the fourth crop when the weather is cooler and more humid.

At present there are no satisfactory commercial varieties resistant to black-stem. Selections, however, have been obtained which are somewhat resistant, thus showing the possibilities. The breeding of good varieties of alfalfa resistant to black-stem will probably be the only practical control of this disease.

Yellow leaf blotch was first reported in the United States in 1916, when the disease, in many fields in Kansas, caused a loss of 40 percent of the leaves of the first and second crops. During the last 10 or 15 years alfalfa fields infected with yellow leaf blotch have been fairly common wherever alfalfa is grown in the United States. There is no satisfactory
method of controlling this disease. Losses may be reduced by mowing the crop before the disease becomes severe or causes defoliation.

Alfalfa rust is a minor disease of this crop. It generally does the greatest damage to the crop that is being grown for seed. To date, there has been no practical control of this disease. Alfalfa selections vary in their susceptibility to it. Consequently, resistant selections which are good agronomically may be bred in the future.

Leaf spots are common on alfalfa. They occur principally in the spring and fall during periods of wet, cool weather. In some years, however, they are common especially during the early part of the summer. The common leaf spot is probably the most destructive of the foliage diseases of alfalfa. The disease is present in almost every alfalfa field, taking a small toll of the foliage under dry conditions and a large toll under more humid conditions. Recently, resistant lines which are good agronomically may be bred in the future.

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Mosaic of alfalfa is a disease characterized by yellow and green mottling of the leaves. While it does not appear to be of major importance, its wide-spread occurrence and the stunted growth of mosaic plants indicates that some loss is being caused each season.

Insects: Some of the insects which cause serious damage to alfalfa, and which are described and control measures suggested in chapter IX are:

- The alfalfa weevil which feed upon the unfolding leaves and may destroy a half or more of the plant tissues of the first cutting. At one time, many weevil-infested areas were quarantined, but most of these quarantines have now been removed.

- Grasshoppers which are destructive in some parts of the United States nearly every year and must be combated to save the hay and seed crops and new stands of alfalfa.

- Cutworms and armyworms, of which there are several species, and the corn earworm, all of which feed on the alfalfa foliage, mostly at night, and hide in surface litter or in the soil in daytime. One or more of these feeds on the alfalfa plant beginning in early spring, not ending until fall.

The alfalfa aphid which is often present in large numbers and stunts the growth of the plant, giving it a very unthrifty appearance. The infestation may start as small circular spots and ultimately cover the whole field. Hundreds of thousands of acres are sometimes destroyed by aphids.

- Lygus bugs which have become rather well known in recent years because of their damage and often total destruction of the alfalfa seed crop.

- Clover-seed chalcid which consumes the contents of the seed, leaving only a thin seed coat. An expected good yield of seed is occasionally disappointing because of depredations of this insect.

- The garden webworm and beet webworm which are frequently injurious to alfalfa. They not only consume the leaves but they also spin a fine web which may completely envelope the plants.

Other insects, such as the curculio the larvae of which often consume the fibrous roots and nodules and gouge into the taproot and crown of the alfalfa plant, and fly larvae which mine through the leaves, leaving intricate trails behind them.

ALFALFA HAY PRODUCTION

Acreage: Alfalfa exceeds in acreage any of the other perennial crops grown for forage, with the exception of the combined acreage of timothy and timothy-clover mixed. Its culture has extended very rapidly since it was first grown successfully in the West.

The acreage devoted to alfalfa practically doubled in each of the two ten-year periods between 1899, when there were 2,094,011 acres, and 1919 when this crop occupied 8,624,811 acres. In 1929 the area in alfalfa was 11,529,000 acres, which is 33.7 percent above the 1919 acreage, and in 1939 it had in-
creased to 13,234,000 acres which is 14.8 percent more than 1929. The acreage continued to increase until 1942 when it reached 15,814,000 acres which was 19.5 percent over 1939. For the next 6 years (1943-48) it declined to an average of approximately 15,000,000 acres, but in 1949 reached an all-time high of 17,288,000 acres.

The proportion of the total United States acreage in alfalfa hay east of the Mississippi River increased from about 1 percent in 1899 to a little more than 17 percent in 1929, and to about 35 percent in 1939. Between 1929 and 1939 the acreage west of the Mississippi River actually decreased about 8 percent, whereas east of the river during this period the acreage more than doubled. Although the acreage south of the Tennessee-Kentucky line increased appreciably it still remained relatively unimportant. The big increase in acreage east of the Mississippi River was due to a large extent to the decided increase in Wisconsin, Michigan, Indiana, Illinois, Kentucky, Ohio, New York, and Pennsylvania.

In connection with the increased acreage of alfalfa in the East, Tysdal (US-264) calls attention to the fact that "the expanded acreage in the East is due primarily to better information on methods of production, including information on lime, potash, phosphate, and boron requirements, and to recognition of alfalfa as a superior forage crop, rather than to development of varieties adapted to eastern conditions." However, Atlantic alfalfa is well adapted to most of the Eastern States where bacterial wilt is not a factor. It has demonstrated outstanding performance in the Uniform Alfalfa Nursery, especially for short rotations. It will be several years before sufficient seed of Atlantic alfalfa will be available to sow any large percentage of the alfalfa acreage in the Eastern States.

The ten-year average (1935-44) of the acreage in each of ten States was over a half-million acres and the same States had over a half million acres each in 1945, 1946, and 1947. In this group of 10 States the 10-year average total acreage of the four Northcentral States of Minnesota, Michigan, Wisconsin and Iowa (in order of acreage) was over 4,400,000 acres, while the 6 western and midwestern States of California, Idaho, Nebraska, Colorado, Kansas, and Montana was only 4,250,000 acres. In 1945, 1946 and 1947, Michigan took the lead in acreage from Minnesota and was followed closely by California. However, California in these 3 years, because of irrigation and high yields, produced much more alfalfa hay than any other 2 States taken together.

Production of alfalfa hay: The average annual production of alfalfa hay in the United States of 31,900,000 tons during the 12-year period (1937-48) exceeded that of the combined production of timothy and timothy-clover mixed. It ranged from a low of 24,763,000 tons in 1936 to 36,478,000 tons in 1942 and 38,500,000 tons in 1949. The average of the 7 years since 1942 is nearly 34,000,000 tons of hay which is 17 percent greater than the average of the 5 years prior to 1942 of 29,000,000 tons.

There are 11 States with an average annual production of over one million tons of alfalfa hay during the 13 years (1935-47). In the approximate order of production they are California, Minnesota, Wisconsin, Iowa, Idaho, Michigan, Nebraska, Colorado, Kansas, Montana, and Illinois. Of these 11 States, 6 are scattered west of the western boundaries of Minnesota and Iowa, and the remaining 5, including Minnesota and Iowa, are a solid block of Northcentral and Central States. During the 3 years (1945-47), 4 of these 11 States increased their average production over the previous 10-year average in the following order: Kansas 61 percent, Nebraska 53 percent, California 32 percent, and Idaho 5 percent.

Yields of hay per acre: Yields of alfalfa hay per acre over a period of years exceed those of any other perennial forage legume. There is considerable variation in the yields of hay obtained in individual states but not a great difference in average yields for regions where irrigation is not the general practice. The averages over a 10-year period in the latter regions range from 1.8 tons of hay per acre for
the Northcentral region to 2 tons for the Southcentral. In the western regions where irrigation is common the average is around 2.5 tons per acre. California leads all other States with an average yield over a period of years of from 4.2 to 4.6 tons of hay per acre. No other State approaches this yield, all of the others being under 3 tons per acre, and most of them under 2.5 tons. Of the 10 States with over one-half million acres in alfalfa, Michigan, Nebraska and Montana have the lowest average yields of around 1.6 tons of hay per acre.

Quality in alfalfa hay: The factors that affect quality in alfalfa hay are influenced by methods of hay production. The emphasis in all haying operations should be to obtain quality. This is not only true for the hay to be fed on the farm, but is also true for the product to be marketed as hay or meal. The dehydrated products are bought almost entirely on the basis of quality.

High grade alfalfa hay, as stated by Parker, must have high purity, high percentage of clinging leaves, and a green color. Leafiness and color correlate with carotene and protein content, as the leaves contain a much higher percentage of these important nutrients than do the stems.

There are at least 10 different vitamins found in alfalfa hay, vitamins A, C, D, and G being the ones most often discussed in the literature. Vitamin A is the one the livestock feeder associates with quality. A more comprehensive discussion of quality in alfalfa hay is given in chapter VI on hay making.

Effects of time of cutting on stand: Many alfalfa fields have been ruined because of improper cutting treatments. When the last short growth of alfalfa is taken off the field late in the fall, the alfalfa plants are deprived of the necessary plant food and protection to enable them to resist cold and diseases, and the loss of plants is great. The cutting off of this top growth may cause a loss of 75 percent or more of the stand and also reduce the yield obtained from the first cutting the following spring.

How to obtain quality hay and at the same time protect the stand is the problem to be solved. Reports of work in Wisconsin, Ohio and Kansas showed that the fall season is the critical period for the alfalfa plant and that it is necessary to plan the late cutting in order to allow the top growth to supply the roots with plant food for the winter. This supply must be sufficient to give the plant a high degree of cold resistance and furnish food for the spring growth. This can best be done by allowing the top growth to remain on the plants throughout the fall season. The trend of total carbohydrates in alfalfa roots is affected by cutting at different dates in the fall. If in the latitude of Kansas the last cutting is made by the middle of September, sufficient reserves will be built up. If the growth is cut off about the first of October, the reserves would be low throughout the winter; or if the growth is cut off at a later date, not enough time would remain for sufficient top growth to develop, to build up reserves throughout the fall.

Late cutting and food reserves: It has been determined in Kansas (Kan-16 & 17) and Wisconsin (Wi-27), that large reserves in the roots are necessary for maximum cold resistance. Alfalfa plants cannot harden properly to withstand low temperatures without sufficient plant food in the form of sugar. The sugar is obtained by the hydrolyzation of the starch which is manufactured in the leaves of the plant and stored in the roots. If the tops are cut off of the plant at the beginning of the fall dormant period, there can be no starch manufactured for storage.

However, after the alfalfa has completed its growth for the year and has stored the necessary food reserves in the roots, if there is an unused growth of alfalfa remaining, one may remove a large portion of such growth by pasturing or cutting without apparent injury, taking care, of course, to see that the field is not grazed so closely as to injure the crown buds of the alfalfa plant, or to remove all winter protection. The feed obtained in this manner, after drying or freezing in the field, will not be
of high quality but may be useful in case of short supply.

Cutting practices favorable to storage of large food reserves are also favorable to the development of crown buds and to their hardening to cold. In time-of-cutting experiments in Wisconsin (Wi-27) there was a gain of 26 percent in hay the next season from plots cut to insure large food storage and winter protection over those which went into the winter with small reserves and no protection. A similar experiment at Kansas showed a gain of 16 percent in the yield of the first cutting the next spring.

The conclusions are that from the standpoint of hay yield, quality of hay and permanency of stand, alfalfa can be harvested in the early stages of bloom the first and second cuttings, provided the later cuttings are allowed to go to half or nearly full-bloom stage and the last cutting during the growing season is made not later than September 15 in the latitude of Kansas. The only exception to this is that fall-sown alfalfa should not be cut early the first spring. Local conditions will vary and weather conditions may be different from year to year. Some years three crops will be harvested, and in others four crops, or one or two hay crops and a seed crop may be produced; but high food reserves in the root can be accomplished under any condition by careful management.

The curing process: In making the hay, the shorter the time consumed in the curing process, the better the chances are of getting high quality, but the methods employed to obtain rapid drying must not be done to the detriment of a high degree of leafiness. If hay is too dry when handled, the leaves shatter badly; therefore, it is necessary to handle it when it is partially dry or slightly tough. Alfalfa hay with the leaves dry and stems slightly tough contains about 25 percent moisture and can safely be stacked or stored loose in the barn. Hay can be baled from the windrow with a similar amount of moisture if the bales are piled to allow for ventilation. New-mown hay contains from 70 to 80 percent moisture, depending upon atmospheric conditions when cut. Well air-dried hay contains about 12 percent moisture.

Overdrying is probably the most common cause for the loss of hay quality. It is often unavoidable, particularly when the operator is handling too many acres for his equipment. The best method of curing to obtain quality is to allow the hay to wilt in the swath and finish curing in the windrow. Windrowing after wilting will slow down the curing process, and thereby prevent overcuring. Hay cured in this manner will go into storage with a higher percentage of leaves, carotene and protein.

Storing alfalfa hay: There are a number of methods of storing alfalfa hay, the most common practice being to bale, stack or store in the mow from the windrow. With the advent of the pick-up baler, baling from the windrow is becoming quite general and is a good method for obtaining good quality hay, weather permitting. Because of the rapidity with which the hay can be handled, there is a minimum loss of leaves. The hay is moved only once after it is cured sufficiently to cause shattering of leaves, and that is by the baler when it is being picked up.

The weather may change the situation and considerable damage may be done to the hay before it can be baled from the windrow. The difference in time that it takes the hay to become dry enough for the pickup baler, and when it is dry enough for the stack, may mean the difference between good hay and poor hay. The risk is justifiable where large amounts of hay are handled. When small acreages are involved, the best method is to store the hay as quickly as possible in the stack or barn.

Stacking in the field is the most economical method of storing the hay if properly stacked. A well-made large stack is the most practical because of the lower percentage of weather damage on the outside. A rectangular stack with the same width and length as the diameter of a round stack, both having the same overmeasurement, will have much less outside weathered hay per ton than a
round stack. Therefore, the large square or rectangular stack is the most economical one to use.

ALFALFA FOR PASTURE

Alfalfa is growing in popularity, as a pasture crop in this country, especially in mixtures with grasses. In countries such as Argentina it is almost universally used for grazing alone. From the standpoint of seasonal distribution and total yield, alfalfa makes a good pasture crop. It is necessary to pasture it with care or the stand will soon be killed out. The same principles hold true for pasturing alfalfa as for cutting, that is, the plants need protection to build up root reserves, particularly in the late summer and fall.

The grazing should be regulated to allow the top growth to maintain a height of from three to six inches. In the fall it should be allowed to reach a height of six to eight inches and remain that way until the tops are frozen back.

Alfalfa is recommended to be used in grass mixtures as a means of preventing or delaying a sod-bound condition that occurs in some grasses if they are sown alone, and to increase the nutritive value and yield of the forage by supplying nitrogen.

The alfalfas commonly grown are not well suited for pasture mixtures as they have an upright type of growth and the stock keep them grazed too closely unless properly managed. Stock will graze the alfalfa first, if accessible, except in the case of the most palatable species of grasses. Recent attempts to develop new varieties of alfalfa with growth habits better suited for grazing have made some progress. The types showing the most promise are those which have a prostrate habit of growth and a habit of spreading from the crown shoots and taking root. This type cannot be grazed out so quickly.

ALFALFA FOR SILAGE

The best way to conserve and store the feeding value of alfalfa is to ensile the crop when it is in the best stage for hay. In properly made alfalfa silages, the carotene losses in all the processes from field to feeding manger are smaller than by any other economical means, because no leaves are lost and the chemical changes of self-preservation are not extensive.

Like clovers, other legumes, or any crop rich in protein, the making of acceptable silage from alfalfa requires the right moisture-dry-matter relations, the right stage of development, suitable processing to produce fermentations within best temperature range, and when necessary use of suitable added conditioners. Ensiled alone, moist green alfalfa will make highly nutritious silage but one perhaps not highly palatable to animals accustomed to corn silage, or those treated with ground grains or molasses. Alfalfa in full bloom, or later stages even, seems to have lost its tendency to make rank silages when ensiled alone.

Aside from ground grains or molasses as conditioners, meadow grasses, or corn or sorghums in season will be most useful crops to mix with alfalfa. It is always safer to ensile alfalfa grown in meadow mixtures with some grains or grasses, and wilted to a suitable dry matter content than to ensile it alone.

Local experience in making alfalfa silages is the best guide as to what to do and what not to do in settling time of cut, amount to wilt, and the way to treat. Wanting positive local experience, it is well to ensile alfalfa alone when it is further developed than when cut in meadow mixture of legumes and grasses. Wilt young alfalfa when possible to a condition that does not let water out of the tissues when put under considerable pressure and yet still moist enough to remain in a ball when chopped crop is held tightly in closed fist until hand is tired.

The younger or moister the alfalfa or alfalfa mixture, the more added conditioner is needed to get an acceptable silage. From 70 to 35 pounds of molasses per ton of green crop, added preferably without dilution, will be a good range, and from 250 pounds of ground grain down to 100 pounds per ton of green
crop, decreasing each treatment with increase of dry matter in crop, will give good results.

Average yields of grain and alfalfa in the country mean that it takes nearly an acre of grain to treat an acre of good alfalfa of meadow crop. Dairy feed use of much grain may be justified in regions where grain grows, but if lower rates of treatment work, and they do, rates of 150 pounds or less are usually most economical.

For a fuller discussion of silage making, see chapter VII.

OTHER FORMS OF CURED ALFALFA

Alfalfa meal: Alfalfa meal is a product of cured alfalfa, usually sun-cured, stacked and ground later on the farm or by a commercial mill. The quality of the meal depends on the quality of hay used in its manufacture.

Leaf meal is made by screening the leaves from the stems. If made from high quality hay, the meal will be a high protein feed used largely in the making of mixed feeds.

Some of the commercial alfalfa meal is made from stemmy alfalfa hay, which, even though it may be green in color, is of low feed value. Since there is such a wide difference in feed value between extra green alfalfa leaf meal, either sun-cured or dehydrated, on the one hand, and alfalfa meal made from stemmy alfalfa hay on the other, and there are no United States grades in general use, the buyer should use every means at his disposal to know the kind and quality of meal he is buying.

The total alfalfa meal production during the past 20 years (1928-47) has ranged from an average low for 1932-33 of 177,000 tons to an average high for 1946-47 of 1,076,000 tons. During the four years of 1928 to 1931, preceding the low point, it averaged nearly 340,000 tons and after the low production of 1932 to 1933 it gradually climbed to over 500,000 tons at the beginning of World War II, to over 700,000 tons during the War and to an average high of 1,076,000 tons in the immediate postwar years. The production is spread fairly well throughout the months of the year but in most years it is heaviest from June to October or November.

No statistics are available to show the proportion of alfalfa meal that is alfalfa leaf meal or alfalfa stem meal, or that is made up into alfalfa pellets.

Chopped alfalfa: Chopping alfalfa hay and stacking in the field is a common method of storage. The chopping is done by running the field-cured hay through an ensilage cutter. The chief advantage of chopping hay is that the stock will consume both leaves and stems. Otherwise, it is no better as a feed than the hay before it was chopped. It is difficult to keep chopped hay from heating in the stack or mow. Much of the hay handled in this manner may heat sufficiently to be browned. If it does not become very brown probably there will not be a great loss in feed value. Hay that is dry enough for stacking will often heat if chopped and stacked, because it packs more closely.

Barn-cured hay: The artificial curing of hay in the barn is coming into prominence, particularly in areas where difficulty is encountered in field curing because of weather conditions. Curing in the barn is accomplished by the use of the hay drier. Hay that is to be barn-cured is usually cut in the morning, allowed to wilt in the swath from 4 to 5 hours if the weather is favorable for curing, and brought to the barn to finish curing. Hay handled in this manner will be reduced from 75 percent moisture to approximately 45 percent in the field and dried by the drier in the barn down to a satisfactory storage content of 20 percent.

Dehydrated alfalfa: Dehydrating alfalfa is a good method of processing the forage to save the food value of the crop. Dehydrating prevents the loss of leaves, insures high protein and carotene content. Dehydrated alfalfa meal made from good alfalfa is a high carotene feed and is used largely by the mixed feed manufacturers. The carotene content of dehydrated alfalfa is higher than that of the sun-cured
hay. To hold this high carotene content, it is necessary to store the dehydrated product in a cool, dark place or the carotene will disappear rapidly.

ALFALFA SEED PRODUCTION

Alfalfa seed production is most dependable where the climate is relatively dry, as in the arid and semiarid districts of the West. It is under such conditions that the greater part of the seed has been produced in the United States. During the past few years considerable seed has been obtained in the Middle West, particularly in northern Wisconsin, Minnesota, and Michigan, but the production in this portion of the United States is somewhat erratic, being considerable in abnormally dry seasons, and relatively unimportant in wet seasons that favor rank vegetative growth.

Acreage and production: The average acreage of alfalfa harvested for seed in the United States during the 10 years (1936-45) was 800,000 acres which was 5.5 percent of the average total acreage harvested for hay. In the three following years (1946-48) the average acreage harvested for seed increased to 928,000 acres, which was over 6 percent of the hay acreage. With an increased average yield per acre during these 3 years of 9 percent over the previous 10-year period, the total production was 28 percent greater. The average production for the 10-year period (1936-45) was 70,740,000 pounds, and for the three following years was 90,240,000 pounds. The estimate of the 1949 crop (Dec. 19, 1949) was 114,000,000 pounds, which is the largest on record. Since the loss in cleaning is nearly 20 percent, the production of clean seed would be about 80 percent of these figures or 91,000,000 pounds.

Kansas led all the other States in the acreage of alfalfa harvested for seed and in quantity of seed produced for both the 10-year period and the next 3 years, with an average of 111,000 acres and 8,600,000 pounds of seed for the 10-year period, and an average of 210,000 acres and 17,220,000 pounds of seed in the 3 following years. The Kansas production of 26,880,000 pounds of alfalfa seed in 1946 exceeded that ever attained by any other State. Previously, Utah had the record with 26,500,000 pounds produced in 1926. The seven highest producing States, which altogether produced 60 percent of the total United States production, in order of production in the 4 years 1946-49 were Kansas, Oklahoma, Nebraska, California, Arizona, Utah and Montana. In 1949 California, Arizona and Utah production exceeded that of Kansas.

Yields per acre: The average yields per acre were about 90 pounds during the 10 years, 1936-45, and 102 pounds in the 3 following years. The largest yields were in the Southwestern States where irrigation is generally practiced. Of these 7 highest-producing States, California leads in alfalfa seed yields as well as in alfalfa hay yields with an average of 254 pounds of seed for the 4 years, 1946-49, followed in order of yield by Arizona with 187 pounds, Utah 164 pounds, Oklahoma 108 pounds, Montana 95 pounds, Kansas 80 pounds and Nebraska with 70 pounds.

The estimates of average seed yields made by growers in areas of principal commercial seed production are from 50 to 100 percent above the official average of all farm yields, and the estimates of maximum yields made by growers are from 2 to 5 times the average yields.

Factors affecting seed production: The question that is most difficult for the grower to answer is whether to leave the alfalfa crop for seed or harvest it for hay. Some of the factors which the grower can control to make conditions more favorable for seed production are:

1. Having high food reserves in the roots at close of growing season and, when grown under irrigation, regulating the water in order to produce a slow-growing, medium heavy top growth for seed.

2. Control flowering weeds and other crops that may offer beneficial insects, nectar and pollen in competition with the alfalfa.

3. Control harmful insects.

4. Encourage the bee population by
keeping bees or providing space for an apiary.

5. Protect the nesting place of the wild bees usually found on or near the ground in waste places.

If these have been taken care of, then the more or less unpredictable factor is the weather. It would be helpful to study the long-time weather reports to determine the trend of the general weather conditions. Sunshine and below-normal rainfall are usually associated with good seed setting in alfalfa in the more humid regions.

As most of the alfalfa seed produced in Kansas and other high seed-producing States of the Great Plains is non-irrigated, the weather and the amount of soil moisture will affect the type of plant growth. If the alfalfa seed crop starts its vegetative growth with high food reserves in the roots, the ideal weather condition would be one which produces a slow, steady growth throughout the vegetative period with a slight increase at flowering time. This condition will usually accompany a slightly below optimum soil moisture condition up to the bloom stage and optimum soil moisture through the fruiting period.

Recent experiments conducted in Kansas indicate that one of the factors affecting alfalfa seed yield is the accumulation of food reserves. The results of three years of field experiments show that high food reserves increased the seed yield of alfalfa 16 pounds per acre over the low food reserve treatment. Greenhouse and field experiments corroborated these results. If the yield of all of the 153,000 acres harvested for seed in Kansas in 1944 had been increased by 16 pounds per acre, the total increase from this factor alone would have been around 2,500,000 pounds.

Actual farm experiences of some of the alfalfa seed growers in the Central Great Plains have convinced them that more alfalfa seed can be produced per acre by allowing the crop previous to the seed crop to go to the full-bloom stage. The reason usually given for this practice is that the field being left for seed will come into bloom later than most fields in the community, thereby getting a heavier concentration of bees for tripping the flowers.

Insects in relation to seed production: Cross-pollination is necessary to seed-setting in many flowering plants, thus the flower-visit ing insects are essential for production of seed. Alfalfa flowers must be tripped before seed-setting will take place. Tripping is the release of the staminal column from the keel of the flower, allowing it to snap forward onto the standard petal, and this is accomplished largely by insects.

The grower should observe the field closely when in bloom to determine whether the flowers are setting pods or falling off, sometimes called "stripping." If the flowers are stripping, it is an indication that they are not being tripped by the insects.

The alfalfa flower is not easily tripped. Therefore, if the insects are after pollen, they are apt to go to other plants where it may be more easily obtained. Competition between alfalfa fields, between alfalfa and sweetclover, or between alfalfa and wild flowers, may be a factor in determining seed yield. This could be particularly true if the weather conditions at the time the alfalfa is in bloom are unfavorable for insect activity.

As a general rule, insects in their activities are influenced markedly by temperature. Weather conditions in which there is a lack of sunshine and concurrent relatively low temperatures, adversely influence insect activity. The primary attraction in alfalfa to pollinating insects is the available nectar and pollen present in the flowers.

The most important of these insects in alfalfa seed production are certain of the stem and soil-inhabiting solitary bees, *Megachile* spp. and *Nomia* spp. *Megachile* spp. or leaf-cutter bees, are fairly common over large areas, while the *Nomia* spp. or alkali bees may occur on the high plains and do not occur on the mountain plateaus and valleys in the mountain States. Bumblebees, *Bombus* spp., are effective pollinators but, like many other insects that are most effective, are relatively few in number. Honeybees, *Apis*
mellifera, are not the most effective tripping agents, but do considerable tripping if present in large enough numbers, so really play an important part in alfalfa seed production. If honeybees are present in large numbers and other flowering weeds or crops whose flowers are more attractive to the honeybees than alfalfa are not present, they will do a good job of tripping and will serve to make the difference between a profitable or unprofitable crop of seed.

The placing of colonies of honeybees adjacent to alfalfa fields at the rate of from one to three strong colonies for every acre of alfalfa materially helps in pollination and seed-setting. The average seed yield in some States is only a little more than one bushel. This could be increased to two to four bushels per acre by the encouragement of greater populations of the beneficial pollinating insects, provided other conditions are favorable.

The use of DDT as a 5 or 10 percent mixture with sulphur dust has proved effective in the treatment of alfalfa fields for both lygus bug and leafhopper infestations. Some striking results in increased yields of seed have been obtained in Kansas and Nebraska from these applications, but sufficient tests have not yet been made to indicate the most effective methods of application, or what may be expected in all cases from such treatment.

Alfalfa seed yields have been declining in those two States as well as others for several years, and the blame has been laid to several causes, among which are adverse climatic conditions, lack of pollinating insects, prevalence of insects and diseases injurious to the alfalfa plant flowers or foliage, and others. In certain cases where leafhopper and lygus bug infestations were high, the DDT applications practically eliminated both, while at the same time the untreated plants did not come into bloom because of those infestations and were largely destroyed.

The applications of DDT are usually given one to two weeks before the alfalfa plants come into bloom. By making these applications at this time and placing one or three hives of honeybees per acre into the field just when the alfalfa is coming into bloom is a practice that not only destroys the injurious insects prior to blooming, but also prevents injury to the beneficial pollinating insects.

If other flowering crops which are more attractive to the insects, such as red clover, are nearby and come into bloom at the same time as alfalfa, measures might be taken such as clipping the alfalfa early in its growth to hold back its blossoming until after the competing flowering crop has finished blooming. With such controls as these, it appears that at least one or two deterrent factors in alfalfa seed production might be eliminated and better crops of seed obtained in the future.

Harvesting and Threshing the Seed Crop

Which crop to harvest for seed: The crop to be left for seed varies in the different parts of the country with the length of the growing season, the weather conditions, and other factors. As hot, dry weather favors seed-setting, it is customary to save for seed the crop that matures during the hottest and driest part of the summer. In the Northern States where the season is short, either the first or second crop is harvested for seed. Ordinarily, unless the variety is one that is especially grown for seed, the second crop is saved and the first is cut for hay. Under very dry conditions, the likelihood of getting a satisfactory second crop for seed may not be good enough to take a chance on it, so the first may be harvested. In the Central Great Plains, Intermountain, and North Pacific States, the second or third crop is harvested for seed, in the drier portions, the second, and in the portions of greater rainfall the third. In the Southwest, under irrigation, a crop as late as the fourth or fifth may be taken for seed, or, if production is the primary objective, two seed crops may be obtained in one season. The crop to be left for seed should be determined by observing when the most favorable con-
ditions are likely to be obtained. Where the seed-setting period is long enough and an extended acreage is to be harvested for seed, the field or fields might be divided into two or more portions and these staggered as to blooming periods by different cutting treatments, so as to obtain maximum effectiveness of pollinating insects. This problem should be carefully studied for each locality.

When to cut for seed: The quality of the seed harvested depends on the weather condition during the curing of the crop. All the seed pods will never be ripe at the same time. Therefore, the grower must be the judge to determine when a majority of the pods are in the yellow and brown stage. Alfalfa should be cut for seed when two-thirds to three-fourths of the pods are brown. Pods that are plump and yellowing will mature after cutting. If the weather is dry during the ripening period, shattering will be light. If intermittent showers occur, much seed may be lost by shattering.

Method of handling seed crop: The method used in handling the seed crop will depend on the prevailing weather conditions. With favorable drying, the best method is to use a windrow attachment on the mower and allow the hay to cure in the windrow and thresh with a pickup combine. Under the most favorable ripening conditions, seed is sometimes combined standing in the field like wheat. Some growers who cannot thresh immediately from the windrow will cock the hay and allow it to cure in the cock and haul it to the thresher.

A profitable seed crop may be lost because unfavorable weather makes it necessary to allow the crop to become overripe or to be handled several times in curing. The modern combine thresher equipped with proper sieves is a satisfactory machine to use in threshing alfalfa seed. The clover huller has been used extensively for threshing clover and alfalfa seed and is constructed for this specific purpose. When available, it is the best machine to use. A good operator can adjust any of these machines so that very little cleaning will be necessary to obtain seed with a fairly high purity suitable for marketing to the processor who will re-clean and put it into final condition for sowing.

Special Assurances of Variety and Origin of Alfalfa Seed

Certification of variety: Many States certify seed as to variety, each package bearing a certifying tag. Varieties so registered or certified include Grimm, Cossack, Baltic, Ladak, Hardigan, Orcstan, Hardistan, Ranger, Buffalo, Atlantic, Indian, African, and in some States, seed from fields of common alfalfa of long standing. Methods of procedure and regulations have been developed by the International Crop Improvement Association for use of State certifying agencies. See chapter VIII for certification standards for alfalfa.

The need for seed certification of superior alfalfas is emphasized by the finding of the high percentage of cross-pollination effected by bees and by the fact that when a bacterial wilt-resistant strain and a susceptible strain are grown side by side in the field, the seed from the resistant strain is much less resistant than before.

Verification of origin: The United States Seed Verification Service verifies the origin or place where the seed was grown without regard to the variety or pedigree. This is especially useful because of the lack of winter hardiness of common alfalfas from more southern latitudes for growing in the North. Proper labeling with accurate statements of States of origin on the tag has done much to curb the shipment of alfalfa seed of unknown variety or origin from southern into northern States.

In order to identify imported alfalfa seed from domestic seed, the Federal Seed Act of 1939, requires that alfalfa seed from foreign countries be stained before it is permitted entry into the United States. In accordance with this Act and rules and regulations thereunder, 10 percent of the seed from any country other than South America or Canada must be stained red. Alfalfa seed from any of the countries of South America must be
stained 10 percent orange-red, and seed from Canada 1 percent violet.

**VARIETIES AND STRAINS OF ALFALFA**

Prior to 1892, there was no commercial recognition of alfalfa varieties in the United States, whether of foreign or domestic origin. As attempts to grow the crop spread to areas where conditions were less favorable, however, differences in behavior became apparent. This finally resulted in the recognition and adoption of several fairly distinct commercial varieties and strains that show great diversity in their relations to climate and latitude. Some give best results in the North, where the winters are cold and the days are long during the growing season; others do better in the extreme South, where the winters are mild and the days during the summer are shorter than in the Northern States.

The improvement of alfalfa as an organized effort began about 1903 when several forage crop specialists of State agricultural experiment stations undertook this work. The earlier investigations were conducted largely in South Dakota, Nebraska, Kansas, Wisconsin, Michigan, Colorado, North Dakota, and Minnesota, some of which were in cooperation with the United States Department of Agriculture. An account of the work done in improving alfalfa and in the development of improved varieties, including hybrid and synthetic alfalfa, is given in chapter VIII on "Improving our forage plants."

The commercial alfalfas of the United States may be divided into four somewhat distinct groups, each containing strains or varieties that vary considerably within themselves. These groups may be briefly described as follows:

The common group includes mostly the ordinary purple-flowered, smooth alfalfa, of which numerous regional strains have developed naturally in the western part of the United States and in foreign countries. The strains in this group are not ordinarily considered as hardy as most of those in the variegated group.

The Turkistan group includes alfalfas that are similar in flower and color to the common alfalfas, but the growth is generally somewhat shorter and more spreading. No commercial distinction is made between the various strains as imported from Turkistan. Of those that have been mentioned, Hardistan and Orestan have been discontinued, and Nemastan is the only one which is now being increased in this country.

The variegated group includes alfalfas that have originated from crosses between common alfalfa (*Medicago sativa*) and the yellow-flowered species (*M. falcata*), of which Atlantic, Grimm, Canadian Variegated, Cossack, Baltic, Ladak, Ranger, and Hardigan are the best known examples.

The nonhardy group includes rather distinct varieties that are in general very erect in habit of growth, recover quickly after cutting, have a long growing period, and are very susceptible to low temperatures. The Peruvian, Arabian, Indian and African varieties are members of this group.

With the increasing seriousness of the bacterial wilt disease, it became necessary to develop varieties resistant to this disease to maintain alfalfa production. A few new resistant varieties have been developed, the most prominent of which are Ranger and Buffalo.

**THE COMMON ALFALFA GROUP**

The stock from which most of the common alfalfa of our Western States has been produced was brought from Spain to Chile and, after having been grown there for many years, was introduced into California about 1850. In most lots of common alfalfa some plants grow more quickly than others after being cut and have a tendency to produce larger yields. These plants are favored by a mild climate and for convenience are referred to as the southern, or nonhardy type. The plants that recover more slowly after being cut and become dormant earlier in fall are more cold-resistant and are referred to as the northern, or hardy type. These various types furnish a basis for regional strains which, as at
present defined, are produced when com-
mmon alfalfa is grown for several seed
generations in definite localities where
eliminating conditions of one kind or
another normally prevail. See map show-
ing general zones of adaptation of alfalfa.

Even the hardiest strains of common
alfalfa are not dependable where the win-
ters are particularly severe. The hardier
variegated alfalfas are much to be pre-
ferred under such conditions. None of
the common alfalfas as they are produced
commercially has shown any appreciable
resistance to bacterial wilt. The new
variety “Buffalo” has been developed
especially for wilt resistance.

The term “common alfalfa” as ordi-
narily used is applied to the species Me-
dicago sativa and also to the general run
of alfalfa of unknown variety as produced
in the various States. In the latter mean-
ing as applied to common alfalfa of cer-
tain northern States where Grimm and
other variegated alfalfas also have been
grown to a large extent for many years,
it undoubtedly includes not only plants
of the Medicago sativa, but also a sub-
stantial percentage of plants of variegated
alfalfa. This condition has been brought
about through both hybridization and
mechanical mixtures, and applies to Min-
nnesota common, South Dakota common,
and Montana common. Agronomists in
those States estimate the percentage of
Grimm or other variegated alfalfas in the
common alfalfa in their States at from
40 to 75 percent of the total, but these
estimates may be too large. State of origin
on a verified-origin seed label indicates
only State where grown, but when com-
mon alfalfa seed is obtained from a pro-
cessor who blends many lots from a State
into one lot for merchandising purposes
any portion of such lot should represent
the average adaptation of so-called com-
mon alfalfa for such State.

Domestic strains: The various strains of
common alfalfa produced in the United
States are usually distinguished by the
name of the State, as Kansas, South
Dakota, or Montana Common, or else
by some term descriptive of the condition
under which the seed is produced, such
as dry-land, irrigated, and nonirrigated
alfalfa. The environment under which
alfalfa is grown undoubtedly has an im-
portant influence on its characteristics,
but just how many seed generations are
required to bring about a distinct change
doubtless varies with the eliminating cli-
matic conditions and cannot be estimated
accurately.

The so-called regional strains that have
developed in the Dakotas and Montana
have a tendency to recover more slowly
after being cut than those produced fur-
ther south and, being more cold-resistant,
are preferable where winterkilling occurs
rather frequently. Such strains are gener-
ally less productive at the lower latitudes

Map showing general zones of adaptation
of alfalfa.
ducted by the United States Department of Agriculture have not thus far shown any material advantages over seed produced under irrigation.

**Argentine alfalfa**: Practically all the Argentine alfalfa belongs to the common group, though several more or less distinct strains have been developed as a result of having been grown under widely varying conditions of climate and latitude. Most of the seed brought to the United States is produced south of Buenos Aires, where climatic conditions are much less severe than those at a similar latitude in this country and therefore are not conducive to the development of a hardy strain. The tests thus far conducted in the United States indicate that some Argentine strains are less hardy, and that the hardiest are no hardier than our own Kansas common. For this reason, Argentine alfalfa cannot be sown with safety any farther north than Kansas alfalfa is known to succeed. Experimental results in the central or southern parts of the United States indicate that in most areas Argentine alfalfa may be expected to yield 5 to 20 percent less than locally adapted varieties.

Considerable Argentine alfalfa seed has been imported into the United States. The average annual imports during the 5 pre-war years (1937-41) were over 750,000 pounds; the average of the next three early-war years (1942-44) was 2,200,000 pounds; the average for the three years (1945-47) was 6,170,000 pounds; and the average for the past two years (1948-49) was only 210,000 pounds. The falling off of importations from Argentine in the last two years was because of the large importations from Canada.

Under the Federal Seed Act 10 percent of the seed of Argentine alfalfa must be stained orange-red before it is permitted entry, to indicate that it is of agricultural value only in limited areas.

**South African alfalfa**: Most lots of South African seed that have been tested have proved to be somewhat less cold-resistant than Kansas Common. Even where the South African alfalfa survives the winter satisfactorily it has shown no advantage over the adapted domestic strains. This South African grown alfalfa should not be confused with the variety “African” developed at Bard, California.

**Provence alfalfa**: Provence is the name applied to a strain of alfalfa grown in southeastern France. It differs so slightly from the common regional strain produced in Kansas that one can scarcely be distinguished from the other. Provence, however, begins growth earlier in spring and continues to grow later in fall in the southern part of the United States than the strain from Kansas. It also makes somewhat quicker growth after being cut, but is not quite so hardy, and cannot be recommended generally north of the central part of the United States.

**Buffalo alfalfa**: Buffalo alfalfa is a selection made at the Kansas Agricultural Experiment Station from an old line of Kansas Common Alfalfa traceable back as far as 1907 as a Kansas-grown strain. In extensive tests over a wide area, it has shown remarkably superior performance. It compares favorably with Kansas Common in yield and other characteristics and is superior to it in being resistant to the bacterial wilt disease. Buffalo alfalfa is well suited for growing where Kansas Common is adapted. This is generally recognized as the central and southeastern parts of the United States, including the range across the country at approximately the same latitude as Kansas and areas southeast of that State. Because of the more rapid recovery of Buffalo after cutting and its larger fall growth, it can be used more extensively than Kansas Common has been in that part of the country.

Recent tests have shown that it is adapted to certain intermountain areas and in the Pacific States as far north as Washington, and in the eastern plains States, including Iowa, Illinois, Ohio, and east into the eastern States as far north as New Jersey and Connecticut. It also shows a higher stand survival than Kansas Common in the northern alfalfa areas of the United States.

**Williamsburg alfalfa**: Williamsburg alfalfa is a selection from Kansas Common alfalfa developed by R. P. Cocke at the Branch Experiment Station, Williams-
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burg, Virginia. Its principal characteristic is its persistence under Virginia conditions, particularly those of eastern Virginia, much longer than other varieties of alfalfa. It is apparently somewhat resistant to stem rot (Sclerotinia), which is often very destructive to alfalfa and clover in Virginia. This variety has not been thoroughly tested but because of its persistence alone it is being increased for seed production in western seed producing areas for use in eastern Virginia.

Talent (Southern Oregon): This alfalfa (F.P.I. No. 19274) was introduced from France in 1935. It has a very rapid comeback after harvest of hay, is a heavy forage yielder, good seed yielder, and resistant to stem nematode injury in southern Oregon and northern California. In experimental work over a period of 8 years in that area, it has been the high-yielding and long-lived variety.

TURKISTAN GROUP

Alfalfas either directly or indirectly of Turkistan origin include Turkistan, Nemastan, Hardistan, and Orestan of which the last two have been discontinued. They are characterized by slow recovery after being cut, early fall dormancy, susceptibility to leaf diseases, resistance to cold and bacterial wilt, and low seed yields. They are recommended for wilt-infested soils west of the Mississippi River and from Kansas northward. They have not generally given good results in the Eastern or Southern States.

Turkistan: Turkistan alfalfa was first introduced into the United States in 1898. The superior cold resistance of the early importations resulted in a demand for Turkistan seed for sowing in the cold, dry regions of the northern Great Plains. During the years 1908 to 1915, and 1920 to 1928, considerable seed was received through commercial channels, but since 1928 very little has been imported from Turkistan. Unfortunately, much of that imported was sown in the East where it gave very unsatisfactory results, and various means were employed to warn growers against its use, particularly in the East and South. Recently, however, interest in Turkistan alfalfa has revived, mainly as a result of its resistance to bacterial wilt, a disease responsible for serious losses, especially in some of the best alfalfa-growing districts of the Middle West and far West.

Alfalfa seed produced in Turkistan can usually be identified by the presence of seed of Russian knapweed (Centauraea perris), which it almost invariably contains. The seed is considerably larger than alfalfa seed, of an oblong shape, and of an ivory-whitish color. Russian knapweed has become established in certain parts of the West, where it is regarded as a dangerous pest.

Nemastan: This variety is an original introduction by H. L. Westover from the Askhabad district of Turkistan. It has been tested under Forage Crops No. 19304.

In tests in Utah and Nevada, Nemastan has been outstanding in survival where the soil is infested with the stem nematode (Ditylenchus dipsaci). This nematode is so severe in certain sections of these two States that alfalfa growing was becoming very hazardous or even impossible. It was therefore decided to increase this strain for use in infested areas in the two States. Nemastan has another advantage in being somewhat resistant to bacterial wilt, but it was found to be extremely susceptible to leaf spot and often was low yielding. It is, therefore, not recommended except in certain Western States.

Hardistan: Hardistan is a strain of Turkistan alfalfa grown in Nebraska several years, seed of which was originally obtained through commercial channels. In comparative tests it has reacted very similarly to some of the commercial Turkistan strains. Like Turkistan, it produces relatively low yields of seed under most conditions so has been discontinued.

Orestan: Orestan is an alfalfa that was originally introduced from Turkistan, Asia, under Forage Crops No. 19301. It is similar to some of the commercial Turkistan alfalfas. In common with them, it is not a good seeder and has been discontinued.


**VARIEGATED GROUP**

The variegated alfalfas have resulted from a natural cross between the purple-flowered and the yellow-flowered species. The predominant color of the flowers is similar to ordinary alfalfa, but brown, green, greenish-yellow, and smoky flowers are not uncommon, and pure yellow flowers are found occasionally. It is because of this range in flower color that the designation "variegated" is applied to the group.

There has been some confusion in the use of the term "variegated alfalfas." True common alfalfa may show a great range of shades of purple or blue in its flowers but not green or greenish-yellow. It is the presence of these latter colors which indicates a mixture of yellow-flowered alfalfa with common alfalfa and the term "variegated alfalfa" should be used only for such mixtures.

The Grimm, Cossack, Baltic, Atlantic, Canadian Variegated, Hardigan, and the new variety, Ranger, are all variegated alfalfas and more cold-resistant than any of the common alfalfas, and may be used to advantage from about the fortieth parallel northward and at higher altitudes farther south. The Ladak is adapted to the western part of the same area, and the Atlantic to the North Atlantic States. Narragansett, Southern Oregon, and Creeping have been tested only locally so are of unknown adaptation beyond the locality of development.

There are many areas within this region where soil and climatic conditions are particularly favorable to the growth of alfalfa and where some of the common alfalfas may be used to advantage, especially in short rotations, the seed being somewhat cheaper. Even under these more favorable conditions, however, the variegated alfalfas have generally been somewhat more productive in the northern half of the United States and have usually been inferior to the common alfalfas in the South. With the exception of Ladak and Ranger, none of them has shown any appreciable resistance to bacterial wilt. Ladak is somewhat tolerant to the disease, and Ranger has been especially developed for its resistance to wilt. Grimm: Grimm alfalfa is the best known member of the variegated group in the United States. It was introduced from Germany into Carver County, Minnesota, in 1857 by Wendelin Grimm and eventually attracted considerable attention on account of its cold resistance.

To the casual observer Grimm alfalfa differs little from the common strains growing in the areas to which Grimm is adapted, but a closer examination will reveal usually a greater diversity of forms and color of flowers. Variegated flowers are usually more in evidence in semiarid than in humid districts.

The hardiness of Grimm is probably due in part to the presence of yellow-flowered alfalfa in its ancestry, and in part to the process of natural selection that took place under the severe climatic conditions to which it was subjected for many years in Minnesota. On account of its superior hardiness, Grimm alfalfa has been recommended particularly for all the Northern States where winter-killing is a serious factor, but because of its susceptibility to the bacterial wilt disease it is becoming less popular where that disease is prevalent. In ability to produce seed, Grimm is at least the equal of common alfalfa.

Cossack: Cossack alfalfa was introduced into this country from Russia in 1907. It is a hybrid between the common and yellow-flowered alfalfa. The flowers show a higher percentage of variegation than Grimm, the yellow and white flowers being more abundant. On the whole, Cossack has not shown evidence of being appreciably superior to Grimm for most conditions.

Canadian variegated: Canadian Variegated, or Ontario Variegated, is the name given to an alfalfa of hybrid origin grown in eastern Canada for many years. It is so similar to the Grimm variety in flower color and in general habit of growth that it is seldom possible to distinguish one from the other. Canadian variegated also compares very favorably with Grimm in yield of seed and hay. In New England and other northeastern States of approximately the same lati-
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tude, its superior hardiness as compared with ordinary alfalfa has been pretty well demonstrated. In tests conducted in the Northern Great Plains it has not usually survived the winters so well as Grimm.

The average pre-war (1937-41) imports of all alfalfa seed from Canada were 2,250,000 pounds; the average for the war and post-war years (1942-47) was 2,800,000 pounds. In 1948 they were 7,187,000 pounds and in 1949 they reached a record high of 19,209,300 pounds. A large portion of this seed was Canadian Variegated and Grimm. Under the Federal Seed Act, one percent of the seed of Canadian origin must be stained violet before it is permitted entry.

Ladak: Ladak alfalfa was obtained from India in 1910 by the U.S. Department of Agriculture. In the preliminary tests in the northern Great Plains, it suffered less winter injury and generally was more productive than most others. No other alfalfa grown commercially in the United States shows such a wide variation in growth habits of individual plants. Plants obtained from the original seedings were predominantly yellow-flowered, but hybridization in subsequent generations has resulted in a gradual increase in the proportion of purple flowers. The variety, however, still shows more variegation, with a greater percentage of yellow flowers than any other alfalfa in the group.

In the region where Ladak is adapted one of its outstanding characteristics is its ability to make an exceptionally heavy first crop. As it excels all other varieties in this respect, it is especially valuable where only one good cutting is normally obtained. It recovers slowly after being cut, and as a result the second and third crops of other varieties often exceed in yield those obtained from Ladak. Because of the heavy first cutting, however, the total seasonal yield of Ladak is often in excess of that of other varieties.

Like Turkistan, Ladak has a tendency to become dormant early in the fall. Being relatively free from leaf diseases, it retains its leaves remarkably well, and thus yields a high quality of hay. It has also shown considerable resistance to bacterial wilt, though it is not equal in this respect to the alfalfas of the Turkistan group.

In many tests Ladak has proved superior to all others for the cold and dry conditions found in the northern Great Plains, and it has also given good results under irrigation in the Northwest. Even as far south as Manhattan, Kansas, yields obtained from Ladak have compared very favorably with those from other alfalfas. Where wilt is prevalent in this general region, Ladak has considerable advantage over other variegated and common varieties. East of the Mississippi River, it has given variable results. It is not suited to the southern half of the United States and is one of the poorest to grow along the eastern seaboard, except possibly at high elevations.

Baltic: There is no authentic record of the introduction of Baltic alfalfa into this country, although there is no doubt that the original stock came from Europe. The name Baltic was first applied to it by W. A. Wheeler at the South Dakota Agricultural Experiment Station in 1906, for the reason that it had been grown for about 10 years near Baltic, South Dakota, and not, as has been supposed by some, in the Baltic Sea region of Europe.

This alfalfa differs from Grimm in some minor details, but the two are so similar that it is seldom possible to distinguish one from the other, and the description given for Grimm applies equally well to Baltic. In some tests Baltic has slightly exceeded Grimm in yield and in others the reverse has been true, but in general the two varieties may be considered of about equal value.

Baltic alfalfa has unquestionably been developed in much the same way as Grimm and therefore owes its hardiness to the same causes—the presence of the yellow-flowered alfalfa in its ancestry and natural elimination of the less hardy plants as a result of having been grown under severe climatic conditions.

This variety is best suited for sections where the ordinary alfalfas suffer con-
siderable winterkilling. These sections include practically the same territory as that to which Grimm is best adapted. Meeker Baltic is a regional strain of Baltic alfalfa grown in Colorado.

**Hardigan**: Hardigan alfalfa was developed by F. A. Spragg at the Michigan Agricultural College from Baltic alfalfa selections furnished him by W. A. Wheeler of South Dakota in 1907-1910. Both these breeders were trying to develop a good forage type alfalfa that would give good yields of both forage and seed under northern humid and subhumid conditions. In general growth Hardigan is similar to Grimm and other variegated alfalfas. The flowers, however, are largely purple, very little variegation being in evidence. Hardigan blossoms more freely and, where conditions are conducive to seed setting, produces larger yields of seed than almost any other alfalfa. This characteristic of setting seed under more humid conditions than those ordinarily considered favorable for alfalfa it has in common with its parent, the Baltic, and certain other selections made from it. In many parts of the East, however, Hardigan has not always produced profitable yields of seed, indicating that the problem of seed production under humid conditions cannot be solved entirely by its use. In cold resistance and productivity it is similar to Grimm and Baltic and is, therefore, adapted to about the same region as other variegated alfalfas, namely, the Northern States, where winterkilling is likely to be serious.

**Ranger**: Ranger alfalfa is a synthetic variety produced through the cooperative efforts of the Nebraska Experiment Station and the United States Department of Agriculture. It may be called a multiple-strain variety, having been synthesized from selections originating from the varieties Cossack, constituting 45 percent, Turkistan, 45 percent, and Ladak, 10 percent.

In morphological characters, Ranger exhibits considerable variability, both in habit of growth and flower color, being distinctly variegated in the latter. Occasional yellow-flowered plants are found. It would be classified, therefore, in the variegated group. The plants vary in habit of growth from decumbent to upright. The variety has greater rapidity of recovery after cutting than Ladak or Cossack, being about the same as Grimm in this respect. It is slightly more susceptible to leaf-spot diseases and leafhopper yellowing than Grimm, but not so susceptible as Hardistan or the Turkistsans in this respect. These latter characteristics should not prove a handicap under conditions west of the Mississippi River, but may be somewhat detrimental for eastern areas. Where bacterial wilt is a serious factor, however, its resistance to this disease will more than offset its susceptibility to leaf diseases.

Ranger is distinctly superior in seed production to Hardistan, or the Turkistsans, being about equal to Grimm. In forage production it is intermediate between Grimm and Hardistan when all have equally good stands. It is about equal to Grimm in cold resistance. The outstanding characteristic of Ranger alfalfa is its resistance to the bacterial wilt disease. It is greatly superior in this respect to all domestic strains and equal or superior to the Turkistsans, including Hardistan and Orestan. It will be found most useful where bacterial wilt is a serious factor in the northern part of the United States.

**Atlantic**: Atlantic alfalfa is a vigorous, high-yielding variety, adapted to areas in the Eastern States where bacterial wilt is not a serious factor and where short rotations are used. It was developed at the New Jersey Agricultural Experiment Station. In many characteristics Atlantic is similar to Hardigan or Baltic and should be considered as a variety of the variegated group. It is not resistant to the bacterial wilt disease, although slightly more tolerant than Grimm or Hardigan. Seed of this variety is being increased as rapidly as possible. It has shown outstanding performance in comparison with other varieties in more of the Uniform Alfalfa Nurseries of the Eastern States where wilt is not a factor, than any other variety.

**Narragansett**: Narragansett is a selection
made at the Rhode Island Agricultural Experiment Station which has shown itself, in the past 9 or 10 years during which it has been tested there, to be higher-yielding and longer-lived than ordinary alfalfa or other varieties of alfalfa under conditions where the wilt disease is not a major factor. More extensive tests will have to be made to determine its adaptability over a larger area of New England and elsewhere.

Creeping (Unnamed): This alfalfa, the origin of which is unknown, is being developed by a commercial concern in Oregon. It is the result of selection of a number of types from an old stand in Klamath County, Oregon, and represents a wide-range of definitely underground, creeping forms or strains. These vary from slow, low-growing forms, to semi-erect and erect-growing ones. The apparent superiority of practically all of the forms present in this creeping variety over other types of creeping alfalfa tested in Oregon, is in vigor, long-life, and relatively rapid underground spread.

NONHARDY GROUP

Certain alfalfas distinct from the regional strains of common alfalfa have been developed in the southern part of this country. These are especially characterized by long periods of growth, by ability to make better growth under short days than the hardier northern strains, and by quick recovery after being cut. Because they are so much more seriously affected by low temperatures than the other commercial varieties or strains, for lack of a better group designation they have been classed as nonhardy alfalfas. All nonhardy alfalfas tested for wilt resistance have proved highly susceptible.

Peruvian: Peruvian alfalfa was first introduced into the United States in 1899. Two distinct types have been noted in alfalfas from Peru, differing in several respects but most noticeably in the abundance of hairs on the leaves and stems. These two alfalfas are distinguished by the names "smooth Peruvian" and "hairy Peruvian."

The Peruvian alfalfas are characterized by rapid growth, quick recovery after being cut, and in sections having a mild climate, by their ability to grow in cold weather and short days after the growth of ordinary alfalfa has ceased. Under such conditions they begin growth earlier in spring and continue to grow later in fall than most other commercial varieties, thus lengthening the growing period and therefore giving more cuttings during the season. Hairy Peruvian exhibits this characteristic to a somewhat greater degree than smooth Peruvian.

Peruvian alfalfa cannot be grown to advantage without irrigation or where the temperature falls below 10° F., and efforts to extend its culture into the Central and Northern States or into dry-farming sections are unwarranted and sure to result disadvantageously. The section to which this alfalfa is adapted includes the greater part of California, except the mountainous areas, southern Arizona, southern New Mexico, and southern Texas. In general it has not performed well in the Southeastern States.

Indian alfalfa: Indian alfalfa was introduced into the United States in 1913 by the United States Department of Agriculture under F.P.I. No. 35,443. The seed came from Poona, southwest India, and was furnished by the Indian Government. It has been tested at the United States Field Station at Bard, California, since 1918. Like the African, it has shown itself to be adapted only to conditions of the southwestern part of the United States. The fall, winter and spring growth exceed Chilean and hairy Peruvian on heavy soils. Unlike Ladak, which came from the mountains of India, this alfalfa is not at all winter hardy.

African alfalfa: African alfalfa was introduced into the United States in 1924 by the United States Department of Agriculture from Hegazi, Egypt, under F.P.I. No. 58,969. It has been tested at various places but has shown special adaptation only to the far Southwest where it has been under trial at the U.S. Field Station, Bard, California, since 1938. Like the other alfalfas specially adapted to that
region it is not winter hardy. It is a good fall, winter and spring growing type for both hay and pasture, and its seeding habits are good.

Arabian: Arabian alfalfa was introduced into the United States in 1902 and first attracted attention because of its rapid growth. It has a tendency to be short-lived but because of its rapid growth might be of value in short rotations. At present, however, there is no known source from which seed can be obtained in commercial quantities.

YELLOW-FLOWERED GROUP

The yellow-flowered alfalfas are of no commercial importance in the United States, but have given some good results in Alaska. Being generally more cold-resistant, they have been of value for hybridizing with common or purple-flowered alfalfa in an effort to produce a hardier variety. They exhibit a wide range in growth habits, some being prostrate and others upright. Even the upright types ordinarily produce only one satisfactory cutting, and the yields are therefore relatively low. Furthermore, seed is produced in small quantities and shatters badly. At one time there was considerable interest in two yellow-flowered alfalfas, Orenberg and Semipalatinsk, but they did not show superiority to some of the variegated strains, so they were not increased, and no seed is commercially available at present.

ALFALFA HIGHLIGHTS

1. Alfalfa is the most important forage crop in the United States today. In total United States production and in quantity of forage and feed value per acre, it leads all other grasses and legumes. It is also most widely distributed.

2. Though alfalfa produces maximum yields of hay in a dry warm climate under irrigation, it gives profitable returns over a large part of the United States where the climate is humid and with natural rainfall, provided soil conditions are favorable.

3. Alfalfa can be grown as a forage crop in every State of the United States, in every province of Canada, in Mexico, and in all countries of Central and South America.

4. Nearly one-fifth of the total harvested acreage of principal crops in the five Southwestern States in 1947 was harvested for alfalfa hay. This was 13 percent of the total U.S. alfalfa acreage.

5. The average annual production of alfalfa hay in the United States in recent years has been around 28 to 33 million tons, ranging from a low of 26.7 million tons in 1937 to a high of 38.5 million tons in 1949.

6. Eleven States had an average annual production of alfalfa hay of over one million tons each in 1936-48, four of which are Central States, three Northcentral, and four Western. California led with an average of 3,700,000 tons.

7. Alfalfa hay yields in States largely under irrigation average mostly from 2.3 to 4.4 tons per acre, and in States where irrigation is not a general practice the averages range from 1.6 to 2.3 tons per acre.

8. The average feed returns per acre from alfalfa hay are two-thirds greater in yield of hay and three-quarters greater in total digestible nutrients than those of timothy and timothy-clover mixtures. Alfalfa also ranks higher in minerals and carotene than other forages.

9. The qualities farmers like about alfalfa are drought resistance, high yields, good feeding value, and long life in the rotation.

10. Alfalfa has proved its ability to make stands and produce higher yields than red clover under drought conditions in States adapted to red clover. Also, it can be carried over into the third or fourth year.

11. Alfalfa requires more water than most crops. It is estimated that 750 tons of water are used in the production of one ton of alfalfa hay.

12. Alfalfa will draw on water supplies from a greater depth than any other commonly grown farm crop. It depletes soil moisture for great depths in from 2 to 5 years after sowing, and it takes a still greater number of years of fallow in the drier areas to restore the equivalent of the moisture removed.

13. Alfalfa is ideally adapted for irrigation, but all conditions should be carefully studied before one decides the need for irrigation and the methods to use.

14. Alfalfa is coming to be used more generally for pasture. Care should be used
in pasturing to prevent reducing the stand of alfalfa and bloating of livestock by improper feeding. Alfalfa-grass combinations in many ways are superior to alfalfa alone for pasture.

15. Alfalfa or alfalfa-grass silage, properly made with the addition of carbohydrates, is the best method of preserving alfalfa forage to conserve all the high feed value of the plant. Whether it can be efficiently and profitably made and used should be determined in each case before entering into its production.

16. The commercial alfalfas of the United States may be divided into four rather distinct groups, each containing strains or varieties that vary considerably within themselves: (1) the common alfalfa group, (2) the Turkistan group, (3) the variegated group, and (4) the nonhardy group.

17. The variegated alfalfas are superior to common in the North, and less hardy common varieties are preferable in the South. In wilt-infested areas, only wilt-resistant varieties will give profitable returns over a period of more than 2 or 3 years.

18. From the numerous tests of varieties and strains of alfalfa made by State and Federal Experiment Stations, it is now relatively easy to determine the varieties or strains best adapted for any particular locality.

19. Sowing alfalfa seed of varieties and strains not adapted to the particular locality where sown is one of the principal causes of failure in growing this crop.

20. The purchaser of seed is aided materially in obtaining the variety or origin desired by the State seed certification services, the United States Seed Verification Service, and the seeding requirements of imported seed under the Federal Seed Act.

21. Cooperative Federal-State alfalfa improvement programs are under way in many States. Superior synthetic varieties adapted to various regions are gradually becoming available for seed increase and commercial production.

22. "Hybrid" alfalfa on the order of hybrid corn is still in the preliminary stages but appears to be a development of the near future. It may be the solution to the problem of combining in one strain and reproducing commercially such qualities as high forage and seed productivity, disease and insect resistance, longevity, and other inherited traits.

23. Alfalfa is best adapted to productive soils high in organic matter. Well drained, well aerated, friable loams or sandy loams are best.

24. It is best to precede alfalfa for a year or two with some cultivated crop, such as corn, potatoes, or cotton, to free the land from weeds. The ideal seedbed is a well-settled subsurface with the soil moderately firm above the seed.

25. Liberal applications of phosphoric acid and potash are essential to satisfactory growth if the soil is deficient in these elements, which is usually the case in the eastern half of the United States.

26. A three-ton crop of alfalfa removes about the same quantity of phosphorus from the land as a 60-bushel corn crop and two-thirds more potash.

27. In the Central and Eastern States applications of lime are almost universally beneficial in increasing yields and prolonging life of stand. The quantities required should be determined by soil test and should be applied early in the preparation of the seedbed. Acid soils require liberal applications to insure success.

28. In the Central and Eastern States artificial inoculation of the soil or seed is required where alfalfa, sweetclover, or burclover has not been successfully grown in the past few years.

29. Alfalfa should always be sown early enough in the fall to permit the plants to become well-established before winter sets in, or late enough in the spring to avoid damage from late frosts. Otherwise, it can be sown almost any time of the year, provided weather and soil conditions are favorable.

30. The sowing rates per acre generally recommended are 15 to 20 pounds in the East and South, 10 to 15 pounds in the Middle West, 8 to 12 pounds in the West under either dry-farming conditions or under irrigation. Higher rates than these up to 25 and 30 pounds per acre are often used in the Southeastern States and California.

31. A companion grain crop is frequently sown with alfalfa in an effort to get maximum returns from the land, with occasional good results, but it is usually discouraged except under most favorable conditions because of its probable long-time detrimental effects on stand and yields of forage and seed. It is not recommended under dry land conditions.

32. In the eastern half of the United States alfalfa is frequently sown in mixtures with timothy, bromegrass, orchardgrass,
and certain other grasses. The alfalfa-bromegrass mixture is very popular in the Central and Northcentral States for either hay, pasture, or silage. The addition of one-half to one pound of Ladino clover per acre where adapted improves any mixture of alfalfa and grasses.

33. It is not practical to try to thicken old stands by sowing seed or by cultivation. Cultivating solid alfalfa stands is almost an obsolete practice.

34. Time of cutting is very important. Stands are maintained longer and the yields are generally larger when cutting is delayed until the plants are well in bloom. However, hay of a higher feeding value is obtained from cuttings made at the bud or early bloom stage.

35. Early fall cutting of alfalfa so as to permit the storage of adequate food reserves before freezing weather sets in is necessary for winter survival and for best forage and seed production the following year.

36. In making high quality hay the curing should be done quickly without severe weathering so as to retain leaves and preserve green color, which mean high protein, high carotene, and high mineral content of the hay.

37. The stacking of alfalfa hay from the swath in small, loose, poorly made stacks in the field is the cause of much poor quality hay through discoloration, leaching, and loss of minerals and protein.

38. Baling hay directly from the windrow as soon as dry enough after cutting and storing under cover with least possible exposure to sunlight, is recommended.

39. Special ventilating systems for mow-drying or barn-finishing hay are now recommended and are coming into general use, because of the desirability of curing hay under cover before it has become thoroughly dried in the field.

40. Alfalfa hay is a roughage but when dehydrated extra-leafy alfalfa hay is made into alfalfa leaf meal, the resulting product competes directly with the more concentrated high-protein feeds.

41. The highest grades of alfalfa meal are made from dehydrated U.S. Extra Leafy Extra Green or U.S. Extra Leafy No. 1 Alfalfa Hay.

42. The average United States production of alfalfa seed during the period 1936-45 was over 70 million pounds. The average of the three following years was over 90,000,000 pounds, or 28 percent larger. Kansas has led all States in both acreage and production with a 13-year average of over 127,000 acres and a production of 10,600,000 pounds of seed. The two highest single-year alfalfa seed production records for States were 26,900,000 pounds in Kansas in 1946, and 26,500,000 in Utah in 1926.

43. The average yields of alfalfa seed in the principal commercial seed-producing areas run from 80 to 120 pounds per acre in the Great Plains and Northcentral States, to 180 to 240 pounds per acre in the Southwest under irrigation.

44. Profitable alfalfa seed yields are dependent upon several important factors, the four most important of which are favorable weather, absence of harmful insects, the presence of suitable insects to "trip" the flowers, and deep-water supply sufficient to support moderate top growth.

45. In trials in a number of the States, the use of DDT to control hoppers and lygus bugs has resulted in greatly increased yields of alfalfa seed.

46. Alfalfa flowers must be tripped to produce seed, and this is accomplished largely by certain insects. Tripping of alfalfa flowers can be increased materially by the addition of one or more hives of bees to each acre of alfalfa for seed.

47. Sowing alfalfa for seed in rows for cultivation is practical in the Great Plains and some other areas, particularly for increasing special varieties where stock-seed supply is limited.

48. Grasshoppers and leafhoppers probably do more damage to alfalfa than any other insects. The most effective means of control of grasshoppers is the use of poison baits, and of leafhoppers by dusting as instructed.

49. Bacterial wilt is one of the most serious diseases of alfalfa. The only means of control lies in the use of resistant varieties, such as Ranger and Buffalo.

50. In spite of all the hazards that have been encountered in alfalfa production, it has continued to maintain its reputation as the greatest of all forage crops.

THIS CHAPTER

Publications of the U.S.D.A. and State agricultural experiment stations, agricultural periodicals, and independent works contain abundant material on alfalfa in all its phases. Most of the information in these works relating to alfalfa in the United States is based on the investigational work of the
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U.S.D.A. in cooperation with State experiment stations, which has been conducted under the general guidance of R. A. Oakley (1912-18), H. L. Westover (1918-42), H. M. Tysdal (1942-48), and O. S. Aamodt (1948 to date). In this chapter the larger part of the basic material has been drawn from "Alfalfa in Kansas" (KAN-18), and from U.S.D.A. publications "Alfalfa Varieties in the United States" (US-283), "Growing Alfalfa" (US-282), "Irrigation Practices in Growing Alfalfa" (US-68), and from the U.S.D.A. Yearbooks for 1937, 1943-1947, and 1948. Additional material has been used from some of the more recent State bulletins of Colorado (COL-17), Connecticut (CONN-10 and 14), Indiana (IND-11), Kentucky (KY-11), New Jersey (NJ-7), New Mexico (NM-5), and South Dakota (SD-9). Much other scattered material from various sources and from the author's own observations has also been used. The statistical data are from Edler and Kuzelka of the B.A.E. The preliminary manuscript was reviewed by Tysdal of U.S.D.A., G. Ahlgren of New Jersey, Graber of Wisconsin, and Robertson of Colorado and the final manuscript again by Tysdal. All of these reviewers have made many valuable suggestions which have been incorporated in this chapter.

Chapter reference numbers: 1 ALA-10, 15; ARIZ-10; ARK-9, 15; CAL-3, 10, 17, 18, 19; COL-4, 7, 9, 14, 15, 16; CONN-10, 14; DEL-3, 5; GA-4; IDAHO-2; ILL-19; IND-1, 7, 11; IOWA-8, 28; KAN-15, 16, 17, 18, 20, 21, 23, 24, 29; KY-11; MD-12; MICH-7, 8, 13, 20-23; MISS-11, 23; MO-9, 11; MONT-4, 5, 11; NEB-11, 14, 20-23; NEV-3, 6, 7, 8; NH-6; NJ-2, 7, 10; NY-1, 8, 31, 32, 33; NC-4, 19; ND-1; OHIO-2, 6, 36, 41, 42, 45; OREG-3; PA-13; SC-8, 19; SD-9, 11, 12, 15; TENN-7, 9, 17; TEX-1, 5, 61; UTAH-3-6, 11, 13, 15, 16; VT-4, 5, 13; VA-7, 9, 15; WASH-2, 3, 4, 10, 12, 22, 23; WVVA-2, 7; WIS-7, 26, 27, 29, 30, 35; WYO-4, 8, 10; US-9, 28, 68, 72, 79, 91, 107, 127, 141, 212, 255, 247, 249, 260-266, 281-284, 288, 298; MISC-1, 2, 25, 28, 34, 58.

1 The reference numbers given here refer to references which are given in full by State, U.S.D.A., and Miscellaneous, on pages 682 to 724, and which are cross-referenced by author on pages 725 to 731. Citations in the text are indicated by abbreviation and number in parentheses.
CHAPTER XI

THE TRUE CLOVERS

(Trifolium species)

Throughout the world there are approximately 250 species of the genus Trifolium. More than 80 species indigenous to the United States have been described, although more detailed study may prove that many of them are only variants of other species. Nine species are now of regional or national importance in agriculture. None of the native species has proved to be of agricultural value in this country, although they contribute to grazing and to the wild hay crop and supply the associated grass with needed nitrogen.

The origin of the true clovers is believed to be southwestern Asia Minor and southeastern Europe, for it is in this general location that the greatest number of species, with wide diversity of forms, is found. The genus is one of the most widely distributed of the legumes. Its wild species are found on all continents except Australia. All are herbaceous.

The clovers are perennial or annual. For the most part, except at high latitudes, the growth period of the annual species is confined to the fall, winter, and spring months. In general, they thrive in a cool, moist climate on soils where there is an available supply of phosphorus, potassium, and calcium.

Many of the perennial species may behave as biennials and annuals because of the action of unfavorable climatic conditions and attacks of diseases and insect pests which have shortened their life cycle.

Photoperiodism (length of day) is important in the adaptation of species and varieties. Generally speaking, most of the species are long-day plants, although many continue to flower into early fall. Wide differences exist in the ability of different species to tolerate unfavorable environments and in habit of growth, flowering and reproduction.

Red clover, alsike clover, and crimson clover form crowns, zigzag clover (T. medium) and Kura clover (T. ambiguum) produce underground root stocks. White clover and strawberry clover spread by creeping stems that root at the nodes. The growth of subclover is decumbent with the stems lying on the soil, while Hungarian clover (T. pannonicum) produces stiff, woody stems.

The flowers of all species are borne in heads, with the number of florets or individual flowers varying from as low as 5 in subclover, to as many as 200 per head in red clover and white clover. Seeds per pod vary from 1 to 8, depending upon the species. Subclover gets its name from the fact that it buries its seed as they are maturing. The flowers of some species are self-sterile, requiring cross-pollination. Others are self-fertile but must be tripped or shaken to insure pollination; still others are self-fertile and self-pollinating.

The nine species that are of agricultural importance, and which are covered here, are red clover, white clover, crimson clover, alsike clover, small hop clover, large hop clover, strawberry clover, Persian clover, and subclover.

RED CLOVER

(Trifolium pratense)

Red clover is one of the most important and most widely known of all cul-
tivated legumes. Either alone or in mixture with grasses, or with both grasses and other legumes, it is the most used forage and soil-improving crop throughout northern and central North America and Europe, and its culture as a rotation crop extends far beyond these boundaries. For centuries red clover has been regarded as the cornerstone of a permanent system of agriculture in the Old World, while in this country since early settlement it has been a leading factor in conserving productivity of the soil. The distinguished part which red clover has played in maintaining a profitable world agriculture can scarcely be overstated. Even with the increasing popularity of certain other legumes, red clover is still holding its own as one of the most important.

Red clover is adapted primarily to growing in rotations with other crops, and it has therefore been used largely in those regions where a variety of crops is grown. The most common method of utilization is to grow it in a three- or four-year rotation, including a cultivated crop and a small-grain crop, the first crop of clover being cut for hay, and the aftermath being turned under or allowed to go to seed. This is a very economical and convenient procedure and, together with the high feeding and fertilizing value of the plant, largely accounts for its dominant position among farm crops.

The most serious problem at present confronting the American farmer in many of the clover sections is the increasing difficulty of successfully maintaining stands of clover.

With continuous cropping and the consequent reduction of the humus and plant nutrients in the soil and the increasing inroads of diseases, the difficulty of growing red clover has been greatly increased. This condition must be met and solved, since the loss of clover or its equivalent from the rotation leads rapidly to a run-down farm and unprofitable crop yields.

Red clover is native to the greater part of Europe and portions of Asia. The exact date of its introduction into America is not known, but in a work on agricultural plants written in 1747 by Jared Eliot, observations concerning its adaptability to conditions in the New England States are noted. Since its introduction into this country, it has spread greatly and is now grown to a considerable extent in nearly all sections of the United States where there is sufficient rainfall. In the irrigated sections of the arid portions of the West red clover is largely replaced by alfalfa, but even in the irrigated sections in mountain valleys red clover is an important forage crop.

DESCRIPTION

Red clover is really a short-lived perennial but in field culture it ordinarily acts as a biennial and is used agriculturally as a biennial. However, in any population of red clover plants, even though most of them live only two years, there are some that will live through the second winter and act as true perennials. In
Idaho and other western areas, probably because of greater freedom from diseases, many stands extend into their third year. Because of its short life, red clover is especially useful in short rotations.

The red clover plant is herbaceous and is composed of numerous leafy stems arising from a thick crown. The flowers are borne in compact clusters or heads at the tips of the branches. There may be as many as 200 flowers to a single head, but the average is probably 100 to 120. The flowers are rose-pink, somewhat similar in shape to pea flowers but much more elongated and smaller, being half an inch in length and one-sixteenth of an inch in width. The pods bear little resemblance to those of most other legumes; they are small, short, and break open transversely instead of longitudinally as do pea and bean pods. The kidney-shaped seeds are one-twelfth of an inch long and vary in color from yellow to deep violet. The stems comprise about three-fifths of the total weight of the plant above ground, and in the American strains are usually somewhat hairy. Each leaf is composed of a slender stalk bearing three oblong leaflets, usually with a pale spot in the center of each. The roots are much branched but usually deep feeding, and are ordinarily well supplied with nitrogen-gathering tubercles when inoculated with the proper nitrogen-fixing Rhizobia.

ADAPTATION

Regional: The principal red clover belt extends from the Atlantic Ocean to about the 97th meridian and is bounded by Canada on the north and approximately the Tennessee-Georgia line on the south. Recent studies indicate that red clover may have greater usage farther south, especially with the advent of such disease resistant strains as Kenland. Red clover may also be successfully grown throughout the West under irrigation. It has long been a valuable crop in the Pacific Northwest.

Through the extensive testing of strains and varieties, the eastern belt may be divided into three general regions of adaptation: The northern, approximately from the Wisconsin-Illinois boundary into Canada; the central, from the southern boundary of the northern region to the fortieth degree of latitude; and the southern, southward from the fortieth degree of latitude.

To be adapted to northern areas, varieties must be winter-hardy and tolerant to long periods of dormancy, resistant to northern anthracnose, and capable of making large yields in the long days of the growing season.

The clover root borer is widely distributed; it reduces the yield of the second crop, destroys the roots, weakens the plants, and makes them susceptible to diseases and winterkilling.

Other diseases, such as powdery mildew, crown rot, and leaf spots, contribute to reduction in stands and lower quality of the feed. Dollard, a Canadian variety developed at Macdonald College, has some resistance to northern anthracnose and appears to be one of the best in many locations of the region. Midland has also given good yields in the eastern and southern parts of the region. Numerous strains grown on farms in the northern region for many generations constitute a good source of seed, even though they do not have much resistance to diseases.

In the central region, factors of adaptation resemble somewhat those of the northern region. There is more alternate freezing and thawing, and the day lengths during the summer are shorter. The cool, rainy weather of 1944-46 favored severe epidemics of northern anthracnose. The yields of the Dollard variety, which has some resistance, have been relatively high where previously it has not yielded so well. Midland and many farm strains that have been identified and tested, continue to give good yields.

In the southern region the new variety, Kenland, which has high resistance to southern anthracnose, has been strikingly superior to all others and in many places good stands remain through the second harvest year or the third year from seeding. It has also been shown to be adapted...
to the southern part of the central region wherever northern anthracnose is not prevalent. Cumberland, Ky. 215, and Tennessee Anthracnose Resistant have also continued to be superior to most others. In many localities the crown rot disease has become increasingly severe, and studies are in progress to develop more resistance in present varieties.

In the western region, the practice of producing red clover seed is increasing. Since much of this seed is used in the Central and Eastern States, it is important that the varieties used be those adapted to conditions in the East. Such seed should be produced and marketed as certified seed in order that farmers in the Middle West and East may be assured of the trueness of variety.

Soils: While somewhat deep-rooted in its habit most of the root system of red clover is in the top 12 inches of soil. It requires a soil of good moisture-holding capacity. On the other hand, it is sensitive to poor underdrainage. On heavy soils practically saturated with water during winter months, serious winter-killing is often experienced.

Red clover is moderately exacting in its requirements with respect to soil reaction. Soils more acid than pH 5.6 rarely produce good clover crops. It is fairly tolerant of alkali and saline conditions. Being a legume, when the soil contains the proper strain of Rhizobium for nodule production, it is practically independent of available nitrogen from the soil. Soils that are especially deficient in humus, however, rarely provide suitable physical conditions. Readily available phosphorus in the soils is especially important, and phosphorus-deficient soils must be liberally fertilized with phosphatic fertilizers. This crop, which uses a relatively large amount of potash, is capable of utilizing both surface and subsoil potassium to good advantage. As a result, potash fertilizer gives direct benefit only on a few especially potash-deficient soils.

This crop is grown extensively on a wide range of soil types, from eastern Nebraska to New England, and from Tennessee to northern Minnesota. It is also important in the Pacific Northwest and Intermountain States. The chief factors that have restricted its success are heavy, intractable subsoils, excessive soil acidity, and depleted mineral fertility.

**OBTAINING A STAND**

Preparation of seedbed: Clover seed is small and must have a fine seedbed, but while fine on top, the bed must be firm. A loose seedbed is fatal to young clover; it dries out too fast. When clover is to be sown on freshly plowed land, the field should be worked several times with soil packers (cultipackers) unless a heavy rain should intervene and pack the soil. On corn ground, one or two good diskings, perhaps followed by one or two harrowings, will usually put the seedbed in good shape.

**Fertilizers and lime:** Red clover is not a crop for extremely poor soils unless heavily fertilized and limed. As a general rule throughout the clover belt any well limed soil that will grow corn will grow clover. Lack of nitrogen in the soil will not matter, since the clover will get nitrogen from the air. Clover must have lime, phosphorus, and potash, however, and if the soil is poor in any of these, it must be supplied before red clover can be expected to do well. It is also extremely desirable that the soil contain a reasonable proportion of organic matter. The limestone areas of the country are usually well suited to red clover though even in these areas there are localities where the soil has become deficient in lime.

When lime is needed, burnt lime, dehydrated lime, or finely ground limestone can be used. Roughly, their relative effectiveness is about as 100, 75, and 50, and if this relation is borne in mind, the cost when laid down on the farm will indicate which form is best to buy. A ton of ground limestone is suggested unless the land is known to be very poor in lime, when 2 tons is recommended.

Many soils in the clover belt are poor in phosphorus, and this can be supplied readily by the use of 200 or 300 pounds of 18 or 20 percent acid phosphate per
Potash is frequently lacking. There are soils, especially in the East, where this element must be added. On such soils, 50 to 100 pounds of muriate of potash per acre will prove very helpful. When the grain with which clover is sown is well fertilized, the clover will usually make a good growth on the same fertilizer. Manure is very valuable for clover, both when used in the corn preceding the clover, and later as a top-dressing. In the Pacific Northwest, sulphur and gypsum have proved useful, and 75 or 100 years ago gypsum or land plaster was used a great deal in the East. It has now been replaced by lime and phosphates.

The questions of lime and fertilizers are largely local ones. The soils in the clover belt vary widely, and the various fields on the same farm may need different treatments. The most suitable treatment for each farm or each field may be approximately determined by a test. This may be one of the quick chemical tests, or may be an actual field test.

Source of seed: The source or geographical origin of commercial red clover seed of United States production is considered of greater importance now than it was 25 years ago. Then, it was recognized that a large part of the red clover seed from Europe was not well adapted to the principal red clover producing States. Since the imports of red clover seed from Europe during that period were considerable, the Seed Importation Act was amended in 1926 to provide for staining imported red clover and alfalfa seed by country of origin. Shortly afterward, provision was made through the Seed Verification Service for verifying the States of origin of domestic red clover and alfalfa seed, but as there appeared at that time to be no recognized zones or areas of adaptation for domestic red clover seed in the United States, except as between commercial seed produced in Oregon and Washington west of the Cascade Range, and that produced east of the Cascades, relatively little use was made of this service as it applied to red clover.

In 1928 some 75 lots of seed, each of which had been grown on the same farm for ten or more years without admixture of other seed, were obtained by the United States Department of Agriculture from all over the red clover belt of the United States and tested at three different places in that area. From these and other tests, three general regions of adaptation were recognized (southern, central and northern), along with groups of factors which were important in each region.

Concurrent experiments indicated that the red clover seed of the central northwestern seed-producing States was not so satisfactory when used in the eastern seed-consuming States. Results of experiments also indicated that the growing of red clover varieties for successive generations in a location differing from the place of origin in factors affecting adaptation, reduced the productiveness of the variety when the progeny was planted in the original location.

Later, an intermountain region was recognized but not on the same adaptational basis, because red clovers adapted to any of the three eastern regions appeared to be adapted to much of the Intermountain region. And this latter region, with its much larger (three times as large as those of the heaviest producing States of the Corn Belt) seed yields appeared to supply the answer to the desire for a greatly increased production of red clover seed, especially of the new improved varieties of which foundation seed is limited. It appears necessary, however, not to grow eastern adapted strains in the Intermountain region for use in the eastern regions for more than three generations without recourse to foundation seed from the region for which the seed of any particular variety was being produced.

Methods of sowing: Clover is most frequently sown on winter rye or with spring grain. Of all these companion crops, oats is the most harmful, since its heavy growth makes a shade too dense for the young clover. When sown on wheat the seedbed is usually in fair condition, and the clover seed may be sown on the ground when it is still freezing and thawing, as these processes will help to work the seeds into the ground. One successful practice is to sow half the seed in
RED CLOVER

February. If there is a good stand no more seed is necessary; if not, the remainder of the seed is put on in April. When sowing is delayed until the surface of the ground dries, it is a good practice to harrow before and after sowing. The harrow, if set to work about an inch deep, will not hurt the wheat. Or the seed may be put in with a drill. This latter is the better practice, since less seed is needed and it can be put in at a fairly uniform depth.

It is well to sow the clover crosswise of the wheat rows, which are best run north and south, as this enables the young clover to get the maximum light. Among seeders, a wheelbarrow seeder or a seeding attachment to a 1-horse weeder are good tools. Among drills the special clover and alfalfa drill will give better satisfaction than a grain drill having a grass-seed attachment, especially when the clover is sown alone, as on winter wheat. The clover-seed drill puts the seed in rows 4 inches apart and covers it to a more nearly right and uniform depth than can be done with a grain drill.

When sown with spring grain the clover seed is put in at the same time as the grain, but the grain is sown at a greater depth than the clover. On heavy land, clover seed should be placed not more than 1/2 inch deep, but on light soils one inch is all right. The companion crop, especially if it should be oats, should be sown at only one-half to two-thirds the usual rate if the clover is to have a good chance for success.

Value of companion crops: The advantage of using a companion crop is that a grain crop is produced, avoiding the loss of the use of the land for a season and, too, the grain keeps down the weeds. The stubble of the grain also serves as a winter protection to assist in catching and holding the snow, which otherwise might drift from the field and render the clover plants more likely to be winterkilled. However, the companion crop interferes somewhat with the growth of the clover, and on land where a stand of clover is badly needed and hard to get, it is better to prepare a good seedbed and sow the clover alone. Clover is sometimes sown in corn at the last cultivation, and this practice has been found very successful in parts of New England. Generally it is risky, since success depends upon good rains coming at that particular time.

Rate of sowing: If the clover seed is sown broadcast, 10 to 15 pounds per acre are used, but if drilled, only 6 to 8 pounds are needed. There are about 250,000 red clover seeds in a pound, and evenly scattered on an acre 1 pound will leave five seeds on every square foot, enough for a good stand if every seed makes a plant. The extra seed is merely insurance, but the most valuable insurance of a good stand is obtained through proper preparation of the seedbed and adequate fertilization.

Time of sowing: As far north as central Indiana late-summer sowing of red clover is quite successful. Sowing in late summer has the advantage that the grain stubble can be plowed and thus the Hessian fly, wheat joint-worm, and other insects will be destroyed. Of course, it means more work, and only a study of local conditions can determine whether such practice will be economically justifiable. When sown alone clover should be put on clean land. Spring or early-summer sowing without a companion crop cannot be practiced on foul land, as the weeds will get the best of the clover; but when the weeds are not too thick they may be held back by clipping. The method adopted in any locality must depend on the rotations followed and the labor and weather conditions in each place. It may be emphasized here, however, that to get a good stand the clover must have a fair chance. As usually sown, too little attention is paid to the weakness of the young clover plant and to its needs. In the clover belt clover is important enough to warrant special care in selecting the sowing method and time of sowing best suited to the special soil and to the other conditions prevailing.

Inoculation: In order to make its best growth, the red clover plant must be supplied with nitrogen-gathering bacteria. This crop has been grown so long in this country that most soils appear to be fairly well supplied with these bacteria,
and usually no artificial application of them is necessary. When the clover is being tried as a new crop in a section it often does not become well-inoculated until it has been grown for two or three seasons on the same piece of land, after which natural inoculation takes place and good crops are grown without further difficulty. When sowing clover upon land for the first time, it is always well to provide for artificial inoculation, but if clover has been established recently on a field, this procedure is usually unnecessary.

However, it is advisable to use artificial cultures occasionally, even where red clover has been grown previously, in order to establish some of the most efficient nitrogen-fixing strains on the farm where clover is grown. Cultures of such improved strains may be obtained from certain field seedsmen or laboratories which prepare such cultures.

First season: When sown with a small grain companion crop no special treatment is given the clover the first season. Straw, weeds or trash should not be allowed to remain in the field after grain harvest, as they encourage the development of disease in the clover. It develops, in the stubble after the grain has been cut and occasionally may afford some pasturage in the fall. If the late summer be especially favorable, sufficient growth may be made for a cutting of hay, and in some cases a crop of seed has been secured. The stand is not likely to be injured by cutting before September 1, and may not be injured if cut after October 1. It is usually best to clip back the growth to check the development of the plants, but this should not be done while the plants are storing up root reserves in early fall. When sown in the fall in corn or with rape, one or two crops may be expected the next season. It is usually not advisable to pasture spring-sown clover the same season with sheep or hogs, as they are likely to injure the young plants. Pasturing with cattle is less injurious.

Second season: As a rule common red clover lives but two years. The second season the first crop is usually cut for hay and the second crop for seed. The after-math is then pastured or plowed under. In sections where the season is not long enough to permit the clover to set seed after a full hay crop has been harvested, it is necessary, if seed is desired, either to pasture back the first crop of clover, or to cut it early when just coming into bloom, rather than to wait until it is in full bloom as is usually recommended. When mixed with timothy the stand is often allowed to remain three or four years with the clover gradually decreasing.

HANDLING THE RED CLOVER CROP

Time of cutting hay: Wilsie and Hollowell (Iowa-27), in field experiments with medium red and mammoth red clovers at Ames, conducted over a period of years, showed that the stage of maturity of the plants at the time the first crop was cut had a marked influence on total yield of forage, actual and potential seed yields, and the quality of forage. Their results are discussed and summarized by them as follows:

"It is recognized that while the stage of maturity at which a forage crop is harvested has a great influence on its nutritive value, it may not be possible to put an ideal cutting system into operation. From the standpoint of yield of forage alone, best results with medium red clover would be obtained by harvesting both the first and second crops at the full-bloom stage. Hay curing would be more easily accomplished than when cut at a more immature stage, but the risk of loss of leaves is also greater.

"The effects of leaf loss were brought out strikingly in this study, where in mammoth red clover the total dry matter was less for plants harvested at maturity than for plants harvested at the full-bloom stage. Hay curing would be more easily accomplished than when cut at a more immature stage, but the risk of loss of leaves is also greater.

"Dry matter production in the first crop of medium red clover increased until maturity was reached, while in mammoth red clover, the highest yield was obtained at the full-bloom stage. Leaf loss, as the plants of mammoth red clover approached maturity, apparently accounted for an
actual decrease in the yield of dry matter. The highest yield of forage of medium red clover, for the whole season, was obtained by cutting the first crop at the late-bloom stage and the second crop at the full-bloom stage. With mammoth red clover, the highest yield was obtained by cutting the first crop at the early-bloom stage, and the second crop at the full-bloom stage. Data on actual and potential seed yields of medium red clover indicated that seed production was favored by cutting the first crop for hay at the early-bloom stage.

The data on chemical composition show the importance of leaves in the total forage. The protein and calcium fractions, especially, are concentrated in the leaf portion of the plant, and every effort must be made to prevent loss of leaves in harvesting. It should be emphasized that while the percentage of leaves was 60 or more for all stages of the first crop of medium red clover, the forage samples were shade-cured, with no loss of leaves after cutting. Under field-curing conditions, however, it is impossible to prevent leaf loss, and this loss rapidly increases with approaching maturity of the plant.

Early harvesting favors leaf retention and a higher protein content, but at the same time makes curing more difficult and results in a lower yield of forage and of total protein. A compromise must be reached, and the practice that appears most desirable with medium red clover is to cut the first crop in the early-bloom stage, and the second crop at or near the full-bloom stage.

Because of the early loss of leaves in mammoth red clover it appears that the hay crop should be cut in the bud to early-bloom stage. This will give an aftermath of considerable value, and if moisture conditions are favorable, possibly a second crop of hay.

The percentage of leaves in the forage was higher in medium red than in mammoth red clover. Forage from the first crop of medium red clover was higher in percentage of leaves than was forage from the second crop. With mammoth red clover, however, because of the considerable loss of leaves after the plant started to bloom, leaf percentage was higher in the second crop than it was in the first crop.

The percentage of protein decreased with advancing maturity. In general the first crop of medium red clover was higher in percentage of protein than was the second crop. In mammoth red clover forage, because of less leaf loss, the second crop was higher in protein than was the first crop at a comparable stage of maturity.

Data on production of total protein and crude fiber per acre showed that following the bud stage of maturity, the total crude fiber increased much more rapidly than did the total protein, indicating that the feeding value of the forage decreased with approaching maturity.

Mineral analyses indicated a trend toward lower percentage of phosphorus at the more mature stages of growth, both in the first and second crops. In general, the second crop apparently was slightly lower in phosphorus than was the first crop.

The percentage of calcium in the leaves was approximately three times that in the stems; the percentage of calcium tended to increase as the crop approached maturity. Second crops were slightly higher in percentage of calcium than were first crops.

Analyses for fat showed that a fairly constant level was maintained in the stems and leaves from the bud stage to maturity. In the heads, however, the fat percentage rose rapidly as the plants approached maturity, due undoubtedly to translocation to, and storage in, the developing seed.

Harvesting red clover hay: The methods of harvesting red clover hay vary somewhat in different sections of the country. It is desirable to handle the hay so that it will reach the barn or stack with the least possible exposure to the weather and the minimum loss of leaves. Clover should not be allowed to become too dry in either the swath or the windrow, else the leaves will crumble resulting at best in a very dusty hay, to say nothing of the loss of much of its nutritive value.
Keeping the leaves alive and giving all the plants in the swath nearly an equal chance as possible to get rid of moisture is the whole art of curing hay. Hence, the advantage of using a side-delivery rake instead of the tedder, if used before the top leaves get too dry. The tedder stirs up the cut clover too much and breaks off too many leaves, while the side-delivery rake rolls up the clover without stirring it and gives all the leaves a chance to dry evenly and rapidly.

If the hay can be cocked before the leaves are entirely dry, the movement of the water from the stems through the leaves will continue. When the leaves become well wilted in the swath, the clover should be raked into windrows, and then bunched into cocks when the hay is about half dry. Each cock should contain only enough hay so that two men can place the entire cock on the wagon at once, as in this way the loss of leaves due to handling is reduced to a minimum.

One method of curing hay is to cut the clover not later than when in half-bloom. The next morning after the dew is off, the hay is raked into windrows, put into medium-sized cocks, and allowed to remain for 24 to 36 hours. The hay is forked over once to prevent heating and is then put in the barn. In threatening weather the hay is put into the barn at the end of 24 hours, but it is preferable to leave it in the field for a somewhat longer time.

Importance of leaves in hay: The leaves are much richer in protein than the stems. In properly cured red clover hay the leaves contain about three times as much protein as the stems and the heads about twice as much. While the leaves constitute on an average only about 40 percent of the total weight of the plant, they contain nearly two-thirds of the protein of the entire plant. Owing to improper methods of harvesting and to untimely rains one-half or more of the leaves may be lost, thus resulting in a marked deterioration in the feeding value of the hay.

Stacking red clover hay: The same general rules used for stacking other hays apply to the stacking of red clover hay; but it must be remembered that red clover sheds water much less readily than the grasses and for this reason greater care is necessary in building and protecting the stack from the action of rain. It is advisable to build some kind of foundation for the stack. This foundation may be composed of poles or rails or some less valuable hay. By care in stacking, a comparatively large bulge may be put on the sides of the stack. This reduces the proportion of the hay in the stack bottom and causes the rain to drain off at some distance from the base of the stack. By keeping the middle full and well trampled the hay will settle in such manner as to cause the water to run off rather than into the stack. As red clover absorbs moisture readily the hay which lies next to the ground is almost sure to be spoiled. If canvas covers are not available for covering hay which must be left outside, it is an excellent plan to top the stacks with green grass, straw, or millet. After the stacks have settled they should be retopped with more grass or straw, placing an additional layer as far down the sides of the stack as possible. This materially reduces the quantity of clover hay exposed to the elements.

When the hay is stacked or stowed away in the barn in a slightly damp condition, it is sometimes the practice to mix salt with it for the double purpose of salting the animals and of preventing mold. If the clover must be put up when thought to be a little too green, alternating layers of straw will do much toward absorbing the excess of moisture.

Spontaneous combustion of red clover hay: When red clover hay is stacked or mowed with any external moisture on it, such as dew or rain, heating is inevitable until not only the hay itself is damaged, but the heating process may go so far as to cause the entire mass to ignite and burn the stack or barn in which the hay has been placed. An excess of internal moisture may have the same result. The absence of air from the mass of heated hay in a barn is often the only thing which prevents it from breaking into flame, and such instances are made manifest the following winter by finding
charred masses within the interior of the mow.

Red clover for silage: Silage has been made from red clover as from other legumes, but the process is always risky and rarely satisfactory. If a red clover crop is too mature to make a leafy hay and one that will be eaten without waste, it can usually be made into a silage that conserves more of the leaves and will be consumed with practically no waste.

Red clover as pasture: Red clover is a most excellent pasture for all livestock, especially while they are growing. The early growth of red clover is less nutritious, pound for pound of green matter, than when near or at the blooming stage, since in the early stages of growth it is high in moisture content, thus requiring the animals to eat relatively larger quantities. Furthermore, close early pasturing is injurious to the stand of clover.

Ordinarily red clover will furnish some pasture during the first fall after spring seeding. It should not be grazed too closely at this time, else the succeeding season's hay crop may be decreased. The plants should rather be allowed to go into the winter with some growth upon the crowns in order to prevent winter-killing and also to enable them to store up material in the roots for an early vigorous growth the following spring.

When pasturing cattle or sheep on red clover, care must be taken not to pasture when the animals are very hungry, especially when the clover is young and succulent or when wet with dew or rain, as bloating may result. Should bloating occur, the customary remedies are usually at hand which should afford material relief.

As a soiling crop: Where pasturing is impracticable, red clover is sometimes used as a soiling crop; that is, cut and fed green to livestock. Feeding in this way reduces or eliminates the danger from bloating which attends the use of red clover as pasture. It makes a good early feed, is palatable, and from 6 to 10 tons of green feed per acre is not an unusual yield.

Red clover in mixtures: It is often advantageous to sow red clover in a mixture with other clovers and tame grasses. The root systems of the different species are not the same, and as a result the soils of both the upper and lower layers are more fully occupied than they would be by a stand of a single crop. In case the stand is to be used for pasture, a mixture will usually insure a better succession of good pasturage than would the use of any single crop; that is, by proper selection of the constituents of the mixture it is possible to obtain a pasture which will provide for early as well as late grazing and at the same time give fair returns during the heated months of summer.

By far the most common mixture is red clover and timothy, but the practice of adding Ladino clover to this mixture is increasing. It is a good plan to replace about one-third the red clover seed with half a pound of Ladino clover seed. In the winter-wheat section, except in the South, the timothy is sown with the wheat and the clover is sown on the wheat the next spring. In the spring-wheat section, the timothy is sown with the red clover at the same time the wheat is sown, mixing 10 to 12 pounds of timothy with 8 to 10 pounds of red clover or of red clover and Ladino clover. The timothy is longer lived than the red clover, and as a result the proportion of timothy in the mixture of the hay increases very rapidly after the second season. Ordinary red clover matures about two weeks earlier than the timothy, and for this reason mammoth clover, being about two weeks later, is frequently used in mixtures with the timothy.

For commercial purposes medium red clover and alsike clover are much preferred, particularly when mixed with timothy. The trade objects to mammoth clover on account of its coarse texture and somewhat woody nature. Mixtures of red clover and alsike clover with most grasses other than timothy are also discriminated against both in price and demand.

Other mixtures suitable for hay are red clover combined with orchardgrass, tall meadow oat-grass, and a small admixture of Ladino or alsike clover. In any low spots in the meadow it is advisable
to replace the orchardgrass and at least half of the red clover with alsike clover. On rough-land pastures red clover may also form a minor constituent of a regular mixture of bluegrass and white clover. **Red clover in rotations:** In the northeastern United States the common rotations include a cultivated crop, a small-grain crop, and clover, or clover-and-grass. These rotations may be of various kinds and may include one or two crops of corn or other cultivated crop, one or two crops of small grain, of which one or both may be fall or spring sown, and the clover or clover-and-grass stand may be left for one, two, or more years. In such rotations clover is commonly sown with the small grain and turned under for the cultivated crop, usually corn. This procedure starts the clover without extra cost and with the benefit of whatever fertilizer is applied to the small grain, and the sod in decaying affords a steady supply of nitrates to the corn throughout the summer. The utilization of the sod in this way is the most economical and efficient. In long rotations, clover may be grown but one year in four or five. Unless the soil is exceptionally rich, such rotations will in time exhaust the organic matter in the soil and with it the nitrogen, thus making it difficult to grow clover.

In a system of grain farming, the chief purpose of the clover in the rotation is to help in maintaining soil productivity. For this purpose, sweetclover of late years has replaced red clover to a considerable extent. Sown with a small grain, the sweetclover is turned under the following spring for corn. Besides these more or less standard rotations in which clover is used, it is sometimes sown in corn or alone on the disked cornland in spring, to be turned under at some later time for another crop of corn.

In Minnesota red clover is often sown with spring grain and turned under the same fall when the land is prepared for the next grain crop. Mammoth red clover is used more frequently in rotations with potatoes because of the larger growth in one crop to be turned under in one operation, and because of its lower lime requirement, since lime tends to encourage scab in potatoes.

**CLOVER FAILURE**

The too frequent failure to get and hold a stand of clover is due to several causes. Perhaps the chief of these is lack of lime or of phosphorus in the soil. Another is loss of organic matter by reason of unwise methods of farming. Use of unadapted seed and in some sections diseases play a part, but there are no data to show how great is the responsibility of any one of these factors.

There is no mistake about the fact that good stands of red clover have of late years been harder to obtain than formerly. Frequent clover failures have been experienced mostly in the East, but also as far west as Iowa. Many factors have worked toward this end, but they may be placed in five groups: (1) Soil exhaustion; (2) unadapted seed; (3) improper methods of sowing, companion crops, etc.; (4) diseases; and (5) improper treatment the first autumn. Clover fails more often because soils have become poor in lime, phosphorus, and potash, than for all other reasons. If lime is badly needed there is no use sowing clover seed unless sufficient lime is added. If phosphorus is the limiting factor, the addition of lime alone, even if the land is “sour” will have slight effect. Manure will do good more often than anything else, but when lime is needed the results from manure will be much greater after this need has been supplied than before.

Improper methods of sowing, etc., are frequently responsible for the failure to get even the start of a stand or for the death of the plants after grain harvest. A poor seedbed, poor seed, weeds, careless sowing, or too heavy a companion crop may all make for the early destruction of the small plants. If the season is dry, the vigorous companion grain will take the moisture and leave the clover seedlings to dry up, or the tender plants
cannot endure the sudden exposure to a hot sun. Where the soil is rather hard it will help to top-dress the wheat with manure or to even scatter straw on the wheatland immediately after sowing to wheat. This will mulch the soil and help keep it cool and moist.

The total yield of hay may be cut down, and in some cases destroyed by the various insect or fungous troubles. But, even in Idaho where the nematode, one of the causes of clover sickness in England, is sometimes serious, the crop is seldom destroyed outright or even materially hurt before June of the second year.

DISEASES AND INSECTS

Red clover is attacked by a large number of diseases and insects, some of which are very serious and determine in large measure whether the crop can be grown profitably in certain areas where it is otherwise adapted. With the clovers, as with most other legumes, direct control measures, such as spraying and dusting, are usually impractical. Control must be sought through the development of resistant varieties and the use of cultural practices. Even though control of these diseases and insects may be difficult or impractical, a better knowledge of them and how they develop will enable one to adopt the cultural, insecticidal and fungicidal practices most likely to reduce losses from them.

Among the more important of the diseases and insects injurious to red clover are the following, which are discussed more fully in chapter IX:

Diseases: The two anthracoses of red clover known commonly as the southern and northern anthracoses cause considerable defoliation. They are indistinguishable to most clover growers since their symptoms are similar. Two varieties resistant to southern anthracose, Cumberland somewhat resistant, and Kenland strongly resistant, have been developed for the more southern part of the red clover-growing area, and one variety, Midland, which is somewhat resistant to northern anthracose for the Northern States.

The powdery mildew has at times seriously alarmed growers for fear of injury to livestock, but this fear has been dispelled. However, the disease causes considerable loss in both yield and quality of hay each season. All the common clovers are attacked by rust, which is often severe enough to seriously affect the hay.

Red clover is also subject to mosaic which mottles and curls the leaves, to a bacterial leaf spot which destroys the leaves and is carried by the seed, to stem rot which rots the stem bases and upper tap roots, resulting in the death of affected plants, and to several other soil-inhabiting fungi which rot the roots of clovers and other forage legumes.

Insects: Many insects feed on red clover, varying in their preference for tops or roots. They cause some damage and may reduce the yield of forage or seed, but rarely cause complete failures. Two species of clover leaf weevils attack red clover, one the clover leaf weevil which feeds mostly at night and eats holes in the leaves and irregular patches in the leaf margins, and the other, the lesser clover leaf weevil, the larvae of which attack newly forming buds and heads of the first crop causing them to blast and fail to develop.

The potato leafhopper punctures the foliage of red clover and sucks the juices, but seldom does much damage to the hairy adapted strains. The clover rootborer is one of the most destructive enemies of red clover. It tunnels into the roots, mostly of plants a year old, where it lays its eggs, causing the roots or stems to break off at ground level.

There are two insects which often seriously injure the seed crop. The clover seed midge lays its eggs in the flowers, and the injury to them by the larvae prevents seed formation. The clover seed chalcid lays its eggs in the newly formed seeds, where the larvae eat the contents of the seed coat and then eat their way out. A large part of a harvested seed crop may be lost in this way.
VARIETIES OF RED CLOVER

For general purposes red clover is classified into two types or groups, (1) medium red or common red clover, also called double-cut or Junc red, and (2) mammoth red clover, also called single-cut, sapling, or perennial red clover.

Red clover is extremely variable, so a collection of strains from many sources would exhibit a range from one extreme to the other, and it would be difficult to say where the dividing line was between medium red and mammoth red clover. As a practical matter, however, with commercial red clover there is usually no difficulty in recognizing both types as they occur in general culture.

Mammoth red clover differs from medium red in being about two weeks later in maturity and in being under similar conditions larger, coarser, and more hairy. In the autumn of the first season it can usually be distinguished in the field by its closer adherence to the low rosette habit. Only one crop of mammoth clover can be harvested each season, since it does not recover quickly. On the other hand, it is generally longer-lived than common red clover.

On low ground the stems of mammoth red clover are likely to become somewhat woody. It grows less rank on poor soils where it is ordinarily grown rather than on the heavier soils. Furthermore, on the poorer soils it is excellent as a seed-producing crop, being used in a rotation of corn, grain, and clover, each one year. The mammoth clover is allowed to stand for seed, and no attempt is made to utilize the straw other than as a fertilizer for the land.

If grown for hay, mammoth red clover should be cut when in early bloom rather than when past bloom, on account of the tendency of the stems to become woody. In the northern part of the tier of Northern States, where only one crop of ordinary clover is possible, mammoth clover is usually preferred on account of its higher yield. It is impossible to tell mammoth-clover seed from that of common red as there are no absolute distinguishing marks. The seeds are of the same size and coloring, the variations observed in one form occurring also in the other.

Much work has been done in the selection and breeding of medium red clover, but little has been done in the United States with mammoth red clover because it is much less important than medium red.

Four varieties of medium red clover have been introduced and are listed here: Cumberland, Midland, Kenland, and Dollard. The first two are synthetic combinations of several high-testing regional strains, and the last two are the product of plant-breeding programs. All of these four except Dollard were developed by the United States Department of Agriculture in cooperation with the State experiment stations. Dollard was developed by McDonald College Experiment Station, Ontario, Canada.

Cumberland: Cumberland formerly called Southern Disease Resistant Blend, originated in 1937 as a composite of equal proportions of three identified superior strains, Kentucky No. 101, or No. 215, Tennessee Anthracnose Resistant, and Virginia (Sanford). This variety, the result of 13 years of breeding, testing and increasing, was developed through a cooperative program of the Kentucky, Tennessee, Virginia, Idaho, Montana, Washington, Utah, Colorado and Oregon Agricultural Experiment Stations, crop or seed improvement associations, the International Crop Improvement Association, and the U.S. Department of Agriculture. Provision is made for the substitution of other strains equal or superior to those used in the original composite in order to maintain an adequate stock of foundation seed necessary in the program.

Cumberland has good growth characteristics, is resistant to Southern anthracnose and crown rot, and is adapted to the southern region of the principal red clover belt.

In 1942, a total of some 120,000 pounds of certified Cumberland seed was produced in the States of Montana, Idaho, Washington, Utah and Oregon. In 1945, this was increased in those
States to nearly 400,000 pounds, in 1946 to about 900,000 pounds, in 1947 to 700,000 pounds, and in 1948 to 850,000 pounds, half of which was produced in Idaho, and one-third in Montana and Washington.

Midland: Midland, formerly called Central Corn Belt Blend, originated in 1935, as a composite of equal proportions of four old strains, Illinois (Rahn and Letcher), Ohio (Poland), Indiana (Otten), and Iowa (Emerson). Due to drought conditions in 1930-1936, the foundation seed stocks of the Indiana and Iowa strains were reduced to a few pounds and these have not been included in the composite for several years. These strains are being increased and as soon as sufficient seed is available, they will be included in the composite. Provision is made for the substitution of other strains equal or superior to those used in the original composite in order to maintain an adequate stock of foundation seed necessary in the program. The more satisfactory Ohio (Kirch and Van Fossen) strains have been substituted for the Ohio (Poland) strain.

Midland, the result of thirteen years of breeding, testing and increasing, was developed through cooperative efforts of the Ohio, Indiana, Illinois, Iowa, Idaho, Washington, Utah, Oregon, Colorado and Montana Agricultural Experiment Stations, crop or seed improvement associations, the International Crop Improvement Association, and the United States Department of Agriculture. The procedures and regulations pertaining to the handling and increasing of Midland to preserve the superior characteristics are given in the annual reports of the International Crop Improvement Association.

Midland has good growth characteristics, is winterhardy, and has some resistance to northern anthracnose. As the name suggests, it is adapted to the middle or central part of the Corn Belt States.

In 1942 some 220,000 pounds of certified Midland Red clover seed was produced. In 1945 about double this quantity was produced, in 1946 the production was increased to more than 700,000 pounds, in 1947 to about 870,000 pounds, and in 1948 to nearly 950,000 pounds, over 90 percent of which was produced in Oregon and Idaho.

Kenland: Kenland is the name given to a new superior red clover variety (called Southern Selection during the testing period) that has been developed by cooperative research of the Kentucky Agricultural Experiment Station and the U.S. Department of Agriculture.

Kenland is adapted to the southern part of the red clover belt where southern anthracnose (Colletotrichum trifolii) is normally prevalent and frequently a serious disease. Results of yield data and observations over a period of three years at Lexington, Kentucky, Columbus, Ohio, and other locations in that area, indicate that when southern anthracnose is prevalent, Kenland will produce greater yields than other improved varieties such as Cumberland, Kentucky 215, and other adapted strains. When southern anthracnose is not a limiting factor Kenland will yield as much as the others, except where northern anthracnose is present to which it is not resistant. When subjected to heavy artificial inoculation with southern anthracnose, Kenland has proved to be more than twice as resistant to it as any other variety.

In the southern part of the red clover belt, the most outstanding characteristic of Kenland is that it is longer lived than other strains, having maintained good stands into the third year or second harvest year. Whether this will occur regularly over a period of years is not known nor is information available on the length of life of an original stand. As yet, the definite range of adaptation of Kenland has not been established, though the results of preliminary tests indicate it will at least thrive from northern Alabama and Mississippi, north into New Jersey, Ohio, Indiana, and Illinois, to the zone where it runs into northern anthracnose.

C. J. Willard of Ohio, says that it "is much the most outstanding red clover for southern Ohio and southern regions generally that has ever been produced" and that "it is much superior to its near-
Work on the development of Kenland has been in progress for approximately ten years. Seven old superior farm strains grown in the southern part of the red clover belt were used as basic material in its development. Plants originating from these strains have been subjected to artificial inoculation with southern anthracnose during each of four generations. Susceptible plants were eliminated in each generation before intercrossing among desirable plants was permitted.

When grown outside the designated region of adaptation, the production of certified Kenland seed will be limited to three generations. It is not known how many generations can be grown from foundation seed in the southern part of the red clover belt and still maintain the high resistance to southern anthracnose.

About 37,500 pounds of Kenland red clover seed was certified in 1948, two-thirds of which was produced in Washington and Oregon.

Dollard: The Dollard red clover was developed at McDonald College to meet the need for a strain better adapted to Quebec, less subject to winterkilling and more reliable from year to year. It has its origin in foundation material introduced at McDonald College back as far as 1911, but extensive testing and efforts at multiplication did not begin until 1931. Since then, it has been tried in comparison with other strains in eastern Canada and northeastern United States and has given a good account of itself, but especially in the Province of Quebec. In tests at several stations there, it has yielded on an average about 15 percent more hay than the average of other varieties, and has shown more resistance to northern anthracnose than Midland or other northern strains. It is not distinguishable from other double-cut varieties. There is no evidence of either superior or inferior yields of seed from Dollard as compared with other varieties. Since it has shown promise of superior performance in the northeastern States, it should be given extensive tests there and some effort made to increase the seed for use in that area. As yet (1949) Dollard red clover seed is not available commercially.

SEED PRODUCTION

Conditions favorable to seed production:
Red clover seed is produced in small quantities on a very large number of farms throughout the clover area. In some sections, as in some of the Intermountain States, the production of seed is a regular business, but generally, in the Eastern States, the production of clover seed is incidental. If conditions are right and there seems to be a good setting of seed, the field is left for seed. If there is not a good prospect for a seed crop the clover is turned under, or it is cut for hay if this is needed or the price is high enough to warrant making hay for sale. In some sections red-clover seed is taken from the first crop, but this practice is confined to special localities. A number of factors influence the yield of seed, but most of these are as yet imperfectly understood. It can be said in general that the ideal conditions for seed production are the following: (1) A strong, vigorous recovery after haying; (2) clear, warm, but not extremely hot weather at the time the second crop is in bloom; (3) an abundance of bumblebees and other pollinating insects; (4) the absence of injurious insects, such as the clover-flower midge and the chalcis fly; and (5) good harvesting and curing weather. The second and fifth of these factors are wholly beyond human control and sometimes exert a profound effect. A hot wave when the clover is in full bloom may destroy a seed crop that looks promising. A vigorous recovery depends somewhat on weather conditions, but also on the stage of ripeness at which the hay is cut. If this is allowed to get overripe the plants do not recover well, while the earlier the hay crop is cut, the better for the seed crop.

As a specific instance it may be cited that mowing was commenced on one side of a 40-acre clover field when the plants were two-thirds in bloom. Several days were required to cut the field and the last of the clover was not cut until
the plants were just past full bloom. The effect of this time of cutting on the seed crop was remarkable in that the early cutting induced the second crop to produce seed at the rate of 5 bushels per acre, whereas the cutting a week later resulted in a subsequent seed yield of only 2 bushels. The difference in the value of the preceding hay crop by reason of the early cutting on the one side was probably not more than 20 percent, whereas its increase of the yield of seed was more than 100 percent.

Early cutting will also help to control the injurious insects mentioned above in connection with the fourth factor, as the first brood of the season will be destroyed in the hay and there will be few adult females to bother the seed crop. The same object may be attained by pasturing the clover in the early part of the season and taking a seed crop only.

Short season production: In the northern portion of the northern tier of States, the short growing season will not ordinarily permit the first crop to reach full bloom and still allow time for a seed crop to mature. For this reason it is usually necessary to pasture the crop or cut it earlier than would otherwise be desirable. If a full cutting of the first crop of clover is made for hay and the second left for seed, the seed yield is likely to be disappointing on account of the lack of suitable growing weather for the seed crop. In the latitude of northern Michigan the clover may be pastured until June 18 or 20 in normal seasons and then allowed to produce seed. If livestock for pasturing is not available, the clover may be clipped back about the middle of June with equally good results. Even when the land is pastured, it is a good practice to run the mower over the field after the stock is removed, to clip back any bunches which may be left by the stock. In this way, the seed crop will mature much more evenly over the entire field.

Estimating the seed crop: Inasmuch as clover straw is of little value as feed, if the crop is allowed to go to seed a decision must be made when the field is a little past full bloom as to whether the second cutting should be allowed to stand for seed or be used for hay. It is usually possible to estimate with fair accuracy the probable seed production by the time the plants are well out of bloom. If examination of the field shows a uniform stand of a goodly number of heads with an average setting of 25 to 30 seeds to the head, it may be taken as an indication of a sufficiently good crop to profitably cut it for seed, as under normal conditions this indicates a yield of 1 to 2 bushels per acre. If the heads which are turning brown show less than 20 seeds to the head, it will usually be better to cut the crop for hay, even though it is a little too late for the best quality of hay.

Seed production: The total average annual production (threshcr-run) of red clover seed during the 10 years (1935-44) was 78,850,000 pounds. The average of the postwar years (1945-48) was over 106,000,000 pounds, which represented an increase of 34 percent over the average of the previous 10 years. The 1949 production is estimated at 75,700,000 pounds, which is 30 percent smaller than 1948, and lower than the 1935-44 average.

The principal red clover seed production area in the United States is in the Central and Northcentral States including the 8 States of Ohio, Indiana, Illinois, Michigan, Wisconsin, Minnesota, Iowa, and Missouri. These States during the 4 years 1945-48, produced over 80,000,000 pounds or over 80 percent of the total. The only remaining large-producing State is Idaho which produced for the same 4 years an average of 8,600,000 pounds, or nearly 9 percent of the total, and in 1949 over 10,000,000 pounds or 14 percent of the total.

Harvesting and hulling: The best time to cut red clover for seed is when the heads have turned brown and the flower stalks deep yellow and the seeds have begun to show a distinct violet color. If cutting is delayed until the heads are black or until the seeds have completely colored, the loss of seed from the breaking off of the heads is certain to be heavy. If the stems are heavy and full of sap,
cutting can be done earlier than if the stems are short and dry, as the abundant sap will ripen the seed. When cut early, before the leaves are dead, the stems dry better and cure more quickly. Sappy stems when cut after the leaves are dead cure slowly and therefore, cutting should be done before the leaves reach that stage.

Various machines are used for cutting clover for seed, but the most common is a mower with a windrowing attachment. This attachment is popular because it puts the cut clover out of the way of the tractor or horses on the next round. Farmers use various methods and different machines, but the principle to be kept in mind is to handle the crop between cutting and hulling as little and as carefully as possible. Every time a clover head is broken off some seed is lost.

The cut clover is allowed to lie in the field until cured when it is picked up with a combine, or it is allowed to remain there until it is partly cured and is then put into cocks. These should be small, not more than 2 or 3 bushel basketfuls in size. Large cocks will not dry in the center without being pulled apart, and that involves risk of loss. A somewhat prevalent idea is that the clover must rot in order to hull well, but this is not necessary. The important thing is that it must be thoroughly dry. Damp clover is tough and does not handle well.

The principles involved in the successful handling of the clover-seed crop are: (1) Cut when the seed is ripe enough, but before it begins to shatter; (2) handle carefully and no more than is necessary; and (3) hull as soon as possible after the clover is thoroughly dry.

Any tools or methods that make it possible to handle the crop in this way are good tools and good methods. It is the usual practice to hull from the field, but if the clover must lie for weeks before a huller can be secured it is much better to put the dry clover in the barn or to stack it, than to leave it in the field exposed to all sorts of weather. When the seed crop is stacked, it is very important that the clover be bone dry; otherwise, it will remain damp in the center and will have to be torn apart and spread before hulling. This extra handling will entail the loss of seed. To protect the base of the stack 6 to 8 feet of dry straw should be placed on the bottom, and the stack should be carefully covered with grass hay or with a stack cover. When stowed in the mow, the only care is to have the clover bone dry before bringing it inside. In damp clover a considerable quantity of seed may be lost by sprouting, in fact, more than would be lost by handling the crop during hauling and stacking. Besides the actually sprouted seed in damp rotting clover, there is also a lot of seed that swells and is ruined. Many of these seeds are later blown out as light seeds, while others lower the value of the entire crop because they are brown and shriveled.

Hulling clover from the cock or stack is commonly done by special clover hullers. There are also clover-huller attachments to grain separators. A clover huller is simply an ordinary threshing machine equipped with an auxiliary cylinder and concave with rasps or other devices for rubbing off the hulls from the threshed seed. The huller will not do good work when the clover is at all damp, even from dew; hence, six hours is usually found to be a good day's run when hulling from the field.

Pollinating insects: The dependence of seed setting on the number and activity of honeybees and bumblebees is not realized by most farmers who grow red clover seed. The red clover flower is practically self-sterile; that is, the pollen of a flower will not fertilize any other flower on the same plant. Therefore, before fertilization can occur, it is necessary that the pollen be transferred between flowers on different plants. This cross-pollination is done principally by honeybees, bumblebees, and other kinds of bees whose presence in large numbers at the time red clover is blooming is essential for large yields of seed. If other nectar and pollen-producing plants more liked by the bees than red clover are available, the honeybees in
particular will work the other plants in preference to the red clover flowers.

If only the second growth is saved for seed, the time of cutting the first growth may be regulated so that the second growth will be in full bloom when other flowering plants are scarce and when large numbers of bees are present. There is reason to believe that in sections where an increase in acreage has been accompanied by declining yields of seed, the introduction of additional colonies of honeybees would prove profitable. Bumblebee nests should not be destroyed, and every effort should be made to provide desirable nesting places for queen bumblebees.

Insects injurious to seed: There are many insects that are injurious to red clover and thus indirectly cause lower yields, although not directly affecting the development of the seed. There are, however, two insects that especially damage the seed crop, namely, the chalcid fly and the midge. Recognizing their presence and making the first cutting not later than the time when the clover is 1/2 to 3/4 in bloom will materially reduce infestation by these two insects. Where the practice of cutting two seed crops in one year is followed, heavy infestations of both insects may cause such serious injury that seed return will become unprofitable. In order to destroy the overwintering larvae, it is advisable to rotate the clover fields, allowing the clover to occupy a field for only one harvest year. Such practice will not only control the insects but will do much toward improving the fertility of the soil.

**Red Clover Seed Production in the Intermountain States**

At present most of the domestic red clover seed is produced in the Corn Belt States, and while not enough is produced there to supply the need for adapted seed, it is believed that no increase in seed production in the Corn Belt is practicable under present conditions and methods of farming.

In the State of Idaho the production of red clover seed has averaged over 7,700,000 pounds for the 10-year period (1939-48) which has been exceeded by most of the Corn Belt and Northcentral States. However, the yields in Idaho have averaged 280 pounds per acre which is nearly seven times that of the average of the Corn Belt and Northcentral States where most of the red clover seed is produced.

In those sections of the Intermountain States where red clover can be grown, there is an excellent opportunity for profitably producing red clover seed. In many cases bulky crops grown in this region have to be transported long distances to the place of consumption or of shipment, and this lowers their net value. Because of its smaller bulk and higher unit value, red clover seed can be marketed more profitably under long-haul conditions than can staple crops such as hay or grain.

In many of the older irrigated sections where the supply of organic matter in the soil has been depleted, red clover has corrected this deficiency and in short rotations has materially increased the yields of the crops that follow, such as potatoes, beans, and sugar beets. The first growth of red clover during the harvest year is often grazed by sheep and the second cutting is harvested for seed, the clover thus providing early grazing as well as producing a cash crop.

With the exception of those sections in Oregon and Washington that lie west of the Cascade Mountains, red clover seed production in the Northwestern States is largely confined to land under irrigation, although on a few plateaus not under irrigation and receiving an average yearly rainfall of 17 to 25 inches, red clover seed has been produced under special row culture. The east and west boundaries of this intermountain area extend from the river valleys at the base of the eastern slope of the Rocky Mountains to the Cascade Mountains on the Pacific Coast. In this region red clover seed has been produced as far north as northern Montana and as far south as Arizona. While red clover seed may be produced in the Intermountain States outside the arbitrary boundaries given,
and while even within the area described there may be irrigated valleys unsuitable for the purpose, it is believed that in general the area outlined offers unique opportunities for increasing red clover seed production.

**Treatment the first year:** When red clover is grown under irrigation with a companion crop, it is important to irrigate when the young clover needs water, rather than at a time most beneficial to the grain crop. The number of irrigations and the quantity of water applied depend on the rainfall and the temperature to which the seedlings are exposed; as a rule, three to five irrigations will be necessary the first year. The early irrigations may be applied advantageously when the seed is sown, again a month or more later, and immediately before the harvesting of the small grain. Neglecting this last irrigation often causes poor stands.

After the removal of the grain crop, the clover plants should be irrigated throughout the summer as often as necessary for good growth. The clover must not go into the winter in a dry condition. Pasturing heavily or cutting a crop of hay in early fall may cause winterkilling of the plants. In a few sections in the southern part of the Intermountain region, a small crop of seed is often harvested in the fall of the year in which the clover is sown.

**Treatment the second year:** During the spring of the second year red clover should be given ample moisture to produce vigorous growth, but the number of irrigations will depend upon the amount of effective rainfall. The first crop may be utilized in any of several ways: It may be grazed, cut for hay, or cut for seed. The individual grower must decide the best use. If the clover is grazed, it is advisable to pasture lightly, removing the animals during the first part of June, after which the clover should be clipped in order to produce uniform blooming during the second growth for seed production. If the clover is cut for hay, the cutting should be done earlier than usual; that is, when the clover is about one-third to one-half in bloom. This earlier cutting will favor a rapid and vigorous development of the second growth and will also control some of the insects that are injurious to seed production. Whether it is advisable to cut the first crop for seed may depend upon the prevalence of pollinating insects, such as bumblebees and honeybees, the interference with the harvesting of other crops, and the need for hay or pasturage.

If the first crop is to be harvested for seed, the last irrigation of the first growth should be made when the plants are approximately one-half in bloom, and the maturing heads should be examined from time to time to determine the best time for cutting in order to secure the greatest number of well-filled, mature heads. If a sufficient number of pollinating insects are prevalent throughout the blooming period, the time of cutting will probably depend upon the time of maturity of the greatest number of heads. Cutting the crop too early will yield a large number of immature, shriveled seeds, while cutting too late will result in shattering and loss. Cutting and windrow the seed crop when the plants are wet with dew will help to prevent shattering. The seed may then be combined or hulled from the windrow. In order to start rapid development of the second growth, the field should be heavily irrigated as soon as possible after the first crop is removed. The second growth may be handled like the first.

**RED CLOVER HIGHLIGHTS**

1. Red clover is one of the most important leguminous forage and soil-improving crops in the northeastern quarter of the United States. It fits well into crop rotations and makes excellent hay and pasture, especially when grown with timothy or other grasses.

2. Red clover will grow on any well-drained, fairly rich soil that has plenty of lime, phosphorus and potash in it, but will not thrive on hard, run-down land in which the organic matter and these chemicals are lacking.

3. The most common method of sowing red clover is in winter grain, but it is also often sown with spring grain. Late sum-
mer sowing is successful in much of the southern and eastern part of the clover area.

4. Red clover is sown most often with timothy, though sometimes with other grasses. With timothy, the hay of the first crop year is mostly clover; the second year the timothy predominates, and after that, the clover largely disappears.

5. The use of high-quality seed of a variety or strain adapted to the locality in which it is sown is recommended, instead of seed of unknown origin or adaptation. When growing red clover especially for seed production, if possible, sow seed of one of the new improved varieties.

6. Clover and simple clover-grass mixtures are used mostly in rotations with a cultivated crop and a small-grain crop in three, four, and five-year rotations.

7. If a companion crop is sown with the clover, a grain with short, stiff straws, sown at from one-half to two-thirds the normal rate, is considered best.

8. The seedbed should be firm, and the seed should be sown early in the spring at the rate of 10 to 15 pounds per acre if broadcast, and 6 to 8 pounds if drilled.

9. The crop may be lightly grazed, or a hay crop may be taken if it is desired to utilize the clover in late summer of the year that it is sown. Do not cut a crop of hay or graze the plants closely in the fall.

10. If irrigation is practiced for seed production, irrigate for the best development of the clover rather than the small grain, in order to secure a good stand of clover. The last irrigation before harvesting for seed should be applied when the red clover plants are approximately one-half in bloom.

11. Root borers and other insects, as well as fungous diseases are responsible for the death of clover plants and may make it impossible to keep a field of clover more than one crop year. Using disease-resistant varieties, such as Kenland or Cumberland, will largely eliminate the disease hazard.

12. Seed is usually taken from the second crop. The yield is always more or less uncertain, and over much of the clover area it is cut down materially by the clover-midge and the clover seed chalcis fly.

13. Early cutting for hay, or grazing the first growth in order to harvest the second growth early for seed, are the best means of controlling injurious insects affecting the seed.

14. Introducing hives of honeybees into or near the fields at the time when red clover is in full bloom will increase cross-pollination and consequently increase the yields of seed.

15. The highest seed yields are obtained in Idaho and other nearby Intermountain States, so these States offer excellent opportunities for increasing seed production of new improved varieties for use in the Eastern States. Yields of red clover seed in Idaho average over three times as much as those of the large-producing Central and Northcentral States.

**ALSIKE CLOVER**

*(Trifolium hybridum)*

Alskie clover is used in the agriculture of northern Europe and is known also as Swedish or hybrid clover. The names alsike and Swedish refer to the locality and to the country from which this plant was introduced into England, while the name “hybrid clover” was given it because it was thought to be a cross between red and white clovers. It was named *Trifolium hybridum* by Linnaeus in 1753, as he too believed in the hybrid origin of the species. In its native home it has been cultivated since early in the tenth century, but it was not until about 1834 that seed was brought to the United States. In 1854 a distribution was made by the United States Patent Office. Doubtless there were other importations. Some of the immigrants to this country from northern Europe are known to have brought alsike clover seed with them.

In the region where red clover is the standard leguminous rotation crop, there are soils and situations in which red clover will not thrive. Low, wet land and soils that are low in lime content, or have been run down by long and unwise cultivation, are less suited to red clover. On many of these soils alsike clover can well replace it. Alsike clover succeeds better than red clover on wet land, and when mixed with red clover on uplands it will insure against failure from lack of lime or other unfavorable soil conditions. When red clover seed is extremely high in price,
Alsike clover can be substituted on many soils. The seed being smaller than that of red clover, less is required to the acre. Since Ladino clover has come into use in recent years as a pasture legume in mixtures of grasses and legumes, it will to a large extent replace alsike clover in pasture mixtures where soil and moisture conditions are suitable for Ladino clover.

**DESCRIPTION**

Alsike clover is a perennial, though it usually behaves agriculturally as a biennial. Many smooth stalks come from the crown, and they bear smooth leaves, each with three leaflets. The heads of the flowers are partly pink and partly white. In some heads the flowers are all white, and in others all pink.

Under favorable conditions the stalks grow 3 to 5 feet long, but on drier soil they may not grow more than 18 inches in height. The stem bears flower heads along its entire length, the oldest below and the youngest at the top of the stem. This character is important not only from the standpoint of seed production but in making alsike clover fit to cut for hay over a longer period than in the case of red clover.

The seeds of alsike clover are small, there being about 700,000 to the pound. This is more than twice the number of red clover seeds in a pound.

**ADAPTATIONS**

**Climate:** Alsike clover prefers a cool climate. Its home on the Scandinavian Peninsula shows that it is fitted to withstand cold weather and this is confirmed by experience in this country. In the United States alsike clover is very generally grown in the area north of the Ohio and Potomac Rivers, and as far west as the Dakota-Minnesota boundary. It is also grown in Idaho and on the Pacific coast of Washington and Oregon. In the South it is less successful, thriving only where an abundance of moisture enables it to overcome the injurious effects of the warm summers. It usually disappears during the hot summer months.

**Soils and moisture:** Alsike clover prefers a rather heavy silt or clay soil with plenty of moisture. It usually does not do well on dry, sandy, or gravelly soils. A rich, moist bottom soil suits it best and on such soils it will grow luxuriantly. Alsike clover responds to an application of lime, but is not as sensitive to acidity as red clover and Ladino clover, and can be successfully grown on many wet, cold and "sour" soils on which these clovers do not succeed.
ESTABLISHING A STAND

Sowing the seed: In the Northern States the seed is usually sown in early spring, though in some places in late summer. In New Jersey the sowing of alsike clover often follows early potatoes or cabbage in July and August. In Indiana and Ohio, it is sometimes sown in corn at the last working, but there is always considerable risk connected with this and the practice cannot be recommended save in exceptional circumstances. Sowing in July with buckwheat is successfully practiced in southern Michigan, but this method is not general. In the South wherever alsike clover is used, it is commonly sown in the fall.

When sown with spring grain with the seedbed in good shape, the clover can be most advantageously put in with a drill. When the soil is dry enough, harrowing after sowing will rather benefit the grain and will make a stand of clover more certain. The use of a drill will save seed, and the seed being put into the ground at a proper and uniform depth, the seedlings will have a better chance to grow and the stand will be better. The use of the pulverizer-packer-seeder, if available, will do much to insure a good stand.

Care should be taken not to sow too deeply. On heavy soil not more than one-half inch, and on light soil not more than one inch, is deep enough. For success a good seedbed is important. It should be firm but fine on top so that the young plants may be well supplied with moisture.

Since there are some 700,000 seeds in a pound, every pound of seed sown to the acre, if evenly scattered will put about 16 seeds on every square foot of ground. If 6 pounds of seed per acre are evenly scattered, there will be one seed on every 1 ½ square inches. This quantity of seed will make a heavy stand if less than half the seeds finally produce plants. When broadcast on winter grain, rather more seed should be used than when drilled, as much of it will be wasted.

The rates of sowing mixtures of alsike with red clover and timothy vary in different sections, not only in the proportion of each component but also in the total quantity of seed sown per acre. Recommendations vary from as low as a total of 6 to 8 pounds of the mixed seed per acre in Indiana and 16 to 20 pounds in New York, to 30 pounds in Maine. Wherever the seedbed is properly prepared and the land has had adequate applications of lime and fertilizers (which should be the requirements in any case), no more than 10 or 12 pounds of the mixed seed per acre should be needed to obtain a good stand. When equal parts of alsike and red clover are sown, there is more alsike than red clover in the stand; when the quantity of alsike sown is half that of red clover, the resulting stand of each is about the same.

The methods of sowing alsike clover and other clover and grass seeds, either alone or in mixtures, and the equipment to be used, are more fully described in chapter V on "Establishing Meadows and Pastures.

Alsike in mixtures: Alsike clover, except when grown especially for the seed crop, is almost always mixed with one or more grasses or other legumes. In the past these have been either red clover or timothy, mostly the latter, or even more often both red clover and timothy. The use of alsike in mixtures has been practiced wherever it has been difficult to get a stand of red clover. A common practice is to sow timothy in the fall and to sow alsike alone, or alsike and red clover, in the spring. Rather more seed of timothy and red clover than of alsike clover is then used. A common formula has been alsike clover one part; red clover, one to two parts; timothy two to three parts, sown at the rate of 8 to 12 pounds of the mixture per acre.

Besides the mixture of alsike clover, red clover and timothy, which is by far the most common one in use, various other mixtures are recommended for different situations and sections. The sowing of alsike clover with orchardgrass is not uncommon in the South, especially in Kentucky and Tennessee. In Franklin County, Kentucky, where orchardgrass...
seed is harvested, the two are frequently sown together.
Sowing in natural meadows: Alsike clover is often sown in natural meadows, especially when these are wet or can be irrigated. Methods for getting a stand of clover on these lands differ, but it is often not necessary to plow. On irrigated land the natural meadow may be disked or harrowed several times with a heavy spike-tooth harrow. The broadcast seed will usually start readily after irrigation.

At high altitudes alsike clover does well. It seems particularly adapted to high, fertile mountain valleys, often appearing as a volunteer in the natural meadows where it improves the quality of the wild hay.

Volunteer sowing: In some States alsike clover is especially valued for its habit of voluntarily reestablishing itself. If the soil conditions are favorable and soil fertility is maintained, it will come back in a field for many years. Farmers in the States of Arkansas, Kentucky, Michigan, Minnesota, and Colorado have for years practiced rotations in which the only clover crop is the volunteer alsike from an original sowing made in some cases as much as 20 years before. Enough seed shatters to resow the ground and the rotation is resumed. Or, the clover may simply alternate with a grain, such as wheat and clover, or barley and clover. Or, there may be two years of cultivated crops followed by two years of alsike clover.

Where conditions are favorable, alsike clover may work into all parts of a farm from a small start. This is especially true if seed is harvested and may, indeed, be an undesirable feature in some sections where white clover seed is also produced. The seeds of white and of alsike clover are so nearly alike in size that when once mixed, they cannot be separated.

When alsike clover is fed, the manure always carries a large quantity of seed, and enough clover may volunteer in fields where the manure is spread to make a good stand.

DISEASES AND INSECTS

Alsike clover does not appear to be seriously affected with diseases or insects such as trouble red clover. However, little study has been made of them so far, so they may not even have been recorded as found on alsike clover.

UTILIZATION

Hay: Alsike clover, though not usually as heavy a yielder as red clover, makes a better quality of hay. Chemical analyses show that there is not much difference between red clover and alsike clover hay, but that alsike clover may contain more digestible protein and have a higher fuel value than red clover hay. Since alsike clover is a smooth plant, it makes a cleaner, less dusty hay than red clover. It also has the advantage of being finer-stemmed. There is not so much waste as in red clover.

Because of its weak, slender stems, alsike clover usually should not be sown alone for hay. When in a pure stand, especially on moist or wet land, the stems mat together and the plants are difficult to cut. Sown with timothy or red clover, the weaker stems of the alsike clover are supported by the more upright ones of the red clover and of the timothy, and the alsike clover acts as a filler, making the stand thicker below and thus adding materially to the weight of hay cut.

The best time to cut alsike clover for hay is when it is in nearly full bloom. It blooms irregularly, and when the field as a whole is in full bloom there will be many heads with seed which is already ripe. Fortunately, the fine stems of alsike clover do not get hard as quickly as the stems of red clover. They keep on growing and blooming as the lower flower heads mature, and consequently, good hay may be made within a range of several days.

When grown in mixture, especially with timothy, this characteristic of remaining good for some days is especially valuable. If it is to be cut before any
heads are ripe, it will doubtless be ready before timothy, but it will also remain in good condition to cut after a few of the lower heads contain ripe seeds, and in that case usually will be ready for harvest with timothy.

In most cases alsike clover does not make a second growth worth cutting. However, on river-bottom lands and on moist, rich lands in the North, two crops are sometimes obtained, especially if the first crop is cut rather early when just coming into bloom. When a second growth is made, the need for winter protection should not be lost sight of in determining whether or not to cut the crop. Clover is more likely to live through a hard winter when it has 4 to 6 inches of growth, than when it has been cut close in the fall and has not had a chance to make a new growth.

Pasture: Alsike clover has been used especially in pasture mixtures. Its vigorous growth enables it to hold its own against the competition of other plants, and its persistence in seeding provides for its continuance. In the South, where this clover is little used for hay, it has proved valuable as a part of the permanent pasture mixture on bottom lands. Wherever Ladino clover is adapted and conditions are suitable, it has largely replaced alsike clover in pasture mixtures.

In the North, alsike clover is commonly sown with timothy and red clover for pasture as well as for hay. When it is grazed or cut early it at once sends out new branches, and these will produce flowers and mature seed when not more than a few inches long; in this way the ground is constantly full of seed and the pasture is kept in good shape.

Alsike clover in pasture is perhaps more hardy than red clover and Ladino clover; it will withstand more trampling than red clover and does not heave out as readily but will not spread by stolons like Ladino clover.

Meadows containing alsike clover intended for seed are often pastured until May or early June. On rich land alsike clover tends to grow very long, with few branches. When pastured it puts out many branches, and the number of heads and consequently the seed crop, may be very greatly increased. However, on poor, dry soils it is not advisable to pasture before a seed crop because, if the season should be dry, the plants will not recover enough to make a profitable crop of seed.

Since the advent of Ladino clover, under soil and climatic conditions favorable to the growth of Ladino, it is probable that it will to a considerable degree in the future take the place of alsike in pasture mixtures.

**SEED PRODUCTION**

Sowing for seed production: When sown for a seed crop in the East, the sowing should be made on the poorer lands. On rich, low lands the growth is rank and the yield of seed may be small. On the higher or poorer land the clover will be short but the flower heads are likely to be more numerous. When the growth promises to be rank and a seed crop is wanted, the field may be pastured until about June 1. This will cause many additional shoots to start, each of which will bear flower heads and thus increase the yield of seed.

In Idaho and Oregon, seed is grown mostly on irrigated land. The general practice is to water only once in the spring, and when one-third in bloom, to water more frequently, leaving the water on for 12 hours. This frequent watering is continued until a large part of the heads have turned brown. Alsike seed is also frequently harvested along with timothy seed and the mixture of these is sold as such, because of the difficulty of separating these two seeds, and also because they can be used for sowing as a mixture.

In Idaho, it is said that two crops of seed can be profitably cut and sometimes several. The best practice, however, appears to be to take no more than two consecutive crops. If a field is left longer, weeds get into it too badly. In the seed-growing areas of Oregon and Idaho, the crop is grown largely for seed and is sown especially for that purpose. In the
Harvesting seed: The seed is taken from the first crop, which ripens sometime in July or later, depending on the season, latitude, and method of handling. The most favorable conditions for seed production are cool, moist weather for growth until early bloom, after which dry warm weather is best.

In some cases but not usually, fields are pastured in the early part of the season, perhaps until late May or early June. This delays maturity and the seed crop is ready to cut in August. Owing to its irregular flowering habit, there will be overripe heads and buds on the same plant. Cutting should be done when the largest number of heads can be saved, which usually will be when about 90 percent of the heads turn brown.

Cutting is best done with a mower with windrower attachment, preferably in the early morning when the dew is on. Since alsike clover seed shatters readily, great care should be taken in handling it. As soon as dry the clover should be stacked, unless combined or threshed direct from the field. In the latter case, canvas should be laid on the wagon bottoms to catch shattered seed.

Seed production statistics: The estimated 10-year average (1935-44) production of alsike clover seed in the United States was 18,250,000 pounds which was produced on a yearly average of over 140,000 acres, with an average yield of around 134 pounds per acre. The average production of the postwar years (1945-49) was 22,240,000 pounds, which was produced on about the same number of acres, with a yield of 163 pounds per acre which represented an increase of 22 percent over the yields of the previous 10 years. The highest total United States production for any one year was in 1929 with a total of 35,000,000 pounds.

Oregon led all other States in production of alsike clover seed during the 12-year period (1937-48) with an average of 5,125,000 pounds, followed by Minnesota with 3,770,000 pounds, Idaho with 2,450,000 pounds, Wisconsin with 2,370,000 pounds, Ohio with 2,350,000 pounds, Michigan with 1,235,000 pounds, and Illinois with 1,140,000 pounds. These seven States produced over 92 percent of the total United States production of alsike clover seed.

Yields of seed per acre: The highest State average yields of seed in these seven States have been obtained in Idaho and Oregon, with annual averages of from 300 to 375 pounds per acre. The highest in other States were Wisconsin and Minnesota with averages of 141 and 127 pounds, respectively. The next five States of Michigan, Illinois, Iowa, Ohio and Indiana averaged from 65 to 105 pounds of seed per acre.

The average yields given here are State averages of the Division of Agricultural Statistics. In Idaho and Oregon where seed production instead of forage production is the rule, these averages probably give a nearly correct picture of average yields in seed-producing areas, except that they occasionally have phenomenal yields of 1000 pounds or more per acre. In the Northcentral and Corn Belt States, where forage production and not seed production is the rule, it is known that in the more specialized seed-producing areas of those States, higher average yields are obtained than those given. In Minnesota and Wisconsin the average in such sections is nearer 160 to 200 pounds, with occasional yields of 500 to 600 pounds per acre. A comparable difference also exists in yields of seed in special seed-producing sections of Michigan, Illinois, Ohio, and Indiana.

ALSIKE HIGHLIGHTS

1. Alsike clover, though less used than red clover, is a "true" clover and has occupied an important place in the red clover area that could not be filled by red clover. In recent years, Ladino clover has to a large extent replaced alsike clover in pasture mixtures.

2. Alsike clover is most at home in northern latitudes or at high altitudes. It thrives best in a cool, moist climate.

3. In the Ohio Valley, alsike clover is espe-
WHITE CLOVER

(Trifolium repens)

White clover is a widely distributed but often unappreciated plant of pastures, lawns, roadsides, and thin woodlands—wherever there is sufficient moisture for it to survive. It probably arrived with early settlers from Europe, but it appears to have preceded the white man into the Ohio Valley and the Middle West. Common white is a perennial legume, produces many seeds, and spreads by creeping stems that root at the nodes.

It normally grows with grasses and even when sown alone, creates an ideal condition for grass, which soon appears and makes a good growth. For the most part, the white clover of permanent pastures has not been sown by man but may have spread by animals and water or as an impurity in other field seed. When grown in mixtures with grass it increases the carrying capacity of the pasture and provides a nutritious feed relished by livestock.

Between 3 and 5 million pounds of white clover seed are sown annually in the United States, of which about half is common white and the remainder Ladino and Louisiana white. It is believed that in the Northern States 90 percent or more of the common white is used in lawn-seed mixtures. Formerly, most of the white clover seed was produced in the northern Corn Belt States. While the quantity fluctuates widely from year to year, the three principal seed-producing regions are (1) Idaho, California, Oregon, and Washington; (2) Louisiana and Mississippi; and (3) the northern Corn Belt States, principally Wisconsin.
DESCRIPTION

White clover is ordinarily a long-lived perennial but in the South often behaves as a winter annual and is often used as such. It is shallow-rooted and spreads by creeping branches (stolons) which root at the nodes. The flowers are white or pinkish and are in clusters or heads which in common white clover are present in large numbers, while in Ladino white clover they are fewer in number. This feature and the very large growth, long internodes and thick stems and stolons of Ladino distinguish it from common white clover. The three leaflets of white clover are free of hairs and frequently have saw-toothed margins and whitish marks in the center. Under favorable conditions, there are usually 75 to 150 seeds per head.

POLLINATION

White clover is practically self-sterile; that is, the florets have to be cross-pollinated before seed will form. This means that pollen must be transferred from plant to plant rather than from one floret to another on the same head or the same plant. The florets produce an abundance of easily accessible nectar and therefore are visited by all kinds of bees. In their quest of nectar the bees cross-pollinate the flowers, thus bringing about continuous variation in the clover. This is important, particularly as related to the problems of producing pure seed of a variety or type. Under different environmental conditions various types and forms of white clover have developed and survived, giving this plant a wide range of adaptation.

ADAPTATION

White clover, like all the other clovers, thrives best under cool, moist growing conditions in soils with plenty of lime, phosphate, and potash, but it will tolerate poor conditions better than some other important clovers. Clay and loam soils that have sufficient moisture to keep the plants growing seem better suited to it than sandy soils, which are usually droughty and contain less minerals.

ESTABLISHING A STAND

Time of sowing: Except when sown for seed production, common white clover is usually sown with grass. When new sowings are made in spring, the two are mixed and the entire mixture sown at one time. Occasionally, the grass part of the mixture is sown in the fall and the white clover early the following spring. Fall sowing of the clover is not recommended unless soil and climatic conditions are such as to cause early and rapid growth before cold weather arrives.

Preparation of seedbed: Regardless of the time of sowing, the seedbed should be well compacted. This may be done by rolling the soil, preferably with a corrugated roller, and applying liberal quantities of lime and of phosphate and potash fertilizers. The seed may be broadcast and need not be covered if sown early in the spring. If it is sown later it may be advisable to stir the soil lightly to cover it. When it is to be sown on turf, the grass should be short and kept mowed until the clover becomes established.

Rate of sowing: Usually 2 to 5 pounds of seed per acre, or 1 to 3 ounces per 1,000 square feet, will produce an excellent stand, especially with seed of 95 percent germination, including the hard seed.

Fertilizers: The application of 200 to 400 pounds of phosphate per acre and 50 to 100 pounds of potash fertilizers has proved beneficial to the growth of white clover. Although it will grow on acid soil, it is never so thrifty as when available lime is present. Occasionally clover leaves become spotted with irregular light-brown areas, even in the absence of disease-producing organisms, a condition that can be remedied by the application of potash.

On most soils, after stands are established, an application of phosphate at frequent intervals has benefited the stand. Top-dressing with limestone and potash has in many places given profitable returns. Repeated applications of fertilizers containing a high percentage of nitrogen
stimulate the growth of grasses, and this frequently crowds out white clover. As it usually grows in association with grass, climatic conditions and cultural treatments affecting the grass may indirectly affect the clover. Close grazing in spring reduces the growth and density of the grass and gives the clover a better chance of surviving and spreading.

Inoculation: Highly effective strains of bacteria from red and white clovers have been shown to successfully inoculate any of the strains of white clover. Therefore, under favorable soil conditions in areas where these clovers have been grown successfully for a number of years, the necessary legume bacteria have probably become established in the soil and have maintained their nitrogen-fixing power so as to make artificial inoculation unnecessary. Where unfavorable soil conditions have persisted, namely, low fertility or high acidity, the natural clover bacteria may have been killed or their ability to fix air nitrogen impaired to such an extent that artificial inoculation with fresh, effective, nitrogen-fixing bacteria cultures may be necessary for maximum crop production. Here, as elsewhere, "when in doubt, inoculate." You can't afford to take a chance on any of the clovers.

DISEASES AND INSECTS

More than 30 parasitic bacterial, fungal, and virus diseases are known to attack white clover in the United States. Although usually of limited economic importance, certain of them occur commonly and may be destructive. There are several insects which feed on white clover, some of which occasionally cause serious losses. The more important of these are mentioned here but are more fully discussed in chapter IX.

Diseases: Crown rot occurs throughout much of the important white clover-growing region and is known to thin the stands and, when severe, to destroy entire areas within fields. This disease is probably responsible for what is often called excessive winterkilling.

Pepperspot and sooty blotch are leaf diseases. They occur commonly, and when severe bring about defoliation and reduction of pasturage.

Leaf rust occurs wherever white clover is grown. When severe, leaf rust causes defoliation and reduction of pasture.

Insects: During late spring and summer, infestations of the leafhopper occasion a reddening and browning of the leaf edges, stunt the growth, and kill young leaves outright. With the advent of cool moist weather the surviving plants recover. Ladino white clover is particularly susceptible to leafhopper injury.

A grayish mottled appearance of the leaves of white clover may be caused by the garden flea hopper. This minute black bug is widely distributed, sucks up the sap as food, and occasionally seriously injures the plants.

Both the roots and leaves may be attacked by the clover root curculio which is common throughout the humid States and the irrigated lands of the West. The grubs gnaw the roots; and when abundant, the adults may riddle the leaves.

Both the clover leaf weevil and the lesser clover leaf weevil frequently attack white clover, especially in lawns. As both larvae and adults feed exclusively upon the foliage and young shoots, they may do considerable damage. Most of it occurs in April and May, as a fungus disease usually attacks and kills the larvae later in the season.

VARIETIES OF WHITE CLOVER

White clover may be divided into three general types: (1) The large, represented by the variety Ladino; (2) the intermediate, as in the naturalized Louisiana strain; and (3) the low-growing, represented by the New York and English wild white varieties, or by naturalized low-growing domestic strains of common white developed in pastures by years of continued close grazing. These differ principally in growth, size, performance, and other characteristics, and variation occurs within them. In each type there are usually plants of one or both of the others. Seeds of all types are similar both in size and color and cannot be distinguished. In addition, each type has
developed strains, some through natural selection, others from improvement programs.

Common white: In the commercial trade, common white clover may be composed of either intermediate or low-growing types or a mixture of the two. Even plants of the large type may be present. The type obtained from common white seed may have resulted from one or more factors: Source of seed, percentage of cross-pollination between plants of different types, failure of some types to germinate, and—most important—long-continued grazing or clipping practices. When seed is harvested from pastures that have been closely grazed for years the low-growing type predominates, even though an intermediate type may have been sown. Likewise, seed from moderately grazed fields has more of the characteristics of the intermediate type.

The blending of different lots from widely different sources adds to the mixture of types. Common white clover is truly common. The name "White Dutch clover" which is of general usage in literature and may once have represented the intermeditae type, is a synonym of common white clover. The use of the name White Dutch clover is not recommended since it does not now represent any particular type. Except in more northern localities, where winterkilling has been reported, plants produced from Louisiana seed have appeared to be slightly more productive than those from other sources.

Ladino: Ladino (or Ladino white clover) is a variety of the largest growing type of white clover. When Ladino and common white clover are planted under similar conditions, Ladino grows three to five times as large as the common white clover but does not produce as many flower heads. Except for size of leaves, flower heads, stolons, and length of internode, there is little difference between the two in other plant characteristics, and the seeds look alike. The performance records of Ladino clover over such a large part of the United States are so outstanding as compared with other strains of white clover and other legumes, that it is given separate treatment here.

Louisiana white clover: The seed of this strain of common white clover has been produced largely in Louisiana and Mississippi, and in the last few years also in Tennessee. This southern strain of common white clover is generally recognized by its larger, ranker growth than the common white of the Northern States. It is considered more desirable than the dwarf strains for forage purposes, but is not so hardy in the extreme North. Because of its being the principal source of domestic white clover seed for many years, and there being no restrictions on its distribution, it was shipped into the Northern States for both lawn and pasture purposes and naturally constitutes a good portion of our northern common white clover. It is not considered as desirable for lawns as the dwarf strains.

Wasson (La-18) says that Louisiana white clover "is the most important permanent pasture clover in the South. It provides grazing over a longer period than other clovers under most permanent pasture conditions. It mingles freely with all common pasture grasses and spreads naturally on soils adapted to its growth. It begins growing with the first fall rains
and provides grazing until retarded by freezing weather. It resumes growth in early spring, and grows well in partial shade where moisture is plentiful even in mid-summer temperatures. It is rarely grown alone when used primarily for grazing, due to the likelihood of causing bloat in cattle.

“Louisiana white clover has a place on every Louisiana farm where beef and dairy cattle are included. It furnishes an abundance of nutritious pasturage over a long period. The seed constitutes a valuable cash crop and the by-product hay from seed harvesting operations can always be used to good advantage on the farm or sold for cash. There are not many crops so versatile that they can be grazed, harvested for seed and hay, followed by other grazing plants immediately after harvest, and which will reseed themselves indefinitely.”

Blaser et al (Fla-7) say that white clover is the most important legume of pastures in the eastern part of the United States, and that the Louisiana variety of white clover is best adapted to Florida. It seeds prolifically in late spring, producing sufficient seed for harvesting in addition to reseeding for the next season’s volunteer crop, and under good management and favorable environmental conditions many plants live through the summer. This clover is best adapted to low soils in northern and central Florida. The peak growth period occurs from March through May, but under favorable moisture and temperature conditions grazing is furnished from January through to June or July.

During World War II the price of Louisiana white clover was supported by the Government but all the seed produced moved in regular commercial channels. Much of the production of Louisiana, Mississippi, and Tennessee, amounting to an average of over a million pounds a year, has been used in the Southern agricultural programs.

New Zealand: New Zealand white clover, which has been imported into the United States in large quantities, is mostly of the intermediate type. It is not tolerant of extremely cold weather and is less vigorous than Louisiana white clover.

Northern European: Prior to World War II, much of the United States supply of white clover seed was imported from Northern and Central Europe, a large part of which came from Poland. Most of this seed was of the dwarf type but not of the very dwarf strains such as English wild white. Much of the dwarf Northern white clover of the Northern and Central States has probably come from this source.

English wild white: For many years farmers in England have been harvesting white clover seed from old pastures and using it to reseed other areas. English investigators who have found it low-growing, long-lived, persistent, rapidly spreading, and sparse blooming, have called it English wild white, or Kent wild white. When sown in the United States, it has not proved so well adapted as some of the domestic strains of common white. Sowing with grass, however, has been successful in many places. Compared with those of the intermediate type, the leaves, stems, and flower heads are found to be much smaller, and blossoming is not so free. In fields of common white from commercial seed, a few plants may be found that cannot be distinguished from the English wild white. Examinations of old pastures indicate that they contain persistent low-growing types that cannot be told from the English wild white.

New York wild white: This is likewise a variety of the low-growing type, similar to English wild white, except that it usually has more bloom. It also originated as a natural selection in a closely grazed pasture. Except under close continual grazing, varieties of the low-growing types are not so productive as the intermediate or large types and are not recommended for forage purposes.

SEED PRODUCTION

Common white clover is naturally a free-blossoming plant in all parts of the United States, but in only a few sections
has seed production developed as a farm enterprise. This is due chiefly to the difficulty of handling a seed crop, the irregularity of seed production, and the presence of large numbers of troublesome weeds. Yields range mostly from 100 to 450 pounds or more per acre, but yields of 150 pounds are considered profitable. The yield depends on the number of flowers in a unit area and on the thoroughness of cross-pollination.

Climatic factors have a great influence on seed production. Bright warm weather following early cool moist days favors abundant blossoming, bee flights, and cross-pollination. Even when there are blossoms, moist, cloudy weather is unfavorable to bee activity, thus restricting necessary cross-pollination and reducing seed production. The presence of colonies of honeybees nearby usually insures maximum cross-pollination. A profitable seed harvest may be obtained if the flower heads are numerous and contain 75 to 150 seeds each. When supplied with abundant moisture, common white clover continues to grow and blossom throughout the summer. Seed is continually setting, and two or more seed crops are often produced.

White clover seed may be cut with a mower with windrower attachment and picked up with a combine, or raked, shocked and threshed with a huller or threshing machine in the ordinary way, the method used depending upon weather and condition of the crop. In the Central States, if conditions are favorable, it is sometimes combined directly from the field, but probably more frequently conditions are such that it is mowed, windrowed, and combined from the windrow.

The largest grower in Louisiana says that it must be mowed and that the usual practice in recent years is to mow, and if the growth is heavy, leave it in swath until dry enough to pick up with combine; if the growth is light, it is raked into small windrows and combined. He says that the former practice of mowing, drying, raking into windrows, and pulling up to threshers with bull-rake shattered too much seed. In the Northwest, it is usually windrowed and picked up with combine, or bunched and run through a clover huller.

Damp, moist weather at curing time is responsible for the browning of seed, which makes it less attractive but may not materially reduce germination. In the Northwestern States two seed crops are often harvested at one time by leaving the first crop of seed heads until the second crop matures. Because of the necessity of irrigating the clover for the second growth, the water somewhat discolors the first crop. To produce a seed crop of high purity the field must be free from pigweed, charlock, catchfly, cinquefoil, sorrel, alsike clover, and timothy, as ordinary cleaning equipment cannot separate the seeds of these plants from those of white clover.

Production statistics: The production of white clover seed has fluctuated quite widely during the past 25 years or more. For the 10-year period (1922-31), in each year of which, except 1924, over 1,000,000 pounds of seed was produced, the average was 1,240,000 pounds. For the following 9-year period (1932-40), in each year of which less than 1,000,000 pounds was produced, the average was 623,000 pounds. For the remaining 9-year period (1941-48) during which the annual production ranged from a low of 1,360,000 pounds in 1941 to a high of 3,980,000 pounds in 1946, the average was 2,550,000 pounds. The average of the last 4 years of this period was 3,230,000 pounds. These figures cover all white clovers except Ladino clover the figures for which are given under Ladino clover.

Up to 1939, practically all of the white clover seed was produced in Louisiana and Wisconsin. From 1930 to 1932, and from 1939 to 1948, Wisconsin averaged 390,000 pounds of seed per year, but from 1933 to 1938 it produced an average of less than 50,000 pounds a year. For the entire 18-year period Louisiana averaged 520,000 pounds.

For the past four years (1946-49) Idaho has been far in the lead of all other States with an average production
of over 1,400,000 pounds which is nearly two and one-half times Idaho’s production of the previous three years (1943-45), and is the principal factor in the greatly increased United States production of the last three years.

Yield per acre: The yield of white clover seed per acre in the United States has increased in recent years from an average yield of 61 pounds per acre for the seven-year period (1936-42) to 110 pounds per acre for the six-year period (1943-48). This increase is largely because of the increased acreage in Idaho where the largest yields are obtained. The average yield for Idaho for the past eight years was 278 pounds, while the United States average for that period was only 104 pounds. These are statistical averages. In important commercial seed producing areas, the estimated averages of commercial growers are 25 to 50 percent higher than these.

HIGHLIGHTS OF WHITE CLOVER

1. White clover is of European origin and is widely distributed over the United States in pastures, meadows, lawns, roadsides and waste places.

2. White clover is a long-lived perennial under conditions in the Northern and Central States, but in the South it behaves as a winter annual.

3. The dwarf strains of white clover are the only legumes particularly suitable for lawns in combination with bluegrass or other lawn grasses in the Northeastern and Central States.

4. Louisiana or southern white clover is larger growing than the northern strains of common white clover, and more desirable for forage, except in the extreme North where it often does not survive severe winters.

5. White clover, regardless of variety or strain is ordinarily grown in combination with grasses except when grown for seed purposes.

6. The average total annual United States production of white clover seed from 1941 to 1948 was over 2,500,000 pounds. Louisiana was the largest producer up to 1939. Since 1946 Idaho has been far in the lead with an average production in 1946 to 1948 of over 1,600,000 pounds.

LADINO CLOVER

(Trifolium repens var.)

The phenomenal extension of popularity of Ladino clover (or Ladino white clover) across the continent from the valleys of Oregon and California east to the New England and the North Atlantic States, and from Minnesota and New York on the north to Texas, Louisiana, and Georgia on the south, is comparable to the extension of alfalfa and bromegrass far beyond the areas of earlier production. Like both of those crops, Ladino clover did not become popular in areas with different climatic conditions until certain peculiar requirements of the crop were recognized and observed in its culture and use. However, these minor handicaps which showed up earlier have been largely overcome so that now Ladino clover competes with all other forage legumes for first place as a pasture crop.

Ladino clover is rapidly becoming the foundation of an intensive grassland agriculture over a large part of the United States. Its culture and soil requirements in some respects are more exacting than those of common white clover and its seed habits are not so good, but the diversity of its uses, its high carrying capacity for all classes of livestock and poultry, the high nutritive value of the forage, and its general adaptation are important characteristics which give it a dominant position as a pasture crop. Although primarily a grazing crop, Ladino clover is being used also for hay and silage, particularly in combinations with grasses and other legumes, and also as a cover crop.

When Ladino clover first came to be recognized as a promising addition to our pasture legumes, it was considered particularly for the Central and Northwestern States, as well as for its earlier home on the Pacific Coast. In recent years, however, it has become prominent and is really establishing itself in the agriculture of practically all States where there is an ample water supply, either natural or artificial.

Ladino clover appears to have come
from and to have derived its name from Lodi, a town in the Province of Lombardy in northern Italy, where it was first found to be growing extensively. Seed was brought into the United States shortly before 1900, but it was not until 1912 that large quantities were imported and the crop successfully grown in the irrigated valleys of the Western States.

DESCRIPTION

Ladino clover is a large type of white clover (Trifolium repens) with the same general habits of growth as the common white clover. It is a rapid-growing perennial spreading by creeping fleshy stems that root at the nodes. Depending upon the favorableness of the soil, climate, and management, the leaves, stem, and flower heads of Ladino clover grow from 3 to 5 times as large as those of the English wild white clover.

The shape, color, and markings of the leaves, and the shape and color of the flower-heads of Ladino clover, are similar to those of the common white clover. Ordinarily Ladino clover does not flower so profusely as most other types of white clover. In more or less thin stands, or when young, the leaves are relatively far apart, giving an open appearance. In size and color Ladino clover seed is the same as that of other white clovers.

ADAPTATION

Ladino clover has about the same soil and climatic requirements as ordinary white clover. It is capable of surviving cold winters in most of the Northern States if given proper fertilization, proper grazing or cutting management, and compatible grass association.

In portions of Minnesota, Ladino clover is reported not to be fully winter hardy. Further studies there and in other Northcentral States should be made before an unqualified recommendation of Ladino for pasture use under those conditions can be made.

Ladino clover has been considered as best adapted to the more fertile moisture-retaining soils in the States having relatively cool summer temperatures. However, good stands and growth have been obtained on thin upland soils by means of heavy fertilizer applications, and excellent results are recorded in the northern parts of some of the Southern States where these supposedly ideal conditions do not prevail. Although Ladino clover is not drought-resistant, it will tolerate periods without rainfall if associated grasses do not offer too much competition. In the Great Plains and Intermountain States of lower rainfall, Ladino clover has given excellent returns under irrigation. In some places stands of Ladino clover have been lost when sown on soils that remain wet for long periods.

ESTABLISHING A STAND

Preparation of seedbed: For early spring sowing, fall plowing is recommended, as it provides an opportunity for the soil to settle during the winter months. For fall sowing, the soil should be prepared during the summer months. For all seedings the soil should be thoroughly compacted, preferably with a corrugated roller. A loose seedbed is the forerunner of stand failure. Fertilizers should be applied to the soil before it is disked, harrowed, and rolled to prepare a firm seedbed. In moist years good stands have frequently been established on thin turf by thorough disking, harrowing, heavy fertilizing, sowing, and rolling.

Sowing the seed: Ladino clover may be sown alone or with grasses and other legumes, with or without a companion grain crop. When sown alone, one or two pounds of seed, or at most three pounds per acre should be adequate, provided the seedbed has been thoroughly prepared and the sowing properly done. Heavier rates of sowing are often recommended but hardly seem necessary. If sown in combination with other legumes or grasses, one-half pound per acre will usually give a good stand of Ladino, but one to two pounds are more often recommended. With the present high
cost of Ladino seed, one is inclined to use the smallest quantity that will bring satisfactory results.

Ladino clover seed often contains a high percentage of hard seed, and unless there is an actual germination of 60 percent, it should be scarified. The presence of from 10 to 40 percent of hard seed is not objectionable, however, because the delayed germination of such seed may insure the establishment of a stand if some of the early seedlings are killed by unfavorable weather conditions.

Ladino in clover mixtures: Under the most favorable fertility and moisture levels, orchardgrass appears to be a suitable grass to grow with Ladino clover, as it withstands frequent grazing. Sometimes, however, orchardgrass, if sown at a heavy rate, tends to crowd out the Ladino clover by the end of the second year.

Timothy and Ladino clover mixtures have been successful, particularly where the soil productivity level is not high, or where summer temperatures remain favorable for a continuous growth of timothy. Mixtures of Ladino clover and alfalfa, red clover, alsike clover, bromegrass, meadow fescue, or reed canarygrass also appear promising.

Under favorable conditions for Alta and Kentucky 31 fescues, they may prove to be too vigorous growers to be used with Ladino clover, especially when no other crops are sown with them. Both Ladino clover and these tall fescues are outstanding pasture crops, but should be used in mixtures with other crops, and if any of the tall fescues are used, they should be sown at a light rate. For short rotations, meadow fescue, because of its less vigorous growth, shorter life, and finer texture, may be a more suitable component part of mixtures in which Ladino clover is included than any of the tall fescues.

A mixture of 2 pounds of Ladino clover seed and 4 to 6 pounds of orchardgrass seed per acre has been extensively used, but a smaller quantity of Ladino in some localities is being used with good results. Under most favorable conditions for the grass, this rate of sowing of orchardgrass has frequently resulted in a pure grass pasture by the end of the second year. At the higher fertility levels the following seed mixture and rates per acre have proved satisfactory: Oats, 1 bushel; red clover, 5 pounds; alsike clover, 2 pounds; Ladino clover, 2 pounds; orchardgrass, 3 pounds. At lower fertility levels or where summer temperatures are relatively cool, from 5 to 7 pounds per acre of timothy seed may be substituted for orchardgrass.

Kentucky bluegrass should not be sown with Ladino clover except when a permanent grass pasture is desired, as the Kentucky bluegrass tends to crowd out the Ladino clover. This condition may also obtain with bromegrass in areas especially favorable for bromegrass. Many seed mixtures have been recommended, some of which have resulted in a predominance of grass to the detriment of the Ladino clover, which has tended to discourage the use of any grass in the mixture. This is unfortunate, as a grass mixture counteracts the excessive succulence of pure Ladino clover, reduces the hazard of bloating, and facilitates the curing of the hay and the handling of the herbage for silage.

Fertilizers: Like alfalfa and many other legumes, the high production potentiality of Ladino clover indicates that it requires large quantities of available plant food, particularly minerals. The addition of substantial quantities of phosphates, calcium, and potash is necessary for satisfactory plant growth. The quantities to use depend upon the character of the soil and the previous cropping practices. Four to six hundred pounds per acre of 20 percent superphosphate and if there is a potash deficiency, 200 pounds per acre of muriate of potash, or their equivalents, have been profitable. In establishing a stand small amounts of nitrogen in some instances have been beneficial. Three to five tons per acre of well-rotted manure worked into the soil before sowing aids rapid establishment of a stand and growth but does not take the place of mineral fertilizers.

Ladino clover responds to annual top dressings of fertilizers, as the greater part
of its root system is shallow. In the North, applications should be made in the early spring, but farther south fall applications are generally preferable. The returns from Ladino clover more than compensate for the cost of the additional fertilizer.

**Life of Ladino clover:** The average life of a field of Ladino clover and grass is from four to seven years, depending upon the fertilization and management practices and the rate of encroachment of Kentucky bluegrass from either voluntary stands or seeding. If a stand of Ladino clover is crowded out by a thick growth of Kentucky bluegrass and reestablishment is desired, the turf should be fall-plowed and planted to corn or another cultivated crop the following year, after which Ladino clover may be sown. Care should be taken in the cultivation to thoroughly kill the bluegrass, otherwise it will spread rapidly.

**USES OF LADINO CLOVER**

**Pasture:** All classes of livestock have been grazed on Ladino clover or Ladino-clover-grass mixtures with excellent results. It is particularly valuable for dairy cattle and poultry where a high-yielding, nutritious, high-protein feed is needed, where labor is scarce, and where land suitable for cultivation is limited. Methods of grazing and heights at which the clover is grazed largely determine the amount of forage produced and the length of life of the stand.

Rotation grazing, which permits the development of new growth before the animals are turned back into the field, has been found to increase the carrying capacity and prolong the life of the stand. After each grazing the clover should be allowed to grow to a height of 8 to 15 inches. Ladino clover should not be grazed closer than 3 to 5 inches. Close, continuous grazing delays recovery, weakens the plants, and encourages the encroachment of Kentucky bluegrass.

Maximum utilization can be obtained when the cattle are permitted to graze until they complete a fill and are then removed. On good stands with good growth, two to three hours’ grazing in the morning and for a similar period in the afternoon are sufficient. This practice minimizes the loss of good grazing by flattening as the animals lie down to ruminate. Because heavy grazing is conducive to winterkilling, lighter grazing should be practiced in the fall. It is believed that grazing mature leaves reduces the possibility of bloat in cattle and sheep, as young succulent leaves are more conducive to bloat.

**Hay and silage:** Although primarily a grazing crop, Ladino clover is increasingly used for hay and silage, particularly when grown with other legumes and grasses. A heavy growth is difficult to cure, because of the high water content of the herbage, and in ensiling the crop this must be taken into account. A good quality of Ladino clover-grass silage can be made by allowing it to wilt in the swath and by the use of preservatives.

Oats used as a companion crop with the mixture of red clover, alsike clover, Ladino clover, and orchardgrass may be grazed off when approximately one foot high. The red clover and alsike clover, together with the oats, furnish the bulk of the grazing the first year. If preferred, the first crop may be harvested for hay or silage and the subsequent crops grazed or made into hay. In the second and third years Ladino clover and the grass compose more of the herbage.

**LADINO SEED PRODUCTION**

**How to produce seed:** There are four rules that are important in the sowing of Ladino clover seed for forage, but they are especially important and cannot be over-emphasized when sowing for seed production. (1) Use only certified seed; (2) use seed free from noxious weed seeds; (3) sow only on land free from noxious weeds or weed seeds; and (4) have a well-prepared firm seedbed. A few extra dollars in money and a few extra hours of time and effort spent in obtaining these four essentials will pay big dividends in seed production.

In Oregon and California most of the Ladino clover seed is grown under irriga-
LADINO CLOVER

...tion at altitudes below 3000 feet. In the Intermountain region of Utah, Idaho, and Montana, some of the seed fields are located at somewhat higher altitudes. Along the Gulf Coast Ladino clover does not bloom freely so little or no seed is produced there, and practically no natural reseeding takes place.

Because cross-pollination is necessary for seed formation, it is advisable to move hives of honeybees adjacent to the fields before the plants bloom. A minimum of one hive per acre materially increases seed production.

The period of greatest blooming is generally in the latter part of June and in early July. Bright, warm, dry weather is conducive to abundant flowering. During cool, moist, cloudy weather the plants continue to make rapid vegetative growth and bloom sparingly, with the result that the seed yield is low. Grazing or clipping the early lush spring growth is conducive to free blooming, or the early growth may be pastured and followed by a cutting for hay before leaving for seed. If the clover is grazed, the cattle should be removed four to six weeks before the time when the maximum number of flower heads is expected. Greater uniformity of growth and seed setting usually follow a hay cutting than a period of grazing.

Harvesting and threshing: In the area of largest Ladino seed production in southern Oregon, Ladino clover for seed is grown only under irrigation. The seed crop is usually taken from the second or third cuttings, the one before the seed crop always being cut for hay. The first cutting is usually too grassy for profitable seed production. Late spring and early summer pasturing is considered detrimental to seed production. Close grazing encourages the growth of common white clover in the fields of Ladino.

If the third cutting is left for seed, the previous cutting is removed the latter part of June. Usually the seed is ready for harvest three to four weeks after the greatest number of flower heads have bloomed. It requires from 60 to 75 days after the hay cutting to mature the seed crop which should be harvested when nearly all (75-90%) of the heads are brown and the stems start to become dry, which is usually late in August or early in September.

The seed crop may be cut with an ordinary mower, windrowed with a side-delivery rake, shocked and cured three or four days in the field before threshing, or it may be cut with a mower with windrowing attachment and picked up and combined direct from the windrow. If shocked, it may either be threshed directly from the shock or stacked for threshing later. It is usually threshed with a stationary threshing machine with clover hulling attachments. Clover hullers would be better for this purpose but are not usually available. After the crop is harvested and dried, it should be handled with care through all operations to avoid loss of seed by shattering.

Since Ladino clover seed has not been produced in large commercial quantities east of the Rocky Mountains so far, little can be given of the best methods of handling the crop for seed production in that region until more experience has been gained in areas where seed production may become feasible and profitable.

Weed seeds: With proper attention to preparing and handling seed fields comparatively little trouble has been experienced with weeds in Ladino under irrigation. The weeds most commonly troublesome, none of which are classed as "primary noxious weeds," are buckhorn, pigweed, dock and sorrel, with occasional dodder.

Ladino seed statistics: The commercial production of Ladino clover seed on which records are available started in 1936 with a production in Oregon of slightly over 100,000 pounds. Since then, there has been almost a gradual increase to a high in 1949 of nearly three and one-half million pounds from 25,800 acres. The average production for the three-year period (1936-38) was 130,000 pounds, for the 6-year period (1939-44) 507,000 pounds, and for the 4 years (1945-48) 1,100,000 pounds. In 1949 it reached the record high of 3,400,000...
pounds. The average yield of seed per acre for this 13-year period was 80 pounds.

Nearly the entire production of Ladino clover seed has been in California and Oregon. The averages for the 6 years (1943-48) were 360,000 pounds in Oregon and 575,000 pounds in California. In 1949 the Oregon production increased to 2,200,000 pounds and California to 1,100,000 pounds. Idaho has developed a small acreage in recent years which, for the 6 years (1944-49), averaged 83,000 pounds of seed.

The larger part of the Ladino clover seed is produced in the Western States under irrigation. Some seed is produced in small quantities in scattered localities of the Central and Eastern States, but in all such localities, that produced is required for local use and does not enter commercial channels to any extent. In the Eastern States the generally unfavorable climatic conditions and the difficulty in keeping fields free from common white clover make seed production hazardous as a farm enterprise.

**LADINO CLOVER HIGHLIGHTS**

1. Ladino clover is altogether the most promising pasture legume in the United States today.

2. In feed value Ladino clover is equal or superior to other forage legumes. It is very palatable, high in proteins, minerals and vitamins, and low in fiber.

3. Ladino clover appears to give up as much or more nitrogen to associated grasses than any other legume, and is a valuable soil-improving crop.

4. Ladino clover is an excellent crop in pasture mixtures, either with grasses or with other legumes, or with both grasses and legumes.

5. Under proper management, Ladino clover, with a compatible grass combination in areas where both are adapted, can produce more and better pasture than any other legume-grass mixtures.

6. Ladino clover may be used in mixtures including red and/or alsike clover and timothy or bromegrass to provide nutritious hay or pasture for two or more years.

7. Ladino clover is not as good a seed producer as common white clover, therefore, the price of seed will probably remain relatively higher.

8. The relatively small quantity of Ladino clover seed required in pasture mixtures makes the relatively high price per pound of small consequence.

9. Ladino clover in pasture mixtures in areas where it is adapted can do more to reduce the quantity of high-protein feeds required, and thereby the cost of cattle and poultry rations, than any other pasture legume.

10. Ladino clover is extremely aggressive under favorable conditions and retards the encroachment of most weeds and many undesirable grasses.

11. Because of the vigorous growth of orchardgrass and the tall fescues, they should be used cautiously in mixtures with Ladino clover.

12. Ladino clover tolerates wetter conditions and poorly drained hardpan soils where alfalfa does not survive, and is injured less by heaving than alfalfa and red clover.

13. For best results Ladino clover should be grazed in rotation and should not be grazed closely.

14. In order to reduce bloat hazard and increase the quantity and quality of pasture, Ladino clover should be used in combination with compatible grasses.

15. For best results Ladino clover should not be sown with Kentucky bluegrass or in fields where Kentucky bluegrass has not been eradicated.

16. Ladino clover provides an excellent ground cover which is effective in reducing water losses due to run-off and soil losses by erosion.

17. Ladino clover is reestablished from natural reseeding, if properly managed.

18. It starts growth very early in the spring, recovers rapidly after grazing or mowing when moisture is adequate, and remains palatable to all livestock up to maturity.

19. Mineral fertilizers should be applied generously to Ladino clover.

20. Ladino clover requires lots of moisture, either natural or artificial, for best results. It will withstand short periods of drought but is not productive during the dryer parts of summer or in dry seasons.

21. Pure stands or those with a high percentage of Ladino clover are hard to cut because of heavy tangled growth, and hard to cure because of the high moisture content.

22. Ladino clover does not appear to be win-
CRIMSON CLOVER

Ter hardy in severe winters in the Northern States, or adapted to the deep South near the Gulf.

23. Ladino clover is an aristocrat among pasture plants so do not sow it unless you wish to apply intelligent judgment to your pasture management.

CRIMSON CLOVER

*(Trifolium incarnatum)*

Crimson clover is the most important winter annual legume of the central section of the Eastern States. This crop can be grown over a much larger area by using seed of adapted varieties for each section, by using better cultural methods, and by fertilizing the soil. Besides being an excellent pasture plant and furnishing plenty of hay, it protects the soil during fall, winter, and spring, prevents soil washing, and provides green manure for soil improvement. This legume has the distinct advantage of producing large quantities of seed that can be easily harvested and sown without the use of expensive machinery.

Crimson clover is a native of Europe and is widely grown in France, Hungary, and other central and southern European countries. Seed was introduced into this country as early as 1819, but it was not until 1880 that the plant became important. The acreage has been steadily increasing.

DESCRIPTION

Crimson clover is a winter annual growing from one to three feet tall and having cylindrical heads of bright crimson showy flowers, from which it derives its common name of crimson clover. In general the leaves and stems resemble those of red clover, but are distinguished by the rounded tips of the leaves and more hair on both leaves and stems. When crimson clover is sown in fall, the leaves develop from the crown and form a rosette which enlarges whenever weather conditions are favorable. In spring, flower stems develop rapidly and end their growth with long-pointed flower heads. Seed forms and the plant dies with the coming of hot summer weather. The seed is yellow and is about twice as large as red clover seed and more rounded.

ADAPTATION

Crimson clover does well in cool, humid weather and is tolerant of winter conditions where the temperature does not become severe or too changeable. It may be sown from midsummer to late...
fall. In the northern part of the region early sowing and growth are necessary for the seedlings to survive the winter. It will thrive on both sandy and clay soils and is tolerant of ordinary soil acidity. On very poor soils, stands are difficult to obtain and the growth is stunted. The use of phosphate and potash fertilizers and manure on such soils will help to obtain good stands.

Crimson clover may also be grown successfully as a summer annual in northern Maine, Michigan, and Minnesota. Winter culture can be extended into Kentucky, southern Missouri, southern Indiana, and Ohio, provided varieties are grown that are adapted to these sections and the seed is sown in fertile soils early in August.

ESTABLISHING AND MAINTAINING A STAND

The most important and difficult part of producing a large crop is getting a stand. Enough soil moisture to sprout the seed and establish the seedlings is the greatest factor in obtaining a stand. When established, common crimson clover usually produces a good crop.

Sowing the seed: Seed may be sown alone or combined with winter grains, rye grass, or grass sod. It is possible also to sow between the rows of cultivated crops, but it is difficult to make an ideal seedbed. Furthermore, the crop plants in the row shade the clover seedlings and use some of the available moisture. If the row crop is in wider rows with a thinner stand, the clover will become better established. When sown between the rows of other crops, the seed is usually broadcast on the surface and covered by cultivating or harrowing. Drilling the seed after the soil surface has been stirred usually gives more complete stands than broadcasting, and it may be done with a small one-horse drill. The seed should not be sown more than one-half to three-fourths of an inch deep, respectively, in clay and sandy soils.

Crimson clover is often sown following a grain crop. This is a surer method of establishing a stand than sowing between the rows of cultivated crops, provided the seedbed is well prepared. After the grain crop is harvested the soil is plowed or disked and allowed to settle. This is followed by light harrowing or diskling to kill weed seedlings. Before the clover is sown the soil should be firmly packed, because a loose cloddy seedbed will not produce good stands. The seed may be either drilled or broadcast, but drilling will give more uniform stands.

Rate of sowing: Under ordinary conditions 12 to 15 pounds of hulled seed to the acre will give good stands unless there is lack of soil moisture. Depending upon the quantity of chaff and pieces of stems, 45 to 60 pounds of unhulled seed is comparable with 15 pounds of hulled seed.

Time of sowing: Crimson clover may be sown from the middle of July until November, depending upon the location, with the expectation of obtaining a good stand. The later it is sown the less growth can be expected and the more readily winterkilling occurs. Early establishment becomes more important as plantings are extended northward. Sowing crimson clover either immediately before or following heavy rains, if possible, increases its chances of making a stand. Spring sowing in or south of the Corn Belt usually results in a short, stunted growth followed by little blossoming and low yield.

Use of unhulled seed: Using unhulled common seed increases the chance of obtaining thick stands. When the soil is dry, light rainfall does not cause the unhulled seed to sprout, but hulled seed germinates readily and the seedlings may die from lack of moisture before they can become established.

Its bulky nature makes unhulled seed more difficult to distribute uniformly than hulled seed. It must be broadcast and may be harrowed in. It is also difficult to market and is not generally handled by the seed trade. But farmers can harvest seed for their own use and save the expense of having it hulled.

Sowing on grass sod: Crimson clover frequently may be sown to advantage on either a bluegrass or a Bermuda sod, as demonstrated for several years at the
CRIMSON CLOVER

Lewisburg (Tenn.) Dairy Station (Tenn-11). In this case, no attention to soil preparation is required; but either the grass should be short—say 2 inches high or less—or the turf open. The growth, of course, lacks much of equaling that obtained on especially prepared land, but may add materially to the early spring pasture, and later will promote the growth of the grass. For this sowing, early October is considered a favorable time. Sowing on Korean lespedeza pasture or stubble offers worthwhile possibilities for pasturage and soil improvement or for a seed crop, but if the crimson clover is allowed to make a heavy growth, the volunteer stand of lespedeza will be greatly impaired.

Fertilizers: Good stands and growth cannot be expected on very poor soils. Soil conditions can be improved by adding phosphate and potash fertilizers and manure, or by turning under such crops as cowpeas, soybeans, or lespedeza. In many soils of low fertility the use of a complete fertilizer will encourage early seedling growth and establishment. On fertile soils crimson clover may be successfully grown without fertilizer, but on most soils applications of 200 to 400 pounds per acre of phosphate and 50 to 100 pounds of potash pay in obtaining good stands and vigorous growth.

Frequently a single large application of phosphate and potash fertilizer is sufficient to produce two crops of crimson clover before it becomes necessary to make another application. In some soils the addition of such minor elements as boron may improve growth and increase seed yields. Since the need for minor elements varies from place to place, their use should be based on the recommendations of the agricultural experiment station of the State in which the clover is to be sown.

Inoculation of seed: In many areas where crimson clover has been grown successfully for several years, it is not necessary to inoculate the seed with bacterial cultures for the production of nodules. But the seed should be inoculated if crimson clover has not been grown. If the plants are not inoculated they will develop slowly, become yellow, and die. Inoculated plants are able to obtain about two-thirds of their nitrogen from the air through their root nodules. The plants may be artificially inoculated by applying cultures of the bacteria to the seed.

When crimson clover is grown for the first time, an additional inoculation treatment is recommended if weather conditions are dry and hot after sowing. This supplemental inoculation consists in mixing commercial cultures with sand, soil, or cottonseed meal and broadcasting the mixture over the soil surface during cloudy, rainy weather as the young seedlings are emerging. A bushel-size culture mixed with 60 pounds of the above-mentioned material is sufficient for an acre, if distributed evenly.

Companion crops: Rye, vetch, ryegrass, and fall-sown grain crops are often seeded with crimson clover. Such crops are sown at half to a third the normal rate, and the crimson clover is seeded at half to two-thirds the normal rate. Seeding is done at the same time, but as a greater depth is required for most of the seed of the companion crops, two sowing operations are necessary.

Farmers often use a mixture of 5 pounds of red clover and 10 pounds of crimson clover per acre with excellent results. The first growth of the mixture may be grazed or harvested for hay or for crimson clover seed, while the second crop is wholly red clover. Dixie crimson clover has given good results when planted with Johnson and Bermuda grasses.

DISEASES AND INSECTS

The most serious disease that affects crimson clover is crown rot. The effect of this disease is seen early in spring and is characterized by the plants dying in patches. The stems rot at the surface of the soil or where they join the crown. Continued damp, cool weather during winter and early spring favors the development of the disease. This disease can be controlled by not growing clover or other legumes in rotation for 2 to 5 years.
Sandy soils in the southern part of the crimson clover belt are often infested with nematodes. Nematode injury stunts and yellows the plants. While the clover seed chalcid, the pea aphid, and other insects sometimes become numerous in crimson clover, insects do not ordinarily cause appreciable damage. Further information on diseases and insects is given in chapter IX.

**UTILIZATION**

**Pasture:** Crimson clover grows rapidly in fall and spring and furnishes an abundance of grazing. If planted early and good fall growth is made, the clover may also be grazed during the fall and winter months. Such a practice has been successfully followed in many States where crimson clover is providing winter pasture. Crimson clover combined with small grains or ryegrass has been most widely used for winter grazing. It makes little growth during cold periods in winter. Under such conditions, to prevent close grazing, it is necessary to remove the animals or shift them to other fields that have not been grazed. In Oregon, subclover is somewhat more popular for pasture than crimson clover, as the latter is said to become tough and unpalatable.

Animals grazing on crimson clover seldom bloat; however, it is not advisable to turn them into clover fields for the first time when they are hungry. Bloat is less likely to occur on a mixture of clover and grass or grain than when clover alone is grazed. As crimson clover reaches maturity the hairs of the heads and stems become hard and tough. When it is grazed continuously or when it is fed as hay at this stage, large masses of the hairs are liable to form into hair balls in stomachs of horses and mules, occasionally with fatal results. If small quantities of other feeds, particularly roughages, are fed along with the clover, the formation of these balls will be reduced. Cattle, sheep, and swine do not seem to be affected.

**Hay:** Crimson clover is not used generally for hay, but makes excellent hay when cut at the early-bloom stage, although the yield may be slightly reduced. For best yields it should be harvested in full bloom. The hay is easily cured either in the swath or in the windrow. Fewer leaves are lost and less bleaching occurs in windrowed hay. Although yields as high as 2½ tons per acre are not uncommon on fertile soil, 1½ to 2 tons is the usual harvest.

**Green manure:** Crimson clover is an ideal green-manure crop. For best results it should be plowed under 2 to 3 weeks before the succeeding crop is planted. This gives enough time for decomposition which is rapid unless the crop is ripe when turned under. Occasionally strips are plowed in which row crops are to be planted, allowing the clover between the plowed strips to mature. Seed may be harvested by hand from the clover between the row crops and the remaining clover straw allowed to mat and serve as a mulch, or the entire plant may be permitted to form a mulch.

**Silage:** Crimson clover may be made into silage by the same methods as are used for other legumes and grasses. In orchards it is often allowed to mature, after which it is disked into the soil. A volunteer stand from shattered seed may be obtained in fall by using the Dixie variety.

**VARIETIES**

The seed of common crimson clover, one of the most important forage legumes of the southeastern States, has the undesirable characteristic of immediate germination. This may occur at any time throughout the summer after seed is mature, or after sowing in the fall. Light rains frequently provide enough moisture to establish the seeding plants. For this reason, stands of common crimson clover are frequently lost.

Recognizing this weakness of common crimson clover, the Georgia Coastal Plains Station and the North Carolina Experiment Station, in cooperation with the United States Department of Agriculture, collected many samples from farms where crimson clover had been grown continuously on the same farm for a period of at least 10 years as founda-
tion material for the development of a variety that would be more satisfactory than common crimson clover in meeting these conditions.

After extensive testing, three strains, Allen, Hardy, and Thornton were selected from these as outstanding in growth and as having the desired volunteering characteristic. Laboratory germination tests and field studies showed that these strains had a high hard seed content and successfully developed volunteer stands under wide variations of field conditions.

**Dixie crimson clover**: Dixie crimson is a composite of equal proportions of the three superior strains, Allen, Hardy, and Thornton. Dixie crimson clover or one or more of the component strains, has produced good volunteer stands for a period of several years at Quincy, Florida, Beaumont, Texas, Statesville, North Carolina, Tifton and Experiment, Georgia, and as far north as Columbia, Missouri, and New Brunswick, New Jersey. These results indicate that Dixie crimson clover may be even more widely adapted than common crimson clover.

The seeds and plants of Dixie crimson clover cannot be distinguished from common crimson clover. Since common crimson clover will contaminate Dixie crimson clover, both by cross pollination and by mechanical seed mixtures, it is imperative that only certified seed of Dixie crimson clover be recommended for seed production in order to maintain varietal purity and to insure purchasers that the variety is true to name.

It is fortunate that Dixie is widely adapted for use in the southeastern part of the United States so that seed of this one variety can be produced in various localities and blended to form large uniform lots for commercial distribution and thus become more generally established.

**Auburn crimson clover**: Auburn crimson clover is a strain of crimson clover selected from an area near Auburn, Alabama, where it has been volunteering since sometime prior to 1921. It cannot be distinguished from ordinary crimson clover. This strain of crimson clover has been used in combination with grain sorghum, Sudan grass, Johnson grass, soybeans, and in permanent pastures. The clover has given satisfactory volunteer stands when followed by the above summer crops. Better results are obtained in central and northern Alabama than in the extreme southern part of the State.

Following combining, the area is prepared and planted to the summer crop. The crimson clover volunteers during the late summer and early fall in the summer crop, or in the stubble following the harvesting of the summer crop.

**SEED PRODUCTION**

Crimson clover is a heavy seed-producing plant, and yields of 300 to 600 pounds per acre are common, depending upon the thickness of the stand, the extent of growth produced, and the care used in harvesting the seed. The statistical average annual yield for the past 10 years is about 240 pounds, ranging from an average of 188 pounds in 1947 to an average of 312 pounds in 1942.

The florets are self-fertile, but bees increase the number of seed per head by tripping and transferring the pollen. Placing colonies of honeybees next to blooming fields will increase pollination.

More seed is usually produced on soils of medium fertility than on rich soils, since fertile soils seem to stimulate the growth of stems and leaves rather than develop flower heads.

Large yields and ease of harvesting seed are two important reasons why crimson clover is such an ideal legume crop. Farmers can save seed with very little expense other than their own labor. In Oregon the oft-recurring unfavorable weather at harvest time, often destroying the crop, has prevented many farmers from trying to produce crimson clover seed.

When the seed heads are mature they readily shatter and are easily harvested either by hand stripping or by using horse-drawn home-made strippers. One bushel of unhulled seed contains about 2 pounds of hulled seed, and although bulky, it can be easily stored on the farm until fall.
When the seed is mature the crop is cut with a mower which may be equipped with a bunching or windrowing attachment, or it can be harvested with a combine. During wet seasons it is sometimes difficult to combine the seed from standing plants. Under such conditions the plants can be cut and windrowed and then threshed by the combine from the windrow. As crimson clover shatters easily when ripe, cutting with the mower when the heads are damp with dew or rain is recommended. If it is allowed to stand too long after ripening, a beating rain will shatter much of the seed. After a few days of curing, the seed is hulled with an ordinary clover huller, with a grain separator equipped with hulling attachments, or by a combine with pickup attachments, or used as a stationary machine. The less the clover is handled, the less seed will be lost by shattering.

Many troublesome weeds are encountered in growing crimson clover seed; field peppergrass (Lepidium campestre) and wintercress (Barbara praecox), and the bulblets of wild onion (Allium spp.), are probably the worst. Seed of the mustards, rapes, and turnips (Brassica spp.), dock (Rumex crispus), wild geranium (Geranium dissectum), sorrel (Rumex acetosella) and catchweed (Galium aparine) are also found in the seed. Little barley (Hordeum pusillum) is a pest in unhulled seed, and the use of such seed will naturally increase the prevalence of this weed.

Imports of crimson clover seed: Prior to World War II, most of the crimson clover seed used in the United States was produced in Europe. Since then, the imports have been practically nil, except that several hundred thousand pounds have been imported from Italy during the last two or three years. The average annual imports from Europe for the 10-year period (1922-31) were over 3,700,000 pounds; for the 4-year period following (1932-35) they declined to an average of 1,160,000 pounds; during the 5-year period immediately prior to the war (1936-40), the imports more than reached the earlier 10-year period, averaging over 4,000,000 pounds yearly.

Production statistics: The United States production of crimson clover seed has gradually increased during the past 25 years. For the 9-year period (1922-30), the production was approximately 300,000 pounds. The production each year for the next 7 years was over 1,000,000 but less than 2,000,000 pounds, averaging 1,240,000 pounds. For the next 4-year period (1938-41) it averaged nearly 6,000,000 pounds, and for the last 8-year period (1942-49) it has averaged nearly 15,000,000 pounds. The 87,000 acres harvested for seed in 1949 and that year’s production of 18,000,000 pounds of seed were the largest on record, in spite of a lower than average yield per acre.

Over 60 percent of the crimson clover seed production during the past 10-year period has been in Tennessee. Prior to then, that State was the only producer of commercial quantities of seed. The Oregon production for the past 8 years, except for the years 1941 and 1942 when it produced over 2,000,000 pounds each year, has averaged only a little over a half million pounds. The southern States of Alabama, Georgia, and Kentucky for the past 7 years have altogether produced an average of 4,500,000 pounds. These figures indicate that the United States is not likely to return to importing a large part of its crimson clover seed in the near future as it did before World War II.

CRIMSON CLOVER HIGHLIGHTS

1. Crimson clover is the most important winter annual legume of the central section of the Eastern States. Its acreage is steadily increasing.
2. Crimson clover thrives on both sandy and clay soils and is somewhat acid-tolerant.
3. Winter culture of crimson clover extends from the Southeastern States north into Kentucky and southern Missouri, Indiana, and Ohio. It is also grown as a winter legume in western Oregon.
4. Crimson clover may be sown from July to November alone, or with winter grains at the rate of 12 to 15 pounds of hulled seed per acre.
5. Crimson clover, combined with small grains or ryegrass, is widely used for winter grazing.
6. Crimson clover is not generally used for hay, but makes an excellent hay when cut in early bloom.

7. Crimson clover is an ideal green manure crop. Best results are obtained by plowing under two or three weeks before the succeeding crop is planted.

8. Crimson clover has the faculty of quick germination, which characteristic makes it difficult over dry periods to maintain stands in successive years by volunteer resowing.

9. Two new varieties, Dixie and Auburn, have been developed with a good percentage of hard seeds to overcome the hazard of quick germination. Stands of these varieties are easily maintained by volunteer resowing for several or many years.

10. Prior to World War II, most of the crimson clover seed used in the United States was imported from Europe. Since then (1940-48) the imports have been practically nil, except for small quantities from Italy (1946-48).

11. Seed production of crimson clover in the United States has increased in the past 20 years from an average of 300,000 pounds a year to an average for the past 8 years (1942-49) of nearly 15,000,000 pounds.

12. Nearly two-thirds of the United States production of crimson clover seed in the past 10 years has been in Tennessee. Alabama, Georgia, Kentucky, and Oregon also grow substantial quantities.

13. Large yields and ease of harvesting seed are two reasons why crimson clover is such an ideal legume crop. The statistical average yields of seed for the 10 years (1938-47) were 240 pounds per acre. Yields of 300 to 600 pounds of seed per acre are common in commercial seed-producing areas.

PERSIAN CLOVER

*(Trifolium resupinatum)*

Persian clover, a native of southern Asia Minor and the Mediterranean countries and a valuable pasture and hay plant of Persia and Egypt, has found a useful place in the agriculture of the Southern States. Its ability to produce feed in late winter and early spring when the southern grasses are dormant extends the grazing season. The forage is nutritious and is relished by all kinds of livestock and poultry. When grown with grass, Persian clover supplies nitrogen, as do other legumes, thus improving the quality and quantity of the grass. Once it is established with grasses and properly fertilized and managed, sowing is not necessary as an abundance of seed is produced for volunteer stands. Although primarily a pasture and hay legume, Persian clover is used in some places as a green-manure crop.

In 1928, following the Mississippi flood of 1927, Persian clover began to flourish in a section near Hamburg, Louisiana. Since that time it has spread rapidly through the sale of seed and from natural resowing. Earlier attempts to introduce this clover into the United States on a field scale were unsuccessful.

DESCRIPTION

Persian clover is a true winter annual. The seed germinates in the fall, and the plants grow throughout the winter months in the form of a low rosette. With the
advent of spring rapid growth occurs, and many slender upright flowers develop. Seed is produced in late spring or early summer, after which the plants die. Persian clover grows from eight inches to two feet in height, depending upon the favorability of growth conditions. When grazed heavily or when the stand is thin, the stems become decumbent, giving the appearance of a low spreading plant. When it is in the rosette stage, the leaves developing from the crown are similar to the leaves of young white clover plants, making identification somewhat difficult. However, the individual leaflets are slightly more tapering at the base than those of white clover. Persian clover stems do not creep on the soil surface nor root at the nodes as do white clover stems. The light purple flowers, forming a head somewhat flat in appearance during the early bloom stage, are self-pollinating and self-fertile and are borne in the leaf axils on stems from \( \frac{1}{2} \) to 2 inches in length. As the seed matures the calyx around each pod becomes inflated, forming small balloonlike envelopes which break off when mature and readily float on water or may be blown about by the wind, thus bringing about a wide dissemination of the seed. Persian clover seed is predominantly olive green and blackish purple; however, most samples contain some yellow and reddish-brown seed. The seed is difficult to separate from white clover seed.

ADAPTATION

Persian clover is best adapted to the low-lying, heavy, moist soils of the Southern States. It has been successfully grown as far north as Tennessee and makes good growth in sections of the coastal region of the Pacific States. It is not recommended for upland sandy soils. In the North, Persian clover is not winterhardy and makes only a short growth when spring-sown, and fails to reproduce. The occasional plants found in the northern humid States are the result of its occurrence as a mixture in Louisiana white clover seed.

ESTABLISHING A STAND

Preparing the seedbed: Although Persian clover is generally sown in a grass turf, successful stands have been obtained from sowing on cultivated soil. One of the main reasons for failure is the occurrence of hot dry weather before the seedling plants have become established. A firm seedbed is essential, and this may be obtained by rolling or dragging. The seed is usually broadcast and may be lightly covered. When sown on heavy soils between cotton or corn rows, a slight loosening of the surface soil is recommended before sowing. When the clover is sown on a grass turf, the grass should be either closely grazed or clipped before the sowing is done. While short grass serves as a protection against the rapid drying out of the soil, tall grass prevents the seedlings from obtaining sufficient light and in addition utilizes more of the soil moisture. The best stands are obtained on Bermuda-grass and Dallisgrass turfs. Although carpetgrass is less desirable because of its dense spreading growth, good stands have been obtained with it. Disking a thick carpetgrass turf, even to the extent of turning over slices of turf, aids in the establishment of a stand and has the added advantage of placing the fertilizer deeper.

Sowing the seed: Persian clover must be sown in the fall to produce good yields the following spring. When spring-sown, the plants make a dwarfed growth and die before setting sufficient seed for a satisfactory volunteer crop. The most favorable sowing is at the beginning of fall rains, which varies from place to place and from season to season. Even in the southern part of the region sowing should be done by the middle of December for best results. If conditions are favorable for germination and stand establishment, 5 to 8 pounds of seed per acre will produce a good stand. With lighter rates of sowing, or when dry, hot fall weather occurs, the stand the first year is frequently thin. The second year's volunteer stand should be thick, however, if the first year's sowing has been properly managed as Persian clover is a heavy seed pro-
PERSIAN CLOVER

Gucer. "Here an individual field varies in fertility and contains both upland and lowland soil, a mixture of 2 pounds per acre each of Persian clover, hop clover, and white clover is recommended.

Fertilizers and lime: Persian clover can be grown successfully on medium to slightly acid soils. On strongly acid soils 1 to 2 tons per acre of finely ground limestone is recommended. This should be applied in midsummer for best results. All fertilizer applications should be made in the fall shortly before sowing, or in the fall of following years just before the volunteer seed is germinating. All fertilizers may be either drilled or broadcast. However, drilling is preferred, as with this method the fertilizer is placed in the soil and concentrated in the drill furrow, making the plant food available over a longer period. In some cases disk ing the sod before broadcasting has aided stand establishment and increased yields. In rotations the available residual minerals from applications to cultivated crops are sometimes sufficient to produce satisfactory stands and good yields. If they are not sufficient, supplemental quantities should be applied by drilling preferably, or by broadcasting, immediately before sowing.

For successful growth Persian clover requires mineral fertilizers. On soils somewhat deficient in minerals, stands can be established, but the plants are dwarfed and seed production is meager. It does not require so high a fertility level as white clover but does require a higher one than hop clover.

Phosphate deficiencies vary throughout the entire southern region. On the more fertile soils, 200 pounds per acre of 20-percent superphosphate, or its equivalent, applied in the fall at time of sowing has given excellent results. On less fertile soils as much as 500 pounds per acre may be needed to produce similar growth. Following the large initial application, supplemental quantities from 100 to 300 pounds per acre should be applied annually or every second or third year as needed. Potash is sometimes deficient, and where it is needed 100 to 200 pounds per acre of muriate of potash, or its equivalent, is recommended every second or third year.

Inoculation: Lack of inoculation is one of the principal reasons for failures to obtain productive stands. When the weather is hot and dry at sowing time, even inoculated seed sometimes fails to produce inoculated plants. Occasionally volunteer plants are un inoculated the second year, even though they were well inoculated the first year. Such occurrences are more frequent when the clover is used as a cover crop, and less when it is sown with grasses. Because of the availability and low cost of commercial cultures, and the often unsatisfactory results from other methods, the former are the most satisfactory to use. It is not necessary to inoculate, however, after Persian clover has been successfully grown in the same field for 2 years.

UTILIZATION

Pasture: Persian clover is an excellent grazing plant. It produces a high quality, nutritious, protein feed from late winter to late spring. It provides grazing from 10 days to 2 weeks earlier than white clover, but does not last so long in late spring. The greatest and most rapid growth is made during March, April, and early May, at which time it has a high carrying capacity, two cows per acre being not uncommon on bottom lands.

The grazing of Persian clover should be started early. Light winter grazing is possible if good stands can be established early in the fall. Heavy grazing is not recommended in late spring, because the rapid removal of most of the top growth when the plants are beginning to bloom kills them before they have a chance to produce seed. However, if they are only lightly grazed during the last thirty days, the growth of associated summer grasses may be pronouncedly checked, causing a gap in the grazing period from the time when the clover dies until the grass has recovered from crowding. Moderate grazing is desirable since it shortens this period and the grasses are less adversely affected.

Where soil conditions are favorable to
white clover and a mixture of Persian and white clover is sown, continual close grazing favors a rapid increase of white clover and a corresponding decrease of Persian clover. The spreading of animal droppings in a clover pasture is not recommended as the ungrazed plants growing around the droppings set an abundance of seed valuable for resowing. The combination of Persian clover and lespedeza is not recommended, because the Persian clover makes its most rapid growth when the lespedeza is starting and thus crowds out the latter. Persian clover should be grazed carefully in order to avoid bloat of cattle and sheep. The danger from bloat may be reduced by early and continued grazing, by having a mixture of grass and clover, and by giving the animals free access to strawstacks or haystacks.

Hay: Properly cured Persian clover hay is relished by all kinds of livestock and has a high nutritive value, as is indicated by analyses which show over 16 percent crude protein when the clover is in full bloom. Yields average from 1 to 2 tons per acre, depending upon the rate of fertilizing, method of handling, and seasonal rainfall. Persian clover should be cut for hay when the plants are from one-fourth to full bloom. The largest yield is obtained in the full-bloom stage, but the quality is higher when the hay is cut earlier. Although it has a high moisture content, Persian clover is not so difficult to cure as coarser stemmed legumes, such as cowpeas and soybeans. After being mowed, it should be allowed to wilt in the swath and then windrowed for final curing. If cut when in full bloom, a stage producing the most hay, it will not produce seed for resowing.

Green manure or cover crop: On heavy, low-lying soils of the Southern States the use of Persian clover as a green-manure crop is increasing with satisfactory results. When used for this purpose, it is frequently lightly grazed during the late winter and early spring months. If it is allowed to approach maturity before being turned under, yields of as much as 30,000 pounds per acre of green material have been obtained, and sufficient seed is placed in the soil for volunteer stands for 2 years. In following this practice, corn or sorghum is planted later than normal during the year that the clover is being left to replenish the seed for volunteer stands. When Persian clover is harvested for seed and is followed by a summer-growing cultivated crop, sufficient seed shatters to insure a thick stand in the fall. The value of the clover for soil improvement is not materially decreased where only the straw is turned under.

SEED PRODUCTION

Persian clover is a prolific seed producer. Under ideal conditions yields of 600 pounds of seed per acre have been harvested and a sufficient quantity of shattered seed left to produce a thick volunteer stand the following fall. Yields from 150 to 300 pounds per acre, however, are more common. The flowers are self-fertile and self-pollinating, which favors seed setting even under unfavorable weather conditions. Honeybees work Persian clover flowers for nectar and pollen, and are undoubtedly of help in increasing seed production. It is frequently difficult to save the seed because of shattering. The mature inflated seed capsules break off easily from the heads, and a heavy rain when seed is mature may mean a complete loss.

The use of Persian clover for both grazing and seed production is possible. For such use the clover should be grazed closely until approximately 4 weeks before it normally blossoms, at which time the animals should be removed. This practice reduces heavy vegetative growth and the prevalence of weeds and favors abundant uniform blossoming. This method is preferable to harvesting the entire growth, as an additional return is obtained from the crop, and the quantity of straw to be handled is reduced.

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The seed crop should be cut when the greatest percentage of the seed capsules have turned a light-brown color. Cutting is generally done by equipping the mower with lifter guards. In thick stands, and particularly when the crop is lodged and
entangled, the use of a heavy short weed bar without guards has proved effective. Although the crop can be cured in the swath, curing in the windrow is recommended. In windrowing the best practice is to roll the heads to the inside of the windrow, since this reduces shattering. The crop can be threshed either by grain separators equipped with hulling attachments, by combines used as stationary machines, or with attachments to pick up the crop from the windrow. The use of a combine direct is not recommended. The lightness of the inflated seed capsules and the losses from shattered seed should encourage experimentation with suction machines.

PERSIAN CLOVER HIGHLIGHTS

1. Persian clover, another legume from the Middle East, has found a place in southern agriculture. It is distinguished from other clovers by its lavender flowers and inflated fibrous pods. It also matures and dies before white clover.

2. Persian clover is adapted to low, heavy moist soils in the Southern States from Tennessee south. It will not thrive on sandy upland soils.

3. Persian clover extends the grazing season of southern pastures and stimulates its companion summer grasses.

4. Persian clover has a high feed value for both pasture and hay.

5. Persian clover pastures have a high carrying capacity during spring months from March to early May.

6. Persian clover produces more feed in late winter and early spring than white and hop clovers, and does not require as fertile soil as white clover.

7. Though primarily used for hay and pasture, Persian clover also is a good cover or green manure crop.

8. Persian clover has fertility requirements between white and hop clover. It requires phosphate, and usually, potash fertilizers on most soils.

9. Persian clover must be artificially inoculated. To insure success, double inoculations are often justified.

10. Sow Persian clover in the fall on closely clipped or grazed grass turf or on firm seedbed, at the rate of 4 to 8 pounds per acre. Where variable soil fertility and moisture conditions exist, sow 2 pounds each of Persian, white and hop clovers.

Best stands are obtained on Bermuda or Dallis grass-turf.

11. Grazing of Persian clover should start early but should be restricted because continual close grazing checks early growth of associated summer grasses and reduces quantity of seed for volunteering.

12. Persian clover produces an abundance of seed that volunteers during the fall. Harvesting seed must be done at proper stage to prevent heavy losses.

SUBCLOVER

Subc1over, also known as subterranean clover, is a winter-annual legume that is well adapted to use in pastures. Subc1over is so named because of its habit of burying the developing seed heads in the soil, or beneath the vegetative mat that the plant forms on the surface of the soil. The plant normally starts from seed in the fall. Development during the winter is rather slow. Growth during the spring is very rapid, and by midsummer the seeds have matured and the plants have died. Most plants from spring seedlings live over into the second year.

Subc1over is native to the Mediterranean regions of Europe, Asia and Africa. Its forage value was first recognized in Australia. The plant was introduced into the United States from Australia. The first sowing in Oregon was made in 1922 at the Oregon Agricultural Experiment Station at Corvallis with seed supplied by the Division of Forage Crops and Diseases, Bureau of Plant Industry, United States Department of Agriculture. Subc1over did not attract widespread attention in Oregon until 1937 when new Australian strains were tested. Since that time, its use for forage in pastures has increased rapidly in western Oregon. The plant is proving to be of particular value on lands that are too dry or too low in fertility for the persistence of white clover. The first commercial seed harvest in Oregon was in 1941.

DESCRIPTION

Subc1over is an annual with prostrate stems up to one foot in length. It has...
white flowers sometimes marked with pink in clusters of two to seven. The plants reseed well. It is unique among clovers in that the ripening heads turn downward and bury themselves under the soil where the seeds mature. It develops a mat of creeping stems which tends to retard soil erosion.

ADAPTATION

Subclover is adapted to climates having relatively warm, moist winters and dry summers. It is not tolerant of poor drainage. The plant appears to be adapted to that portion of Oregon lying west of the Cascade Mountains. Possible exceptions are the higher, colder elevations and areas in the southern portion that receive less than 20 inches of rainfall annually. Well established subclover seedlings can survive temperatures as low as 10 degrees F. Subclover is naturally suited for growth in combination with grasses which give winter protection to the seedlings. In this association the grasses are stimulated as a result of the excellent soil fertility improving properties of subclover. The later strains require the more favorable growing conditions.

ESTABLISHING AND MAINTAINING A STAND

Sowing the seed: Subclover should always be sown in mixtures with adapted, companionable grasses when it is to be used for forage. Growers often establish subclover on old grass sod by broadcasting the seed in the fall without seedbed preparation. A better method of establishing subclover without seedbed preparation is to scatter threshed subclover straw over the land and trample it into the soil with livestock. The best method to use in mixture with grasses is to sow at the time the grass is sown. When subclover is to be used primarily for seed production, highest yields of seed are obtained when grown alone.

Time of sowing: Subclover is naturally adapted to early fall sowing. In Oregon, sowing in September and not later than mid-October is recommended. If sown later in the fall, the young plants may suffer winter injury due to soil heaving. They are also more susceptible to damage by slugs. Spring sowing in April, May or June on well prepared seedbeds is often practiced where soils heave badly by winter frosts.

Rate of sowing: Subclover is usually sown alone for seed production at rates varying from 6 to 10 pounds of seed per acre. When the crop is to be utilized as forage, the recommended rate is not less than 3 pounds of seed per acre in combination with grasses. The following kinds and quantities in pounds per acre of subclover and grass seeds in mixtures are recommended for forage production in Oregon. Under ideal conditions of seedbed or high prices of seed some of these quantities may be reduced slightly:

For good western Oregon lands: subclover, either Mt. Barker or Tallarook, 3 pounds; Alta fescue, 8 pounds; perennial ryegrass, 6 pounds; and, orchardgrass, 4 pounds; total seed, 21 pounds.

For western Oregon hill lands (either cultivated or logged-off and burned): Subclover, Mt. Barker, 3 pounds; Alta fescue, 8 pounds; perennial ryegrass, 4 pounds; orchardgrass, 2 pounds; red fescue, 2 pounds; and, Highland bentgrass, 1 pound; total seed, 20 pounds.

Inoculation: Subclover develops root nodules with the same nodule bacteria that inoculate white, red, crimson, and alsike clovers. On fields where these common clovers are growing successfully and show healthy nodulation, subclover will generally develop nodules. Where these bacteria are not present in the soil, they must be applied artificially to the seed. Since it is easy to obtain a commercial inoculant especially adapted to subclover at a small cost per acre, it is always better to follow the practice of artificially inoculating the seed before sowing.

Fertilization: Subclover requires fertilization to maintain high production of forage and seed. A general recommendation for western Oregon is a yearly application of superphosphate (16 percent) at 200 to 300 pounds per acre, or gypsum and triple phosphate (45 percent) at 100 to 150 pounds of each per
acre in early March. Seedling growth may be encouraged on phosphate deficient soils by applying the phosphate fertilizer in the fall. Lime applied at 1 to 2 tons per acre may be beneficial on the more acid hill soils.

Field care: Good management is essential to the maintenance of a balance between subclover and grasses in pastures. Very close grazing may cause the clover to increase at the expense of the grasses. Tall-growing, vigorous grasses, such as Alta fescue, if allowed to make considerable growth, may reduce excessive amounts of subclover in pastures. Dense-sodded grasses, such as red fescue and Chewings fescue, tend to prevent domination by subclover. Sometimes, under conditions that are especially favorable for clover, it may be necessary to reduce the amounts of legume-stimulating fertilizers applied, or omit them entirely when other methods of management do not prevent domination of the grasses by the clover.

UTILIZATION

Subclover is relished by all kinds of livestock. It is best adapted for use as a pasture plant when grown in mixture with adapted companion grasses. It is also suited to use as silage or hay. The plant has persisted under very close grazing in Oregon since 1930.

The season of green forage production of subclover in Oregon is usually from late March to mid-July. Its beneficial effect on companion grasses, however, is perceptible throughout the year. In experiments conducted at the Oregon Agricultural Experiment Station from 1941 to 1944, the average production of silage from perennial ryegrass sown alone without fertilizer was less than two tons per acre; when sown with subclover, it was over 8 tons. The production of hay was respectively about 1.1 tons and 2.3 tons per acre, or, more than double with hay, and more than four times as great with silage.

In Tennessee (Tenn-11) "it was found to perpetuate itself only moderately well, and is considered inferior to crimson clover for general use, but may prove of practical value for special purposes."

VARIETIES OF SUBCLOVER

Subclover is quite variable in plant types. A large number of different strains have been isolated and recognized. These are grouped into three types: early, mid-season and late. The early strains are relatively low in production and are useful in areas of low rainfall where later maturing strains cannot persist. The early strains have shown little value where tested in Oregon. For Oregon conditions, Mt. Barker, a mid-season strain, and Tallarook, a late strain, are well adapted, are generally recommended, and are used almost exclusively. In general, the later strains are the highest forage and seed yielders and require the most favorable growing conditions. Subclover, for persistence in pastures, must be late enough to bury and mature sufficient seed for future stands.

Mount Barker Subclover: Mt. Barker subclover was introduced into Oregon from Australia by the United States Department of Agriculture about 1922. Early plantings were made at the Oregon Agricultural Experiment Station. This variety is considered as midseason and as one of the most satisfactory for forage purposes, especially for pasture, in that it buries a high percentage of the seed which in turn is conducive to self perpetuation, particularly when closely grazed.

It is well adapted to the Pacific Northwest, west of the Cascade Mountains. Its most extensive use at present is in this region. It shows indications of forage value in other parts of the country having similar climatic conditions, such as the eastern portion of the Mid-Atlantic States and the Southern States.

The first commercial production of seed was in 1941. A considerable tonnage of commercial Oregon-grown seed and also imported seed of this variety from Australia is now offered for sale by seedsmen in the Pacific Northwest, west of the Cascade Mountains, and in northern California.
Tallarook subclover: Tallarook subclover is considered as a medium late or late strain, about ten days later than Mt. Barker. It differs from Mt. Barker in plant characteristics, particularly because it buries much less of the seed; consequently, under close grazing, it may be of less value in perpetuating itself naturally. This fact makes it a higher seed producer, so is liked better by seed growers. In forage production, it is about the same as Mt. Barker.

DISEASES AND INSECTS

Diseases: Stem rot, when present, is seldom destructive but causes rapid dying of infected plants and is most active on subclover in late winter and early spring. The disease is most severe on land that is frequently cropped to legumes. Mosaic, a virus disease spread by aphids, is most prevalent during years when these insects are numerous. But few serious outbreaks have been reported.

Insects: The principal insect pests of subclover in Oregon are the common garden slug and the eleven-spotted cucumber beetle. Slugs are generally most destructive to the young seedlings of fall plantings. They can be controlled by applications of commercially prepared poison bait pellets containing metaldehyde and arsenic. The eleven-spotted cucumber beetle is destructive to the seedlings of spring plantings. No effective control method is known, but a timely application of DDT dust might control them.

SEED PRODUCTION

The seedbed: When subclover is to be grown for seed, it should be grown alone and the land selected should be clean. The seedbed should be well prepared, firm and level. This condition favors close cutting which is essential in harvesting a seed crop of subclover. If a field is to remain in seed production for more than one year, the land should be re-worked each fall in preparation for the next seed crop. The seedbed for spring sowing should be fine, firm, and weed-free. This condition favors soil moisture retention during the summer. When sowing subclover in the fall for forage purposes, looser, rougher seedbeds are satisfactory.

Harvesting the seed: Subclover seed is ready to harvest when the plants are dead and thoroughly dry. This time is usually in late July or in August, depending on the strain grown and the season.

The most satisfactory equipment for harvesting a heavy crop is a tractor-driven, power take-off mower equipped with a fescue cutter bar and windrower. This bar clips closer to the soil surface than the standard mower bar. Where the mat of clover vines is especially dense and heavy, pea-lifter guards that attach over the upper surface of the bar should be used. Lifter guards that are attached underneath the bar cause higher clipping than is desirable. A five-foot cutter bar, because of less side-draft, is preferable to a longer bar for cutting vigorous, heavily producing strains such as Tallarook. When cutting the crop, the bar should be tilted forward and the tractor operated in low gear to give the mower knife plenty of speed. This prevents pulling of the vines and clogging. Where the power take-off mower is not used, the tractor should be operated at a higher speed.

Another harvesting method that requires no special equipment consists of mowing above the seed heads with a standard mower and windrower, to clip off weeds, grasses and excess clover straw which is removed and may be used for feed. The field is then raked with a strong hay rake. The runners and heads thus pulled up are dropped into windrows. The rake teeth should be of the heavy type for best results. This method is successful only when the clover plants are thoroughly dry and break off easily at the surface of the soil.

After the seed crop has been removed from the field, some ungathered heads always remain on the soil surface. Some success has been achieved in gathering these heads with specially constructed "vacuum cleaner" machines.

Threshing: The seed crop is usually threshed with standard stationary threshers. Some growers thresh directly from
the windrows with combine harvesters. The toothed cylinder machine is reputed to be superior to the rub-bar type for this purpose.

Warm, dry weather is essential for efficient threshing. Rethreshing of the straw is often worthwhile as the seeds are rather difficult to separate from the heads and pods.

Threshed subclover straw almost always contains considerable amounts of heads in which seeds remain. This straw is valuable for scattering over established pastures and hill ranges on which stands of subclover are desired.

**HOP CLOVER**

*(Trifolium procumbens and T. dubium)*

The large hop clover (*T. procumbens*) and the small hop clover (*T. dubium*) are winter annuals widely distributed throughout the Southeastern States, although neither species is indigenous to this country. The small hop clover and to a lesser degree the large hop clover also occur in many sections of the Pacific Northwest.

In the northern part of the Southeastern States the large hop clover predominates, but in the southern part the small hop clover is more abundant. In between, there is a wide transition zone where there is an intermingling of both species. When the large hop clover is grown in the southern part of the United States, it is somewhat more productive than the small hop clover, although on most soils it may not become the dominant species unless minerals are supplied.

Both species are valuable in supplying early spring pasturage and increasing the fertility of the soil for the companion grass. If permitted to bloom, hop clovers produce an abundance of seed since they are self-fertile and self-pollinating, and are tolerant of variable environments.

In many places the occurrence of either of the species is sporadic, being abundant in certain years and scarce in others. Since the seeds of these species germinate in the fall, the hazards in establishment are great, as the very small seed must be near or on the soil surface when germinating. While it appears that hop clover is best adapted to a grass habitat, the competitive effect of the associated plants during the time of establishment of the young clover seedlings may be one of the factors determining their irregular occurrence.

There is some objection to growing the hop clovers because they are susceptible to powdery mildew which gives the foliage a greyish appearance. The mildewed clover is not toxic. These clovers furnish grazing primarily from March to June, and are recommended particularly for mixed clover plantings.

**ESTABLISHMENT**

The seed of hop clover germinates in the fall from September to December and the plants grow rapidly in the spring, after which they flower, set seed, and die. Spring sowing is not recommended. The rate of sowing recommended is from 1 to 3 pounds per acre. Some writers have recommended higher rates of sowing, but these are not necessary or desirable under conditions at all favorable for hop clover.

Hollowell (US-99), in cooperation with several southeastern State experiment stations, conducted a series of experiments on the establishment of large hop clover from 1934 to 1937, which has contributed to our knowledge of this subject. Since both small and large hop clovers are so similar in growth relationships, only the large was used in the experiments and the results are probably equally applicable to both species. Some of the results are recorded here.

Sowings of seed were made from September to March the first year, but as the late winter and early spring sowings were unsatisfactory, they were discontinued after the first year. Higher rates of sowing than 3 pounds per acre were unnecessary and undesirable.

The seed of hop clover was sown on both cultivated ground and on sod or pasture turf, the latter consisting of various grasses and other legumes. The results at the Maryland, Kentucky, North
Carolina, and Missouri Stations clearly indicated that tall grass inhibits successful establishment, regardless of date of sowing. Lack of sufficient light is believed to be the cause of failures. However, the association of hop clover with grass appears to be beneficial to establishment and survival of the clover, for in North Carolina the stands in cultivated plots were much thinner than those with grass, and in Missouri all sowings on cultivated soil failed in establishing stands.

Sowing hop clover with the southern grasses presented less conclusive evidence of this relationship. With Bermudagrass, equal or better stands were obtained from non-clipped as from clipped grass. In Georgia the results from clipped carpetgrass were superior to those from the unclipped grass. Some of these differences may be because of different growth habits of the grasses.

The trials in Louisiana on cultivated heavy clay soils were the only ones where results on cultivated soils were superior to those in association with grass.

As fertility of the soil increases, fall clipping or close grazing may be expected to facilitate the establishment of hop clover.

In Tennessee good stands of hop clover were obtained from fall sowings on sericea stubble. Where undisturbed, the clover may make so dense a growth on fertile soil as to impair the stand of sericea and reduce the hay crop.

**UTILIZATION**

Hop clover is primarily a pasture plant and is mostly utilized for this purpose. In the latitude of Tennessee the pasture period is April—May. In Tennessee, under favorable conditions the large hop clover, when cut for hay, has yielded a ton of hay per acre. At that latitude the hay crop is cut about the middle of May. The seed crop is ripe the fore part of June, the yield being from 100 to 200 pounds per acre.

A very small amount of hop clover seed may well be included in the grass-and-clover mixture for permanent pasture through the Southern States. It is very useful in increasing the pasturage and in supplying nitrogen to the associate grasses. It occasionally produces a very good crop of hay, but this cannot be depended upon. It does not succeed as well with lespedeza in making an all-round pasture as would be expected, for a thick stand of hop clover tends to smother out the lespedeza in late spring as the lespedeza seedlings are becoming established. In mixtures used for pastures, where growth conditions are not optimum, both plants may do well in the same field. Together they make a better all-year pasture than would be possible if either plant were grown alone.

After once established and fertilized, hop clover will rapidly spread over a field. If a very thin stand is started in an old field used for pasture and fertilized, the livestock will eat the mature plants containing the seeds and distribute the clover all over the field.

Hop clover and lespedeza are the most practical plants to establish on waste land or broom-sedge-infested land that is being improved for pasture purposes at a minimum cost. Both of these plants afford nutritious grazing and at the same time improve the soil for the growth of the bluegrass.

**STRAWBERRY CLOVER**  
*(Trifolium fragiferum)*

Strawberry clover, one of the most recent clover immigrants, is native to the eastern Mediterranean and southern Asia Minor countries, but it has been widely and inadvertently spread by man. It has been observed in every continent of the world; and wherever it is grown, the value of the pasture herbage has increased. In Australia its culture on low-lying overflow lands has become extensive.

How and when strawberry clover was first introduced into the western part of the United States is a matter of conjecture. Plant specimens were collected near Philadelphia, Pa., as early as 1878. Seed was brought into this country as early as 1900, but available records do not indicate that it was tested under conditions where it now appears to have a
definite place. In many places, it has been found growing after the land had been sown to Australian grasses and salt-bush, and it has been assumed that the clover seed was mixed with the other seed. Because of its palatability, scattered plants are usually closely grazed, and thus seed production is limited. In many places the spread of occasional plants has been mostly by means of the creeping stems. With the development of interest in this clover, large and small areas of it have been discovered in all of the Northwestern States. These patches range from a fraction of an acre to fields of over 40 acres. Several of them have been known for thirty years or more.

DESCRIPTION

Strawberry clover is a perennial, low-growing, pasture legume spreading vegetatively by creeping stems that root at the nodes. The leaves, stems, and habit of growth are somewhat similar to the white clover, making it generally difficult to distinguish when not in bloom from certain types of white clover. The flower heads, seed pods, and seed are very distinctive, however, making identification easy. In general the flower heads are round, although sometimes they are slightly pointed, and in color they are mostly pink to white, resembling a strawberry, from which fact the common name is derived.

As the seed matures the calyx around each seed pod becomes inflated, appearing like miniature balloon capsules, and shades from gray to light brown in color. When ripe, these capsules break off from the head and readily float in water or may be blown by the wind. The seed color varies but is principally reddish brown or yellow flecked with dark markings. The seed is much larger than that of white clover but slightly smaller than red clover seed.

ADAPTATION

Climate: Strawberry clover has been established successfully in most of the Western States. It thrives under wide extremes of temperatures ranging from 40 degrees below zero to high summer temperatures. Shearman's clover, however, a sparse seed-producing variety of strawberry clover, is easily winter-killed and seems to thrive better under uniform temperature and growing conditions. Strawberry clover has been tested in various places in the Eastern States, and although good growth has been obtained in test plantings, it has not appeared to be capable of competing with white clover under conditions favorable to the latter.

Soils and moisture: Strawberry clover is adapted to a wide range of soil conditions. The plant, however, is of particular value on wet saline or alkaline soils, although it will thrive in normal soils. The degree of tolerance to high concentration of salts is influenced by temperature, moisture content of the soil, and kind, quantity, and dispersion of salts present. Since one or more of the above conditions may vary widely within a short period, it is impossible to state any definite degree of salt concentration that this clover will tolerate.

Strawberry clover is extremely valuable for large areas in most irrigation projects, where drainage is a limiting factor in crop production. A valuable characteristic is its ability to survive flooding for one to two months without the plants being killed. Although it will live under relatively dry conditions and will survive short periods of drought, the clover will not make sufficient growth to warrant its use on dry lands.

CULTURE

Seedbed preparation: Preliminary studies to determine the best methods for seedbed preparation and methods of sowing indicate that where possible, a seedbed should be prepared in the fall by plowing or diskng thoroughly, followed by harrowing to level and firm the soil. This preparation temporarily destroys the vegetation occupying the land and reduces competition. In places where the soil remains too wet for working the seedbed, the vegetation should be mowed
and removed in the fall. This should be followed by late winter sowing of unhulled seed or early spring sowing of scarified seed.

Sowing the seed: Sowing should be done in the early spring on a firm, moist seedbed, since the establishment of strawberry clover seedlings appears to be somewhat slower than that of red or white clover. The seed may either be broadcast or drilled in very shallowly. Although good stands have been established by using two pounds of seed per acre, a heavier rate up to five pounds an acre is more desirable, and this is particularly true if a thick stand is desired the first year. The present price of seed, however, may limit the practice of sowing at the higher rates. Fortunately, this clover spreads rapidly by the creeping stems, and originally thin stands may become thick by the end of the second year, particularly if growing conditions are favorable. On nonsaline soils strawberry clover may be spring-sown with a companion grain crop if an ample supply of moisture is available throughout the season.

T. G. Stewart of Colorado says that, "because of the scarcity of strawberry clover seed, a farmer or ranchman can afford to expend considerable effort to get a small acreage or foundation plot established on the farm or ranch. Once established on the smaller area, the clover can be scattered in desired fields or pastures by transplanting runners or by scattering seed. A few scattered plants, once established throughout a pasture, can successfully compete with salt grass or wire grass and the spread of the clover will be rapid. Best results can probably be secured on most farms by planting strawberry clover seed on well-prepared land, adjacent to an alkaline sected area or meadow which it is desired to seed."

Field care: If the sowing is made on a prepared seedbed, it is not often that the other vegetation will crowd out the seedlings and prevent their establishment. When the seed is broadcast, however, without seedbed preparation, rushes and sedges are very likely to crowd out the seedlings. Mowing to reduce this competition is, therefore, highly desirable and should be done when necessary. After the seedling plants are well established the areas may be grazed. Grazing is very desirable for two reasons: (1) The grass and sedges are grazed with the grazing of the clover, which reduces the competition to the benefit of the clover, and (2) the sedges and rushes are trampled, which also retards their growth, giving the clover more opportunity to spread. When strawberry clover is sown with other grasses and legumes in normal soils it may be grazed at the same time as other pasture plants.

UTILIZATION

Strawberry clover is principally a pasture plant, though it may be used as a green-manure crop, particularly on soils where salinity prevents the growth of other legumes. It is very palatable and is as rich in animal feed units as white clover. When the plants are grown on saline soils the composition of the vegetation is somewhat higher in minerals than when they are grown on salt-free soils, but all available reports have indicated that animals have not been injuriously affected from grazing it. Like other legumes, strawberry clover may cause animals to bloat and necessary preventative measures should be taken. All types of animals and poultry have grazed strawberry clover with good results.

Strawberry clover will survive under close grazing similar to the low-growing forms of white clover, but it may be more productive if grazed moderately. Close grazing, on the other hand, will reduce the number of many of the other less desirable plants and in that way will encourage the spread of the clover and the development of a good pasture turf. It has been grazed continuously from early spring until late in the fall without affecting the stand, although rotational grazing would probably favor greater production. With an increase of the salt concentration of the soil to the point where growth is inhibited, the advisable practice is to remove the animals until
the clover makes additional growth. Close grazing in late fall is not recommended, as such a practice may result in partial killing of the stand during the winter months.

Farmers who have used large acreages for grazing claim that on similar soils the carrying capacity of strawberry clover is far superior to that of other pastures. Many claim that one acre will carry from one to two cattle through the entire growing season, provided growing conditions are favorable.

The blossoms of strawberry clover are visited by honeybees. Apparently they obtain considerable nectar, which indicates that this is a good honey plant.

SEED PRODUCTION

Strawberry clover is a prolific seed-producing plant if properly handled. Yields range from 40 to 300 pounds of seed per acre, and higher yields in exceptional cases have been reported, although the production of 100 pounds of seed per acre is more common.

The flowers of strawberry clover are self-fertile, that is, seed will form without cross-pollination, which is necessary with red clover and white clover. Honeybee visitations from flower to flower, however, are of assistance in insuring a movement of the pollen to the stigma. Placing of colonies of honeybees immediately adjacent to blossoming fields is suggested as a means of increasing seed yields.

The blooming period of strawberry clover usually begins from two to three weeks later than white clover, and its flowering is completed earlier in the summer. Under most conditions strawberry clover does not bloom until the first year after sowing, and thick stands appear to bloom more profusely than thin ones. Thin stands and unfavorable growth conditions have a tendency to encourage the formation of short-stalked seed heads that make seed harvesting difficult.

Harvesting seed: Since the flowering and growth habits of strawberry clover and white clover are similar, the same methods may be followed in seed harvesting. When strawberry clover is grown on an uneven soil surface, harvesting has been done by hand-picking, which limits the amount and increases the price of the seed. Rough, hummocky soils supporting a thick stand of clover have been disked, harrowed, and rolled early in the spring without doing serious damage to the stand, and this practice has enabled the seed to be cut with a horse-drawn mower.

Some farmers follow the practice of grazing the clover until the first of June, when the animals are removed. This permits additional growth to be made, followed by blooming and seed formation. They claim that this practice reduces the amount of weed growth, which often handicaps seed-harvesting operations and reduces seed yields.

The seed crop should be cut when the majority of the seed capsules or envelopes are light brown in color. An examination of the maturing seed is recommended to see whether it is ripe. If cut too early, the seed will be shrunken and immature. Close grazing up to the time of blooming will not prevent blooming and seed production, but the heads will form close to the soil and can only be harvested by hand-picking. When the clover is grown in strongly saline soils preceding and during the blooming period, the heads are also short-stalked and cannot be cut with a mower.

Because the heads of strawberry clover shatter readily when ripe, it is advisable to cut and handle the crop when the heads are slightly damp, as then the seed envelopes will be tough.

The crop may be harvested with a mower and later picked up from the swath or windrow. The use of mowing machines equipped with windrowing attachments and bunchers closely set reduces the number of times that the crop must be handled and in turn the possibility of excessive shattering. Harvesting by means of vacuum machines has not been successful.

The seed crop may be cured in and threshed from the windrow or stack by
clover hullers, grain separators, or combines equipped with hulling attachments. The seed coats of strawberry clover seed are hard; even after hulling as much as 40 to 75 percent of the seed often remains hard. Such seed should be scarified before being sown, to obtain more complete germination.

STRAWBERRY CLOVER HIGHLIGHTS

1. Strawberry clover, a native of eastern Mediterranean and Asia Minor countries, has spread naturally and from cultivated fields throughout the Northwestern States.

2. The adaptability of strawberry clover to wide extremes of temperature and soils, but more particularly to wet saline or alkaline soils, distinguishes it from all other forage legumes.

3. The strawberry clover plant resembles white clover in appearance. Its flowerheads, seed pods, and seed, however, are distinctive.

4. Strawberry clover is a most useful legume for pasture on wet, saline soils, such as seepy lands in irrigation districts where other legumes will not grow. It is very palatable and as rich in feed units as white clover.

5. Sow seed shallow in early spring on firm moist ground at 2 to 5 pounds per acre. Since the plants spread rapidly, thin first-year stands will usually become thick the second year.

6. Heavy grazing is often beneficial to strawberry clover after establishment by reducing growth of weeds and sedges. It may be more productive, however, under only moderate or rotational grazing.

7. Since flowering and seed habits of strawberry clover are similar to white clover, the same methods may be followed in harvesting seed.

8. Since strawberry clover has a high percentage of hard seed, it should be scarified before it is sown.

Chapter reference numbers:

This chapter

A large part of the material on red clover in this chapter is from Pieters (US-194), supplemented by Fuellman (ILL-8), and notes from Hollowell. The material on white clover and Ladino clover is largely from Hollowell (US-98 and 102), supplemented by information on Louisiana clover from Wasson (LA-18), Thompson (MISS-20), and other State sources, and on Ladino clover from many sources. The larger part of the material on crimson clover is from Hollowell (US-100). That on Persian clover is a rearrangement of Hollowell’s bulletin on Persian clover (US-103), and that on subclover is largely from Rampton (OREG-21), and from Schacht’s notes. There is comparatively little written on the culture of hop clover in the United States. The material used here was largely from Hollowell (US-99), supplemented by Blaser et al (FLA-7), Moers (TENN-11), and Niel (TENN-13).

The material on strawberry clover is largely from Hollowell (US-101), supplemented by Weihing (p. 339a), Weihing and Watson (p. 339b), and J. M. Thompson of Colorado. Acreage and production statistics on all the above clovers, where given, are from Edler and Kuzelka of B.A.E. Much information on seed production came from commercial sources. Hollowell of U.S.D.A. reviewed the manuscript of the entire chapter, Wilsie of Iowa those portions on red clover, white clover, and Ladino clover, Burton of Georgia the part on crimson clover, and Schacht of Oregon the portions on Ladino clover and subclover.

Chapter reference numbers:

Red clover: ILL-20, 23; IOWA-14, 15, 19, 26, 27; KY-5, 6, 15; MICH-18; MINN-22; NH-5; NY-9, 13, 39, 42; OHIO-3, 42; ORREG-13; PENN-12; TENN-11; VT-4, 9, 10; WASH-5; WIS-1, 36, 37; US-96, 97, 99, 105, 110, 115, 138, 192, 193, 199, 200; MISC-7.


White clover: ALA-3; CONN-4; FLA-7; LA-18; MICH-10; MISS-20, 21; NEV-8; NJ-8; NY-19; OHIO-8; PA-18, 21; SC-18; TENN-11; VT-10; WIS-1; US-33, 98, 182, 217.

Ladino clover: CAL-12, 13; CONN-9; IDAHO-9; ILL-12; KY-19; ME-5, 6; MD-16; MASS-4; MICH-24; NH-1; NJ-19, 27; NY-23, 37; NC-10, 12, 13; OHIO-32; ORREG-23; PA-4; WIS-8, 31; US-72, 102, 109; MISC-49.
Crimson clover: ALA-9, 13, 20, 28, 30; DEI-4; CA-2, 19; KY-10; NC-16; OREG-10; TENN-10, 11, 15; US-100; MISC-53.


Subclover: ALA-29; OREG-2, 21; TEX-32; US-77, 112.


Strawberry clover: US-72, 101. a

a The reference numbers given here refer to references which are given in full by State, U.S.D.A., and Miscellaneous, on pages 682 to 724, and which are cross-referenced by author on pages 725 to 731. Citations in the text are indicated by abbreviation and number in parentheses.


CHAPTER XII

SWEETCLOVER

(Melilotus species)

The sweetclovers occupy a prominent place among forage legumes in the United States, especially for use as pasture and soil improvement, although formerly they were considered noxious weeds and still are to a large extent in European countries. It is in the Corn Belt and the Great Plains States that sweetclover has come into most extended use and its highest development as a forage and soil improvement crop. The growing of sweetclover, however, for hay and pasture is not confined to the Corn Belt. There are other parts of the country where sweetclover has become a very useful forage and soil improvement crop. The two annual white varieties, Hubam and Emerald, have made their gains largely in Texas and some other southern States. In the Pacific and Intermountain States of Oregon, Washington, Idaho and Montana, both under irrigation and under natural rainfall, Hubam and the biennial white and yellow sweetclovers are used extensively.

Tremendous expansion in the use of sweetclover has occurred on Corn Belt farms during the last thirty years. It is used there mainly as a temporary pasture or as a means of maintaining or restoring fertility to soils that have been depleted by long-continued cropping with corn and small grain. It has become well established as a regular crop in the organization of farms in many sections of the Corn Belt. Its outstanding value as a pasture and soil-improving crop, the relative cheapness of the seed, and the ease with which it may be fitted into established cropping systems have all contributed to its widespread use.

ADAPTATION

Sweetclover will grow almost anywhere, provided there is more than 17 inches of rain suitably distributed, and there is sufficient lime in the soil. It is very resistant to cold and drought and is not troubled by heat. Good sweetclover may be found anywhere in the United States, except where the rainfall is too scant or the soil is sour. Sweetclover is able to obtain phosphorus from relatively unavailable soil phosphates and consequently will grow on soils where alfalfa or red clover requires phosphate fertilization. Sweetclover will thrive in soils too high in alkali for alfalfa, or, in fact, for most cultivated crops.

KINDS AND VARIETIES

When sweetclover was first generally recognized as a valuable crop, the only kinds considered were the two distinct biennial species, white sweetclover (Melilotus alba), and yellow sweetclover (Melilotus officinalis). These are not merely varieties, but different kinds or species of plants, as different botanically as red clover and alsike clover. White sweetclover and yellow sweetclover have not been cross-pollinated, even artificially. There are many other species of Melilotus, two of which, the yellow annual sweetclover (M. indica) more generally known as sourclover, and Daghestan sweetclover (M. suaveolens), have been grown commercially in the United States. The term “sweetclover” is generally applied to the two species, M. alba and M. officinalis.
Practically all bulletins and articles on sweetclover have described and recommended the white species. Nevertheless, in many sweetclover-growing regions in the United States there has come a gradual increase of yellow sweetclover.

Common yellow sweetclover is earlier maturing than most strains of common white. In most places it is in a mixture of common white and common yellow sweetclover, the yellow goes to seed first, and furthermore, it sets abundant seed. Even though the field is cut early to check seed production, if any seed is left on the field to volunteer, it will be of the yellow.

Yellow sweetclover really deserves more recognition than it has had. For one of the most important uses of sweetclover (that is, as a catch crop between small grain, wheat or oats one year and corn the next), the common yellow is equal in value to common white. Common yellow sweetclover does not make as much top growth in the fall of the first year as common white, but it makes proportionately more root growth; hence the quantity of material plowed under the following spring is essentially equal for the two species.

In the second year's growth the hay yields of the two species are substantially equal until early June, at which time the yellow sweetclover comes in bloom—10 days to 2 weeks earlier than most varieties of white. The white continues to grow during this period so that its total hay or pasture yield for the season is always greater than that of the yellow. The yellow is shorter and matures more uniformly; hence, it is more readily harvested for seed than is the white. The seed crop is also usually larger.

Common yellow establishes itself in dry seasons and dry seedbeds better than common white; consequently, it should be used in dry climates or for any summer sowing, whether in corn or alone, in the Corn Belt. Following summer sowing, the yellow is much less easily winterkilled by heaving than the white. For pasture in the year after sowing, the yellow is definitely undesirable, since it dies in early July just when pasture is needed most.

In general, therefore, as between common white and common yellow, white should be used whenever it is desired to cut hay in the year sown or for any pasture use, because of its later maturity and larger yield. Either the white or the yellow may be satisfactorily used for soil improvement as a catch crop in a 2-year corn-small-grain rotation. The yellow is much superior for any summer sowing and for establishing itself in dry seasons or climates. For this reason it is probably generally superior where used for soil improvement only.

**Biennial Varieties**

Up to ten years ago, practically the only white sweetclover grown was the standard medium-late biennial white sweetclover, now known as common white, and this is the one considered in
the previous discussion of the relative merits of yellow and white sweetclover. Since then a number of strains have been developed and tested by the State experiment stations in cooperation with the Forage Crops Division of the United States Department of Agriculture. An attempt is made in the following list to give a fair appraisal of those about which most has been written and to include those of outstanding superiority. The list, however, is not complete.

**Common white**: This is a large, white-blossomed coarse sweetclover. Under favorable conditions it may attain a height of 30 inches in its first year and seven feet in the second year. As a general purpose crop, it is distinctly superior to Grundy County and common yellow, as it normally produces more hay and pasture and matures later in its second year. Great variations occur in the growth from different lots of seed purchased under this name, which in many instances are due to mixtures with Grundy County and common yellow. The true common white sweetclover flowers in late June and early July and may be classed as medium in time of maturity.

**Common yellow**: The standard yellow-flowered sweetclover known as common yellow is smaller and less upright than common white. With many of the lower branches prostrate, the internodes are shorter and stems finer. Second-year growth is more upright and it may attain a height of three to five feet. It generally flowers and matures 10 to 15 days earlier than common white.

The first and second-year hay is of comparatively good quality. Due to early maturity, this variety generally is not recommended for use as a second-year pasture crop. It is relatively easy to establish stands of common yellow, and it has shown an ability to overcome first-year drought and weed competition better than have the commonly grown white-flowered varieties. Probably the ability of common yellow to better withstand adverse climatic and soil conditions and to establish good stands is the cause of its yields approaching those of the naturally larger-growing common white.

**Grundy County**: This early-maturing strain of white sweetclover was introduced in the early 1920s from Illinois. It is short, matures early, and produces a good crop of seed which matures more nearly at one time than any other strain of white sweetclover. A considerable proportion of commercial sweetclover seed is of this type, which makes it difficult to obtain seed of the common medium-late white sweetclover.

Grundy County sweetclover seems to have the faults of both the yellow and the late white sweetclovers but has the advantages of neither, except for seed production. It is reasonably good for soil improvement but is inferior to both yellow and late white varieties as shown by root yields.

**Spanish**: Spanish, a variety of white sweetclover formerly called Madrid White, originated as an introduction from Madrid, Spain, in 1910. It is biennial in growth habit and is white flowering. The first year’s growth is vigorous, medium in height, upright, with foliage somewhat resistant to fall frost, though not so resistant as Madrid. The second year’s growth is leafy, upright, medium in height and in maturity. Seed production is heavy and early enough to escape the drought hazard common to the summer months in the eastern part of the Great Plains States. General regions of adaptation are the Corn Belt, Great Plains, and the Intermountain States. The value of the variety has been clearly shown by comparative trials in nurseries and field plots for the past fifteen years.

**Madrid**: Madrid, a variety of yellow sweetclover, formerly called Madrid Yellow, originated as a seed introduction from Madrid, Spain, in 1910. When compared with other varieties and strains of yellow sweetclover, the first year’s growth is characterized by exceptional early seedling vigor, medium height, somewhat decumbent, and foliage resistant to fall frost. The second year’s growth is leafy, upright, of medium height, and about 2 weeks earlier flowering than Spanish. Madrid is finer stemmed and more leafy for hay production than common white sweetclover. It is dark green in color,
with occasional bluegreen plants. Seed production is heavy and of sufficient earliness to escape the hazard of drought common during the summer months in the Great Plains.

Myers of Kansas says that "Madrid matures about a week later than the common yellow in Kansas, but nearly two weeks earlier than the common white. It is a somewhat more dependable seed producer than the common white. The seed crop is more easily handled because Madrid does not grow so tall and the stems are finer. Two of the most desirable features of Madrid are its earliness and resistance of the foliage to frost."

About 550,000 pounds of Madrid sweetclover seed was certified in 1948 of which 70 percent was produced in Nebraska and Kansas.

**Evergreen:** Evergreen is a variety of sweetclover originated by the Ohio Agricultural Experiment Station. It is well adapted throughout the Corn Belt and the eastern edge of the Great Plains States. When compared with common white, the first year's growth of Evergreen is taller, more upright and somewhat coarser. The second year's growth is also taller and coarser and is two to three weeks later in maturity than Spanish and common white. It blooms over a longer period and sets seed freely. The harvesting of large seed yields, is difficult because the seed shatters, due to the rank growth characteristics and the long blooming period. However, the average yields of seed of Evergreen in Nebraska (Neb-9) for the 3 years 1944-1946, which were favorable years for seed production, exceeded those of Madrid and common white by 28 and 56 percent, respectively, and were only 5 percent below the highest producer, Spanish (Neb-387).

**Willamette:** Willamette is a white variety which originated as a selection made in 1921 at the Oregon Agricultural Experiment Station. In all respects Willamette is like common white except in its susceptibility to stem-rot (Sclerotinia trifoliorum) to which it is resistant. Willamette is adapted wherever the common white is adapted, particularly in the Pacific Northwest, west of the Cascade Mountains, where stem-rot is one of the primary limiting factors to sweetclover growing.

**Redfield:** This is a yellow-flowered variety of Melilotus suaveolens which is distinctly different from common yellow. It was derived from seed received by the United States Department of Agriculture from Manchuria and first distributed by the Redfield, South Dakota, Field Station in 1923. Redfield sweetclover is distinguished from common yellow by the uprightness of growth and lateness of maturity. Plant growth is comparatively compact and leafy. It has averaged slightly less than common yellow in first and second-year hay and pasture yields at Lincoln, Nebraska. It is more susceptible to the diseases prevalent in southern and eastern localities and, consequently, not well adapted to culture in those areas.

**Switzer:** Switzer, sometimes called Madison County, is a variety of common yellow grown to a considerable extent in Madison and adjoining counties of Nebraska. It is regarded as finer-stemmed and more prostrate than common yellow.

**Canadian varieties:** Several Canadian biennial varieties among which are Alpha, Zouave, Arctic, Pioneer, and Daghestan, have been tested rather extensively in this country and have proved generally unsatisfactory and not nearly as productive as our better adapted varieties, except in occasional trials along the northern border. This is probably because of the difference in adaptation to length of day.

**ANNUAL VARIETIES**

**Hubam:** This variety was introduced by the Iowa Agricultural Experiment Station before 1920. Since then it has been tested at many of the State experiment stations. It is adapted to growing over a large area but has not fitted into the agriculture of many of the States in such a way as to supersede the biennial type. In the Corn Belt States in particular, where the common white and common yellow sweetclovers are used extensively, most of the experiment stations appear to find little place for Hubam sweetclover. In central and southern Texas, and in
New Mexico and Arizona, however, it has become popular as a winter annual, soil improvement legume.

Hubam is an annual form of biennial white sweetclover (Melilotus alba), but there are all stages between the true biennial and the true annual form. Its general growth habits in the Southwest resemble Melilotus indica, although it has white flowers and grows larger and later in the spring. The seeds of Hubam sweetclover are indistinguishable from those of biennial white.

Fall-sown Hubam in the Southwest when it survives the winter furnishes abundant spring and early summer grazing under favorable moisture conditions. It is also sown in late winter. It may be plowed under for soil improvement. At the experiment stations at Beeville, Angleton, Temple, and Denton (Texas), yields from 1.25 to 1.75 tons of air-dry material per acre have been obtained. Under irrigation at Winter Haven and Weslaco, hay yields of 4 tons or more have been produced. In north Texas, the biennial types of sweetclover are to be preferred.

In the lower Rio Grande Valley, Friend (Tex-17) says that "Hubam clover stands out as the greatest contribution ever made to cattle production in this area. Its offspring, Emerald clover, which was developed by the Texas Agricultural Experiment Station, runs it a close second in total production, and the fine-stemmed, leafy plants are more palatable than Hubam."

Emerald: This new variety of white-blossomed, annual sweetclover was developed by selecting among the progeny of a hybrid between Hubam clover and a many-stemmed, crown-branching, leafy, green-seeded, biennial, white-blossomed sweetclover selected at Brookings, South Dakota, in 1935. The original cross and first selections were made at Lincoln, Nebraska, and the later development and introduction were by the Texas station.

Emerald sweetclover is a white-blossomed annual having the plant characteristics of its biennial parent. It is shorter and not nearly so coarse as Hubam, but is well adapted wherever Hubam is grown and best adapted as a pasture and forage crop where Hubam becomes objectionably coarse and rank, particularly in the irrigated sections. In trials at the Weslaco, Texas, Station, Emerald grew to a height of 4 feet and Hubam to a height of 6 to 10 feet. Under grazing near Bishop, Texas, Emerald demonstrated greater usefulness than Hubam or Melilotus indica.

Out-crossing with Hubam, which occurs freely wherever bees visit the blossoms, causes an immediate return to the Hubam type of growth in the next generation, so seed fields of Emerald should be isolated from Hubam and other white varieties, and from M. suaveolens. Although Emerald produces smaller yields of total forage than Hubam, it is a better quality hay and grazing plant and is likely to replace Hubam wherever annual sweetclovers are used for forage.

Recommended varieties: For both pasture and hay production, Madrid, Evergreen, and Spanish are outstanding and merit distribution for farm use over a large part of the Great Plains and the western Corn Belt areas. In the eastern Corn Belt, the relatively large first and second-year yields and prolonged pasturing season in the second year make the Evergreen variety of special promise. Because of its late maturity, its seed yields are more subject to drought than are those of earlier varieties. Spanish is comparatively uniform in type of growth and reaches maturity at about the same time as common white. It gives especially heavy yields of pasture and hay in the first year, but in the second year its forage yields do not differ greatly from those of common white. Madrid also gives comparatively heavy first-year yields. Compared with common yellow, its second-year yields are larger, and its maturity is slightly later. Spanish and Madrid are good producers of seed.

Evergreen and Spanish appear adapted to irrigated areas and the more favorable growing conditions in the eastern Great Plains, while Madrid seems better-suited to the drier areas of the Central Great Plains. Under favorable moisture conditions common white will not only supply more forage than common yellow but
SWEETCLOVER

will also provide a longer pasturing period. In a dry cycle and in dryland areas, greater assurance of stands will be had with the more drought-resistant common yellow.

ESTABLISHING A STAND

Preparation of the seedbed: Sweetclover has seedbed requirements similar to those of alfalfa and red clover. It is grown to best advantage after an intertilled crop, such as corn, but may follow other crops with almost equal assurance of success, provided the seedbed is relatively free of weeds and is properly prepared. A fine, firm, moist seedbed is most favorable for quick seed germination and rapid seedling growth.

In the western Corn Belt when sweetclover is to follow small grain the stubble ground should be fallowed after harvest to permit accumulation in the soil of late summer precipitation, and to give opportunity for more effective eradication of weeds. Such preparation should be employed only on land little subject to wind or water erosion.

Old pastures may often be prepared for sowing to mixtures which contain sweetclover by thorough disking and harrowing. Top growth that interferes with sowing should first be removed by intense grazing or clipping, with excessive trashy materials cut up or removed. A thin cover of grass and the absence of weeds may permit drilling without seedbed preparation.

Use of lime: Though the calcium content of most soils in the areas where sweetclover is grown, is sufficient for its growth, there are calcium-deficient areas where it should be supplied, and this may be done by the application of ground limestone. Further soil benefits are derived from the better growth of the sweetclover.

The lime requirements greatly exceed those of red clover and approximate those of alfalfa. If soil acidity is suspected, the need for lime may be determined by soil tests, or by applications of ground limestone to narrow test strips across the field. Farm work is generally so distributed that it is most convenient to make applications of lime during the fall and winter before the sweetclover is sown.

On slightly acid or moderately acid soils and where a combination drill and lime distributor is available, 300 to 500 pounds of pulverized limestone to the acre may be applied in the row with the sweetclover seed. This method reduces the cost of limestone, but requires a larger investment in machinery.

Fertilizers: Sweetclover has high nitrogen and phosphorus requirements. Its nitrogen is obtained largely through the action of the proper legume bacteria when they are present in sufficient numbers. It seems to be able to obtain its phosphorus ordinarily from relatively unavailable soil phosphates, so in many fertile soils the addition of phosphates may not be necessary. Johnston (Tex-23) of Texas, however, has called attention to the necessity of applying phosphates liberally to the Blacklands of Texas if maximum, or even satisfactory results are to be obtained with either annual or biennial sweetclovers. The desirable effects are probably due (1) to the stimulation of the growth of legume bacteria and nodule formation, thus increasing materially the supply of available nitrogen, and (2) to the direct use of the phosphates by the sweetclover plant.

Johnston further states that “Phosphate fertilization in many cases means the difference between success and failure with sweetclover in the Blacklands. The poor and worn-out soils need more phosphate per acre than do the richer and more fertile soils. If the band-placement method of applying fertilizer is used, 100 to 200 pounds of 20 percent superphosphate is sufficient. If the phosphate is spread on the land and disked in, 400 to 700 pounds per acre should be applied for best results. Band placement of fertilizer and seeding of sweetclover can be accomplished in one operation. This is done by using a grain drill which is equipped with a small seed attachment and fertilizer distributor. Placing the fertilizer band 2 inches below the seed will give maximum results.”

Albrecht, Klemme, and Mierke (Mo-1)
in “Some tests with sweetclover as the
green manure crop in a rotation grown
on Putnam silt loam on the South Farm
of the Missouri Experiment Station in
1947, demonstrated that potassium as
well as calcium is needed if this crop is
to be a producer of considerable tonnage
of vegetative bulk. Potassium also dem­
onstrated its service in raising the con­
centration of nitrogen in the crop, and,
preumably thereby, the fixation of nitro­
gen from the atmosphere.”

In these experiments, “it is significant
that potash used along with calcium
and phosphate had the most outstanding
effect of the three soil fertility factors
concerned in these trials, not only in
making for more plant bulk, but also in
making for more total nitrogen in the
crop per acre of tops and per acre of
roots. Potash was the major factor also in
making for a larger concentration of
nitrogen in the tops where there was a
lower concentration in the roots.

“While sweetclover is commonly con­sidered the crop that can be established
on most any soil by liming alone, after
other and more desirable forage legumes
have failed, one dare not forget that
nitrogen delivery by this crop as well as
its greater production of bulk call for
other fertility elements beside calcium
and phosphate.”

Inoculation: Sweetclover may successfully
follow alfalfa without inoculation, as the
same symbiotic bacteria are common to
both crops. In regions where sweetclover
or alfalfa have not been successfully
grown, and in fields where a lack of
nodules on roots and weak plants indi­
cate the absence of the proper bacteria,
artificial inoculation should always be
employed to assure nitrogen fixation and
vigorous plant growth. Since suitable
bacterial cultures for seed treatment are
on the market and their cost is compar­
atively small, being only a few cents per
acre, it is a desirable practice always to
use artificial inoculation where there is
any doubt as to the adequacy of present
inoculation of the soil with suitable active
nitrogen-fixing bacteria for sweetclover.

Though suitable bacteria are present
in many soils, there are sharp differences
among strains in ability to fix nitrogen,
so the use of commercial cultures selected
for high nitrogen-fixing ability usually
brings results that cannot be obtained in
any other way.

Time of sowing: In the Central and
North Central States, sweetclover grown
alone, or with a companion crop, or with
perennial grasses, is usually sown in late
March or as early in April as weather
conditions and farm work will permit the
preparation of a good seedbed. In some
instances, sweetclover and red clover seed­
lings have seemed to withstand lower
spring temperatures than alfalfa seedlings.
In 1940, the stand of alfalfa sown at
Lincoln, Nebraska, on March 31 was re­
duced 40 percent by early April freezes,
while corresponding sowings of sweetclo­
er and red clover remained uninjured.
Soil moisture conditions are usually most
favorable for sowing early in the season.
Sowing in May and early June is usu­
ally successful, but late June and late
August and September sowings are likely
to fail. Sowing in the late summer should
not be undertaken except when August
moisture and temperature conditions are
favorable and when grasshoppers are not
numerous. The proper date of sowing the
companion crop is the usual time in the
spring for sowing sweetclover with oats,
barley, or flax.

Rate of sowing: The rate of sowing sweet­
clover should be based largely on seed
quality and seedbed condition. Where
the seed is dehulled (hull-free) and scarif­
ed and of good germination, sowing 10
to 15 pounds to the acre is commonly
recommended, though 25 percent less
seed may be sufficient under especially
favorable conditions. If unhulled seed is
used in connection with winter sowing,
the quantity should be increased one-half
or doubled by weight.

As an average for all companion crops,
sowing the sweetclover at 16 pounds per
acre resulted in a 10 percent better stand
than was obtained from 8 pounds. In
comparison, when sown alone 16 pounds
gave a 16 percent better stand than did
the 8-pound rate. No great differences in
yield or quality of forage are to be ex­
pected from such small differences in
stand. These results indicate that material savings in amount of seed may be effected when seedbed conditions are favorable.

Sowing alone or with a companion crop: Owing to the relatively short time that sweetclover occupies the land in a crop rotation, sowing with a companion crop is most desirable east of the Mississippi River or in other regions where severe drought is not of frequent occurrence. Half the normal rate of sowing an early-maturing, lodging-resistant variety of a spring-sown companion grain crop is usually recommended. In Nebraska, if a small grain companion crop is used, better stands of sweetclover are usually obtained by harvesting the small grain crop for hay in the early dough stage, or about ten days before it is ripe, but this practice is not advisable in the eastern Corn Belt.

Companion crops, particularly oats and smooth-awned barley, have considerable value as hay. The yields are usually fair and the hay of excellent quality when harvested in the soft dough stage and well cured. Though smaller grain yields resulted from the reduced rates of sowing the companion crops, the returns were substantial and compensated in large measure for the use of the land in the first year.

When sweetclover is sown alone, weeds commonly become established and offer severe competition. Efforts are often made to control them by clipping with a mower set high when the weeds are about a foot tall, but this often results in severe injury to the sweetclover. In Nebraska, clipping twice at a height of 6 inches resulted in better stands than did closer clipping. Such treatment gave almost double the stand obtained without clipping. The methods of sowing and equipment recommended are similar to those used for alfalfa and the true clovers.

UTILIZATION

Sweetclover is grown primarily for pasture and soil improvement, though in an emergency, biennial varieties may be cut for hay in the first year of growth. The hay obtained has a composition and feeding value approaching that of alfalfa, and curds in about the same time.

First-year pasture yields in the drier farm areas are comparatively light, except in years of abundant precipitation. Second-year growth is particularly rapid through April and May in the Central States, during which period abundant pasturage is produced. Evergreen and similar late-maturing varieties extend the second-year grazing season through August. To insure continuous pasture and hay through a period of successive years, it is necessary that new stands be established each year. Annual varieties in the Central States are of chief value as green manure crops and for sowing in formal rotations when biennial sweetclover, and red and alsike clovers have failed. In southwest Texas where the biennial sweetclovers are not adapted, the annual Hubam and Emerald are used for hay, grazing and soil improvement.

Sweetclover fits well into rotation systems. No other commonly grown cultivated crop leaves the soil in better physical condition for succeeding crops. It is commonly preferred to alfalfa for use in short rotations and for pasturing certain kinds of livestock, green manuring, and for growing on the less favorable soil types. Increased yields of other crops generally follow its judicious use in the cropping system. It thrives under conditions of drought where red, mammoth and alsike clovers and many other legumes fail.

Since sweetclover has a high protein and mineral content, its use as hay, pasture or silage is most economically supplemented by feeds high in other constituents.

Sweetclover for Pasture

Sweetclover is of prime importance as pasture for livestock, and with good grazing management will furnish abundant feed of good quality through extended periods of two successive growing seasons. In regions of relatively low rainfall, first-year pasture production is generally light in comparison with that of the second-year crop, though yields may
exceed those of perennial grasses. During late April and through May of the second year, sweetclover will furnish more grazing than any other legume in the Central States, and with favorable moisture conditions substantial pasturage of late-maturing varieties may continue until early September. The first reaction of stock to sweetclover may be unfavorable, but after they become accustomed to its characteristic bitter taste, they eat it with relish. **Carrying capacity:** Both intensive grazing and close cutting for hay in late fall should be avoided in the first year if maximum second-year production is desired. The number of animals grazed should be regulated to keep first-year growth down to a fairly uniform height of six to twelve inches and second-year growth to a height of from 12 to 16 inches. Clipping high with a mower will correct the effects of uneven grazing. The best grazing procedure prolongs the pasturing season of each year. Good pastures may be maintained for several years by removing the stock sufficiently early in the second year to permit flowering and natural reseeding.

The quantity of grazing afforded by sweetclover is greatly influenced by many factors. In pasture trials at the Nebraska Agricultural Experiment Station in 1933, common yellow provided 150 steer-grazing days per acre in the first year and 187 in the second year. In comparison, common white supplied 159 and 224 steer-days in its first and second years, respectively.

**Intensity of grazing:** The maintenance of stand and the amount of pasturage produced at different periods of the year may be controlled to a large extent by the discreet regulation of the number of animal units. While many animals may be grazed when soil moisture is abundant and growth luxurious, light or deferred grazing is advisable in periods of drought. Also, to avoid undue injury to plants, stock should be removed in wet periods when the ground is soft. Precautions to prevent bloat should be taken when animals are returned to pasture.

The minimum height of grazing permitted in the first year should be not closer than four inches for short, fine-stemmed varieties, and six inches for large, coarse-stemmed types. Too close grazing before stands are well established and before plants are eight to ten inches high should be avoided. On the other hand, excessive development of the rank growing varieties should not be permitted, and this may be controlled best by grazing sufficient livestock or by clipping. Better second-year growth results if stock is removed from the pasture by early September of the first year. Cutting to a height of 6 inches in simulated pasture tests whenever the plants had grown to a height of 12 to 14 inches has resulted in good recovery after each of three cuttings in the first year, and a good survival of stands in the second year.

Early second-year growth is very rapid and sufficient stock should be utilized to keep it uniformly at a height of 12 to 16 inches or it will quickly become coarse and unpalatable, with cessation of new shoots from the lower parts of stems, and a loss in total pasture yield.

**Pasturing periods of varieties:** Varieties of sweetclover differ more in time of maturity than do those of alfalfa and red clover. There is usually as much as a week difference in the time that varieties reach a height most suitable to begin grazing in the first year, while there may be as much as two months difference in the time that they cease to bear pasturage in the second year.

Varietal comparisons in livestock pastures at Lincoln, Nebraska, have indicated that Madrid and Spanish, which are new outstanding varieties from the standpoint of rapid first-year growth, may usually be pastured by June 10 if sown early in April. Within the following four or five days, an equal growth is usually attained by Evergreen and Iowa Late White, with comparable growth continuing through the remainder of the season. The first-year growth from different seed lots purchased as common white has differed greatly, but true common white will reach a good height for pasturing before common yellow. Common yellow and Grundy County are of distinctly slower growth, being fully a week behind Madrid and
Spanish, and their first-year June and July pasture yield is distinctly less. Annual varieties of sweetclover may usually be pastured about June 5 in the first year, which is slightly earlier than for the earliest biennial varieties. These pasturing dates are all on the basis of sowing in late March or early April in the Central States.

The second-year pasturing season of the commonly grown varieties usually begins in late April and terminates between July 15 and August 1. New, late-maturing varieties may normally prolong the pasturing season of the second year into late August and terminates between July 15 and August 1. New, late-maturing varieties may normally prolong the pasturing season of the second year into late August and terminates between July 15 and August 1. New, late-maturing varieties may normally prolong the pasturing season of the second year into late August and terminates between July 15 and August 1.

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At the Nebraska Experiment Station, first-year pasture yields taken by frequent cutting to simulate grazing were obtained each year from ten varieties in July, August and October. Some grazing would have been available for livestock beginning about June 10. The total yields of the three cuttings of all varieties averaged 43 percent as much forage as did the second-year crop. Pasture yields of the Evergreen, Spanish, Madrid, Willamette, and Sangamon varieties significantly exceeded those of common white and common yellow.

Averages of first and second-year pasture yields obtained in the two-year test show that Evergreen yielded 1.85 tons of cured forage per acre, Spanish 1.66 tons, and Madrid 1.52 tons, in comparison with 1.35 tons for common white, 1.30 tons for common yellow, and 1.14 tons for Grundy County.

Precautions to prevent bloat: Though bloat occurs less frequently in livestock pastured on sweetclover than on alfalfa, red clover or alsike clover, there is some danger and certain precautions must be taken in grazing. Bloat is the cause of occasional death of cattle and sheep, and it seems to occur with greatest frequency in May and June of the second year. It is usually the result of animals gorging themselves on the green succulent feed. The following precautions include those generally recommended: The hunger of the animals should be sufficiently satisfied with dry feed to avoid gorging when they are turned into pasture; animals should not be turned into sweetclover pasture while the plants are wet from dew or rain; straw, grass hay, or other dry feed, and water should be accessible to stock while pasturing; animals should be in healthy condition when turned into pasture and observed at frequent intervals to detect and treat those that are affected by bloat.

Sweetclover for Hay

Sweetclover is not in common use as a hay crop, although well-cured first-year hay has a feeding value approaching that of alfalfa. When the first-year crop is fairly clean and has sufficient growth in late fall to warrant harvesting, hay of good quality may be obtained. The second-year crop may be managed to provide either two hay cuttings or a cutting each for hay and seed. The stage of growth and height at which sweetclover is harvested have very marked effects on the extent of plant recovery and continued growth. Some varieties also have greater ability to continue growth after cutting.
than others, which is of great value in a crop grown for pasture or hay.

Harvesting in the Central States early in October after buds have formed underground on the root crown is best the first year. This permits a normal storage of root reserves and a maximum first-year yield. Close cutting at the end of the first season should be avoided, as it results in greater stand reduction and lower yield in the second year. Injury due to lack of vegetative cover during the winter months may be reduced by leaving a stubble of four or more inches to catch protective coverings of snow.

Where the first growth is taken for hay in the second year, it should be cut in a pre-bloom stage when the plants have attained a height of 24 to 30 inches, varying with the earliness of the variety. Stubble of eight to twelve inches should be left to provide for the second growth. The lower leaves die and fall off with advance into maturity and their axillary buds may also die, necessitating higher cutting as the plants become older. Timely harvest of the first cutting in the second year is directly related to growth renewal and yield and quality of hay. Stand losses and yield reductions increase with delay and closeness of cutting.

**Haymaking practices:** The curing and storage methods employed in the harvesting of alfalfa and red clover for hay will generally prove feasible for sweetclover, if cuttings are made at the stages of growth conducive to the best quality forage. This crop has a high moisture content and a relatively long period is required for curing. The stems are particularly slow in drying making difficult the obtaining of well-cured hay without serious leaf loss. Curing tests have shown that hay quality is not influenced by the time of day that it is cut. When the first-year crop of sweetclover is utilized for hay, it is preferably cut early in October, leaving a four-inch stubble.

A second-year haymaking procedure may be followed that is similar to that of the first year if the first crop is cut before the height exceeds 24 to 30 inches. The best quality hay is obtained by cutting at least this early, and a more substantial second growth is assured by leaving a stubble of at least nine inches.

The harvesting of sweetclover for hay should be done when conditions are favorable for curing. Due to the late harvest of the first-year crop and the characteristically coarse stem in the second year, more difficulty is usually experienced in curing sweetclover than either red clover or alfalfa.

Improper curing may result in spoilage and the production of a substance in the hay, called dicoumarol, that is dangerous to livestock fed thereon. Toxic hay does not always show signs of spoilage, and hay in which spoilage is apparent or suspected should be discarded.

**Varietal tests for hay yield:** Three of the newly introduced varieties, Spanish, Madrid, and Evergreen that are superior for pasture use, have given outstandingly larger hay yields in the Central States than the older common white, common yellow, and Grundy County white, though some of the other introduced and domestic varieties have shown no superiority in hay production over common white and common yellow.

Averaging the first and second-year hay crops for two years at Lincoln, Nebraska, Evergreen yielded 2.75 tons, Iowa late white 2.33 tons, Spanish 2.26 tons, Madrid 2.03 tons, and Wisconsin late white 1.94 tons, in comparison with 1.89 tons for common white, 1.62 tons for common yellow, and 1.44 tons for Grundy County.

The average yields of hay from Spanish sweetclover for 7 years at Manhattan, Kansas, exceeded those of common white 10 percent; at Hays, Kansas, the 4-year average yield was 12 percent greater; at Columbus, Ohio, the 3-year average yield was 4 percent greater; at Ames, Iowa, the 5-year average was 21/2 percent greater; at Lincoln, Nebraska, the 2-year average was 20 percent greater.

The average yields of hay from Madrid (yellow) sweetclover for 7 years at Manhattan, Kansas, were 33 percent greater than those of common yellow; the 4-year average at Hays, Kansas, was 22 percent greater; the 3-year average at Columbus, Ohio, was 12 percent greater; the 5-year average at Ames, Iowa, was 13 percent greater.
percent greater, and the 2-year average at Lincoln, Nebraska, was 25 percent greater.

The average yield of hay from Evergreen sweetclover at Columbus, Ohio, for 3 years was over 40 percent greater than either common white or common yellow; at Ames, Iowa, the 4-year average of Evergreen was, respectively, 35 to 75 percent greater than the 5-year average of common white and Grundy County; at Manhattan, Kansas, the 4-year average of Evergreen was 35 percent greater than common white and 68 percent greater than common yellow; and at Lincoln, Nebraska, the 2-year average hay yield was, respectively, 45 percent and 70 percent greater than common white and common yellow, and the pasture yield 40 percent and 43 percent greater.

**Sweetclover for Silage**

The practice of harvesting under-grazed pastures of sweetclover for silage in Iowa, Minnesota, and Wisconsin, is reported as having increased markedly in the last few years.

Sweetclover has merits for silage approximating those of other legumes when the crop is harvested at the proper stage of growth, allowed to wilt slightly, then firmly packed when storing in the silo. Excessive moisture causes a wet, unpalatable silage, but if the forage at time of ensiling is too mature or too dry to allow firm packing, unsafe quantities of dicoumarol may develop in the silage. For better silage, it is recommended that either 150 to 200 pounds of ground shelled corn, or 40 to 60 pounds of molasses be added to each ton of green sweetclover.

**Sweetclover for Bee Pasture**

The value of sweetclover as an excellent source of high quality honey has long been recognized. The honey derived from it, being light-colored and mild-flavored, finds ready acceptance by the consumer. By growing several varieties ranging from early to late maturity, the bee pastureage season of this crop in the Central States may be extended from the beginning of June to the end of July, and if moisture conditions are suitable, through August. It may be extended still later by use of annual varieties.

**Sweetclover as a Soil Improving Crop**

Sweetclover is unexcelled for restoring the productivity of soils where the absence of legumes and grasses in the cropping system or intensive cropping practices have led to losses in soil fertility and soil erosion by wind and water.

The residues of sweetclover, including an extensive root growth, decay rapidly at maturity. The fixation of atmospheric nitrogen in the soil is effected by the nodule-forming bacteria. Upon plowing, various elements of plant food are made available through decay and better yields are normally obtained from the crops that follow. Erosion is reduced and moisture penetration and workability of the heavy soil types are greatly improved.

Maximum soil benefits from sweetclover are derived from its use as a green manure crop. It is considered that plowing under sweetclover in early May of the second year when the growth is six to eight inches tall, provides 75 to 80 percent as much fertilizing value as when plowed at the full flower stage. Under average moisture conditions, such early plowing is most favorable for a following crop grown in the same year. While maximum soil improvement is obtained by plowing in the full flower stage, such growth usually dries the soil so thoroughly as to prevent production of another crop in the current season.

The biennial type of sweetclover is usually best suited for soil improvement, except in some portions of the extreme southern states, using the variety that has proved most satisfactory for forage production. Its vegetative growth is large and root development extensive. The annual type of sweetclover in the Central States makes a smaller growth and is of lesser value for soil improvement, but may be grown in small grain and plowed under as green manure in the same fall.
Annual sweetclover may also be sown for this purpose in a formal rotation following failure to obtain a stand of biennial sweetclover, red clover or alfalfa. In southwest Texas and some other southern areas where the biennial sweetclovers are not adapted, the annual Hubam and Emerald varieties may be used for grazing, hay and soil improvement.

The yields of crops that follow sweetclover are substantially larger under favorable moisture conditions than those that follow non-leguminous crops. The increases in yield of small grain, cotton, and corn have been most marked, showing the value of the legume in rotations. Under conditions of moisture deficiency, as in the western portion of the Corn Belt, the frequent use of sweetclover in the rotation must be avoided as it may result in over-stimulation of the vegetative development of the following crop. This increased growth creates a need for more water by the crop, and if this demand is not supplied, the crop may "burn" and yield less because of the sweetclover.

Sweetclover, instead of being sweet as its name implies, has a bitter, burning taste due mainly to a substance known as coumarin. This bitter substance, though not injurious in itself, is now definitely known to be responsible directly for making spoiled sweetclover hay dangerous as a livestock feed. When sweetclover hay spoils, the coumarin is converted into another compound that causes toxicity which is manifested in the animal by a failure of the blood to clot, so that animals afflicted in this manner may under certain conditions bleed to death from slight external or internal injuries. The elimination of these two shortcomings of sweetclover, i.e., unpalatability and toxicity of spoiled hay, would be a highly desirable accomplishment, and to that end considerable effort is being expended in the breeding of plants that are low or free from coumarin.

DISEASES AND INSECTS

Diseases: Sweetclover in the Great Plains States is comparatively free from serious diseases. Especially is this true in the drier sections since moisture is essential for infection by many of the diseases of this crop. Furthermore, since diseases appear mainly on second-year plants, little damage can be expected where the crop is plowed under for green manure early in the season. When sweetclover is grown for forage or seed in the Corn Belt, black stem and root rot may cause severe damage. Mosaic and leaf spots are also prevalent.

Observations made on sweetclovers in variety trials point out the necessity of using strains that are adapted to the particular region. Since some disease organisms may live from year to year by over-wintering on old plant residues, the growing of successive crops of sweetclover on the same land may lead to increased disease damage. Crop rotation, therefore, is a means of keeping losses to a minimum.

Root rot in the Texas Blacklands has brought about the almost universal use of annual instead of biennial sweetclovers. This disease has also limited the use of perennial legumes like alfalfa in that area. It kills a very high percentage of spring-planted sweetclover and other legumes. Fall-planted annual winter legumes are more successful because they mature before July and August when root rot is most damaging.

Insects: Insects having the most serious effect on this crop are the grasshoppers, cutworms, and the sweetclover weevil. In recent years, the sweetclover weevil has become destructive of first-year stands in Northcentral States that had ranked high in seed production. This has resulted in a reduction of 80 percent in the annual acreage of sweetclover grown in North Dakota. For further information on diseases and insects injurious to sweetclover, see chapter IX.

SEED PRODUCTION

A desired characteristic in a variety of sweetclover is that it be a reliable producer of seed under the conditions where it will be grown. Common yellow, Grundy County, and Madrid are early
varieties that reach maturity before mid-season drought becomes most severe and may be grown for seed production with reasonable assurance of success in the drier areas. Varieties that are intermediate in time of maturity as Spanish and common white or late as Evergreen and Wisconsin Late White, must be grown where moisture conditions are more favorable.

Favorable soil conditions conducive to high seed yields: Lime deficiency which occurs in some soils is detrimental to seed production and may be corrected through application of ground limestone. There also must be present in the soil an abundance of the symbiotic nodule-forming bacteria necessary for inoculation. Phosphates in ample supply are necessary for good nodule formation and maximum seed production. Although this crop is fairly drought-resistant, its first-year survival and a vigorous plant growth in the second year are enhanced by a favorable moisture supply.

Relation of stand to seed yields: Thickness of stand is an important factor in seed setting and development, particularly under the drier farm conditions. Stands may be relatively thick on moist, fertile soils and yet produce good seed yields. From two to three plants to the square foot is regarded as satisfactory under such conditions. Soils of low fertility and moisture content, however, require somewhat wider spacing for the best results. To obtain the best quality seed, it is also necessary that weed growth be controlled. This cannot be accomplished on most soils with an average stand of less than one plant to the square foot. Field weediness may also result from too intense grazing or clipping in early spring of the second year. Both of these practices tend to reduce seed yield.

Relation of pollinating insects to seed yield: The seed yields of sweetclover vary with the number and activity of pollinating insects. Many insects are known to visit and pollinate sweetclover flowers. Included among the more common are the honeybee, sweat bee, bumblebee, and leaf-cutter bee. Due to large numbers and the many flowers visited in a relatively short time, the honeybee is regarded as the most valuable of the pollinating agents. Hives of honeybees placed near the sweetclover field, one hive or more to the acre being recommended, have been found to cause greatly increased pollination and seed production.

Time of flowering and seed maturity: Adapted varieties of sweetclover differ widely as to time of flowering and seed ripening. The crop at Lincoln, Nebraska, requires a period of about one month from the full-bloom stage to time of harvest. The early-maturing Madrid and common yellow varieties reach the full-flower stage between June 15 and 20, the intermediate Spanish and common white between July 1 and 5, and the late-maturing Evergreen, between July 15 and 24. Assuming the proper stage for seed harvest to be when 60 percent of the pods have turned brown or black, the respective varieties will be ready for harvesting in approximately one month after reaching their full-flower stage, as indicated above. This period is slightly shorter for the biennial yellow than for the biennial white varieties.

Effects of field management on seed yields: Pasturing and clipping for weed control in the first year are more conducive to second-year seed production than is cutting for hay. In the second year the largest seed yields generally may be obtained from the first growth. This growth is so rank in some varieties, however, that it may be advantageous to take the second growth following early grazing or clipping, though some sacrifice in seed yield may result. The smallest seed yields have followed a first cutting for hay. When the first crop in the second year is harvested for hay, the cutting must be early and high to assure substantial second growth for seed production.

Sweetclover clipped frequently in the first year to simulate grazing has given better second-year stand survival and seed yield than when cut once for hay. Harvesting the first-year crop for hay resulted in 80 percent as good stand in the second
year as did simulated pasture, and the respective seed yields were 2.8 and 3.5 bushels per acre. The seed crop in the second year followed one early clipping to simulate early grazing.

The first growth in the second year normally produces the best seed yield. Under conditions at Lincoln in 1942, the first growth of common yellow attained a height of 48 inches and gave a seed yield of 5.0 bushels to the acre, in comparison with a height of 33 inches and 3.5 bushels where one early clipping had been removed to simulate early grazing. Where a hay crop in the early bud state was first removed, the seed crop attained a height of 22 inches and gave a seed yield of 1.3 bushels to the acre.

Time of cutting the seed crop: Most varieties shatter badly when approaching maturity, causing heavy seed losses. Atmospheric humidity is a most important factor to consider in selecting a time for harvesting sweetclover for seed. The effects of degree of shattering before and during harvest on the volunteer stand the following year and also the effects of harvesting at different stages of maturity on seed weight, hard seed content, and germination should always be considered.

Maturity stage for harvest: In a Nebraska experiment, the optimum stage of harvest for maximum yield of good quality seed was when about 60 percent of the seed pods were brown or black. It was concluded from these results that sweetclover should be windrowed or bound when from 30 to 60 percent of the seed pods have turned brown or black. Harvesting at the earlier stage is generally advisable in the drier areas, due to the great shattering tendency where humidity is low and high winds are frequent.

Seed loss through shattering: The loss of seed by shattering before and during harvesting and threshing is much greater for sweetclover than is generally realized. The quantity of seed lost per acre by shattering of the standing crop at various stages of maturity in a Nebraska experiment ranged from 30 pounds if harvested when 30 percent of the seed pods were brown or black to 77 pounds when 90 percent were brown or black.

The quantity of seed shunted during harvest will depend largely on maturity and dryness of the crop, and on the prevailing atmospheric humidity. Binders and windrowers are operated with smallest seed losses early in the morning, or better still, from midnight to 8 A.M., while the atmospheric humidity is relatively high, or soon after a rain. Shattering increases rapidly after 9 o'clock in the morning, and is greatest in mid-afternoon when humidity is lowest.

The quantity of seed normally lost per acre in harvesting with a binder ranged from 12 to 44 pounds in 1944, and 16 to 18 pounds in 1946. Results obtained in 1946 also indicate that loss from shattering becomes greater with an increase in row spacing. The taller and coarser growth of widely spaced rows apparently shattered more seed in passing between the elevator canvasses and over the binding deck.

Volunteer stands from shattered seed: The maintenance of sweetclover in pastures in which it is a desired constituent, is greatly aided by the tendency of plants to shatter seed and establish volunteer stands. In 1945 a stand of Evergreen established in this manner produced a yield of 9.5 bushels to the acre. In short rotations with other crops, however, this is an undesirable characteristic and much trouble is sometimes experienced in eliminating volunteer plants. Where a volunteer stand of sweetclover is not desired the only safe way is not to sow sweetclover, or certainly not to let it mature a seed crop. Even with the utmost precautions, it is impossible to prevent some shattering if a seed crop is harvested, with a resulting volunteer crop of sweetclover.

Methods of harvesting: Methods that may be employed in the harvesting and threshing of sweetclover seed include: (1) binding with a grain binder or corn binder and threshing with a stationary threshor or combine; (2) windrowing with binder, windrower, mower, or self-rake reaper, and threshing with pick-up combine; (3) harvesting with a "beater" or converted grain binder; (4) combining direct. The bound or windrowed crop is
SWEET CLOVER

permitted to dry before threshing, while the seed and trash obtained in harvesting with a "beater" must be spread and dried before hulling. The seed obtained in combining direct also must be dried before hulling and cleaning.

The methods of harvest studied at Lincoln and in outstate fields during the 1944 to 1946 period included those that appear most feasible under Nebraska conditions. Harvesting with mowers, headers, corn binders, self-rake reapers, and combining direct are now obsolete or little used. Binding with a grain binder and threshing with a stationary separator has been the most common procedure. However, the relatively new method of windrowing followed by threshing with a pick-up combine has much in its favor, and merits rather general use. Its principal advantages are the elimination of hand labor, lower cost of operation, and reduction in seed losses.

Several modifications of the grain binder are desirable for reducing losses from seed shattering during its operation. These include: (1) The reduction in number of reel slats to three; (2) the placing of metal pans under the binding deck and below the point where elevator canvases meet, for the purpose of catching shattered seed; (3) extending the elevator and binding deck to catch seed that shatters from the tops of plants. This seed is thereby diverted to the pan below. When shattering is great and the acreage large, the savings in seed will more than compensate for cost and the added labor involved in emptying the pans during harvest.

The corn binder is best suited for the harvest of large, coarse types of sweetclover grown in wide-spaced rows. The grain binder is the most generally available machine for windrowing, but windrowers are becoming increasingly common. No changes in operation of a binder are necessary except that the crop is released without binding and the bundle carrier is not used. Various methods of converting an old grain binder into a windrower for small grain have been reported which have proved rather satisfactory.

Threshing: Threshing is best performed in the afternoon as soon as the harvested material becomes well dried and the atmospheric humidity is low. Thorough drying of the crop facilitates the passage of chaff over the straw racks and screens, and results in a more complete separation of hull and chaff from the seed. Windrowed sweetclover will cure in from four to six days of good drying weather. Prompt threshing of the crop from the windrow as soon as dry is particularly important, due to the danger of large seed losses resulting from high winds, hail and heavy rains.

Bound sweetclover may be shocked in rows at harvest, which will facilitate driving a combine from shock to shock for threshing, or the bundles may be laid separately on top of stubble. Racks used in hauling bundles should have floors that are tight or covered with a canvas. There may be an additional saving of seed by placing canvases at places around a stationary thresher where losses occur.

Processing the seed crop: Removal of the hull, reduction of the hard seed content, and cleaning and grading to the degree desired for field sowing are the problems involved in processing sweetclover seed. Because of the tenacity with which the hull adheres to the seed, it is practically impossible to remove all hulls in a single threshing operation. This may be most nearly accomplished when the seed is well advanced in maturity, the crop well cured, and when the atmospheric humidity is low. By running the seed through a properly adjusted combine a second time, most of it will be threshed free of hull. Seed that has the hull removed in threshing is often scratched or scarified sufficiently by this operation.

The seed scarifier effectively removes hulls and at the same time scratches the seed coats, thereby increasing the percentage of germination. There is danger of seed injury by this treatment when not properly applied. Hulls may also be removed by putting the seed through a feed mill that has adjustable burrs which do not break or crush the seed.

Sweetclover seed may be partially
cleaned with a farm-size fanning mill or the entire process may be done at a central cleaning plant. By equipping the fanning mill with clover or alfalfa screens and with proper wind adjustments, a fairly efficient removal of loosened hulls, weed seeds, stems, and other foreign matter can be accomplished prior to marketing the seed.

The market demands high quality seed. Few farmers have efficient cleaning equipment, so the seed produced is generally sold as thresher-run seed to the seed dealer on a "recleaned basis." It is a practice of seedsmen to separate the hulled from the unhulled seed with cleaners and put the unhulled seed over the scarifier to remove the hulls. The percentage of hard seed in unhulled sweetclover is very high, and in this operation the hull is not only removed but the seed coats are scratched, thereby reducing the hard seed content.

Factors affecting seed quality: To determine the effects of immature harvest on seed quality, plants of Evergreen sweetclover were harvested at the Nebraska Station at different stages of seed development. The seed size and weight varied from 527,433 seeds to the pound when all pods were green to 253,404 when 90 percent had fully ripened. The germination plus hard seed percentages likewise ranged from 18 to 93 percent. The respective number of seeds calculated to the pound where 30, 60 and 90 percent of the seeds had ripened, were 300,799, 266,086, and 250,293 seeds. The total percentages of viable seed at the respective stages of maturity were 83, 88, and 89 percent. The results of these tests show increases in seed size and percentage live seed with advance in maturity.

The seed was of good quality, however, for all harvests in which 30 to 90 percent of the pods were brown or black.

The results of tests at two stages of maturity to determine the relation of seed color to seed quality, showed that the percentage of yellow seeds increases with maturity. As an average for the two stages of maturity, the yellow seed constituted 62 percent of the bulk by number and 71 percent by weight. The quality of seed decreased in the order of yellow, greenish-yellow, green, and brown or black. The total viability of seeds so classified was, respectively, 98, 79, 70 and 19 percent.

Scarification: Since most of the seed that is harvested in one season is normally sown the following spring, the change in germination during this period is of importance in determining the need for special scarification.

During four months (November 2 to March 5) of storage in a dry garage after harvesting, the germination of seed that was hulled in threshing increased 20 percent, while that of unhulled seed increased 36 percent. The smaller change in the hulled seed was apparently due to much scarification having taken place during the threshing operations. The degree of scarification that may occur in threshing is indicated by a hard seed content of 44 percent in hulled seed on November 2, as compared with 83 percent in unhulled seed. This difference shows the extent to which seed is protected by the hull, and indicates that 39 percent of the seed was given a needed scarification by the threshing operation.

Results of tests indicate that a normal increase in sweetclover seed germination takes place between the time of threshing and the following spring, and that seed hulled by the thresher may not need further scarification. The germination of the seed that remains unhulled in threshing, however, would have been very materially benefited by scarification.

It is generally recognized that unscarified sweetclover seed will remain viable for many years under good storage conditions. The results of tests indicate that both moderately scarified and unscarified sweetclover seed will gradually improve in germination over a period of at least two years under favorable storage conditions, but that scarification of seed for early sowing is advantageous.

An experiment with Madrid sweetclover in 1944 demonstrated the harmful effects of severe scarification. Laboratory tests of cleaned, thresher-run seed were made in comparison with corresponding seed that had been scarified by a com-
mmercial scarifying machine run at high speed. Although the hard-seed content was reduced from 56 to one percent by this treatment, 26 percent of the seed was injured, producing defective sprouts that would not survive under field conditions.

These two lots of seed were planted in comparison with an intermediate sample in the spring of 1944 and the relative stands of established plants determined on October 24. Considering the stand from unscarified seed as 100 percent, moderately scarified seed gave a plant survival of 123 percent, while the corresponding survival was 67 percent for the severely scarified seed.

The germination of hard seed under field conditions: The results of sowing hard seed indicate that their value will vary with conditions, but that such seed may contribute materially to the thickness of stand when moisture and temperature continue favorable for an extended period after sowing. In the Nebraska tests it was indicated that unscarified seed may best be sown in late February or early March and that moderately scarified seed appears most desirable for sowing thereafter.

Acreage and production: The ten-year average (1935-44) production of sweetclover seed in the United States was 53,000,000 pounds. This was produced on an average of 337,000 acres with an average yield of 160 pounds per acre. The average production in the last 5-year period (1945-49) declined to 36,000,000 pounds, or only 67 percent of the previous 10-year average. The largest total United States production for any one year was in 1939 with a production of 91,452,000 pounds. During this 10-year period Minnesota, the largest producing State, produced nearly half (47 percent) of the total United States production, but during the last five years (1945-49) this had declined to 23 percent, and Kansas had become a close second with 20 percent of the total. Other States that are important producers of biennial sweetclover are Nebraska, Illinois, Colorado, Ohio, Missouri, North Dakota, Wisconsin, Montana, South Dakota, Iowa, Michigan, and Indiana. In 1947, Texas produced about 11,000,000 pounds of Hubam sweetclover seed which is several times the usual production, but the details for other years are not available. In 1948 a total of 650,000 pounds of all varieties of sweetclover was certified, of which 85 percent was Madrid.

Yields per acre: The average yields per acre for many years have been around 160 pounds. The highest average yields per acre have been obtained in Colorado with a 10-year average (1938-47) of 240 pounds per acre. The same State averaged 285 pounds per acre in 1945-49.

The lowest yielding States are Ohio, Indiana, Illinois and Iowa with annual averages of 90 to 130 pounds. The differences in yields per acre by States may not be particularly significant because of the varietal differences in yields of seed. The late, leafy, high forage-producing but usually low seed-producing varieties like Evergreen and Iowa Late White, which are produced in some central States, if harvested for seed on any extended acreage in any State, might lower the average seed yields per acre materially for that State.

Since the statistical average yields are based on seed production on scattered farms and include production for use locally as well as for large-scale distribution, it is natural that seed dealers and processors of sweetclover seed in surplus-producing areas estimate average yields considerably higher than the statistical averages given above. Such estimates from Colorado range from 500 to 600 pounds for average yields, and around 1,200 pounds for maximum yields; Kansas estimates, from 300 to 400 pounds for average, and from 700 to 800 pounds for maximum yields; and Minnesota estimates from 250 to 450 pounds for average, and around 1,000 pounds for maximum yields.

SWEETCLOVER HIGHLIGHTS

1. Sweetclover, a roadside weed 40 years ago, is now a crop of considerable economic importance over large areas of the United States.
2. Sweetclover fits readily into most of the established cropping systems, and in many sections is the most important leguminous crop grown.

3. Sweetclover best follows an inter-tilled crop that was kept free from weeds the preceding season by thorough cultivation.

4. Sowing sweetclover with a companion crop is the most economical practice where moisture conditions are favorable, and is generally followed. Under the dried conditions of the West, stands are more certain when it is sown alone.

5. Sow to a depth of 1/4 to 1/2 inch on a firm moist seedbed at the rate of 8 to 15 pounds per acre, depending upon the condition of the seedbed.

6. Sweetclover will furnish pasture through two successive growing seasons. First-year pasture is generally rather light, but during late April and through May of the second year in the Corn Belt, it will furnish more grazing than any other legume. Late-maturing varieties may be pastured until early September.

7. Intensive first-year grazing should be avoided if maximum second-year forage or seed production is desired.

8. Pasturing precautions must be taken to reduce danger from bloat in livestock.

9. Sweetclover is not especially recommended for hay production, but under favorable conditions a cutting of good quality hay may be made in early fall the first year, and in early summer the second year.

10. The obtaining of well-cured sweetclover hay without spoilage or serious leaf loss requires more favorable curing conditions and careful handling than do most other hay crops. Spoiled sweetclover hay should not be fed to livestock.

11. Sweetclover is a valuable soil-improving legume. Improved soil structure and nitrogen fixation by nodule-forming bacteria result in better yields of succeeding crops where moisture is ample.

12. Sweetclover should not occur too frequently in the rotation, especially where moisture is short. Under such conditions "burning" may result, because of over-stimulation of the crop.

13. Sweetclover may be used for silage when weather conditions prevent its storage as well-cured hay.

14. New varieties have been developed for special regions and conditions. Such biennial varieties as Evergreen for the central and eastern Corn Belt, Spanish and Madrid for the Corn Belt and Great Plains, and such annual varieties as Hubarn and Emerald for Texas and other parts of the South have stimulated sweetclover production in their respective regions.

15. Sweetclover seed production is greatly influenced by field treatment. Beneficial first-year treatments, when sown alone, are early light grazing and clipping for weed control. Neither grazing nor clipping can be recommended the second year for either early or medium-late varieties, and only at a very early date for late varieties.

16. High seed yields require favorable soil, moisture and temperature conditions, and the presence of abundant pollinating insects and clear weather during the flowering period.

17. The newer recommended varieties are usually more productive of seed than is the old common white. However, the comparative seed yields of early, medium and late-maturing varieties fluctuate from year to year according to weather conditions and the abundance of favorable pollinating insects during the flowering period.

18. Highest yields of good quality seed have been obtained by harvesting when 30 to 60 percent of the seed pods have turned brown or black.

19. Harvesting may be done with a grain binder or windrower without serious difficulty where the growth does not exceed five feet. Very tall varieties, as Evergreen, may require grazing or clipping in early spring to reduce the plant height sufficiently to facilitate harvesting with such equipment.

20. Loss of seed by shattering at harvest is greatly reduced by cutting when the plants are damp from dew or rain. The best cutting periods are between 4 A.M. and 8 A.M., and late in the evening.

21. No machine has proved entirely satisfactory for harvesting sweetclover. Windrowing with a grain binder or windrower and threshing with a pick-up combine when cured is becoming a popular practice.

22. Combining the standing crop ordinarily is not practical, because serious shattering accompanies the advanced stages of maturity necessary for such harvest.

23. Prompt combining of the windrowed crop as soon as dry is particularly important, due to danger of large seed losses that may result from wind, hail, and heavy rains.
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24. Removal of hull, scarifying, cleaning and grading are processes involved in preparing sweetclover seed for sowing.

25. The benefits of scarification may be nullified or germination of the seed seriously impaired by improper adjustment of the scarifying machine.

26. Hard seed may contribute materially to the thickness of stand when moisture and temperature conditions continue favorable for an extended period.

27. The annual production of sweetclover seed has fluctuated during the past 20 years from a 3-year average high in 1937-39 of 73,740,000 pounds to a 7-year average low in 1942-48 of 35,500,000 pounds.

28. The United States statistical average yields of sweetclover seed are around 160 pounds per acre, but dealers estimate average yields in their particular surplus-producing areas at from 250 to 600 pounds, and maximum yields from 800 to 1200 pounds per acre.

THIS CHAPTER

The material in this chapter was obtained from a number of sources, among the more important of which are the two recent Nebraska bulletins by Garver, Slatensek, and Kiesselebach (NEB-9 and 10), Crosby and Hollowell's revision of "Sweetclover in Corn Belt Farming" (US-45 and 46), Willard's "Kinds and Varieties of Sweetclover" (OHIO-39), Hollowell's "Registration of Varieties and Strains of Sweetclover" (US-104), and the writings of Brooks, Friend, Johnston, Manke, and Mortensen of Texas on annual sweetclovers. The acreage and production statistics are from B.A.E. reports of Edler and Kuzelka. The preliminary manuscript was reviewed by Kieselbach of Nebraska, Johnston of Texas, W. K. Smith of Wisconsin, and Willard of Ohio, and many of their suggestions incorporated in the text. The final manuscript was reviewed by Hollowell of the U.S.D.A.

Chapter reference numbers: ARIZ-11; ILL-26; IND-15; IOWA-3, 17, 20; KY-9; MICH-5; MINN-17; MO-1, 14; NEB-9, 10; NEV-8; NM-4; ND-2, 3, 5, 10, 12; OHIO-35, 39, 44; OKLA-6, 7, 8; OREG-4; SD-13, 15; TEX-4, 6, 7, 9, 11, 16, 23, 33, 34, 35; WASH-9; WIS-9; WYO-8; US-45, 46, 104, 106, 196, 253; MIS-40, 56.

The reference numbers given here refer to references which are given in full by State, U.S.D.A., and Miscellaneous, on pages 682 to 724, and which are cross-referenced by author on pages 725 to 731. Citations in the text are indicated by abbreviation and number in parentheses.
LESPEDEZA

(Lespedeza species)

Lespedeza in recent years has become a crop of major importance in the eastern half of the United States. In the western half, it is not so well adapted. Aside from the acreage sown annually, lespedeza occurs as a volunteer crop that has spread more or less naturally over millions of acres of pasture. No other legume plays a more important part over so wide a territory in the Southern States in checking erosion and in gradually improving worn land with the least outlay of cash. At the same time, lespedeza will pay its way in hay, pasturage and seed.

The acreage of lespedeza hay now is about one-third that of cotton; much larger than that of flaxseed; twice that of peanuts; and four times that of tobacco. In the last 20 years the acreage of lespedeza hay increased in each of half a dozen States from only a few thousand to more than half a million acres.

A million acres of lespedeza hay is harvested annually in Tennessee, and in Missouri the acreage jumped from 62 thousand in 1934 to one and three-quarter million in 1942. In nine States the 1949 acreage of lespedeza hay was larger than that of any other one kind. That year more than 7 million acres of lespedeza were cut for hay in the United States, compared with only 349 thousand in 1929.

In seed production lespedeza is first among all small-seeded legume and grass seeds, and is equal in quantity production to the combined total of the next two seeds of this group which in order of production are red clover and alfalfa seed. All of this production of both hay and seed is in the eastern half of the country and mostly in the South.

ORIGIN AND HISTORY

There are about 125 species of the genus Lespedeza occurring mostly in the temperate latitudes of eastern Asia. About 20 species are native to the eastern United States. Most of the species are perennial. The only two known annual species (L. stipulacea and L. striata) are those under cultivation in the United States. The only perennial under cultivation is sericea lespedeza (L. cuneata). All three of the cultivated species originated in eastern Asia.

The common lespedeza (L. striata) has long been in the United States, the earliest record being from Monticello, Georgia, in 1846. It spread to Alabama and Mississippi in 1867 and was known in parts of Tennessee in 1870. In 1880 it was being cut for hay in Louisiana, and by 1887 it was established near Fredericksburg, Virginia. It had moved into Kentucky in 1893, and by 1912 had become established in southern Indiana. It is now known to be naturalized as far north as Indianapolis.

Kobe, a variety of common lespedeza, was brought into the United States by an explorer of the United States Department of Agriculture in 1920, and the first seed crop was grown at Hyattsville, South Carolina. Tennessee 76, another variety of common, was introduced by Essary of the University of Tennessee in 1915. It was the best of a number of selections with which he was working at
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that time. Little seed of Tennessee 76 is available to-day.

Korean lespedeza (L. stipulacea) was sent to the United States in 1919 by Ralph Mills, a medical missionary in Korea. The first seed was harvested at the Arlington Experiment Farm, Virginia, in 1921. A small distribution was made in 1922, and a more extensive one in 1923.

It took several introductions and trials of sericea lespedeza in the United States before it became recognized as a useful crop. It was first tried in 1896 by McCarthy of the North Carolina Station. In 1899 and 1924 the United States Department of Agriculture received seed of sericea lespedeza from Japan. Distribution of seed from both of these introductions was made under numbers 12087 and 04730. The sericea in cultivation in the United States today is descended from these two numbers.

KINDS AND VARIETIES

Species characteristics: Although there are a large number of species of lespedeza, some of which are native, only three are of interest to the American farmer—two annual species, L. striata and L. stipulacea, called common and Korean, respectively, and a perennial species, L. cuneata, known by the common name, sericea. While these annual species are more or less similar, they can be readily distinguished. Korean lespedeza is a coarser, and earlier maturing plant than common lespedeza and has broader leaflets and larger bracts or stipules at the base of the leaves. At maturity the leaves of the Korean turn forward so that the tips of the branches resemble small cones, but the leaves of common lespedeza do not turn forward. Another distinguishing characteristic is that the hairs on the stems of Korean lespedeza are appressed upward, whereas those of common lespedeza are appressed downward.

The annual lespedeza varieties are all low-growing plants with relatively small three-parted leaves and bluish or purplish flowers. In thin stands, they are rather spreading but in thick stands more erect.

All varieties of lespedeza are very leafy, having a higher percentage of leaf than alfalfa, and produce an abundance of seed. In common lespedeza and its varieties seed shatters easily, but in Korean and its varieties and in sericea there is much less shattering.

Varieties of common lespedeza: Two selections from common lespedeza, known as Kobe and Tennessee 76, are distinguished chiefly by the size of the plant. Tennessee 76 and Kobe plants are larger than those of the ordinary, unselected common lespedeza, the leaflets are broader and longer, and in Kobe the seed is larger. Kobe usually matures a little earlier than Tennessee 76. Kobe is being grown extensively, but the acreage of Tennessee 76 is small and seed is not available commercially.

Varieties of Korean: Selected varieties of Korean lespedeza are Harbin, Late

Common lespedeza.
Korean, Early Korean, Climax, and Iowa 81. Sometimes these selections are known by the numbers used with them in the process of selection. Number 19604 is Early Korean, 65280 Harbin, 19601 Late Korean, and 31249 Climax. Harbin lespedeza is very early maturing and makes small growth. Late Korean and Climax are later maturing and give larger yields of hay than the other Korean lespedezas. Iowa has introduced several strains of Korean lespedeza developed for earliness, yield and disease resistance. Iowa 81 has looked promising in some places in Missouri and southern Iowa. However, Wilsie and Hughes (Iowa-30), report that Iowa numbers 6, 39 and 48-1 in 3-year tests at Ames have averaged higher yields of dry forage than Iowa 81 or any other variety of Korean under trial during that period.

Perennial lespedeza: Sericea lespedeza, the perennial form, is a tall, erect plant with a growth habit somewhat like alfalfa. Although the perennial sericea is somewhat variable, selected and named varieties have not come into commercial use. Sericea lespedeza has been distributed under three numbers—12087, 17291, and 04730. Of these, 12087 and 17291 are of identical origin, though some observers claim that the latter is somewhat finer-stemmed. Number 04730 is a week or ten days earlier in maturing seed and grows a few inches taller than the other numbers. The height varies so greatly with soil and moisture conditions, however, that it is impossible to tell from the growth of the plants in any one field which number is being grown. For hay, all probably have equal value.

ADAPTATION

Climate: Lespedezas are summer-growing plants and are sensitive to cold. Sericea lespedeza, however, is winter-hardy and survives temperatures much below zero. The stems are killed by ordinary heavy frosts, but the crown and roots survive.

Lespedezas are hot-weather plants and will not bloom under a long day. All are slow in starting growth in the spring, though the varieties of Korean begin to grow earlier than those of common. All continue to grow until frost except Korean which stops growing with the maturity of the seed. This fact makes it less well suited to the extreme South. None of the annual lespedezas withstand severe frosts. Seedlings that start during warm days in late winter may be killed by a late freeze; mature plants are cut down by the first sharp frost in fall.

Lespedezas are strongly drought-resistant but during prolonged drought little, if any, growth is made. The effect of drought on the different varieties will depend somewhat on the stage of growth reached. If maturity is not too far ad-
advanced late rains will revive growth and fair to good yields may be secured. The annual lespedezas, especially Korean, are much more drought-resistant in the early stages than are alfalfa or the clovers. Abundant growth is, however, directly dependent on moisture. In dry seasons lespedia may not grow tall enough to be cut for hay except in favored places, whereas, in a year of abundant and seasonable rains, it will grow one to two feet high and produce a heavy crop of hay.

Soil: Lespedea will grow on almost any type of soil except those extremely sandy. It does well on the sandy loam soils of the Coastal Plain, the clays of the Piedmont, and the limestone soils of Virginia, Tennessee and Kentucky, and will grow on soils too sour to grow clover without the use of lime. It will not stand high-lime or extremely wet soils. Like most other farm crops, lespedia does better on good land and makes its best growth on fertile, moist bottomland, where yields of 2 to 3 tons of hay per acre are not uncommon.

Adaptation of varieties: The natural range of native lespedeza species in the United States is roughly from the Atlantic seaboard to the Great Plains. The commercial species cover much the same area. The northern limit of common lespedeza follows an irregular line from southern Iowa through central Illinois, Indiana and Ohio, to southern Pennsylvania and New Jersey. To the west it is established in eastern Kansas, Oklahoma and Texas. The varieties Kobe and Tennessee 76 are adapted from Kentucky to the Gulf of Mexico. Korean lespedeza can maintain itself somewhat farther north than common lespedeza, and the Harbin variety has reseeded at Ottawa, Canada, and in Vermont. In the northern limit of its range ordinary or unselected common lespedeza is a low-growing pasture plant only, whereas Korean has made good hay crops as far north as central Iowa, Illinois and Indiana. Korean is too early in maturing to serve best south of northern Mississippi, Alabama and Georgia. It may be possible there to use late-maturing varieties, such as Climax.

Sericea lespedeza is best adapted to the middle latitudes of the eastern United States but has survived winters in Michigan. In southern Georgia and in Florida fairly good growth has been made, but it is not so satisfactory there as farther north.

SOWING THE SEED

Time and rate of sowing: In North Carolina, Tennessee, and farther south, annual lespedezas should be sown in late February or the first half of March. Farther north sowing should be delayed until late March or early April. North of the Ohio River sowing in late April or early May is advised.

Sericea should be sown a little later than the annual lespedezas and after danger of frost is past. Good stands can usually be obtained by sowing at the time early corn is planted. In the lower South stands are more certain at this time than later, when drought periods may kill the young seedlings before they are well established. Farther north, late sowing will give good stands. In the latitude of Washington, D. C., good stands have been secured by sowing as late as June. In Missouri good stands of sericea have been obtained by sowing unhulled seed in winter.

Korean and common lespedeza and Tennessee 76 should be sown at the rate of 20 to 30 pounds of seed per acre; Kobe at the rate of 30 to 40 pounds; and sericea at the rate of 20 to 30 pounds of scarified seed or 50 pounds of unhulled seed per acre.

Method of sowing: The seed of the annual lespedezas should be drilled alone or on winter grain. If broadcast sowing is done too late or if the ground is too hard for freezing and thawing to work the seed under the surface, the field should be lightly harrowed after sowing. Freshly prepared land or a loose seedbed should be rolled or otherwise firm. A firm seedbed is essential in obtaining a good stand. When annual lespedeza is sown on meadows or pastures a spring-tooth harrow or disk should be used to loosen the surface soil before the seed
is sown. This will do much to insure a stand. Sericea should be sown alone in the Gulf States. Farther north it may be sown on winter grain. Sowing it alone on a firm seedbed is usually to be advised.

LIME AND FERTILIZERS

While the lespedezas will grow on soils low in lime and of low productivity, growth will be improved by using lime and fertilizers. On many fields these soil amendments are essential for good growth. If soils are very poorly supplied with lime or other minerals, these elements must be added to insure a vigorous growth of lespedeza. Compared with clover, the lespedezas will do well on acid soils of low productivity. On the other hand, a soil high in lime content, as the black-belt soils of Alabama and Mississippi, may not be suitable for lespedeza.

On rather poor soils, a better growth with a consequently stronger root system is secured by the use of lime and phosphate. The heavier growth provides better soil protection and more organic matter for worn soils. It therefore usually pays to lime and fertilize these soils. Whenever lespedeza is sown on fertilized small grain or fairly good soil or follows a well-fertilized cotton crop, the residual fertilizer is often all that is needed.

In some sections, lespedeza no longer makes the vigorous growth it once did unless lime and phosphate, and in some cases, potash are added. This can only mean that the soil supply of these substances has become depleted to a point where even lespedeza no longer thrives.

Many soils in Kentucky, Tennessee, Missouri and in the Piedmont once produced an abundant growth of red clover. Continued cropping and erosion have lowered the level of fertility of these soils until now lespedeza has largely replaced the older crop. There is real danger, however, that a continuance of this process, the removal of calcium and minerals by cropping and erosion, may further lower the fertility level so that even lespedeza can no longer give the returns it once did. Every ton of hay removes some calcium and phosphorus and when the lespedeza is grazed these elements are removed in the bones of the livestock. The constant removal of these elements over a term of years will so lower the quantities available for plant growth that declining yields will result.

It has also been shown that the application of lime and phosphate to soils markedly deficient in these nutrients results in a higher calcium and phosphorus content in the herbage. For the sake of quality, therefore, as well as for the quantity of hay produced, it is desirable to use lime and phosphate.

INOCULATION

In the region where lespedeza is commonly grown inoculation is generally not needed. On badly eroded soils it may be beneficial or necessary. On land that has not previously grown lespedeza, inoculation will be increased the first year by artificial inoculation. Artificial inoculation has been found more helpful in planting north of the Ohio River than farther south.

DISEASES AND INSECTS

The annual lespedezas are relatively free from bacterial or fungus diseases or insect attack. All lespedezas in the greenhouse have been observed to be rather susceptible to the attack of damping-off fungi, and lespedezas in the field may be susceptible also, though exact observations are wanting. A bacterial wilt disease somewhat similar to the one that attacks alfalfa was reported on annual lespedeza in 1939. The disease is widely distributed in the lespedeza-growing areas of the United States.

The lespedezas are as free from insect pests as from diseases. Insects occasionally feed on the foliage but do so little damage that loss from this source is never noticeable. Nematodes, however, do serious damage to lespedeza in dry, sandy soils in the Coastal Plains area of the South. For further information on diseases and insects, see chapter IX.
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UTILIZATION

Feeding value of hay: Feeding trials indicate annual lespedeza hay is nearly equal to alfalfa. Sericea has been used very little in experimental feeding trials, but general experience of farmers indicates that it is both palatable and nutritious when cut at the proper stage of maturity.

The protein content of annual lespedeza hay, which is usually cut just before or when in first bloom, varies from about 10 to 15 percent, depending largely upon the fertility of the soil. In sericea the range is about the same as in the annuals, but with this variety the time of cutting may vary, and this, as well as the quality of the soil, influences the protein content. Growing it on fertile soil and cutting it at an early stage of growth gives a high protein content. Lime and phosphate content are slightly lower in lespedeza than in alfalfa. An application of lime and phosphate to poor soil will increase the mineral content of lespedeza grown on such soil.

The tannin content varies with the age of the plant, as does the protein, but in reverse order, the tannin increasing as the protein decreases so that the higher the tannin content the lower is the feeding value. Sericea has much more tannin than the annual species. It varies from 5 to 8 percent in the whole plant and from 7.5 to 18 percent in the leaves. What effect the tannin itself has on feeding value, if any, has not been determined. It seems probable, however, that it may at least have some effect on palatability, especially in the green state.

Cutting for hay: To make the best hay the annual lespedezas should be cut when in first bloom. In the latitude of North Carolina this will usually be early in August for the Korean varieties and about two weeks later for Kobe lespedeza. When lespedeza is left until a considerable part of the seed is ripe, the resulting hay is of poorer grade. Sericea lespedeza should be cut when about 12 inches high. This will insure a good quality of hay with comparatively high protein content and low tannin.

Lespedeza contains less moisture than alfalfa or red clover and is consequently more quickly cured. The field-cured hay contains somewhat more dry matter than similarly cured alfalfa or clover hay. Annual lespedezas cut when no more than 10 inches high should be windrowed soon after cutting and in good weather may be hauled to the barn in 2-4 hours. If cut early in the morning it can be stacked late the same day. When more than 15 inches high, the cut hay should lie in the swath longer. In the southern part of the lespedeza area a seed crop may be produced after harvesting a very early hay crop of the annual lespedezas.

If a volunteer stand of annual lespedeza is desired the following year, the
hay must be cut early (about first bloom) and high enough for the second growth to have time to produce seed, or the cutting must be delayed until part of the seed has matured sufficiently to shatter while the hay is being cut. This latter practice, however, will result in poor quality hay.

Sericea hay cut when 12 inches high should not be left in the swath in bright sun more than an hour. It should be windrowed and hauled to the barn the day it is cut if the weather is favorable. Rapid handling of the hay is essential to save the leaves and prevent weather damage. Depending upon the fertility of the soil and length of growing season, one to four cuttings of sericea can be made each season. On very poor soil only one cutting should be made, whereas on very fertile soil as many as four cuttings are possible. Too frequent cutting weakens the plant and shortens the life of the stand.

Acreage, production, and yield: The average acreage of lespedeza harvested for hay in the United States during the 10-year period, 1934-43, was 4,140,000 acres. In the 6 years following it increased to 6,620,000 acres. The total production likewise increased from an average of 4,294,000 tons for the 10-year period to 7,200,000 tons for the following 6-year period, 1944-49.

An average yield of hay for the annual lespedeza is about 1 ton per acre. On good soils, 2 or 3 tons may be expected. Sericea yields have ranged from 1 to 4 tons per acre per season. In the South and up into Missouri, on good lands, Kobe has yielded more than Korean. In Missouri, however, except in the extreme southern part, it is too late to reseed dependably. In Kentucky and farther north Korean has yielded most. The early maturing varieties of Korean give the smallest hay fields. Mainly because of better inoculation and thicker stand, second-year volunteer crops of annual lespedeza usually produce larger yields of hay than do first-year seedings. Third-year volunteer crops are more likely to be weedy and therefore not so desirable for hay.

Utilization for pasture: The annual lespedezas afford good grazing and can be used in both temporary and permanent pastures. They make their best growth during the hot months and provide excellent grazing during the season when many grasses are producing little. In the latitude where Korean is ready to graze early in June, Kobe is ready about 1 week or 10 days later, and common is slightly later than Kobe. The pasture season for the early Korean varieties extends to early fall, when the seed matures and the plants turn brown. The later maturing varieties usually stay green until frost.

Rye or winter barley or other cereal sown early in fall will provide early spring grazing, and by the time the grain is eaten down, the lespedeza is usually large enough to carry the animals through the season. Such pastures can be renewed by disking the land in the fall after the lespedeza seed has matured and again drilling in the small grain, allowing the lespedeza to volunteer. The use of lespedeza in connection with grain and livestock makes possible a diversified farming that is proving successful from the standpoint of soil conservation and crop and livestock production. In the region to which it is adapted annual lespedeza should be included in any grass-legume mixture for permanent pasture. When sown on established permanent pastures it will become established in thin or bare spots, thus affording excellent summer grazing.

The annual lespedezas can be maintained well with grasses that do not form a dense sod. Grasses that make a heavy, matted growth like carpetgrass and Bermuda-grass crowd out the lespedeza almost completely in the second season. Bermuda-grass, however, offers less competition than does the carpetgrass. Such pastures usually must be plowed or otherwise broken up every third year if lespedeza is to be maintained. The use of phosphate with a lespedeza-grass mixture will help maintain the lespedeza in the stand. In a perennial grass pasture close grazing in spring is advised in order to assist the young lespedeza plants to become well established. Common les-
Lespedeza will survive longer in grass pastures than the improved varieties. When annual lespedeza is sown with a grain crop and the grain harvested for seed, the lespedeza, which grows rapidly after the grain harvest, can be used as summer pasture to supplement the regular pasture during the summer period of short growth. By this method overgrazing of permanent pastures can be avoided. Since the seed and leaves of Korean lespedeza remain on the plant well into the winter, late grazing is provided by this variety, as livestock readily eat the dried leaves and seed.

Sericea lespedeza has not been so universally liked for grazing as the annual varieties. In pure stand it has not always given satisfactory results when used as a pasture for beef cattle. Some livestock refuse to eat it, but many of them eat it readily. The favorable results with sericea might seem to indicate that with more experience it can be more widely used.

Use for soil conservation: Because lespedeza grows in thick stands, it affords throughout the growing season an excellent cover for the prevention of erosion. When grown alone or with a grain crop, it affords protection from eroding rains from summer to early fall and by adding nitrogen and organic matter increases soil fertility. If it is allowed to remain on the land without being cut, maximum benefit to soil fertility is obtained, but even when the crop is harvested for hay or seed, or is used as pasture for beef cattle. Some livestock refuse to eat it, but many of them eat it readily. The favorable results with sericea might seem to indicate that with more experience it can be more widely used.

Loss from erosion and decline in productivity of soils is greater in the southeastern part of the United States than elsewhere. It is in this area that the lespedezas are especially useful. The annual lespedezas grow slowly in the spring, but during the summer they cover and protect the soil, and the stubble and debris go far to prevent erosion during the winter. However, unless a winter-growing cover-crop follows the lespedeza there will be loss of plant food by leaching that should if possible be prevented. For soil improvement and erosion control lespedeza may be fitted into the farm program in various ways.

Sowing annual lespedezas on small-grain strips that alternate with corn or cotton will prevent excessive soil wash. The small grain protects the soil during the winter, the lespedeza during the summer. The strips should be moved every 2 or 3 years.

Sericea is well suited for sowing on areas where permanent or buffer strips are needed; also on critical slopes above the flow line of a terrace sericea helps to catch silt and keeps the terrace flow line open. The annuals are also sometimes used for this purpose.

Rolling fields may be kept in annual lespedeza for several years. The lespedeza can be used for hay, grazing or seed. A winter-growing grass should be sown in mixture with the lespedeza or a winter grain sown following the lespedeza crop to insure against leaching and to prevent erosion when the crop is cut or grazed very closely. In continuous cropping to lespedeza there is particularly a reduction of phosphorus in the soil, and the addition of this element as a fertilizer is necessary to insure good yields. After 2 or 3 years the lespedeza field will have a higher productivity and may then be used for cultivated crops. Under a cover of lespedeza little soil loss will occur. Sericea may also be used in this way but should be left on the field 5 to 10 years.

The annual lespedezas fit well into 1-year grain-lespedeza rotations. After the lespedeza has been grazed or cut for seed, the field should be well disked and sown to winter grain with a drill. When handled in this way the lespedeza will volunteer from year to year, thus checking erosion. Korean is best adapted to this rotation. If desired, the rotation may be extended to 2 or 3 or more years.

If spring oats is alternated with lespedeza, the later-maturing varieties of
annual lespedezas may be used. Late in
winter the old lespedeza debris should
be disked and an early variety of oats
drilled in. When once established, the
lespedeza volunteers each year.

In many sections an established field
of sericea may be disked in the fall and
sown to grain with a drill. As the grain
and sericea make their growth at the
same time in the spring, an excellent hay
is obtained by combining them.

When cultivated crops must be raised,
they should be grown in rotation with
erosion-resisting crops. The annual lespe-
dezas are admirable for this purpose. For
example, corn can be followed by oats
with lespedeza in the oats. In the fall
the lespedeza should be disked and the
land sown to wheat. The lespedeza is
then allowed to volunteer the next sea-
son. Where crimson clover does well as
a winter crop, it may be drilled in the
disked lespedeza and the winter growth
turned under in the spring for corn.
Where crimson clover is not successful,
hairy vetch or Austrian Winter peas may
be used. Other rotations with corn or
cotton may be arranged, as the annual
lespedeza fits in more readily than any
other legume.

A winter annual grass such as Italian
ryegrass or rescuegrass may be used with
lespedeza, but ryegrasses are not entirely
satisfactory with it because of competi-
tion. These grasses grow in winter and
protect the soil. In the spring they give
way to annual lespedeza, and some of
them will produce seed for a volunteer
crop the following winter. This makes
an excellent grazing and soil-protecting
combination.

Small gullies can be healed and further
erosion checked by seeding the annual
lespedeza or sericea. Road banks and
shoulders can be covered and held by
lespedeza, which not only offers a good
appearance but prevents washing. Grass
in combination with the lespedeza can
often be used to advantage.

The fact that sericea lasts for many
years makes it especially useful in depres-
sions for water outlets. Here it prevents
cutting and desilts muddy water. The

When a summer crop is needed for the
addition of organic matter and soil im-
provement in orchards, the annual lespe-
dezas can often be used advantageously
for this purpose.

Cropping systems: A great many of the
cropping systems in use in Virginia, North
Carolina, Tennessee, Kentucky, and Mis-
souri include one of the small grains. In
cropping systems that include a small
grain, lespedeza nearly always follows the
small grain and precedes an intertilled
crop, as corn or cotton. In cropping sys-
tems that do not include a small grain,
lespedeza follows an intertilled crop and
occupies the land 1 or 2 years, during
which time it may be cut for hay or
seed. Early Korean varieties mature seed
in time to permit a fall-sown crop to be
sown the same year. A fall-sown crop can
also follow late-maturing varieties when
they are cut for hay.

A field can be sown to lespedeza in
the spring, and a crop of hay or seed can
be harvested the same year. The land
can then be turned for the next crop, or
the lespedeza can be allowed to volunteer
for hay or seed the second year. The
place that lespedeza occupies in the crop-
ping system and the use made of the
crop vary with the type of farming. The
cotton grower located on a sandy loam
soil usually employs a slightly different
cropping system from that employed by
the cotton grower on a clay soil. Both
systems may be different from those in
use on grain and livestock farms.

Few, if any, changes in the crop se-
quence need be made when lespedeza is
added to the cropping system. In many
rotations lespedeza either takes the place
of grass and clover or is grown with
them. Where the soil and climatic con-
ditions are unfavorable for the production
of clover and grass, but favorable to
lespedeza, it can be grown to supply the
nitrogen and organic matter necessary to
maintain soil fertility and round out the
rotation. In a few cases a small grain—
usually oats—has been added to the cropp-
ing system, as a crop of oats and a crop
of lespedeza can be grown on the land the same year without an extra plowing.

SEED PRODUCTION

Harvesting for seed: Lespedeza is harvested for seed throughout the area in which it is grown. Depending upon latitude, common, Kobe, Tenn. 76, and late-maturing varieties of Korean mature from October to November; early-maturing varieties of Korean from September to October; and sericea from the first to the last of October. The seed of common, Kobe, and Tenn. 76 should be harvested just before or immediately after the first frost. Seed of Korean and its varieties does not shatter readily and may be harvested any time after maturity. Unless severe storms occur it will hold its seed well into the winter. Sericea should be harvested when most of the pods have turned brown.

Most of the seed of common, Kobe, and Tennessee 76 lespedezas is harvested now with a combine, but may be harvested with a mower with a shallow metal seed pan attached to the rear of the cutter bar.

The seed of Korean does not shatter so readily as that of common lespedeza and therefore ordinarily is harvested with a combine or is cut with a mower, without a seed pan, then windrowed, and threshed with a pick-up combine or an ordinary thresher. The use of a pan is profitable with the Korean only when the seed is high in price or when the crop is overripe. To avoid harvesting too much immature seed, cutting should be delayed until the plants are brown and, except when combining direct, should be done when the plants are wet with dew. The cut material should be windrowed in the late afternoon, when it is again somewhat damp. This variety, when cut with a combine, should be dry at the time of harvesting.

Seed yields: The usual range of seed yields of the common, Kobe, and Tenn. 76 varieties of lespedeza is from 100 to 250 pounds per acre. Korean yields more than these varieties and averages about 300 pounds. Sericea yields even more than Korean and averages about 400 pounds. Yields as high as 1,200 pounds have been obtained with Korean and sericea, but such high yields of common lespedeza are not obtained, on account of shattering.

A moderately good stand will produce more seed than a very thick stand. This is especially true of Korean. In a thick stand, the plants of Korean are so close together that they cannot branch. Consequently, each plant bears seed only at the end of the main stem instead of on the ends of numerous branches. Early grazing or taking an early hay crop will usually result in a larger seed crop than would have been obtained without grazing or cutting hay.

Acreage and production: The acreage of lespedeza harvested for seed and the total seed production increased almost consistently from 52,000 acres in 1929, and a production of 5,490,000 pounds, up to 1944, with 1,196,000 acres and a production of 255,000,000 pounds. The acreage and production fell off in 1945, 1946, and 1947 to 922,000, 935,000, and 755,500 acres and 187,000,000, 206,800,000, and 154,000,000 pounds of seed, respectively. However, in 1948 and 1949, it reached 241,000,000 and 245,000,000 pounds respectively, both of which nearly equaled the record crop of 1944.

The four principal lespedeza seed producing States, which altogether produced 70 percent of the total for the United States, are Missouri, North Carolina, Tennessee, and Kentucky in this order, with a 12-year (1938-49) average of 57 million, 33 million, 23 million, and 18 million pounds of seed respectively. The average for the United States for the same 12-year period was 184 million pounds. Prior to 1939, Tennessee, Kentucky and North Carolina were the principal seed-producing States, but since then Missouri has maintained the lead.

Recleaning seed: The seed must be recleaned by processors who have the necessary cleaning equipment to take out such weed seeds as ragweed, poverty-weed and dodder. Dodder seed is nearly the same size as that of lespedeza, except Kobe which is larger. In pan-caught lespedeza,
the dodder is mostly in the pod, or puff as it is sometimes called, and these pods are easily cleaned out with the trash. In threshed lespedeza the pods are broken and, since the individual dodder seeds are nearly the same size as the lespedeza seed, it is difficult to separate them from the lespedeza seed. Care must be taken, therefore, in the proper adjustment of sieves to remove as nearly all this dodder as possible.

Appearance of seed: Lespedeza seed is mostly marketed and sown in the hull with the calyx attached. The seeds of common and of Tenn. 76 are indistinguishable. In both, the pods are surrounded with the calyx, the five lobes of which are nearly as long as the pod and bluntly pointed. The pods are pointed and faintly reticulated. The hulled seeds are mottled. They are shaped much like red clover but are smaller. The pods of Kobe resemble those of common in shape but are decidedly larger and not so sharply pointed. The pods of Korean are more rounded, blunt, and strongly reticulated, and the calyx lobes are about one-fourth as long as the pod and are rounded. The hulled seeds of Korean are black or blue black.

Weight and number per pound: The legal weight of a bushel of common lespedeza seed in North Carolina and Arkansas is 25 pounds. Other States have not established legal weights but 25 pounds is generally accepted as the official bushel weight of common lespedeza seed. The actual bushel weight of well-cleaned, unhulled common lespedeza seed is about 28 pounds, Kobe about 30 pounds, and Korean about 45 pounds. The number of seeds per pound varies also with the purity of the seed. The approximate number of unhulled seeds per pound is about 340,000 for common and Tenn. 76, 185,000 for Kobe, and 240,000 for Korean.

Longevity of seed: Seed of lespedeza of all varieties deteriorates rapidly. Under average conditions seed 3 years old will germinate only about 50 percent. Seed 2 years old may give fairly good germination, but this is dependent upon its having been kept under good storage conditions. It is advisable to use seed that is not more than 1 or at most 2 years old and to have a germination test of this before purchasing or planting. Scarcified seed deteriorates more rapidly than unscarified seed.

Hard seed: The annual lespedezas have little or no hard seed and need no scarifying. Sericea has a high percentage of hard seed and must be scarified to insure prompt germination. Scarifying is accomplished by scratching the seed coat with any kind of an abrasive. Unscarified seed planted late in fall or in winter will become scarified by the action of the weather, and in some areas seeding in this way is practiced.

Weeds in lespedeza: Dodder has been the most troublesome weed in lespedeza. Where the crop is used for pasturage or hay the presence of dodder is not serious, but in a seed crop it not only reduces yields but makes the seed unmarketable or salable only at a reduced price. To keep a field free from dodder requires burning, spraying, or cutting and removal of the dodder, or otherwise completely eradicating the plant. Fields that are pastured heavily or are cut for hay have relatively less dodder. The presence of other weeds in lespedeza is objectionable as they reduce the quality of hay and pasturage and, further, it is often difficult to separate the seed from the lespedeza seed. By planting lespedeza after a clean-cultivated crop many weeds are eliminated. The same thing is accomplished by seeding lespedeza with small grain.

LESPEDEZA HIGHLIGHTS

1. The common lespedeza has been grown for hay and pasturage and soil improvement in some of the Southern States for many years.
2. The introduction of Korean and sericea lespedeza, and the development of larger-growing varieties of common and early-maturing strains of Korean have increased the use of the crop in localities where it was already grown and have extended the lespedeza area to other States to the north and west.
3. Lespedeza will grow on soils of low fertility, but on the poorer soils, fertilizer, particularly phosphate, is necessary.
LESPEDEZA

4. Lespedeza is adapted to soils of relatively high acidity, but on the more acid soils, lime will increase the growth materially.

5. Lespedeza seed is usually sown from February to April on top of the ground, much as red clover is sown.

6. Sow Korean, Common and Tenn. 76 lespedeza seed, 20 to 30 pounds per acre, Kobe 30 to 40 pounds, and seneca scarified 20 to 30 pounds and unhulled, 50 pounds.

7. Fall-grown grain should be lightly harrowed either before or after the lespedeza seed is sown with it.

8. Hay made from lespedeza is equal to that made from most other legumes for feeding farm animals.

9. Lespedeza provides pasturage during the summer and fall, when many pasture grasses are more or less dormant.

10. Both the annual and perennial varieties of lespedeza serve well for erosion control in gullies, on road banks, and in cultivated fields.

11. Lespedeza fits readily into most of the well-established cropping systems and can usually be included with little or no rearrangement of the other crops.

12. The annual varieties of lespedeza sown early in the spring will produce a crop of hay or seed the same year, and usually the shattered seed will come up and produce a crop the following year.

13. On some run-down soils yields of corn, cotton, and small grains have been more than doubled after lespedeza has occupied the land for 1 to 3 years.

14. Lespedeza seed average production for the 6-year period 1944-49 of 215,000,000 pounds was 38 times the average production of 5,700,000 pounds for the 2 years, 1929-30.

15. Missouri leads all other States in production of lespedeza seed followed in order by North Carolina, Tennessee and Kentucky.

16. The average acre-yields of lespedeza seed in the 6 highest producing States ranged from 187 pounds in Georgia, to 260 pounds in Kentucky.

THIS CHAPTER

The most notable pioneer in the more intensive modern research with lespedeza was Dr. A. J. Pieters. Most of the material used in this chapter was taken from his works (US-197 and 198), and from the writings of McKee (US-153 and 159), who was associated with Dr. Pieters during his work with lespedeza, and who later succeeded him. McKee, in cooperation with State forage crop specialists, has added much to our knowledge of lespedeza. The manuscript was reviewed by Lovom of North Carolina, Brown and Baldridge of Missouri and McKee of the U.S. Department of Agriculture, and their suggestions have been incorporated in the text.

Chapter reference numbers: 1 ALA-1, 9, 21, 22, 30; ARK-6, 13; FLA-7, 8; GA-15, 17; ILL-27; IOWA-21, 30; KAN-6, 20, 23, 25; KY-22; LA-13; MO-7, 10, 13, 15; NC-6; OHIO-13; OKLA-8; SC-5, 6, 10, 17; TENN-2, 4, 11, 12, 18; TEX-58; US-11, 90, 152, 153, 159, 197, 198, 215, 252; MISC-5, 22.

1 The reference numbers given here refer to references which are given in full by State, U.S.D.A., and Miscellaneous, on pages 682 to 724, and which are cross-referenced by author on pages 725 to 731. Citations in the text are indicated by abbreviation and number in parentheses.
CHAPTER XIV

VETCH AND FIELD PEAS

Though both vetches and field peas can be grown in many parts of the United States, it is in the Southeast where they have made their greatest strides in soil improvement, and in the Pacific Northwest where the enormous quantities of seed have been produced to carry on the winter cover-crop programs of the Southeast. If one were to select from among the number of winter cover crops used in the Southeastern States the two most important ones, they would be vetches and Austrian Winter peas.

These two crops are usually grown as winter annuals and fill a similar place in the large areas in which they are produced, whether for seed or for soil improvement. The increased crops of cotton and corn following well-fertilized vetches and Austrian Winter peas turned under have been outstanding. Without them the greatly increased yields of cash field crops and improvement of the soils of southeastern farms could not have been accomplished during the past decade.

**VETCHES**

*Vicia species*

Plants of the genus *Vicia* are commonly referred to as vetch. A large number of species are distributed throughout the Temperate Zones of both hemispheres, several of which have been recognized as of agricultural importance from very ancient times. Common vetch and hairy vetch have been used extensively in both the Old and New Worlds. One rather universally grown species of *Vicia*, *V. faba*, is seldom referred to as a vetch, but is more commonly called horsebean or broadbean. This species, grown mostly for its seed which is used as a vegetable, is also used for green manure. Other species of *Vicia* are used largely for forage and green manure. The vetches of most importance are common vetch (*Vicia sativa*), hairy vetch (*V. villosa*), smooth vetch (*V. villosa glabrescens*), purple vetch (*V. atropurpurea*), narrowleaf vetch (*V. angustifolia*), woollypod vetch (*V. douxcarpa*), bitter vetch (*V. ervilia*), monantha vetch (*V. articulata*), Hungarian vetch (*V. pannonica*), and Bard vetch (*V. monantha*). With the exception of bitter vetch, which is grown in countries bordering the Mediterranean, these species are all grown and used in the United States.

**DESCRIPTION**

The genus *Vicia* includes both annual and perennial species. Most of the common vetches are annuals. Hairy vetch under some conditions may be regarded as biennial. With few exceptions, vetches are more or less viny. The common agricultural species are all viny or weak-stemmed, with the exception of the horsebean or broadbean, which is quite upright. The stems attain a length of from 2 to 5 or more feet, depending upon the species and conditions under which the plants are grown. In all cultivated species the leaves have many leaflets and are terminated with a tendril, excepting *Vicia ervilia* and *V. faba*, which have few or no tendrils. From few to many flowers are borne in a cluster or raceme. Seed and pod characteristics vary with species, but in general the seed is more or less round or oval and the pods elongated and cylindric compressed.
While some of the vetches have very distinctive characteristics, others are very much alike and sometimes are almost indistinguishable. Woollypod vetch and smooth vetch are hard to distinguish except by the pod and seed characteristics, and purple vetch is difficult to tell from hairy vetch until the flowers and pods are developed. Narrowleaf vetch is similar to some narrow-leaf forms of common vetch and can only be told by its black pods and slightly different seed characteristics. The seeds of hairy and smooth vetch are indistinguishable. Woollypod vetch has slightly smaller flowers than either hairy or smooth vetch, but its leaves and stems are like smooth vetch. Its seed, however, can be distinguished from hairy and smooth vetch, since it is somewhat oval and has a groove through the middle of the seed scar.

Three varieties of common vetch are grown in the United States, the commercial common vetch or Oregon common vetch, Willamette vetch, and pearl vetch. The first two have mottled grayish brown seed and cannot be distinguished from each other, but the pearl vetch has a salmon colored seed which identifies it from the other two. The common commercial vetches can be distinguished by the simple key and short descriptions given later in this chapter.

**ADAPTATION**

**Climate:** The vetches require cool temperatures for their best development. In regions with mild winters, as in the Southern and Pacific States, they make their growth during the fall, winter, and early spring months, maturing in late spring and early summer. In the North, where winters are severe and summers moderately cool, they start growth in early spring and mature in late summer or fall. Species vary with reference to winter-hardiness and the minimum temperature at which they will make their growth. Hairy vetch and smooth vetch are the most winter-hardy of the commercial vetches and are recommended for fall planting in the North.

In regions where temperatures do not fluctuate violently or where there is protection of snow, Hungarian and woollypod vetch will stand a temperature of 0°F, or lower. Common vetch has a great many varieties and types, but without protection, none will stand zero weather. The variety of common vetch grown in the northwestern part of the United States under the name Willamette vetch is one of the most winter-hardy and in general can be said to stand 10°F, without injury under average conditions. Monantha vetch is somewhat less winter-hardy than Willamette vetch. Bittervetch, purple, and narrowleaf vetch are all less hardy than Willamette vetch and with fluctuating temperatures will suffer injury at 10°F to 15°F. In the Gulf Coast States, except in the extreme southern part, these vetches usually are injured by average winter temperatures. A few wild species of vetch are very winter-hardy. One of these, a native of the northern part of the United States, is known as bird vetch (V. cracca). This is a perennial and in some places occurs in considerable abundance.

**Soils and moisture:** In general vetches are not particular in regard to soil, although some do better on certain soils than others. All do well in rich loam. On poor sandy lands hairy, smooth, and monantha vetches do well, while Hungarian vetch succeeds on heavy wet soils where other kinds fail or make little growth. A moderate moisture supply is necessary for vetches, and none are drought-resistant. Under dry-land tests hairy, smooth and purple vetches have stood up somewhat better than the others, but cannot be considered adapted to such conditions. Vetches are more tolerant of acid soil conditions than most legume crops, and outside the lime-belt areas in the eastern part of the United States succeed without the addition of lime.

**Winter-killing:** Winter-killing in any variety of vetch cannot be connected with any definite temperature. The age, rate of growth, and vigor of the plant, the soil moisture, winter protection and rapidity of temperature changes downward are all factors directly involved in winter-killing. Young plants from late seedings
are often winter-killed when older plants of earlier seedings escape without injury. Plants growing rapidly because of high temperatures and ample moisture are injured more by freezing weather than plants that have been growing slowly and have had a gradual approach to a period of freezing.

The quantity of moisture in the soil seems to have some relation to winter-killing. Seedings on wet land will kill more easily than on well-drained land. This may be due in part to the effects of difference in soil-heaving, but most vetches do not thrive in soils that are wet during the winter months. Snow or any other loose covering lessens winter-killing. This is because a more uniform temperature is maintained about the plants and there is less soil-heaving.

CULTURE

Preparation of the seedbed: In the South most of the vetch is sown following cotton. Under such conditions little or no preparation of the soil is needed, as the cultivation of the cotton throughout the season makes a reasonably good seedbed. The same is true when the vetch is sown following soybeans, cowpeas, or Spanish peanuts, or any other cultivated crop. Under such conditions the seed is sown broadcast and disked in, provided the previous crop has been harvested sufficiently early.

On clay soils and where there is a heavy weed growth or the soil is firmly packed, plowing or heavy diskin will be essential in order to give a good seedbed. For best results, it is best to have the soil reasonably well firm, as this will insure better surface moisture conditions and consequently good seed germination.

In the Pacific Northwest disked seedbeds are used when vetch follows cultivated crops or spring-sown small grains, while plowing and subsequent preparation is practiced on fall grain stubble or uncultivated land. Usually no special soil preparation is practiced in orchards that have been clean-cultivated during the summer previous to sowing vetch for green-manure and cover-crop purposes.

Time of sowing: Latitude determines in a general way the time of sowing. In the extreme North or north of latitude 40°, from the Rocky Mountains to the Atlantic coast, all commercial vetches except hairy vetch should be sown in early spring. Hairy vetch in this region should be sown during August or early in September. On the Pacific Coast west of the Cascade and Sierra Nevada Mountains, with few exceptions, vetches can be safely sown in the fall. In the colder parts purple vetch will occasionally winter-kill, but in average winters it is hardy.

In western Oregon, western Washington, and northwestern California, vetch should be sown as early as the seasonal rains will permit. Usually this will be in the latter part of September or early October. In other parts of California, where the climate is mild and where irrigation is practiced, sowing should be done from the middle of August to the first of October. In the mild parts of Arizona, sowing should be done about the same time as in California. For green-manure crops the sowing date should be early, while for hay or pasture later sowing sometimes is equally satisfactory.

In the northern part of the Corn Belt, the best time for sowing vetch is the latter half of September, and in the southern part early in October. Early sowing in the Cotton Belt is desirable in order to get as much fall growth as possible, but where nematodes are numerous, early sown fields may be seriously damaged. In general, fields sown about the first of October escape with but little nematode injury. Those sown as late as the first of December, will usually result in poor stands because of winter-killing, and but little growth will be made by the time the crop should be turned under for corn or cotton.

Rate of sowing: The rate of sowing to give good stands has been reasonably well determined by experimental work. Local variations in the soil, preparation of the seedbed, and winter temperatures are factors that influence the rate of sowing, but in general the range of variation in the quantity needed is not great.

The following table gives the quantity of seed per acre considered advisable for
sowing of the different vetches in the different regions when sown alone.

<table>
<thead>
<tr>
<th>Kind</th>
<th>Southern States (pounds)</th>
<th>Northern and Western States (pounds)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hairy and smooth</td>
<td>20-30</td>
<td>30-40</td>
</tr>
<tr>
<td>Common, Willamette and Hungarian</td>
<td>40-50</td>
<td>60-80</td>
</tr>
<tr>
<td>Monantha</td>
<td>30-40</td>
<td>60-70</td>
</tr>
<tr>
<td>Narrowleaf</td>
<td>20-30</td>
<td>60-70</td>
</tr>
<tr>
<td>Purple and Bard¹</td>
<td>—</td>
<td>60-70</td>
</tr>
<tr>
<td>Woollypod</td>
<td>25-35</td>
<td>40-50</td>
</tr>
</tbody>
</table>

¹ Bard vetch is adapted only to the Southwest.

When a seed drill is used, a smaller quantity is required than when the seed is broadcast, and thoroughly prepared land requires less seed than land that is rough and poorly prepared. Under favorable conditions the smallest quantity of seed indicated may be used, while under less favorable conditions the quantity should be increased.

In sowing in mixture with oats or other small grain for hay, the quantity of vetch seed should be reduced about one-fourth, while the grain should be reduced to about one-half the amount used in sowing it alone. When to be harvested for hay and the hay is to be used for horses, the proportion of grain should be much higher than when the hay is intended for cattle or sheep.

Method of sowing: Vetch seed may be either broadcast or drilled. The use of the drill has greatly increased in recent years, especially in Oregon. Drilling is the more economical in use of seed, and gives evener distribution.

The depth of sowing varies with the type of soil. In loam soils, good stands have been obtained from plantings at a depth of 4 inches. This is deeper than most seedings are made. Deeper sowing will usually result in poorer stands. Shallower sowing is advisable when sufficient moisture is present. The surface-moisture condition should determine the depth of sowing which should not exceed 4 inches.

Vetch may be sown alone or with one of the small grains as a supporting crop. To sow with grain has been, and still is, the commoner practice where the crop is grown mainly for forage, as the grain furnishes a support for the weak stems of the vetch and to a considerable extent prevents lodging. Where oats succeed, they are the favorite grain to use in combination with vetch, though wheat, rye, and barley may be used. Oats are especially serviceable when the crop is grown for seed, as the oats can be readily separated from the vetch seed. There is greater difficulty in separating rye, wheat, or barley seed from vetch seed.

In Oregon, when grown as a seed crop, vetch sometimes is sown alone, but the price for threshing vetch alone in comparison with vetch with oats or other grain is the determining factor in this practice. In the sandy lands of Michigan, where the winters are severe, vetch is sown in combination with rye. Where vetch is used mainly as a green-manure crop, it is nearly always sown alone.

In the Cotton Belt, where vetch is used as a winter green-manure crop the seed is either broadcast or drilled. The green-manure crop usually follows cotton, or other cultivated crops, and the sowing is made between the rows. When the seed is broadcast it is covered with a 1- or 2-horse plow or cultivator equipped with disks or plows that cover the seed. If the seed is drilled, a 3-row 1-horse plow is often used. As the middle of the row is usually low and vetches will not grow well under such conditions, the middle hole should be closed when the three-row drill is used. For hairy vetch and others with seed of similar size the sorghum plate should be used in the drill. Some farmers go twice to the row with a one-row drill or with a fertilizer distributor that sows a mixture of seed, soil, and basic slag or superphosphate. Complete fertilizer is not mixed in this way because of danger of killing the inoculating organism. To avoid injury to the cotton, the drilling should be done immediately following a picking. In the lower part of the Cotton Belt the cotton is picked out before the vetch is planted. This will often permit the use of a large drill.

Furrows made by the small plows on the one-horse drills should be filled by the use of a smoothing attachment, such
as a scratcher, chains, or a small chain harrow, to prevent the young vetch plants being covered with dirt and sand by the first heavy rains. This danger is greatest on sandy lands.

**Fertilizers:** In the Pacific Coast States fertilizers usually are not necessary for the successful growth of vetch. In western Oregon, however, gypsum or land plaster commonly applied at the rate of 75 to 150 pounds per acre is often used with beneficial results. In the Southern States east of the Mississippi River it is almost universally necessary to use fertilizers. Superphosphate seems to be the one thing especially needed, but in planting vetch for the first time on land that has not grown legumes or received applications of nitrogen in commercial fertilizers, nitrogen in some available form should be included. For most parts of the South, the use of from 300 to 400 pounds of 16-percent superphosphate per acre is recommended. This should be applied to the land preceding the planting of the vetch.

Nitrogenous fertilizers are seldom used, as inoculated vetch plants utilize the nitrogen of the air. By analysis vetch contains 2½ to 3½ percent of nitrogen, much of which is from the air: in other words, a ton of dry vetch contains about 60 pounds of nitrogen. A considerable proportion of this nitrogen is returned to the soil when the crop is harvested as hay and fed on the farm. If it is found necessary, however, to use nitrogen, nitrate of soda or sulphate of ammonia at the rate of 100 pounds of the ordinary commercial form per acre probably will be sufficient. Well-rotted barnyard manure at the rate of 15 to 20 tons per acre is one of the best fertilizers to insure a stand and good inoculation and growth of vetch on land that has not grown this crop before. Little, if any, additional fertilizer is needed on lands regularly fertilized for a summer crop of cotton or corn.

**Inoculation:** Inoculation is essential to the growth of all vetches, and the grower of vetch should make certain that the organism necessary to accomplish this is present in the soil in adequate numbers before omitting the use of artificial culture. In the Pacific Coast States vetch is nearly always naturally inoculated, the necessary bacteria apparently being present in the soil. In the eastern part of the United States it is advisable to introduce the proper nodule organisms artificially. Many failures with vetch are directly attributable to the lack of inoculation. Inoculated plants are easily recognized by their greener color and more vigorous growth and by the nodules on their roots.

Inoculation can be accomplished by the use of commercial cultures or by the use of soil from fields that have grown a successful crop of vetch within the past 2 years. The use of soil transfer as a means of inoculation, however, is now antiquated because of the greater expense involved and the lack of assurance of satisfactory results. The use of an artificial culture from a known reliable source is much more likely to be successful and avoids the possibility of transferring diseases that may be present in the soil.

**DISEASES, INSECTS AND NEMATODES**

While there are several fungus diseases reported as occurring on vetch, it is seldom that any of these do serious damage. Leaf spot can usually be found on all species of vetch, but this does little damage. On the Pacific Coast during recent years, stem rot has caused some loss. During wet, warm springs, plantings made alone which have attained a heavy growth are attacked, and some loss occurs. The disease spreads slowly, however, and seldom damages large areas, but it occurs in spots most favorable for its inroads. Land on which stem rot has attacked vetch should not be seeded to this crop again for a period of at least three years.

Many insect pests of alfalfa, clover, and other forage legumes also attack vetch. Among the more important of these are aphids, corn earworm, grasshoppers, cutworms, fall armyworm, various weevils, and leaf hoppers. The vetch bruchid is a particularly serious pest in the production of hairy vetch seed. The control of these pests on vetch is for the...
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most part similar to the control of such insects on other forage legumes. Information is usually available on the biology and control of most of these insect pests, and although the damage caused by various species may look the same, the control measures are usually different.

The vetch seed grower’s attention should be called in particular to aphids, and he should be on the lookout for these little insects in the spring, as they multiply rapidly as the weather becomes warmer and the crop develops and may damage a crop seriously in a very short time. When it seems probable that aphids will destroy the vetch, it is advisable to cut the crop promptly, as a considerable amount of hay may thus be saved. In the Cotton Belt serious damage may be done to a vetch green-manure crop if it is allowed to continue growth too late in the spring. The proper season, however, for turning under the green-manure crop for cotton or corn usually is sufficiently early to avoid serious damage. In the northern part of the Cotton Belt, aphid damage may be expected after April 15, and in the southern part, after the last of March or early April.

When aphids appear in abundance, the green-manure crop should be turned under or disked down at once. In the South, the corn carworm sometimes does serious damage to maturing or late-standing vetch.

All the commercial and other varieties of vetch so far as known are subject to attack by nematodes, and at times serious damage may result. Nematodes are most active in warm weather, and serious damage may be avoided by planting moderately late. In the Cotton Belt this means the last of September or early October, which will bring the growing season into the cooler part of the year.

For further information on diseases and insects, see chapter IX.

UTILIZATION

All of the commercial vetches make good hay, silage, pastureage, and green manure, and can be used for cover crops and green feed. The seed is used as one of the ingredients in poultry and stock feed, which is frequently an outlet for surplus and waste.

Hay: The vetches make good hay either alone or in mixture with the small grains especially oats, and are relished by all kinds of livestock. Common, purple, and Hungarian vetch are the species most generally used for this purpose, but hay from the others is also good. In river-bottom lands of the South where Johnsongrass is established, narrow-leaf vetch often occurs in abundance and makes up a good part of the hay from such areas.

Vetch planted with one of the small grains is often cut green and fed to cattle or other livestock. Common vetch is thus fed in western Oregon. Succulent late-winter and early-spring feed can be supplied in mild climates in this way with little expense.

Vetch is ordinarily cut for hay when the first pods are well developed. When the crop is thin, cutting may be satisfactorily accomplished with an ordinary mower with a swather attachment. It is difficult, however, to cut heavy green vetch and use the swather. After being cut, when partially dry, the vetch should be windrowed with a side-delivery rake, if a swather is not used, or bunched with a horse rake and then shocked with pitchforks. This handling should always be done before the leaves are dry. Vetch should be allowed to cure in the shocks several days, and, if possible, hay caps should be used if rainy weather is feared. When a swather is not used, the harvesting is considerably more difficult. In either case it is the common practice to allow the vetch to lie a day before bunching. With most vetches it is difficult to obtain a bright-green-colored hay. Hungarian vetch is the best in this respect, and hay of this species handled properly can be cured so that the color is practically the same as when fresh.

When vetch is grown with a small-grain crop it should be cut for hay at the stage of its development just described. At that time the grain (if suitable varieties are used) will be in the milk or early soft-dough stage and make good hay. Some growers make a difference in the time of cutting vetch, or
vetch and grain hay, according to the class of livestock to be fed. For horses, it is usually allowed to become more nearly mature than for either cattle or sheep.

It is sometimes desirable to pasture fall-sown vetch in the spring, in order to retard the haying season and also to prevent heavy lodging. This is often done in western Washington and western Oregon.

The yields of hay of the various commercial vetches are more or less comparable when they are grown under conditions to which they are entirely adapted. From 1½ to 3½ tons per acre is the usual range.

Pasture: For pasturage the vetches alone or in mixture extend the grazing season by supplying late-winter and early-spring feed. They stand trampling and are well suited for pasturage. Common, hairy, and Hungarian vetches have been used for pasturage. Common and Hungarian are utilized by Oregon and Washington dairymen for pasturage during late winter, spring, and early summer and are eaten eagerly by all farm livestock. As a general rule, vetch is pastured only when the ground is dry, to avoid packing the soil and to reduce the possibilities of bloat in cattle and sheep. The use of hairy vetch is increasing for pasturage in Washington and Oregon, but common and Hungarian are usually preferred. In the eastern part of the United States, where hairy vetch is more commonly grown, it is pastured to some extent.

Even when vetch is grown primarily for hay or for seed, a limited amount of pasturing is often desirable, especially where the growth is likely to be unusually rank or where it is desirable to make the harvest later. Hogs should not be used for this purpose, as they destroy many of the plants by biting them off below the crown. Sheep and calves do the least damage in pasturing vetch to be used primarily for hay or seed crops.

Silage: Vetch or vetch and small grain combinations cut at the hay stage are used quite extensively for silage in western Oregon and western Washington. Yields of fresh silage material average about 10 tons per acre. The feeding value of vetch silage compares quite favorably with that of corn. All varieties of vetch are adaptable for silage.

Vetch in rotations: In the Cotton Belt vetch serves well as a winter crop, to be followed by corn, cowpeas, soybeans, sorghums, millet, or any late-planted crop. When the summer crop can be planted very late, it is possible to utilize the vetch for winter and spring pasture or hay. If the summer crop must be planted early, the vetch should be utilized as winter pasture or green manure, or as a combination of the two.

In the Northern States it is sometimes possible to cut fall-sown hairy vetch early enough for hay, so that a late crop of millet can be grown. Other vetches in the North must be spring sown; they require the entire summer season for development.

Under irrigation in the Southwest, where the winters are mild, it is possible to grow vetch alone or in combination with a grain crop for hay or pasturage during the winter and then grow a summer crop.

In the Northwest an entire season has to be given over to the vetch, but it is recognized as an excellent crop to use in rotation with the small grains and cultivated crops for the maintenance of soil fertility.

Feed value: The chemical analysis of any plant varies with its age; the protein content is high in young plants and the crude fiber low, while in old plants the protein is lower and the crude fiber higher. Plants with a high protein content are recognized as having high feeding value. The limited number of available chemical analyses of vetches indicate that the vetches are comparable in feeding value to clover, alfalfa, and other common legume crops. The protein content of hay usually ranges from 12 to 20 percent, depending upon the stage of development of the crop when cut.

Soil improvement: Probably the greatest use of vetch is for green-manuring. In the past common and purple vetches have been used extensively for this purpose but are less used at present. Hairy
Vetches, smooth vetch, and common vetch are used for cover and green-manure crops in the Cotton Belt and make up about half of the green-manure and cover-crop acreage of that region. Monantha vetch is used for green manure and as a cover crop in the extreme South, and purple vetch is used for green manure in California. Hairy, smooth, common, Hungarian, monantha, and purple vetches are all grown for seed in limited areas of the United States.

COMMERCIAL VETCHES IN THE UNITED STATES

While hairy, common, and purple vetches are the kinds most commonly used in the United States, others are used in limited areas and some of these offer possibilities of more extended use.

To supplement the previous more general discussion and assist in identification of species, the following simple key and short agronomic descriptions of the different kinds of vetch are given:

Plants decidedly hairy.
Flowers many in a cluster, stalked, purple
Pods hairy, seed scar with white appendage ............... Purple vetch
Pods smooth, seed round, seed scar smooth, without appendage
(Plants hairy or nearly smooth) .... Hairy vetch

Flowers few (2 to 6) in a cluster, not stalked, nearly white
Hungarian vetch

Plants smooth or nearly so.
Flowers many in a cluster, purple.
Pod smooth, seed round  .......... Smooth vetch
Pod finely hairy, seed oval to nearly round .... Woollypod vetch

Flowers one or few in a cluster, light lavender or nearly white (except Bard vetch)—
Leaves without tendrils .... Bittervetch
Leaves with tendrils.
Seed decidedly flattened, flowers one, light lavender
Monantha vetch

Seed oval or round, flowers two, purple ............ Bard vetch

Flowers not stalked.
Plants upright, leaves large and very broad to nearly round; seed very large ................ Horsebean

Plants viny, leaves narrow to oval and obovate, seed not large, flowers purple.
Pods turning black, leaflets always narrow .... Narrowleaf vetch
Pods not turning black, leaflets seldom narrow .... Common and Willamette vetch

Hairy vetch: 1 Hairy vetch (Vicia villosa), one of the oldest and most commonly used of the vetches, is grown in practically all the countries in the temperate zone and is extensively used in the United States. The stems are comparatively weak or viny, and the plants range from conspicuously hairy to relatively smooth throughout. This vetch is winter-hardy and will stand the winter temperatures of much of the northern part of the United States, except in areas where the ground is usually or often bare during the winter months and there is little or no protection to the vetch plants. It is well adapted to the Cotton Belt as a winter-green-manure and forage plant. Hairy vetch (including smooth vetch) is grown as a seed crop in parts of Michigan and in western Oregon and Washington, and in Arkansas, North Carolina, Alabama, Georgia, and Texas. Seed also is grown in quantity in the European countries bordering on the Baltic Sea and in central Europe, and was formerly imported into the United States from that region. The seed produced in the United States is mostly the smooth vetch variety.

Smooth vetch: 1 Smooth vetch (Vicia villosa glabrescens) and the common name "smooth vetch" cover only the smooth form. The nomenclatures and descriptions used here are those approved by the Division of Forage Crops and Diseases, B.P.I.S. and A.E. and by the Seed Act Division, Grain Branch, P.M.A.

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1 Both the botanical and common nomenclature of hairy and smooth vetch are somewhat confusing. The name "hairy vetch" as applied to the species (V. villosa) and as used here is somewhat of a misnomer since the seed offered under this name comprises both hairy and smooth forms which are more or less distinct, not only as to hairiness but as to other traits. The botanical variety name (V. villosa glabrescens) and the common name "smooth vetch" cover only the smooth form. The nomenclatures and descriptions used here are those approved by the Division of Forage Crops and Diseases, B.P.I.S. and A.E. and by the Seed Act Division, Grain Branch, P.M.A.
villosa glabrescens), a botanical variety of hairy vetch, differs from the hairy type in lacking the tufted growth at the ends of the stems and in having few hairs on stems and leaves. It also seems to be somewhat less winter-hardy although this has not definitely been determined. In the Southern States, smooth vetch makes more growth during the winter months and is perfectly hardy throughout that region. The seed of both hairy and smooth forms appears identical. Most vetch seed sold in the United States under the name "hairy vetch" is smooth vetch. Seed imported under the name "hairy vetch" is sometimes of this form and the two are often found in mixture.

Woollypod vetch: Woollypod vetch (Vicia dasycarpa), which is similar to hairy and smooth vetches, is more nearly like smooth vetch, and without the flowers and seed can hardly be distinguished from that variety. The flowers are a little smaller than either those of hairy vetch or smooth vetch, and the seed tends toward an oval shape instead of being nearly round, as in those varieties. The seed scar also has distinguishing marks which are apparent to the seed expert. The plant is comparatively smooth or lacking pubescence. In winter-hardiness, woollypod vetch is comparable with smooth vetch, although possibly a little less winter-hardy. It seems to be perfectly winter-hardy throughout the Cotton Belt and as far north as Washington, D.C.

Seed of woollypod vetch has been grown in western Oregon in very limited quantities and is not regularly available. This species makes a good winter growth in the South, and with cheap seed there is no reason why it should not be used for green manure and forage.

Common vetch: Like hairy vetch, common vetch (Vicia sativa) is of ancient origin. The plants are semi-viny, having slightly larger leaves and stems than hairy vetch. Being less winter-hardy than hairy vetch, common vetch cannot be grown as a winter crop except in regions having a mild climate. In western Oregon and western Washington it is hardy in most winters, but it often winter-kills in the northern part of the Cotton Belt. In the Pacific Coast States it is grown as a hay and seed crop, as well as for green manure, silage, and pasturage. In the Southeastern States its use has been largely for green manure. There are a large number of varieties of common vetch, among which the one commonly grown for seed in western Oregon is the Willamette. Pearl vetch, another variety of common vetch with light pink seed, is grown occasionally in western Oregon as a spring-sown crop but has not become important.

Willamette vetch: Willamette vetch, a variety of common vetch, differs from the original type in being somewhat more winter-hardy and a somewhat better producer of both forage and seed. It seems to be well adapted to the more fertile soils of the Southeastern States and to all other localities where common vetch is adapted. Because of its desirable qualities, nearly all common vetch grown in Oregon today is of this variety. Since it is indistinguishable from the common
VETCHES

type in both seed and plant characteristics, the only way to be certain of getting Willamette vetch is to buy certified seed.

Hungarian vetch: Hungarian vetch (Vicia pannonica) is a native of central Europe, being rather abundant in Hungary and adjoining territory. It has been introduced into cultivation in Europe but is less extensively grown than hairy or common vetch. This vetch is grown in western Oregon, where it has recently become of commercial importance. The plants are less viny than hairy vetch or common vetch and tend to be erect when the growth is short or when the plants have some support. Both the stems and the leaves are covered with medium-long hairs, which give the plants a decidedly grayish color. A stem length of from 3 to 4 feet is attained under favorable conditions, but under average conditions 2 to 2½ feet is more common. Hungarian vetch is rather winter-hardy and is comparable with smooth and woollypod vetches in this respect. Its exact limitations have not been determined, but it has survived winters as far north as Washington, D. C., without injury.

Hungarian vetch is especially well adapted to heavy clay soils and will do better in wet situations than other vetches. In the Southern States it has done poorly on sandy land. The seed habits of Hungarian vetch are good, and comparatively heavy yields of seed are obtained. Its commercial use is confined almost wholly to the Pacific Northwest where it is grown as a hay, silage, green-manure, pasture, and seed crop. The seed is used to a limited extent in mixed ground feeds and pigeon feed.

Monantha vetch: Monantha vetch (Vicia articulata) is a native of southern Europe in which region it has been brought under cultivation, but as far as known it is used only in a very limited way. The plant is weak-stemmed and viny, being like hairy vetch in this respect. In comparison with other commercial vetches, it has very fine stems and leaflets and matures early.

Monantha vetch is not very winter-hardy and for this reason it is adapted only to regions having mild winter climates. In the Cotton Belt, where winter temperatures are subject to great fluctuations, it has not been found regularly hardy except in the extreme southern part. In the Pacific Coast States it has survived the winters in the milder parts of Washington, Oregon and California. At the present time, there is no regular production of monantha vetch seed. It

Purple vetch: Purple vetch (Vicia atropurpurea) is a native of southern Europe; from there it was introduced into the United States. It is a viny plant with much the habit of growth of hairy vetch but differs from that variety in pod and seed characteristics. Purple vetch is one of the least winter-hardy of the com-
Purple vetch has been grown as a seed crop in western Oregon, western Washington, and in northwestern California. In other parts of California it has been used as a green-manure crop and for hay. The seed habits are good and seed yields comparatively heavy.

**Bitter vetch** (*Vicia ervilia*) is not grown in the United States, but is grown in parts of southern Europe and in Asiatic Turkey. The plants are more nearly upright in growth than most other vetches, although it lodges easily when making a rank growth. The seeds are conical or pyramidal in shape and smaller than those of Oregon common vetch. In the western part of the United States this vetch has made good growth and has produced good crops of seed, but it has never been considered superior to other vetches in common use. The seed is used for stock feed, especially for sheep. In the Cotton Belt it has made comparatively little growth and often has winter-killed, indicating that its use in that region will be very limited. It makes very good growth in the Pacific Northwest and produces heavy seed crops.

**Narrowleaf vetch**: Narrowleaf vetch (*Vicia angustifolia*), like the other common vetches, is of European origin, occurring in the United States mostly as a weed. Closely related to common vetch, it is very much like that species, but usually is distinguishable by its black pods, narrow leaflets, and smaller flowers. In the grainfields of the Spring Wheat Belt, it is found in abundance, and in the Cotton Belt it is everywhere along roadsides and in waste places wherever there is an accumulation of weed growth. Elsewhere in the United States it occurs in lesser abundance but usually persists by volunteering.

Seed of narrowleaf vetch is not regularly available in the seed trade. Occasionally it is harvested from volunteer stands in the South and saved from the screenings of the spring-wheat crop in the Northwest.

A few orchardists of the South have found this a good crop for volunteering as a winter-cover and green-manure crop. The crop seems to succeed, however, only where there is good soil or where there is weed growth and an accumulation of organic matter. It volunteers in pasture lands and makes excellent pasturage. Under cultivation, narrowleaf vetch has seldom succeeded.

**Bard vetch**: The general habit of growth of Bard vetch (*Vicia monantha*) is similar to that of hairy and common vetches. It has succeeded well in the irrigated areas of the Yuma and Imperial Valleys of the Southwest, where a very small acreage is grown. Farther north in the West, it cannot compete with the other vetches, and in the Cotton Belt east of the Mis-
Vetches

Mississippi River it has never succeeded.

Horsebean: Horsebeans (Vicia faba L.), coarse, upright-growing plants having large, broad leaflets and large pods, differ decidedly in habit of growth from most of the vetches. There are many varieties of this species, most of which are grown for their seed. The small-seeded varieties are sometimes grown for green manure, but are more generally used as stock feed; the large-seeded varieties are used as a vegetable. Formerly a large acreage of horsebeans was grown in California, but at present the acreage is rather small; in other parts of the country horsebeans are occasionally grown as a home-garden vegetable.

The horsebean requires a cool season for its best development and it is grown as a winter annual in the South wherever it will not winter-kill. In the North it is not winter-hardy, and even in the South it cannot be grown successfully where the temperatures fluctuate rapidly.

Seed Production

Sources of imported seed: Most of the vetch seed of all kinds used in the United States is now produced in this country. Considerable quantities of seed of hairy and smooth vetches were imported into the United States before the War. The seeds of both kinds came in under the name of hairy vetch, as they are indistinguishable. The average annual imports of hairy vetch for the 10-year period ending June 30, 1940, since which time practically no vetch seed has been imported, were close to three million pounds. During the same period the average annual imports of common vetch were less than 600,000 pounds. The imports of other kinds were negligible.

Hairy vetch seed is produced in Europe in the countries bordering the Baltic Sea and south to Hungary; common vetch seed is produced in the more southern European countries and in the British Isles; bittervetch seed is produced in the Mediterranean region, especially in the eastern part, where it is used as stock feed. So far as known, Hungarian and monantha vetches are produced only in very limited quantities in southern Europe.

Vetch seed production in the United States: The early production of vetch seed in the United States was practically all common vetch. Later, hairy vetch seed production became important. In the late 1920's Michigan and Oregon were producing annually around 300,000 pounds each of hairy vetch, and Michigan's production continued at about that figure, while Oregon's production continued to increase to a million pounds in 1932 and 1933 up to over five million in 1935, and nearly ten million in 1939. During the war (1940-44) the average production of hairy vetch seed in Oregon, which was the principal producer, was about 23 million pounds. Since then the average production (1945-49) in Oregon has declined to 12½ million pounds, which is little more than half of the war production. In addition to Oregon, both Arkansas and Washington have been producing some hairy vetch during the past ten or more years, the former an average of about 2½ million pounds, and the latter about 3½ million pounds. Also, North Carolina, South Carolina, Georgia, and Alabama produce some hairy vetch seed of unknown but probably small quantities. The total average production of hairy vetch seed in the United States, 1943-49, was 22 million pounds. During the War the production of common and Willamette vetch increased, while that of hairy vetch declined. From its peak of 51 million pounds in 1945, common and Willamette have also steadily declined to a production of 12.3 million pounds in 1949. The average for the 4-year period (1936-39) was about 5 million pounds; for 1940-43 about 21 million pounds, and for 1944-48 about 39 million, or nearly double the previous 4-year average, and eight times the prewar production.

Two other kinds of vetch seed, Hungarian and purple, have been produced in substantial quantities in recent years. During the 12 years (1936-47) the average production of Hungarian was 3,370,000 pounds. Since 1942 it has steadily declined from 9,400,000 that year to
only 350,000 pounds in 1949. Purple vetch reached its peak of over 12,500,000 pounds in 1946, from a war beginning of 4,300,000 in 1941, and declined to 4,500,000 in 1947 and 7,000,000 in 1949.

Since the vetches are somewhat interchangeable in their production and use, it is well to look at total figures of all vetch for a better understanding of vetch seed production. For the past 13 years, the average annual production of all vetch seed was over 18.5 million pounds in the first 4-year period 1936-39, 60.7 million in the 4-year period 1940-43, and 63.6 million in the last 6-year period 1944-49. Oregon formerly produced nearly all vetch seed produced in the United States but in 1948 and 1949 California, Arkansas and Texas produced one-third of the total.

The three outstanding factors in the increase of vetch seed production and the utilization of vetch have been the winter cover-crop programs in the Southeastern States, the Government support price and purchase programs in the seed-producing areas of the Pacific Northwest, and the export of vetch seed during the War. The increased use of cover-crop seed in the South will probably continue, regardless of Government support, but probably not to the same extent.

Seed yields per acre: There is considerable variation in the seed yields among the several vetches. The statistical average yields (basis clean seed) for the past 9 to 12 years range from 220 pounds per acre in Arkansas and Michigan up to 250 pounds in Oregon and 315 pounds in Washington, or a United States average of over 235 pounds. The average yields of common and Willamette, and Hungarian, mostly in Oregon, have been about 460 pounds, and of purple about 390 pounds. No statistics are available on woollypod and monantha vetches. The yields of woollypod are comparable with those of hairy, and monantha with common and Hungarian. The estimates of yields given by shippers in important producing areas are from 10 to 20 percent larger than these statistical figures. The maximum yields occasionally obtained are much more than double the averages given here.

Exports of vetch seed: During the 6-year war period (1942-1947) over 44 million pounds of vetch seed produced in the United States was purchased by the Government for export under Lend-Lease and by UNRRA and other agencies, or an average of 7,350,000 pounds a year for the 6-year period. Of the total quantity so exported, 90 percent was common and Willamette, and the remaining 10 percent in order named was Hungarian, mixed, and hairy. These exports represented only 10.5 percent of the total United States production of vetch seed for that 6-year period. As soon as European countries return to full production of vetch seed, it is expected that no further exports will be made to those countries from the United States, except under unusual circumstances such as crop failure. On the other hand, it is not expected that the United States will have to return to importing vetch seed from Europe as it did formerly.

Harvesting for seed: The general practice is to cut common, hairy, smooth, woolly-pod, and other shattering vetches for seed as soon as the lower pods are fully ripe, at which time the upper pods will be fully formed and the plant will be carrying a maximum quantity of seed. Later cutting occasions more shattering of the seed, while earlier cutting results in a considerable percentage of immature seed. The practically non-shattering species, such as purple and Hungarian vetches, usually are allowed to ripen 75 to 90 percent of the pods before cutting. In places where but little seed is raised, the crop usually is cut with an ordinary mowing machine. Two men with pitchforks follow the mower and roll the vetch back from the uncut area, enabling the machine to get through when cutting the next swath. Sometimes the first-cut swath is rolled on the uncut vetch, and when the succeeding swath is cut the two are rolled back out of the way. This puts the vetch in larger swaths than the first-mentioned method and also may reduce the loss from shattering.
An ordinary grain binder is used by some growers, especially when the vetch is short and therefore quite erect, or thin, or when it is grown with a supporting crop, such as oats. When thus harvested the crop is put in shocks similar to grain shocks and allowed to dry thoroughly before being threshed. When the binder is used, however, the vetch should be cut a little greener than otherwise would be the case, as there will be some shattering of the pods caused by the canvases and packers. The bundles should be tied loosely so the material will dry rapidly and not mold.

The most common way of harvesting vetch at present in the Pacific Coast States is to use an ordinary mower with a swather attachment. The swather, which is attached to and behind the sickle bar, rolls the vetch in a swath to the outside and leaves the way clear to cut the next swath. The vetch is put at once into shocks and remains there until threshed, unless a combine with pick-up attachment is used, in which case the vetch is left in the windrow. Easily shattering kinds, like hairy vetch, are often shocked immediately after cutting, to reduce shattering losses. The most important rule in the growing of vetch seed is to handle the crop as rapidly and as little as possible when cut.

In the southern part of the Cotton Belt, where vetch seed usually develops poorly, an occasional grower harvests hairy-vetch seed. In this section the pods do not break open readily and the crop can be allowed to become dead ripe, allowing the vines with the pods to be raked from the field and threshed.

Threshing: An ordinary grain thrasher can be used for threshing all kinds of vetch, whether grown alone or in combination with a small grain. Vetches thresh somewhat slowly, and the cost per bushel is much greater than for either wheat or oats. The charge for threshing seed is usually by the hour. It is sometimes necessary, in order to prevent cracking of the seed, to remove a number of the concave and cylinder teeth of the thrasher and to reduce the speed of the cylinder to 800 or less revolutions per minute. The adjustments that may be necessary seldom can be told beforehand and must be determined by the appearance of the threshed material as it comes from the machine. The screens that come with ordinary grain threshers can be used by properly adjusting them. The seed as it comes from the thrasher, however, seldom will be sufficiently clean for marketing and will have to be run through special cleaners, in order to secure a first-class product.

Combine harvesters are being used quite satisfactorily in the Pacific Northwest in harvesting the nonshattering or semishattering vetches. These machines are equipped with attachments which pick up the cut material from the windrow and pass it on to the separating machinery. Combining standing vetch is not considered satisfactory, because of heavy shattering loss.

Cleaning seed: Vetch seed, as it comes from the thrasher, will contain more or less cracked seed, small straws, weed seeds and stems, chaff, and the small grain with which it may have been grown. Ordinary fanning mills and seed cleaners, usually available on farms or at warehouses, will separate readily most of the foreign matter and trash from vetch. These machines will also separate quite readily the seeds of vetch and oats or barley, but wheat and rye seeds are not so readily separated from vetch seed. Separation of these, however, can be satisfactorily accomplished by the use of gravity, spiral and disc seed separators, of the types used in various regions growing vetch seed. Monantha vetch seed is more difficult to clean than that of most other vetches because of its flattened and somewhat oval shape and variations in size. When this seed is mixed with other kinds of vetch or with wheat it is often necessary to rely very largely on the spiral cleaner to separate them.

VETCH HIGHLIGHTS

1. There are many species of vetch, a number of which are grown extensively as forage and green manure crops in the United States.

2. While much of the hairy vetch seed used
in the United States before the War was imported, practically all of the vetch seed of all kinds now used here is produced in the United States, and large quantities were exported to Europe during the War.

3. Hairy vetch and smooth vetch make up about half the green manure and cover crop acreage of the Cotton Belt.

4. Over the larger part of the country all vetches are fall sown. In the extreme North and east of the Rocky Mountains, all except hairy vetch and smooth vetch are spring sown.

5. In the Southeastern States inoculating cultures and fertilizers are essential. In the West they are not so necessary but inoculation always gives added insurance. On lands low in fertility both inoculation and fertilization are desirable.

6. Vetches are not particular as to soil but they need plenty of moisture. They are not drought-resistant. They are more acid-tolerant than most legumes.

7. A liberal application of manure is the best insurance for a good stand of vetch on land that hasn't grown vetch before.

8. A firm seedbed is required. Fall-sown vetch on land occupied by a cultivated crop earlier that season requires little or no seedbed preparation before sowing the vetch.

9. From 30 to 60 pounds of seed per acre are usually required for sowing depending on variety.

10. Stage and condition of growth and soil moisture have more to do with winter-killing of vetches than low temperatures.

11. Vetch and oats cut green are excellent feed for livestock.

12. For pasturage, vetches alone or in mixture extend the grazing season by supplying late-fall and early-spring feed.

FIELD PEAS
(Pisum arvense)

The common name “field pea” as used herein refers to varieties of peas used for seed, forage, cover crop, and green manure. For the most part they have round, smooth seed which may be solid brown, white, yellow, bluish green, or mottled brown or gray. The plants are annual and have slender, succulent stems 2 to 4 feet long, which ascend with support.

While the early colonists grew field peas in a limited way their extensive use was a much later development. During the past 50 years they have been grown for forage and seed more or less in New York, Michigan, Wisconsin, Minnesota, eastern North Dakota, and South Dakota, Montana, Idaho, Oregon, and Washington, and as a winter legume cover crop and green manure in the southeastern part of the Cotton Belt and in the Pacific Northwest.

In more recent years their production has been reduced considerably or has been discontinued in some places where previously grown, except in the Pacific Northwest and in the Southeastern States, in both of which regions the production is largely the Austrian Winter variety which is grown as a winter crop. In Washington and Idaho substantial acreages of white, yellow and green seed varieties are grown for human food and referred to as dry edible peas.

In the Southeastern States the acreage of Austrian Winter peas and vetches exceed all other legumes for soil improvement. Of the 5,225,000 acres of winter legumes in the 1946 Agricultural Conservation Program, 1,890,000 acres or 36 percent were Austrian Winter peas, 1,630,000 acres or 31 percent were vetch, and 1,700,000 acres or 33 percent were other legumes made up mostly of crimson clover, lupines, and roughpeas.

The acreages of Austrian Winter peas under this program in 1946 in the largest-producing States were North Carolina 442,000 acres, Texas 298,000 acres, Mississippi 287,000 acres, Alabama 256,000 acres, Arkansas 177,000 acres, Louisiana 159,000 acres, and Georgia 150,000 acres.

ADAPTATION

Climate: A cool growing season is necessary for the field pea, as high temperatures are much more injurious than frosts and are most disastrous when they occur at the time the pods are setting. These climatic requirements limit its successful production as a summer crop to the Northern States and Canada. It is, however, grown as a winter crop in the Southern States.

When grown for hay or green manure, field peas are more tolerant of high tem-
FIELD PEAS

peratures than when grown for a seed crop. Profitable seed production is confined to northern latitudes or regions with comparatively cool weather. Its moisture requirements are less exacting than its temperature requirements, but other things being equal, it does best where the rainfall is fairly abundant. A 15-inch rainfall in the northern Great Plains is sufficient to produce a good crop, while 20 inches of rain in Kansas, Nebraska, or Colorado are inadequate.

None of the field pea varieties are winter-hardy in the colder areas of the northern part of the United States. Austrian Winter is usually hardy as far north as Washington, D. C. in the East, and central Oklahoma in the Great Plains. For this reason the Austrian Winter has become the popular variety for use as a winter cover crop in the Southern States. In western Oregon and western Washington, hardy varieties seldom suffer winter injury, and in many years medium-hardy varieties survive satisfactorily.

Soils: Well-drained clay loams of limestone origin, or soils that are neutral or of low acidity, are best suited to the field pea, although it does well on fertilized sandy loam soils. Heavy, black soils rich in humus tend to produce a heavy growth of vines with comparatively few pods and give a large tonnage of hay and a small yield of seed. They will not succeed where standing water occurs or where the soil is habitually boggy.

CULTURE

Preparation of seedbed: In the northern United States most growers claim that it is advantageous to fall-plow the land for field peas on account of the necessity for early spring sowing. When the land has been fall-plowed, it is usually possible to sow a week earlier than when spring plowing is the practice. The opening up of the soil to the action of the frost during the winter also improves its tilth. Spring plowing is satisfactory, however, if it can be done early. Fall-plowed land should be disked as early as possible in the spring and smoothed down with a drag harrow in case the seed is to be sown with a drill. If the sowing is to be done by hand, it may be done following the diskmg and the seed covered with a drag harrow.

In the Southern States the largest acreage of winter legumes follows cotton, in which case little or no preparation of the soil is necessary. Other crops, such as tobacco, peanuts, cowpeas, soybeans, and melons, leave the soil in good condition, and but little preparation of a seedbed is essential following these crops. If for any
reason the land needs plowing, the preparation is more expensive and requires more time. On clay soils where weed growth is abundant or where the soil is packed hard, plowing or heavy disk ing is essential.

In the Pacific Northwest the soil usually is quite compact where a fall-sown crop has been grown, and will, therefore, require plowing. A medium-heavy disk ing just before sowing is sufficient for land that has been spring-cultivated. Late winter or early spring plowing is most desirable for spring sowing.

Time of sowing: In the North field peas must be sown early enough in the spring to set pods before the warm weather of summer arrives. The young plants are not harmed by light frosts, and even as far north as southern Canada and the northern part of Michigan, Wisconsin, and Minnesota, the seed can be sown during the latter part of April and early May. In the intermountain sections of Colorado, Wyoming, Montana, Idaho, and the eastern parts of Oregon and Washington, from the first to the middle of April is the most favorable time for spring varieties. Occasionally, winter varieties are sown in late winter or very early spring. Throughout the Southern and Pacific Coast States in localities where there is little danger of a hard freeze during the winter, or where the snows occur in early winter, the winter-hardy field peas should be sown from September 15 to October 15.

In the northern part of the Cotton Belt, sowing should be done, if possible, during the last half of September, and in the southern part, early in October. Seedings made as late as the first of December will often winter-kill severely or make but little growth by the time the crop should be turned down for corn or cotton.

In western Oregon and western Washington, fall sowing should be done from September 15 to November 1. If done after November 1, the seedlings may be winter-killed.

In intermediate latitudes, where hard frosts may be expected during the winter, farmers sometimes sow field peas in February, thus giving them time to mature in May before the advent of hot weather.

Rate of sowing: The size of the seed and the abundance of the rainfall govern the rate of sowing. In northern latitudes with abundant rainfall or irrigation, small-seeded varieties, such as Austrian Winter should be sown at the rate of 60 to 90 pounds to the acre; large-seeded varieties require nearly twice this quantity. Under drier conditions, the quantity of seed should be decreased to one-half or two-thirds of these quantities.

In the Cotton Belt, where the Austrian Winter pea is the variety commonly used, 40 pounds of seed an acre is recommended. When field peas are sown with grain, as is often done in regions of ample rainfall, equal amounts by weight of field peas and grain should be used.

In Wisconsin, dry edible, smooth-seeded varieties of peas are sown at rates of 90 to 120 pounds per acre of the small-seeded varieties, 100 to 135 pounds of the medium size peas, and 150 to 180 pounds of the large-seeded varieties.

Method of sowing: The field pea is best sown with a grain drill, and if either a hoe drill or a disk drill is available it should be used in preference to broadcasting the seed by hand. In the South, where field peas are planted in cotton middles, the three-row one-horse drill is used. Usually the middle hole of the drill is closed, as the crop does not grow well in the center of the row, where the middle is low. In any drill care must be used to see that the feed in the drill does not crack the seed. Where a grain drill is not available, field peas may be sown broadcast and covered with a disk, spike-tooth harrow, or cultivator. Sowing in double rows is frequently practiced in the dry-land portions of the Pacific Coast States. This is accomplished most successfully by using an ordinary grain drill in which part of the holes or feeds have been closed. To allow for easy cultivation two open holes should alternate with four closed ones, so that each pair of rows will be 30 inches from the next pair.

Field peas should be sown 2 to 4 inches deep. In clay loam a depth of
FIELD PEAS

2 inches is best, while in sandy soil a deeper covering is preferable. When sown with grain, the common practice is to mix them and sow them in one operation.

Fertilizers: The use of fertilizers with field peas is not to be recommended in most regions of the northern United States, but in the Cotton Belt of the Southeast the use of fertilizers is often essential. Phosphoric acid is usually the most needed. The fertilizer should be applied in the fall just prior to or at the time of sowing, in quantities varying with soil and cropping conditions. When the summer crop preceding the field peas is heavily fertilized, the peas will need little, if any, fertilizer. If the soil is poor and the summer application of fertilizer is light, the use of 200 to 400 pounds of superphosphate, or 300 to 600 of basic slag, and 50 pounds of sodium nitrate or ammonium sulphate or an equivalent nitrate fertilizer is advisable.

In the Pacific Northwest applying land plaster or gypsum at the rate of 50 to 100 pounds an acre in early March on fall-sown field peas and at the time of sowing on spring plantings, increases yields on most soils.

Inoculation: For best results, field peas must be inoculated. This is especially true in the more recently developed farming districts of the western United States and in the Cotton Belt of the Southeast, where the soils usually do not contain the necessary inoculating bacteria. Inoculation can be accomplished by the use of commercially available pure cultures, directions for which will be found on the container.

The use of commercial fertilizer seems to favor inoculation and helps to insure nodule formation. The fertilizer, however, unless it is basic slag, should not come in contact with inoculated seed, as it may injure or destroy the inoculating organism.

DISEASES, INSECTS, AND NEMATODES

Diseases: Field peas are subject to a number of fungous diseases, practically all of which are difficult or impossible to control. The general suggestions which are made for nearly all of them are (1) rotate crops, (2) sow clean seed, and (3) practice clean cultivation. The development of disease-resistant varieties may be a remedy in some cases.

Leaf spot and stem blight are fungous diseases which occur in most pea-growing sections and may become destructive in the more humid areas. Bacterial blight attacks all above-ground parts of the plant. Leaf blotch kills areas of the leaf and may run into the petioles and stems. The entire leaf and petiole may be killed and brownish dead areas may be produced on the stems.

Powdery mildew is usually most destructive on late-planted or late-maturing varieties of field peas. Downy mildew is widespread but seldom very destructive except in certain humid areas. It is carried in the seed and lives in the soil for an indefinite period. The fungus which causes anthracnose attacks all above-ground parts of the plant but is seldom of much importance, except on Austrian Winter peas in the South. Fusarium wilt is characterized by a rapid wilting of the vines without conspicuous rotting of the roots. A number of root rots attack the underground parts of the plant, causing more or less decay. As a result of the death of the roots, the tops are stunted and often yellowish, and the plant may die.

Field peas, as well as other legumes, are affected by mosaic disease. The presence of these diseases is recognized by the intermixing of light- and dark-green areas in the leaves. The mottled areas are irregular in outline and may follow the small veinlets.

Insects: The pea weevil is the most serious insect enemy of the field pea, and has done more than anything else to limit the acreage of the crop. Continuous cropping to the field pea is almost sure to mean a constant increase of the pea weevil. Practically the only remedy is to stop growing field peas for several years. However, such control measures as burning the stubble and destroying shattered
seed before weevils emerge will help materially.

The pea aphid or plant louse is another insect which occasionally does considerable damage. It frequently does severe damage in the South. It has appeared in field pea sections at intervals and practically destroyed the season's crop, but it does not stay with the crop so continuously year after year as does the weevil. The aphid increases rapidly during a period of warm, dry weather, but a heavy rain, even when the insect is abundant, will sometimes free the vines almost entirely from it.

Another insect which is found in the Great Lakes region and Pacific Northwest is the pea moth. Nematodes: The field pea is subject to attack by a nematode which causes the so-called root knot on the roots. Most damage is done during comparatively warm weather and under such conditions that serious damage may be done. In the Southern States where damage is most likely and where field peas are used for green manure, this can be avoided by late planting in the fall and turning under comparatively early in the spring. Rotation with nonsusceptible crops and growing the crop only during the coolest part of the year will reduce injury from this pest.

For further information on diseases and insects, see chapter IX.

UTILIZATION

Hay: When grown for hay, field peas are usually mixed with oats or some other small grain. These mixtures with grain stand up much better and make harvesting easier and curing quicker. As a hay crop the field pea works into a rotation very nicely because it is removed from the field early in the year, thus allowing ample time for a thorough preparation of the soil during the fall.

The proper time to cut field peas for hay is when most of the pods are well formed. When they have been sown with grain, the time of cutting may be governed partly by the maturity of the grain, but the varieties of field peas and grain should be so chosen that the crop can be harvested at the most favorable period of maturity for both. There are now available for the ordinary mower attachments consisting of guards that extend in front of the cutter bar and lift the vines off the ground, and a windrow attachment which effectively removes the vines from the swath and leaves them in a windrow behind the mower. The hay can be left in the windrower or bunched with a rake and left until dry and ready to stack or put into the mow.

Hay yields of field peas alone or in mixture with grain range from 1 to 3 tons per acre, depending on soil and other factors.

Pasture: Because field peas should not be trampled, they are not a success as a pasture plant except when sown with a small grain or when allowed to mature so that the entire plant may be utilized as pasture. Their use in this latter manner is a common practice in parts of the Rocky Mountain States where they usually are grazed by sheep.

Silage: Field peas make good silage when grown in mixture with a small grain and cut when the grain is nearly mature. Such silage has a high feeding value and has given excellent results when used for fattening cattle and sheep.

Green manure: While field peas are not utilized as green manure or as a cover crop in some of the regions in which they are grown, many thousands of acres are planted for these purposes in the Cotton Belt. As the field pea is a legume, it adds nitrogen to the soil as well as organic matter.

When used as a green manure to precede annual crops, field peas should be turned under about 2 weeks before the sowing of the annual crop. In the South, where field peas are used most largely for this purpose, earlier plowing is advised if the field peas have made sufficient growth. When the weight of green field peas is 14 pounds per 100 square feet, the nitrogen in the crop, calculated on an acre basis, is equivalent to about 300 pounds of nitrate of soda and is sufficient for a good crop of corn. To delay turning under after this growth is attained
in order to get 50 to 100 percent more nitrogen means running risks of dry weather, of unwieldy growth, of greater difficulties in getting stands of corn, and of possible injury from other insects such as vetch worms.

When the peas are at the stage of growth mentioned, they can be turned under with an ordinary 2-horse plow with a 12-inch rolling colter attached. If the growth is heavy, a thorough diskimg previous to plowing under will make the plowing easier.

Rotations: The value of field peas in rotations with hay, grain, and corn has been proved throughout the Northern States and also in a few localities in the mountain districts and irrigated valleys of the West. In the Northeastern and North-central States, where rotations are regularly practiced, field peas usually follow a meadow crop. They have been found very effective in furthering the disintegration of the sod, and this fact has determined their position in the rotation.

The substitution of field peas for summer fallow in the wheat rotations of the Pacific Northwest, where annual precipitation is 20 inches or more, is being practiced by some growers. A crop of field peas leaves the ground in practically as good condition for wheat as fallow, and gives equally good yields.

SEED PRODUCTION

Harvesting for seed: The field pea should be cut for seed when the pods are mature and the seed is firm. It is not well, however, to wait until the vine and pods are both dry, since if that is done there may be considerable loss from shattering, and if the weevil is not field-controlled, the weevil damage is sure to be large. Field peas are most commonly cut for seed with an ordinary mower equipped with a bunching or windrowing attachment. When the bunching attachment is used, a man with a pitchfork follows the mower and moves the bunch out of the path of the cutting equipment on the succeeding round. This method leaves field peas in a better condition to be hauled to the threshing machine or stack than when they are merely windrowed; it also prevents, to a large degree, the shattering which would accompany any use of a hay rake. When growth is heavy, the windrower is probably more satisfactory than the buncher. In a great many cases field peas are threshed directly from the bunches or windrows. In eastern Oregon, eastern Washington, and northern Idaho, considerable harvesting without first mowing is done. If rain occurs while field peas are being cured, they should be turned as soon as the top of the bunch is dry. If this is neglected, considerable loss of seed by shattering will result.

Threshing: The threshing of field peas is usually done with an ordinary grain separator or combine fitted especially for the purpose. In regions of large field pea production, the threshing machine or combine is commonly equipped with an adjustable wooden pulley which makes it possible to decrease the speed of the cylinder to the required number of revolutions, and certain other adjustments are made. Where the field peas are intended wholly for livestock feeding, such precautions are not necessary since cracked seed is not then so objectionable, but there may be some waste by loss of small portions of the seeds. Where the crop is to be sold for seed purposes, great care should be used in threshing, as cracked, chipped, or partly hulled seed is less viable and has low market value.

Recent studies have shown more injury to peas and other legume seeds from rough handling than was previously thought possible. Some of these injuries are physiological and do not show in the seed coat or embryo but affect the germination and later growth of the plant.

Combines are now in rather common use for threshing field peas either cut or standing. The field peas are picked up, and attachments are used in handling the crop from the swaths or windrows.

Preparation of seed for market: Field peas for market should be reasonably true to variety and should be cleaned so as to comply with one of the grades in the official United States standards.

Cleaning may be done with a number of mechanical cleaners, of which there
are several on the market. These cleaners can be adjusted not only to satisfactorily clean but also to grade the seeds to size. For convenience in handling, the seed is usually put in 100-pound strong burlap bags. In cleaning, as in threshing, extra care should be taken to avoid rough handling or damage to the seed.

Fumigation is necessary in regions where the pea weevil is a factor. The fumigating should be done immediately after threshing for best results. Seed should be stored under dry, well-ventilated, rodent-free conditions.

Acreage and production statistics: Although field pea seed can be produced throughout the northern United States wherever there is ample rainfall, most of the acreage planted for this purpose at the present time is in Oregon and Idaho. In recent years the increased use of the Austrian Winter variety for a cover crop in the South, where seed production has not proved practical, has resulted in an increased acreage in the Pacific Northwest, where conditions are especially favorable for seed production.

No records of acreage and production of Austrian Winter pea seed are available prior to 1936. In the first 3 years (1936-38) Oregon is the only recorded producer with an average of 23,300 acres and a production of 18,810,000 pounds. During the next three years the average total United States acreage was 57,700 and the production 40,200,000 pounds, of which the average Oregon acreage was 51,800 acres or 90 percent of the total, and its production 34,700,000 pounds or 87 percent of the total. With a strong price support and an aggressive war production program in 1942 and 1943, the total acreage and production were greatly increased to an average for those 2 years of 145,000 acres and 142,000,000 pounds. Idaho and Washington also had a major part and California and North Dakota a minor part in this production, the percentage production of each being Oregon 50 percent, Washington 22 percent, Idaho 19 percent, California 7 percent, and North Dakota 2 percent. Since then (1944-49) the average production has been about 55 million pounds, nearly 90 percent of which has been produced about equally by Idaho and Oregon. The average annual yield for this period was about 1050 pounds per acre, while in no year prior to 1944 had it reached 1,000 pounds, the annual average yield for that period being only 810 pounds.

Some location problems: During the war the need for seed of winter legume cover crops in the Southeastern States and with a support price for Austrian Winter peas, brought about a greatly increased acreage of field peas for seed in the Pacific Northwest. Since this same general area also produces the larger part of the seed of garden and canning varieties of peas, several serious problems arose.

Where Austrian Winter peas are grown in proximity to seed crops of garden and canning varieties, the two varieties tend to cross and thus injure the purity of both. With the garden and canning varieties this is especially serious. Also, wherever Austrian Winter peas are grown for seed in that area, there is some danger of a mixture of volunteer peas in the fields of grain or whatever succeeding crop may occupy the field. Also, the proximity of Austrian Winter peas near garden and canning varieties of peas has been detrimental because the aphids becomes established in the fall and early spring on the winter-grown Austrian Winter pea and is in a position to more readily infest the summer-grown varieties.

Because of this situation, growers and local agencies have cooperated to limit the growing of Austrian Winter peas to areas somewhat apart from the areas where most of the seed of garden and canning varieties is grown.

FIELD PEA HIGHLIGHTS

1. Field peas can be grown throughout the greater part of the United States. They are used extensively as a winter cover crop in the Southeastern States, and as a seed crop in the Pacific Northwest. As a feed crop, field peas are used for hay, pasture, and silage.

2. Field peas are not exacting in their soil or cultural requirements but respond to good treatments. Clay loams of limestone formation or neutral or low-acidity soils are best suited to the crop.
FIELD PEAS

3. In practically all regions artificial inoculation is essential or very beneficial.

4. In the North the use of fertilizers is not recommended for field peas. In the Cotton Belt of the southeastern United States when Winter peas or vetch are not fertilized with a sufficient amount of phosphate, they usually fail to make enough growth to economically increase yields of cotton or corn.

5. In Alabama, where cotton and corn were grown on respective areas each year and vetch or Austrian Winter peas turned under, the yield of seed cotton was increased over 600 pounds, and of corn over 15 bushels per acre.

6. In northern latitudes where spring sowing is practiced, a number of varieties may be used. In the South as a winter cover crop, the Austrian Winter pea is the most satisfactory variety to use.

7. The production of Austrian Winter peas in the Pacific Northwest, under price support in the war years of 1942 and 1943, reached the enormous total of 133 and 150 million pounds, respectively, or nearly six times the average production of 1936-39. In recent years (1944-49), the production has averaged about 55 million pounds.

8. Nearly all the Austrian Winter peas grown for seed are produced in Idaho, Oregon, and Washington.

9. When field peas are grown for hay, mixtures with oats or barley are recommended. Cuttings for hay should not be made until the lower pods are well formed.

10. Harvesting for grain or seed should not be done until the pods are turning yellow, or later if done with a combine. In regions where pea weevil is prevalent, field control should be practiced and seed should be fumigated promptly after being threshed.

11. In some regions, mature or near mature field peas make a profitable pasture for sheep and hogs.

12. As a precaution against diseases, rotate crops, sow seed free from disease, and practice clean cultivation.

13. In the Southeast, the essentials for success with vetch and Austrian Winter peas for soil improvement are:

(a) Early planting—September or first half of October.
(b) Planting as close as practical to the old cotton or corn stalks.
(c) Inoculation—if planting on a given area for the first time.
(d) Use 250 to 300 pounds of superphosphate or 400 pounds of basic slag per acre unless the land has been well fertilized with phosphate for several years. On areas very deficient in potash, use 50 to 100 pounds of muriate of potash in addition to phosphate.
(e) Turning under in the spring when the green tops harvested from 100 square feet weigh 15 to 20 pounds.
(f) Waiting at least two weeks before planting the succeeding crop.

Chapter reference numbers:

Vetches: ALA-2, 4; ARK-14; CAL-1; ILL-9; OHIO-37; OREG-4, 10, 15, 22; WIS-14; US-113, 123, 150, 167, 202; MISC-31.

Field peas: COL-6; GA-3; OREG-10, 11, 15; WIS-21; US-115, 166, 280.

The reference numbers given here refer to references which are given in full by State, U.S.D.A., and Miscellaneous, on pages 682 to 724, and which are cross-referenced by author on pages 725 to 731. Citations in the text are indicated by abbreviation and number in parentheses.
CHAPTER XV

COWPEA, SOYBEAN, AND VELVETBEAN

The cowpea, the soybean, and the velvetbean are all summer annuals, agriculturally much alike, and for the best results are adapted to nearly the same regions. A comparison of these crops is not so much a matter of determining which is the best crop as it is a careful consideration of their climatic and soil adaptations and the special uses of each on the farm. Among the important points that determine the value of a leguminous crop are its value for forage, both in quantity and quality, either as hay or pasture; its ability to supply additional nitrogen; and the value of the seed as a cash crop or for its utilization on the farm.

The soybean has about the same climatic adaptations as corn, and therefore its culture is much more extended than that of either the cowpea or velvetbean. The velvetbean is especially adapted to the well-drained parts of the Atlantic and Gulf Coastal Plains areas, while the cowpea can be grown successfully not only there but throughout the Cotton Belt and the lower half of the Corn Belt. The velvetbean and cowpea are quite sensitive to cold, whereas the soybean withstands considerable frost in spring and fall. Cowpeas and velvetbeans both succeed on poor soils better than the soybean. For soil improvement the velvetbean is, in general, superior to either the cowpea or the soybean, although the cowpea succeeds under a greater diversity of conditions.

The soybean is to be preferred for forage purposes on account of its upright growth. The cowpea and velvetbean are viny plants, and therefore more difficult to harvest and cure.

Soybeans as a hay crop have not kept pace with soybeans as a seed crop. The acreage for seed or "grain" has expanded greatly during the past 15 years, while that for hay has declined. The acreage and production of soybean hay for the 2 years 1947-48 were less than 40 percent of what they were the 10 years previous (1937-16). This decline, however, is in line with the declines in recent years of several other annual forage crops such as millet, Sudangrass, and forage sorghums.

The explanation for these reductions is to be found largely in the changes in agricultural practices and programs. The development of better grasses and legumes for permanent and semipermanent pastures and meadows, longer rotations, better management, and higher fertility maintenance of meadows and pastures, the tendency toward grassland agriculture, higher prices and greater demand for cash crops, the mechanization of crop production, and other factors, have all tended to reduce the acreage and lessen the need for annual or emergency forage crops. The cause, therefore, is not in their relative productivity or their usefulness as forage, but in the fact that they do not as readily fit into present systems of farming or livestock feeding practices.

As a grazing crop for cattle and hogs in fall and winter the velvetbean cannot be excelled. However, the cowpea and soybean can be grown over a more extended area, and some of their numerous varieties furnish earlier pasture.

For production of seed, the soybean has many advantages over the cowpea and velvetbean. The soybean matures all its seed at one time and can easily be handled by machinery. Hand-picking is most commonly practiced in gathering.
cowpea seed, although machinery can be used to advantage. It is necessary to pick velvetbeans by hand because of the abundant, tangled mass of vines.

The seeds of velvetbeans, cowpeas, and soybeans are all excellent feed for cattle and hogs. Cowpea seed, however, is rarely cheap enough for feed, but it is extensively used, especially in the Southern States, for human food. Soybean seed, in addition to its value for feed, is available for the production of oil and meal, and its use for human food in numerous forms has greatly increased.

The cowpea will undoubtedly continue to be one of the most important leguminous crops in the Southern States. No other crop sown under such a diversity of conditions or receiving so little attention in soil preparation and cultivation succeeds so well. Under the most varied conditions, forage, soil improvement, and human food are obtained.

**COWPEA**

*(Vigna sinensis)*

**DESCRIPTION**

The cowpea, an annual summer legume, came from central Africa. The cultivated cowpea consists of three main groups—the asparagus or yard-long bean with much elongated inflated pods; the catjang, with small erect pods and small subcylindric seeds; and the cowpea, with pendant, rather long pods.

The cowpea is indeterminate in growth; that is, under favorable conditions of moisture and temperature it continues to grow indefinitely. Varieties vary greatly in habit of growth, ranging from perfectly prostrate to perfectly erect. With few exceptions the branches are viny and twining.

The trifoliate leaves, which resemble those of the garden or navy bean, range from small to very large and persist on the vines until the pods are mature. The flowers of the cowpea occur in two colors, white or nearly white, and violet. Seeds of cowpeas differ markedly in color, shape, and size.

**ADAPTATIONS**

**Climate:** The cowpea is a warm-weather crop; therefore, it has the greatest value in the Southern States, gradually lessening northward. It is grown successfully, however, in the southern parts of Ohio, Illinois, Indiana, and New Jersey, and in parts of Michigan. In general, the cowpea is adapted to about the same climatic conditions as corn, but it requires somewhat more heat. It will withstand a considerable amount of drought, but under very dry conditions will produce only a moderate quantity of hay and a very small number of seeds, if any. Both in spring and in fall the leaves are injured by the least touch of frost, and a heavy frost is always fatal. The cowpea withstands moderate shade sufficiently well to be valuable in orchards. In heavy shade the plants are usually much attacked by mildew.

**Soil:** The cowpea succeeds on practically all types of soil. It appears to grow quite as well on sandy soils as on heavy
clays, but will do better than clover or alfalfa on thin soils or soils that are poor in lime. No other legume can be grown so successfully and on such a variety of soils under adverse conditions as the cowpea. A very rich soil is not conducive to the best results with this crop. On such a soil an abundant vine growth is produced, while the yield of grain is small. Poor soils will produce little growth of vine but will generally yield a good proportion of seed.

**VARIETIES**

In the selection of a cowpea variety the characters most desirable both for forage and for seed need to be considered. The variety should be suited to local conditions and to the purpose for which the crop is grown. The characteristics most important in considering the cowpea for forage are (1) size and vigor; (2) habit, especially erectness; (3) prolificacy, the pods being well filled and held well above the ground; (4) disease resistance; (5) ability to retain leaves late in the season; (6) time of maturity; and (7) evenness of maturity. Toward the northern part of the cowpea region early maturity is desirable. For planting in corn or sorghum a strong viny habit is of importance. When grown for human food or to be pastured, the yield of pods and seeds needs special consideration.

Most varieties of cowpeas under different conditions of soil or climate exhibit marked fluctuations. On rich soil or when planted early, the general tendency is to produce a large growth of vine and few pods. Usually, moist seasons have the same effect. On poor land, especially sandy soils, or when sown late, the plants tend to produce much more seed but less herbage. Moderate drought has a very similar effect, but very severe drought prevents most varieties from producing pods.

At present about 15 varieties of cowpeas are in common cultivation, while the varieties grown in a small way number, perhaps, about three times as many more. Owing to the fact that the seed is still largely hand-picked, the tendency is for the variety which was first introduced in a locality to persist; therefore, varieties of relative inferiority are still too largely grown. The varieties are distinguished most readily by the color and size of the seed, and disease resistance.

The most valuable American varieties of cowpeas for forage are the Whippoorwill, Iron, and New Era, and their hybrids, the Brabham and Groit. Important, but of secondary value, are such indefinite groups of varieties as the Unknown, Clay, Red Ripper, and Black. A large number of others are grown to a small extent. For table use, the white-seeded varieties, such as the Conch and Cream, and the Blackeye sorts—California Blackeye and Extra Early Blackeye—are preferable. For descriptions of these and other varieties, see Morse's "Cowpeas: Culture and Varieties" (US-174).

**CULTURE**

Preparation of the seedbed: The cowpea will give fair results upon a poorly prepared seedbed, but the best results are to be obtained when the soil receives as careful preparation as for corn. Even if the crop is sown late in the spring, it is often desirable to plow the ground early and harrow the field at intervals to destroy weeds and to maintain a soil mulch to receive and retain the moisture. When sown as a catch crop after wheat or other small grain, if the land is clean and mellow, the seedbed may be prepared with a disk harrow or seeded with a single-disk drill without previous preparation.

Fertilizers: Soils that are naturally unproductive or badly run down by continuous cropping should be properly fertilized in order to obtain the best results with cowpeas. Nitrogenous fertilizers on soils of good or moderate productiveness have little effect on either the yield or the protein content of cowpeas. For the best results on very poor soils, however, 40 to 50 pounds of nitrate of soda to the acre, or its equivalent in any other nitrogenous fertilizer, should be applied. Phosphoric acid and potash in combination, or either alone, generally give a substantial increase in the yield of peas or forage. On soils
COWPEAS

in need of fertilizer, about 300 pounds of acid phosphate and about 50 pounds of muriate of potash to the acre should be applied when preparing the seedbed. Inoculation: If the cowpea has been grown in a locality for many years, the bacteria are plentiful and inoculation is not necessary. This is quite true throughout the Southern States. In new regions, however, especially in the North and West, when cowpeas are being grown for the first time the soil should be inoculated from an outside source. Successful inoculation is shown by the development of nodules or tubercles on the roots, and may be obtained by using a pure culture of the proper bacteria, which may be purchased from seedsmen. This method is to be preferred to dusting the cowpea seed with soil obtained from an old cowpea field or any other method of soil transfer.

Time of sowing: Cowpeas should not be sown until the soil has become thoroughly warmed and all danger of cold weather is past. After that time they can be sown whenever moisture conditions are favorable. When sown in cold, wet soil, cowpea seed will either rot or give a poor stand of unhealthy plants. The latest date for profitable sowing, however, is at least 90 days before the first killing frost.

The time of sowing will depend largely upon the purpose for which the crop is grown. If grown for seed or hay, the seed should be sown shortly after the corn crop. For green manuring, pasturage, or hay, cowpeas sown as late as the first of August in the South will make considerable growth. When cowpeas are to follow wheat or oats, they should be sown at the earliest possible moment after the crop is cut.

Method and rate of sowing: The best method for the production of seed is to sow in rows about 3 feet apart, with the seeds from 2 to 3 inches apart in the row. Although a corn planter may be used for sowing in this way, the most practical method is to use the ordinary grain drill, stopping part of the grain cups so as to leave the rows about 3 feet apart and setting the drill the same as when sowing about 2 bushels of wheat to the acre.

Cultivation: Under proper soil conditions cowpeas will germinate quickly and cultivation may begin early. When the seedlings first appear above the ground they are very tender and are easily broken, so that care must be exercised in working in them. Usually the crop may be cultivated in 2 or 3 weeks after sowing. Ground sown to cowpeas is sometimes packed by heavy rains soon after sowing. A harrow or weeder can then be used advantageously to break the crust unless the seeds have germinated, when much damage may result from harrowing. When sown in rows the ordinary imple-
ments used in corn cultivation will be found satisfactory, as the culture of cowpeas is essentially the same as for corn. About three cultivations at intervals up to the time the blossoms appear will usually be sufficient. If the ground is well cultivated and cleaned of weeds previous to sowing, broadcast sowings under favorable weather conditions grow rapidly and will smother any weeds which may start after sowing.

COWPEAS IN ROTATIONS

Rotation of crops is one of the most important methods employed for maintaining or increasing yields of subsequent crops. The need for systematic rotations is quite apparent on most types of soil in the cowpea region. It is a general rule that some leguminous crop, such as cowpeas, soybeans, alfalfa, or some of the clovers, should be included in all systems of rotation. The place of the cowpea in the rotation will depend largely on whether the crop is to be plowed under as a green manure or to be harvested for grain or hay. In one case it is sown as a catch crop after small grains and in the other in the spring as a regular crop. The cowpea succeeds under so many different conditions that it is especially valuable as a catch crop and for hay or seed production in almost any system of rotation.

COWPEAS IN MIXTURES

Although the cowpea can be satisfactorily grown alone, it is more advantageously grown for hay in combination with other crops. When grown in this manner, not only is a greater variety and larger yield of feed obtained, but the mixed hay is much more easily cured and handled. Corn is used quite generally with cowpeas, but only to a slight extent for hay. The crop most widely used with cowpeas for hay is sorghum, both sweet sorghums (sorgos) and kafirs, although other crops, such as Sudangrass, Johnsongrass, soybeans, and millet are used.

The cowpea is an excellent crop to grow with corn for silage, and it is being used extensively for this purpose on many dairy farms, especially in the northern part of the cowpea area. If grown with corn for other than silage purposes, cowpeas are allowed to ripen a fair percentage of pods which are gathered for seed and the remainder is pastured.

Cowpeas grown in combination with sorgos or kafirs make an excellent hay or silage crop. As a hay crop this mixture is more easily cured than cowpeas alone, constitutes a well-balanced ration, and is relished by all kinds of farm stock. The Amber sorgo is most generally favored, especially in the Piedmont region of the South, while the kafirs are grown in the Southwest.

When sown "broadcast" for hay, the sowing is best done with a grain drill on well-prepared land, the two kinds of seed being well mixed and sown at the same time. Excellent results are obtained by sowing cowpeas and sorgo or kafir together in cultivated rows 2½ to 3 feet apart.

If Johnsongrass is not a pest, or if it is well established on a field and there is no desire to eradicate it, it can be used very advantageously to form a part of a mixture with cowpeas. Little trouble will be encountered in killing Johnsongrass north of Tennessee and central Virginia, but south of these States the difficulty is much greater. Wherever Johnsongrass and cowpeas are used, excellent results are obtained, both in the yield and in the quality of hay produced.

Sudangrass is an excellent crop for growing in combination with cowpeas for hay, being easily harvested and cured. It can be used without fear of its becoming a troublesome weed in those areas where Johnsongrass is considered a pest. The best results are obtained by broadcast sowing, using about 50 pounds of cowpeas and 10 pounds of Sudangrass to the acre. The mixture is cut for hay about the time the cowpeas are ready for hay.

Cowpeas and soybeans afford a very satisfactory combination, either for hay or for pasture, and the yield is nearly always greater than that of either crop alone. Only the tall strong-growing varieties of soybeans are desirable, as they
COWPEAS

assist very materially in supporting the
viny cowpeas. Varieties of these crops
maturing at about the same time should
be selected. The hay of this mixture is
of high feeding value, as both plants are
rich in protein.

COWPEAS FOR HAY

If cut at the right stage of growth and
properly handled, cowpeas make excellent
hay of high feeding value. This hay is
as valuable as that from other legum­
inous crops and is greatly relished by all
farm animals. Throughout the Southern
States cowpea hay has been extensively
used and is the main dependence for hay
on the plantations. Well-cured cowpea
hay has proved satisfactory for work stock
and for beef or milk production, and has
given good results when fed to poultry,
hogs, and sheep. Cowpea hay is said to
be better suited for feeding to cows than
to horses.

Acreage and production of cowpea hay:
The 10-year (1937-46) average total
U.S. acreage of cowpeas harvested for
hay was nearly 1,500,000 acres but the
average for the last 3 years (1947-49)
was only 440,000 acres. The average
annual production of these 10-year and
3-year periods were respectively 1,260,-
000 tons and 390,000 tons. The largest
producing States were South Carolina,
Georgia, Arkansas, and Mississippi in
this order. The acreage grazed or plowed
under was about 1,570,000 acres for the
10-year period, and 660,000 for the last
3-year period.

Yields of cowpea hay: As with other hay
plants, the yields of the cowpea will de­
pend to a large extent upon the soil, cul­
ture, weather conditions, and the variety.
Under average conditions, the cowpea
compares quite favorably in yield with
other crops commonly grown for hay,
while it ranks very high in yield of feed­
ing value. The cowpea will yield from
one to two tons of hay to the acre, and
frequently, under very favorable condi­
tions, much larger yields are secured.
The statistical average yield for the
United States, as reported by B.A.E. is
.85 ton per acre, ranging from about .7
ton for South Carolina, Georgia, and
Alabama, and .87 ton for North Caro­
lina, to around 1 ton for Mississippi and
Tennessee.

Feeding value of the hay: The feeding
value of cowpea hay has long been recog­
nized throughout the Southern States, it
having been used extensively for all kinds
of stock. Well-cured cowpea hay is fully
as valuable a feed, pound for pound, as
red clover hay, and its value nearly equals
that of alfalfa hay or wheat bran. It has
given satisfactory results when fed alone
to work stock and has been used success­
fully as a maintenance for horses, mules,
cattle, and sheep, and even for hogs and
poultry. The chief value of cowpea hay
lies in its high percentage of digestible
protein which has been verified by num­
erous feeding tests.

COWPEAS FOR PASTURE

The utilization of the cowpea as a
strictly pasture plant is not considered
the best farm practice, but under certain
conditions it is advisable and quite prof­
itable. The cowpea furnishes a pasture
crop during a period of the year when
such forage can be used to the best ad­
vantage. The small amount of work and
the small cash outlay always associated
with the grazing of stock commends the
practice to the average farmer, and scar­
city of labor often makes it necessary to
pasture a crop whenever possible. An­
other advantage in pasturing cowpeas is
that not only is the soil benefited by the
growing of the cowpea, but the waste
vines and animal droppings are also left
on the land. The soil, after cowpeas have
been pastured, is in an excellent condi­
tion of productivity for the fall sowing
of wheat.

COWPEAS FOR SILAGE

The cowpea alone has not proved very
successful as a silage crop. The best sil­
age is obtained when cowpeas are grown
or mixed with corn or sorghum and
planted at the same time. Various meth­
ods are employed in growing and working
in the silo the crops used in the mixed
silage. These are discussed in chapter VII on silage.

For silage, cowpeas should be cut when the pods first begin to turn yellow. In many sections alternate rows of cowpeas and corn are put in the silo, but the most common method, perhaps, is one load of cowpeas to two or three loads of corn. This mixture is easily handled, packs quite satisfactorily, keeps well, and makes a superior quality of palatable silage. Although the vines may be put in the silo without cutting, they will pack much closer if run through a silage cutter. Much care should be taken to see that the silage is well distributed and well packed.

COWPEAS FOR SOIL IMPROVEMENT

The cowpea has been used as a restorative crop throughout the Southern States. It is so easily grown and has such a marked effect on the succeeding crops that its use should be greatly increased. Aside from increasing the productiveness of the soil, the cowpea also improves its general physical condition, making heavy clay soils more open, and sandy soils more compact. The cowpea has the distinct advantage of making a good growth on soils that will not produce profitable yields of other legumes or cereals. It is an excellent green-manure crop for vineyards and orchards.

Except on the poorer soils, results indicate that it is decidedly more profitable to utilize the cowpea as hay or pasture and then plow under the stubble than it is to plow under the entire crop. About 85 percent of the fertilizing and soil-improving value of the cowpea is contained in the hay and about 15 percent in the roots and stubble. Feeding experiments indicate that much of the fertilizing value of feeds is recovered in the manure. It is therefore possible to obtain the feeding value of the cowpea as hay or pasture and in returning the manure to the soil to save a large part of the fertilizing value, provided the manure is well handled. When the whole crop is plowed under, a more beneficial and lasting effect is obtained, but this advantage is not great enough to equal the feeding value of the cowpea.

DISEASES AND INSECTS

Root-knot and wilt are the most serious diseases of the cowpea in the United States. Both troubles are primarily and most generally found in the sandy soils of the Southern States and but rarely become serious on the heavier soils. Of the two diseases, root-knot is the more general and widespread, and the losses from it are more severe. Several other troubles of minor importance are white leafspot, red leafspot, and mildew. These diseases are fairly common and widespread, but do not usually cause appreciable damage to the crop.

Growing cowpeas are more or less subject to attack by various insects among which are the cowpea curculio and velvetbean caterpillar. Cowpea seed is also attacked by several species of weevils of which the cowpea weevil causes the most injury. This weevil is generally distributed throughout the Southern States and California. For further information on diseases and insects see chapter IX.

SEED PRODUCTION

On a very large proportion of the area planted to cowpeas, little effort is made to harvest seed. Moreover, cowpeas have not been grown very extensively for seed in late years, thus creating a high price which has restricted the use of the crop. The principal factors in making the cowpea an undesirable crop to grow in a commercial way for seed production are the uncertainty of a seed crop, the expense of harvesting, and the low yields generally obtained. However, the value of the crop for forage and soil improvement and the high price of seed have made it almost necessary for every farmer to grow sufficient seed to supply at least his own needs.

Time of harvesting: Cowpeas ripen so unevenly that it is difficult to judge just
what is the proper stage of maturity at which to cut them for seed. With nearly all varieties except under certain conditions, as in the cowpea areas of California, blossoms and green and ripe pods occur at the same time, and this condition continues usually until frost.

In harvesting cowpeas for seed the vines should be allowed to mature a greater percentage of pods than when cut for hay. In general, the crop should be harvested when one-half to two-thirds of the pods are matured. Although some loss will occur as a result of overripe pods shattering the seed, more seed will be obtained than if the crop is harvested before a large percentage of the pods are ripe.

Methods of harvesting: Various methods of harvesting the cowpea for seed are employed in different sections of the cowpea region. Hand picking is a common way of saving the seed, although the most expensive and laborious, and is the only practical method when the crop is grown in corn. Small fields of cowpeas, grown alone for seed, are often hand picked, especially the edible sorts, as the Black-eye and White varieties. In this way the seed can be gathered as the pods ripen. When hand picked, the seed yield is much larger, is of a better quality, and a higher price is obtained. The pods are picked by hand into bags and stored. When thoroughly dry, the seeds are either beaten out with flails or the pods are run through a pod huller. The seed is then cleaned by running it through a fanning mill.

Another method of harvesting by hand is to pull up the vines or to cut with a corn knife or sickle. The vines are placed in small shocks and left in the field until well cured. This method is slow and only practicable where the acreage is small.

When large fields are grown for seed production, various machines are used for cutting the vines. Some difficulty is experienced in harvesting cowpeas by machinery, due principally to the vining habit of the plant. The mowing machine with windrower attachment is very generally used and has proved most satisfactory as it leaves the plants in a desirable condition for curing and handling. The combine has been used successfully in several areas of the Southern States.

The self-rake reaper has also given satisfactory results, as the vines are placed in bunches of convenient size for handling and curing, out of the way of the machine and team.

Several types of bean and pea picking machines are on the market, but are not extensively used. These machines gather the pods from the vines in the fields. The crop must be planted in rows for the most successful application of the pea picker, and the entire plant must be mature and dry before the machine will do satisfactory work.

The bean harvester, of which several types commonly are employed in harvesting field beans, will work well with cowpeas planted in rows. The most successful of these harvesters are constructed so that the long knives run under the vine, cutting off the stems beneath the surface of the ground.

When cut, the vines should be allowed to cure until thoroughly dry. The curing or drying may be done in the swath, cock, stack, or barn as desired, weather conditions largely determining the method to be employed. Although the amount of work required is greater, the hay or straw is of better quality if the curing or drying is done in the stack or barn.

Methods of threshing: The ordinary grain separator can be adjusted to thresh cowpeas successfully and is the machine most generally used. For the best results in threshing cowpeas the essential point is to maintain a low and even speed of the cylinder, 300 to 400 revolutions per minute, while the speed of the rest of the machine should be maintained as for threshing wheat or oats. Although satisfactory results are obtained with an ordinary separator, it is generally found that too many of the pods pass through unopened with the straw, the machine is easily choked by the tangled vines wrapping around the cylinder, and the percentage of cracked seed is usually large.

Several modifications of threshing ma-
chines have been devised for handling cowpeas. Many of these machines have adopted the use of two cylinders. The cylinders are adjusted to run at different speeds, the front one about 300 revolutions and the rear one about 450 revolutions to the minute. The employment of two cylinders results in a smaller percentage of unopened pods passing through the straw, but in a somewhat larger percentage of cracked peas.

Storage of seed: Cowpea seed, if good, can be stored for a considerable length of time without much danger of loss of vitality. If the peas are sufficiently cured in the field, mow, or stack before threshing, there is little danger of heating. However, seed not properly cured or stored quickly loses its vitality; consequently a germination test is always advisable.

In the Southern States, on account of the injury to stored grain it has been found desirable in many cases to place in cold storage the seed intended for planting. This is not very expensive and has been found to be a practicable way of preserving the seed.

Cowpea seed more than 2 years old ordinarily has lost much of its viability. Good viable seeds are uniformly bright colored, while seeds which have been exposed to moisture or are dead are duller and darker in color.

Yields of seed: The yield of seed, like that of hay, depends to a very large extent upon conditions of weather, soil, culture, and variety. In many sections the cowpea is rather an uncertain crop, as the yield of seed varies greatly from year to year. The seed yields of the most important commercial varieties reported by investigators at various agricultural experiment stations range from an average of about 3½ bushels per acre in Oklahoma, to about 20 bushels in Georgia, but the statistical yields of dry peas as reported by B.A.E. for the largest producing Southern States are about 5 bushels for Georgia, North Carolina and South Carolina, 6 bushels for Alabama, Arkansas, Mississippi and Tennessee, and 7 bushels for Texas.
13. Harvesting cowpea seed can be done most cheaply by the use of machinery. The crop may be cut with a combine, mower, self-rake reaper, or bean cutter.

14. Cowpea seed may be threshed with an ordinary grain separator with modifications, or, better still, with a machine specially constructed for threshing cowpeas.

15. Good cowpea seed can be stored for a considerable length of time without much danger of loss of vitality.

**SOYBEANS FOR FORAGE**

*(Glycine max)*

The soybean was one of the first crops cultivated by man. It originated in the Orient and records of its culture in China go back more than 4,700 years. It is more intensively grown in Manchuria than elsewhere but is an important crop not only in China and Japan, but in other Oriental countries.

Prior to the introduction of numerous varieties of soybeans by the United States Department of Agriculture in 1898, not more than eight varieties had been grown in the United States, and the culture of these was limited to a few well-defined areas. Now the soybean is one of the major crops of the United States and is represented by more than 100 varieties.

In total production of soybean seed and soybean hay the United States leads the world. The acreage of soybeans for all purposes has increased during the past 20 years from 2,807,000 acres in 1929 to 12,428,000 in 1948. The peak was reached in 1943 with 15,428,000 acres, and a 3-year average for 1942-44 of 14,797,000 acres. The acreage of hay increased from 1,774,000 acres in 1929 to 4,894,000 acres in 1940, and the production of hay from 2,051,000 tons in 1929 to 6,560,000 tons in 1940, but declined to 1,333,000 acres and 1,631,000 tons in 1947, and to 1,171,000 acres and 1,567,000 tons in 1948. The acreage and production of dry beans, however, increased continually from 708,000 acres and 9,438,000 bushels in 1929, to 10,311,000 acres and 220,201,000 bushels in 1948.

There are two groups of States having a relatively large acreage of soybeans grown for all purposes in the United States, including both those acres where soybeans are grown alone, and those interplanted with other crops. These groups are (1) the five Cornbelt States of Illinois, Iowa, Indiana, Ohio, and Missouri, named in order of total soybean acreage, which five States had a 12-year (1937-48) average of 8,061,000 acres, or 65 percent of the total; and (2) the eight southeast-
ern States of North Carolina, Mississippi, Arkansas, Tennessee, Alabama, Virginia, Kentucky, and Louisiana, named in the order of total soybean acreage, which 8 States had a 12-year average of 2,800,000 acres, or 23 percent of the total. These two areas covering 13 States have about 88 percent of the total soybean acreage.

DESCRIPTION

The soybean, also called the soya bean, soja bean, and Manchurian bean, is an annual summer legume native of South-eastern Asia. It is an erect, branching plant, resembling in its early growth the ordinary field or navy bean. The different varieties range in maturity from very early (about 75 days) to very late (200 days or more). With few exceptions, earliness is correlated with size, the tallest varieties being latest.

Nearly all varieties are pubescent; that is, the stems, leaves, and pods are covered with fine tawny (brown) or gray hairs. The leaves vary widely in shape, size, color, and degree of persistence, and they nearly always begin to turn yellow as the pods ripen; usually they have fallen by the time the pods are mature. The small, inconspicuous flowers are borne in the axil of the leaf and are either white or purple. The pods, usually containing two or three seeds, range in color from very light straw through numerous shades of gray and brown to nearly black. The seeds are usually straw yellow, olive yellow (greenish yellow), green, brown, or black. Bicolored seeds occur in several varieties, the most common of the bicolored patterns being green or yellow with a saddle of black or brown.

ADAPTATIONS

Climate: In general, the climatic adaptation of soybeans may be said to be about the same as for corn. The crop is especially well adapted to the northern half of the Cotton Belt and to the central and southern parts of the Corn Belt. In these localities the large and later varieties, which give yields that make soybean cultivation profitable, can be grown. In the Northern States, however, early varieties introduced from northern Manchuria mature good yields of seed and later varieties can be grown successfully for hay, pasture, and silage. The largest concentration of soybean production in the Orient is in Manchuria, where the climate compares with that in the Northcentral section of the United States.

Soils: The soybean will succeed on nearly all types of soil, but the best results are obtained on mellow, fertile loams or sandy loams. In general, the soil requirements are about the same as those of corn, but the soybean will make a more satisfactory growth than corn on soils low in fertility, provided inoculating organisms are present. The crop will not make nearly such good growth as cowpeas on the lighter sandy soils and soils low in fertility, nor does it succeed so well as cowpeas on the heavier clay soils.

VARIETIES

The United States Department of Agriculture has made more than 10,000 introductions of soybeans from China, Manchuria, Japan, Korea, Java, Sumatra, and India, representing over 2,500 distinct types. This large collection of varieties, ranging in maturity from 75 to 200 or more days, has shown wide differences in size, shape, color, composition, and quality of seed and in adaptation to soil and climatic conditions in the United States.

State agricultural experiment stations have cooperated with the Department for several years in the study of adaptation of varieties, and are, therefore, in a position to recommend the best varieties for their respective States. The prospective purchaser should buy seed from reliable sources only. The planting of imported seed is not to be recommended, as such seed usually consists of a mixture of varieties concerning which nothing is known as to their adaptation, and most of which are inferior to the varieties generally grown.

More than 100 named varieties are now handled by domestic growers and seedsmen, and are under test by the
SOYBEANS

Department of Agriculture and State agricultural experiment stations. Unfortunately, there is more or less confusion in the names of varieties, the same variety frequently being known under different names. Since new varieties are easily obtained through introduction, selection, and crossing, it is desirable to limit the varieties in trade to the very best.

Soybean varieties have been classified as early or late, depending upon when they ripen under the latitude and climatic conditions at the location where they are grown. Another means of expressing maturity that is coming into general use among plant breeders is a classification according to relative maturity groups. The varieties being grown in the United States have been divided into nine maturity groups (0 through VIII), with group 0 and group I being adapted to the northern part of the country. The succeeding groups are adapted farther south, with group VIII being grown in the Gulf coast region.

Varieties also may be divided into three utilization groups; namely, commercial, forage, and vegetable. Varieties for commercial seed production are preferably yellow seeded and are used for processing for oil, oil meal, and flour, but these varieties may be used also for forage purposes if heavier rates of sowing are used. Vegetable varieties are those that have been found best for eating as green shelled and mature beans. The varieties used for processing and forage purposes usually do not cook easily and have a raw beany flavor.

Since the number of varieties of soybeans grown is so large, it is not considered feasible to give descriptions of them here. They are given in full in farmers' bulletin No. 1520, revised in 1949.

CULTURE

Preparation of seedbed: In general the land should be prepared as for corn and, like corn, soybeans respond to any extra preparation of the soil. The seedbed is best prepared either by fall or early spring plowing which, followed by frequent harrowings or light diskings before sowing, kills the weeds just starting in the surface soil. A firm seedbed with a light, loose covering of fine soil well smoothed by the harrow, is conducive to uniform depth in seeding and to a good stand of plants.

Fertilizers and lime: When soybeans are grown on land giving good yields of corn, they should produce a good crop without direct applications of fertilizers. The use of fertilizers, however, is recommended on sandy soils or soils of low fertility.

The soybean is not so sensitive to acid soils as are red clover, alfalfa, and many other crops. The application of lime on acid soils, however, has been found invariably to increase the yield of hay and seed and the nitrogen content of both vines and seed. Liming apparently stimulates the production of nodules.

Inoculation: Like other legumes, soybeans are able to utilize the nitrogen of the air through the action of bacteria on the roots. The bacteria of soybean nodules will not inoculate any other of the commonly cultivated legumes, nor will the bacteria found in the nodules of other legumes inoculate soybeans. Some varieties of soybeans are more difficult to inoculate than others. Some strains of soybean bacteria are more vigorous on certain varieties of soybeans than on others.

Where the crop is grown for the first time, soybeans make a rather poor growth unless inoculated. The lack of inoculation is nearly always indicated by a pale- or yellowish-green color of the plant. The soybean, however, may give good results on fertile land even though the bacteria are lacking, on such land the plant draws most of its nitrogen from the soil rather than from the air, as it does when inoculated. Natural inoculation now occurs throughout much of the region where soybeans are extensively grown. It is advisable to inoculate to obtain the best results when the crop is planted on land on which it has not been grown previously.

Time of sowing: Soybeans may be sown during a period extending from early spring until midsummer, depending large-
ly on the latitude and the use to be made of the crop.

For a grain or main hay crop the best time for sowing in the Northern States is about corn-planting time, or when the soil has become thoroughly warm, as conditions then are most favorable for the best germination and rapid growth of the crop. Soybeans germinate and grow very slowly in a cold, wet, or dry soil, and one of the principal objections to early sowing is the difficulty of working a seedbed sufficiently to kill weeds. Ordinarily there is no advantage in sowing earlier than corn-planting time.

In the Southern States the soybean planting season extends from the first of April to the last of June. Long-season varieties do best when planted early. For pasture or green manure, or even for hay, the soybean may be sown as late as the first of August in the Southern States, and the first of July in the Northern States.

**Method of sowing:** Soybeans are sown either in rows sufficiently wide to allow cultivation or in close drills. Broadcasting the seed and covering with a harrow is seldom practiced and is not advisable. The method of sowing will be determined largely by convenience and economy of cultivation and harvesting, rate of sowing, variety used, type of soil, climatic conditions, and the purpose for which the crop is grown.

For seed production, under nearly all conditions, soybeans should be grown in rows and cultivated to keep down weeds. With the development of machinery adapted to soybean production, there has been a marked change to the row method of planting during the past few years. The factors favoring the sowing of soybeans in rows are higher yield of seed and hay, more uniform stand, less lodging, lower seed requirements in planting, and less chance of poor results on account of weeds. Drilling in close rows, however, has some important advantages, such as producing a finer quality of hay, eliminating the need for special machinery, and decreasing the cost of production.

For hay or green manure the soybean is usually sown in close drills. One advantage of close drilling is that on sloping land the solid drilling on this contour will result in less loss of soil than row sowing. If the land is free from weeds or is given a thorough cultivation with the harrow, weeder, or rotary hoe when the weeds are small, larger yields and a finer quality of forage will also be obtained.

**Rate and depth of sowing:** The quantity of seed to be sown to the acre will necessarily vary according to the purpose for which the crop is grown, the variety or size of seed, viability of seed, method of planting, character of the soil at planting time, and the method of cultivation to be used.

Most commercial soybean varieties have a seed size of about 3000 seeds per pound; however, some types used for hay or as green manure have extremely small seeds, running from 6,000 to 9,000 to the pound. Because of the variation in seed size, it is often desirable to determine the sowing rate that will space the viable seeds the proper distance apart. For row planting, a spacing about one inch apart in the row will give good stands under ordinary conditions.

In the main soybean-producing areas, a sowing rate of 45 to 60 pounds of good quality seed per acre in rows and about double that rate for solid sowing, would be a general recommendation for the average soil and favorable planting conditions. When soybeans are sown in mixtures with corn for silage, an addition of 6 to 8 pounds of soybean seed to the usual quantity of corn is desirable.

Poor stands frequently result from covering the seeds too deeply, especially in the case of the large-seeded varieties. The most favorable depth is governed by the character of the soil, amount of moisture present, and the size of seed. In clay or other heavier types of soil, shallow seedings—about one inch—tend to lessen the chance of failure due to the formation of a soil crust after heavy rains. In light loams or sandy soils, the sowing may be deeper, but it should not exceed 3 inches; if the sowing is done during a dry period, 3 inches will not be too deep.

**Cultivation:** When soybeans are drilled solid or in rows, frequently a cultivation
SOYBEANS

is necessary before the young plants appear. If the weed seeds have germinated, a shallow cultivation with the weeder, harrow, or rotary hoe should be given before the seedlings break through the ground. If the soil is of a heavy type and forms a hard crust after a rain, a light cultivation with the rotary hoe, weeder, or harrow should be given to break the crust.

When soybeans are sown in close drills for hay or grain, the weeder, harrow, or rotary hoe may be used, if necessary, until the plants are 8 to 10 inches high. The cultivation of drilled or broadcast seedlings will give much larger yields of hay with a smaller percentage of weeds. If the seeds are allowed to get started, the weeder or harrow is quite effective in killing them as they emerge. The most effective cultivation is to kill weeds in the seedling stage rather than to attempt to destroy them by cultivation after they get well started. The rotary hoe is a valuable implement to cultivate both closely drilled and row seedings, and is particularly effective when pulled rapidly through the field. It is especially valuable for working practically all soils that are inclined to crust, and it gives excellent results when followed by a weeder or harrow.

SOYBEANS IN ROTATIONS

The soybean may be used advantageously as either a grain crop or a hay crop in many systems of crop rotations, but no standard rotation can be given that will apply to every farm. When plowed under, it is an excellent soil builder, adding much organic matter and nitrogen and improving soil tilth. On the other hand, if the soybean crop in the rotation is harvested for hay or seed and the crop removed, it draws on the minerals of the soil the same as other intertillled crops and adds very little nitrogen or organic matter.

In the Corn Belt a common rotation is corn, soybeans, small grain, and a deep-rooted legume. If winter wheat is to follow soybeans combined for seed, the crop must be removed early enough to allow the wheat to be sown at the proper time.

In certain sections of the South the soybean is especially valuable as a crop after early potatoes or canning peas, and also produces a satisfactory seed yield when sown in the late spring after winter grain. In the rice growing districts where soybeans are grown in rotation, soybeans have yielded well, weeds have been controlled, and the yields of rice have been greater than where commercial fertilizers alone were used.

The soybean can also be used as a catch crop where new seedings of grass and clover have failed and furnishes an excellent emergency hay crop in the rotation. It also furnishes excellent cover in orchards, adding to the organic matter and nitrogen supply of the soil and smothering out weeds.

SOYBEANS IN MIXTURES

Soybeans may be satisfactorily grown in combination with other crops, such as corn, cowpeas, Sudangrass, Johnsongrass, and sorghums. The chief advantage of the mixture is the production of better balanced feed, and the yields are often somewhat better than when the crops are grown separately. When used for hay, the mixture is more easily cured. The practice of combining soybeans with other crops, especially corn, has increased very rapidly during the past few years, indicating that the results are highly satisfactory.

Soybeans are more generally grown with corn than with any other crop. When grown with corn, the mixture is commonly used for pasturage or silage. In some of the Southern States, however, corn and soybeans are grown in alternate rows for seed production.

Soybeans and cowpeas in combination make a very satisfactory mixture for hay, pasture, or green manure. The yield of this mixture is nearly always greater than that of either crop alone, and when used for hay the cutting of the cowpeas is easier because of the soybean plants. Varieties of these crops that mature at about the same time should be used.

Sudangrass is an excellent crop for
growing in combination with soybeans for hay. The best results with this mixture are obtained in the regions most suitable for soybeans or where irrigation is possible, under which conditions not only a better yield but a better balanced forage is obtained.

Soybeans may be grown in combination with sorghums for hay, as a soil-improvement crop, or for silage. The best results are obtained in cultivated rows, as the sorghum is likely to choke the soybeans when sown broadcast unless the sorghum is sown thinly. When sown in rows, about 15 pounds of sorghum and 45 pounds of soybeans per acre will be sufficient.

**SOIL IMPROVEMENT**

The value of a crop of soybeans for soil improvement will depend upon the inoculation of the plants, how much of the crop is returned to the soil, and the effect of the roots upon the mechanical condition of the soil. Soybean plants with an abundance of nodules obtain from two-thirds to three-fourths of their nitrogen from the air and the remainder from the soil. If the soil is abundantly supplied with nitrates, the soybean will obtain much of its nitrogen from the soil rather than from the air. The fertilizing value of a crop of soybeans compares favorably with that of other legumes commonly grown for green manure.

As a soil-improvement crop, the soybean cannot be expected to be effective in adding to the fertility of the soil if the entire crop is removed and none of it returned in the form of straw, green manure, or animal manure. On certain types of soil, however, especially sandy soils, increased yields of subsequent crops have resulted even where soybeans were harvested as hay or beans.

**SOYBEAN DISEASES AND INSECTS**

The enormous expansion in soybean acreage and production during the past few years has greatly accentuated the disease problems of this crop. Although no widespread epidemics of disease have been observed or reported, several serious diseases of the soybean are occurring quite generally over the major producing areas and have caused appreciable losses on some farms. Various agricultural stations and the United States Department of Agriculture are conducting extensive investigations of the organisms causing the various diseases and methods for their control.

Soybeans usually are comparatively free from serious insect pests but losses due to their attacks are gradually becoming of greater importance. At present the most important ones are grasshoppers, velvetbean caterpillar, leafhoppers, blister beetles, bean beetles, and various leaf-eating caterpillars.

For further information on Diseases and Insects see chapter IX.

**SOYBEAN HAY PRODUCTION**

The soybean is not a difficult crop to grow for hay and when cut at the proper stage of growth and properly cured, it makes an excellent hay of high feeding value for all classes of roughage-consuming livestock. The chief objection to the soybean for hay is its rather coarse, woody stems, but this can be overcome largely if proper attention is given to rate of sowing and time of harvesting. It is widely adapted to various soil types and as a legume can be used in any rotation and can be grown successfully on soils too acid to grow red clover, sweetclover or alfalfa. It is not to be considered as a competitor of clover or alfalfa in regions suitable to these crops but rather as a supplement and addition to them. In case of the failure of an old or new clover or alfalfa stand, winter grain, or a spring crop, there is ample time to grow a crop of soybeans for hay. Soybeans are also excellent as a summer catch crop following early crops or in fields not in the regular rotation. In the growing of soybeans for hay, the variety and methods of production used will determine largely the quality and yield of the crop. In general, certain well-defined principles should be followed for the best results in yield and quality of hay.
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Varieties for hay: The varieties most suitable for hay are those producing moderately fine stems with an abundance of leaves. This gives the best quality hay and minimizes curing difficulties. In general, there is little difference in total hay yield between adapted seed varieties and the vinier so-called hay varieties.

Varieties of the "hay-type" most commonly used in the Northern States in order of earliness are: Wisconsin Black, Cayuga, Wilson, Peking, Kingwa, Ebony, and Virginia. In the Southern States some of the more commonly grown "hay-type" varieties are: Laredo, Tanner, Hayseed, Palmetto, Gatan, Otootan, and Avoyelles. These varieties make rather tall, viny growth and often lodge quite badly. When lodging occurs, most of the leaves on the underside are shed and the advantage of finer stems is offset by the lower leaf percentage. Most of these varieties give rather low seed yields, and consequently, seed is higher in price than seed of adapted seed varieties.

When a seed variety is planted for hay, the stem size can be reduced by planting thicker than is customary when the crop is to be saved for seed. In the South, delaying planting until mid-June or later aids materially in improving the quality of hay.

Yields of soybean hay: Yields of approximately 2 tons of soybean hay per acre can be expected under favorable conditions. Yields of 4 to 5 tons per acre have been obtained from well fertilized soils in the Coastal Plain area of the Southeastern States. In the Southern States, it is desirable to sacrifice some yield to gain quality from delayed plantings.

SOYBEAN SEED PRODUCTION

At first, and until recent years, soybeans in the United States were grown primarily as a forage crop. Previous to 1930 the acreage harvested for seed was generally less than one-fourth of the total acreage grown for all purposes in the United States as a whole. The more extensive use of the soybean for pasturage, forage, and in the manufacture of bean oil and soybean oil meal and food products has resulted in an enormous increase in acreage and production of seed.

Many farmers in the Corn Belt area first became interested in soybeans as a crop through the acreage control program on corn. They found the crop profitable to grow and also a valuable addition to their rotation. The seed-growing industry has developed in the Corn Belt States, the Coastal Plain section of the South Atlantic States, and in the lower Mississippi Valley.

All soybeans are strictly determinate as to growth; that is, the plants reach a definite size according to variety and environment, and then mature and die. The character of growth, uniform maturing habit, and heavy seed yields contribute to the ease of harvesting and adaptability of the plant for seed production.

If not harvested at the proper time, many varieties will shatter their seed somewhat. This is especially true during hot, dry weather. Growers planting soybeans for the first time should be sure to have adequate combining equipment available so as to be able to begin harvesting soon after the beans are mature. Varieties differ appreciably in degree of shattering. Some varieties will begin to shatter as soon as mature, while others will hold their seed satisfactorily for several months after reaching maturity. At the present time, varieties are available for most production areas that will hold their seed with little or no shattering for two or three weeks after reaching combine maturity.

The harvesting of seed has been one of the most difficult problems in the development of the soybean industry. Until the advent of special harvesters and threshers and the combine, growers of soybeans had to use the machinery at hand, with more or less unsatisfactory results. The combine now used in practically all soybean seed-producing areas has been undoubtedly one of the most important factors in the economic production of soybeans in the United States. Time of harvesting: When the soybean plant approaches maturity, the leaves begin to turn yellow and drop, and before
all of the pods are fully mature the leaves, except in a few varieties, have fallen. In general, when the plants are to be cut and threshed the best time to harvest is when the pods are fully mature and the seed is in the hard dough stage. If cut at an earlier stage, the plants cure more slowly, the yield of seed is lessened materially, and an inferior quality of seed results. On the other hand, if the seed is allowed to become fully mature, there is unnecessary loss from shattering. If, however, the crop has been allowed to reach full maturity, this loss from shattering can be prevented by cutting the plants in the morning when they are damp. Varieties that do not shatter easily may be allowed to stand until fully mature.

When the combine is used, it is necessary for the seed to reach full maturity to obtain the best results. The time of harvesting will vary somewhat with weather conditions. In a hot, dry fall greater care should be taken in the harvesting of varieties tending to shatter. A few varieties of the nonshattering type can be left until fully mature in almost any kind of season with little or no loss of seed.

Growers with little experience often attempt to obtain hay as well as seed from the same crop, but there is no stage at which the soybean can be cut for hay and seed at the same time if quality and yield are to be considered. For the best quality of hay, the crop should be cut three to four weeks before it would be harvested for a high quality of seed.

Methods of harvesting: The combine harvester has become the method almost universally used for harvesting soybeans. Combine harvesters can be obtained in sizes having 4½ to 12-foot cutter-bar lengths. This enables the various size growers to obtain a machine size readily adaptable to his conditions. The self-propelled combine eliminates the loss usually encountered in opening up fields. The combine harvester will operate quite satisfactorily at a speed of 5 miles per hour.

Through the use of a seed tank mounted on the harvester which can be emptied into a truck, the crop can be harvested with no labor other than the combine operator and a truck driver.

Yields of soybeans: Adapted varieties are now available for each soybean producing area, which with proper culture, will produce yields of 25 to 40 bushels (60 pounds per bushel) to the acre. Maximum yields of 50 to 60 bushels per acre have been obtained in all but the most northern production areas. To obtain these top yields it is necessary to have extremely favorable weather conditions as well as good cultural practices and an adapted variety.

Storage of soybeans: The best precaution against storage losses in soybeans is to harvest when seeds are low in moisture. When soybeans containing over 13.5 percent moisture are bulked in large bins, spoilage or heating is quite likely to occur. In areas where soybeans are harvested with a high moisture, bins should be equipped with forced air to reduce the moisture content of the beans.

The storage of soybeans on the farm becomes an important problem in these seasons when they are harvested with a moisture content above that found safe for storage in tight bins. Studies with soybeans to date indicate that storage problems increase markedly with moisture above 12 percent.

The Department of Agriculture, in cooperative storage studies with the Illinois Agricultural Experiment Station, found a close relation between the changes in grade and quality and the moisture content of stored soybeans. At moisture contents of 11 percent or under, there was little decrease in germination, and under 12 percent there was no significant change in fat, acidity, market grade, insect infestation, or temperature. At moisture contents of 12 percent or higher, it was found that soybeans with 13 or 14 percent moisture graded "sample" at the end of ten months because of a musty odor, and all soybeans with 14 percent moisture and above were musty and graded "sample" after storage from January to July. The loss of viability was al-
most complete after twelve months' storage with moisture above 13 percent and severe with 12 to 13 percent moisture.

In a study of the relation of temperature and seed moisture to the viability of stored soybean seed at the Plant Industry Station, Beltsville, Maryland, E. H. and V. K. Toole found that low moisture content and low temperatures were important factors in retaining viability. Seed stored with 18 percent moisture at 86°F. germinated poorly after being stored one month. Lowering the temperature increased the length of life of the seed. At 36°F. this seed maintained good viability for three years, and at 14°F. nearly full germination was maintained for six years.

With a moisture content of 13.5 percent, soybean seed was dead after 5 months storage at 86°F. and after 2 years at 68°F. Full viability was kept for 3 years at 50°F. When the temperature was reduced to 36°F., or lower, full germination was maintained for 10 years. Seed put in storage at a lower moisture content maintained full viability at a slightly higher temperature.

SOYBEAN HIGHLIGHTS

1. Soybeans, an annual summer legume, have been cultivated extensively and highly valued as a food in Oriental countries since ancient times.
2. Soybeans have gained rapidly in importance in the United States as a hay and seed crop during the last 25 years.
3. Increased acreage and greater utilization of the crop have brought about more efficient methods and the use of new or improved machinery.
4. The climatic adaptations of the soybean are, in general, about the same as for corn. It is more drought-resistant and less sensitive to an excess of moisture than cowpeas and corn.
5. Although the soybean will succeed on nearly all types of soil, the best results are obtained on mellow, fertile loams or sandy loams.
6. One of the best assurances against failure with the soybean is the selection of varieties suited to local conditions.
7. The best results with soybeans are obtained on a well-prepared seedbed. When sown on land not previously grown to this crop, it is advisable to inoculate.
8. The best time for sowing for a seed or main hay crop is about corn-planting time.
9. The method and rate of sowing will be determined largely by convenience and economy of cultivation and harvesting, variety used, type of soil, climatic conditions, and the purpose for which the crop is grown.
10. Cultivation of soybeans should be frequent enough to keep down weeds.
11. Soybeans are best fitted for hay when the seeds are about one-half developed.
12. Soybean hay is but little more difficult to care than hay from other legumes and may be handled successfully by about the same methods.
13. Soybean hay requires thorough curing before being stacked, housed, or baled, as danger of molding occurs when the hay is stored or baled too green, or too soon after a rain.
14. Official United States standards have been prepared to provide a definite basis of quality for use in the marketing of soybean and soybean mixed hay.
15. Soybean hay can be fed profitably to all kinds of livestock. It makes an excellent winter ration for young cattle, sheep, horses, and mules, and may be used to good advantage for hogs and poultry.
16. As a pasture crop the soybean is valuable for all kinds of livestock. The most profitable method is to pasture with hogs, supplementing with a corn ration. The crop furnishes a very satisfactory pasture in late summer and early fall when perennial pasture may be short.
17. The soybean is a useful supplement to corn for silage, which is readily eaten by stock and produces no bad effects on the quality of milk and its products.
18. The fertilizing value of a crop of soybeans compares favorably with that of other legumes commonly grown for green manure.
19. Straw obtained from threshing soybeans has value as roughage for wintering dry dairy cows and beef cattle. It is also a good roughage for sheep.
20. Soybean seed should be thoroughly dried before storing. Only under exceptional conditions is soybean seed attacked by weevils.
21. Soybeans usually are comparatively free from serious insect pests. At present the seriously injurious insects are grasshoppers, blister beetles, leafhoppers, green
clover worm, and velvetbean caterpillar.

22. Although the soybean is attacked by fungus, bacterial, and virus diseases, no disease of this plant has yet assumed any great economic importance in the United States.

VELVETBEAN
(Stizolobium species)

The velvetbean is apparently a native of India. It is said to have been introduced into Florida nearly a century ago. It was grown for many years as an ornamental vine for porches and trellises. As early as 1890, the variety known as the Florida velvetbean was used somewhat for green manure in citrus orchards in Florida.

The velvetbean has been an important factor in the development of the livestock industry and as a soil-improving crop in the Southern States. The seeds have a high feeding value and are important as a concentrated feed; the leaves and vines afford good roughage. For soil improvement, especially on sandy soils, the velvetbean is one of the best crops.

DESCRIPTION

The velvetbean is a vigorous-growing summer annual legume. Its vines (except those of the bush varieties) attain a length of 25 feet or more. The leaves are trifoliate with large, ovate leaflets.

The flowers of the different species and varieties are white to dark purple and are borne singly or in twos and threes in long pendant clusters. The pods are of two distinct types; one has a dense, black, velvety pubescence, and the other has white or grayish hairs. The pods of the different species range from 2 to 6 inches long with 3 to 6 seeds per pod. Velvetbeans have numerous rather fleshy surface roots, which are often 20 to 30 feet long and abundantly supplied with nodules.

VARIETIES

The Florida velvetbean (Stizolobium deeringianum) was the only species grown in the United States until about 1906. Since then some 20 or more species and varieties have been introduced and several more, mostly earlier types such as Georgia (or Ninety-Day Speckled) and Alabama (or Hundred-Day Speckled) have been selected from the original Florida variety. Other varieties grown to a greater or lesser extent are Florida Bush or Bunch, Lyon, Osceola, Yokohama and Tracy Black. The larger part of the acreage of velvet beans is devoted to the earlier varieties which differ principally in growth of vine, color of flowers, size, shape, and pubescence of pods; size, shape and color of seeds; and time of maturing.

ADAPTATION

Climate: The velvetbean is definitely a warm-climate species. The older variety Florida seldom matured more than a few pods when grown north of the most southern portions of Georgia, Alabama and Mississippi, where it was grown for a long time as a grazing and green-manure crop.

Since the development of several varieties the successful production of the velvetbean has extended northward until it is now grown practically throughout the Cotton Belt.

Most of the varieties now on the market make considerable growth as far north as the Ohio River, but north of the southern boundary of Tennessee in the Piedmont section and north of southeastern Virginia in the Coastal Plain, seeds
mature only in years with favorable growing seasons and late fall frosts. There the velvetbean should be grown primarily as a green-manure crop.

Soils: The greatest velvetbean acreage is found in the well-drained, sandy Coastal Plain soils of the South Atlantic and Gulf States, where conditions are especially adapted to the crop. The velvetbean has been used extensively as a green-manure crop on cut-over pineland and on sandy soils.

It makes a good growth on clay soils in the northern portion of the Cotton Belt, but it is questionable whether it will do better than the cowpea on the poorer soils in this area. The velvetbean will not succeed on cold wet soils and should never be planted before the soil has become thoroughly warm.

**CULTURE**

**Preparation of seedbed:** Although the velvetbean is easy to raise, the best results are obtained on a well-prepared seedbed. In general, the land should be prepared as for corn. The ground should be plowed thoroughly to a depth of about 6 inches in December or January and harrowed at intervals before planting to kill the weeds.

**Fertilizers:** Although velvetbeans make a fair growth on poor soils, it is sometimes advisable to apply a small amount of fertilizer at the time of planting, the kind and quantity being about the same as for corn.

Phosphatic fertilizers are necessary to obtain good yields. The addition of cottonseed meal at the rate of 200 pounds per acre gave an increased yield of 280 pounds of beans per acre as compared with the yield when 200 pounds per acre of acid phosphate alone was used. At the Florida Station no increased yield was obtained from fertilizers applied singly or in various mixtures. The velvetbean is not sensitive to sour soils but is helped by lime.

**Inoculation:** Inoculation seems unnecessary for velvetbeans, as apparently all of the velvetbean area is provided with the organism that forms nodules on the roots of the plants.

The same strain of the organism that inoculates lima beans, cowpeas, and lespedeza also inoculates velvetbeans. As lespedeza grows abundantly over much of the South, and as cowpeas have been planted widely for many years in all of the velvetbean area, it is easy to understand why the velvetbean has succeeded so well without artificial inoculation.

**Time of planting:** Velvetbeans will not germinate well in cold or wet soils, and as the young plants are very susceptible to injury by frost, planting should be delayed until all danger of frost is past.

In the northern part of the Cotton Belt the seed should be planted early, or at corn-planting time. In the southern part of the Gulf States late varieties should be planted as soon as the soil is in good condition so that the plants will have time to mature before frost; but with early varieties the date of planting may extend over a period of 6 weeks or 2 months. In this section the planting of early varieties too soon is undesirable, as the beans mature so early that the pods split and shatter, and the foliage sheds before the corn is gathered and the stock can be turned into the field, in which case it is best to plant the beans by hand in the corn rows some time after planting the corn. If the crop is to be pastured, many farmers prefer to have the beans frosted before all of the pods are matured rather than to have them mature too early.

**Method of planting:** Velvetbeans, with the exception of the Bush variety, should be planted with a supporting crop. Corn, pearl millet, Japanese sugarcane, sorghum, and other strong-growing plants are used for this purpose, but as corn is an important crop in the velvetbean area, it is generally preferred. When the corn is to be cut for silage or where the soil is so poor that the beans do not make a vigorous growth, they should be dropped by hand 15 to 24 inches apart in a row on poor soil and about twice that distance apart on fertile soil.

Planting corn and beans in separate rows is a popular method, especially planting every third row to beans. Where this method is used, the beans may be planted
at the same time as the corn or at a later date, as the cultivation of the corn will not interfere with the planting and cultivation of the beans.

Rate of planting: The rate of planting will vary with the purpose for which the crop is grown and with the variety. If planted with corn and if it is desired to secure as much corn as possible, from 4 to 6 pounds to the acre will be sufficient for the Florida, Georgia and Alabama varieties. If a heavy crop of beans is desired and if the corn is not of first importance, twice as much seed should be used. If the heaviest possible growth of vines is desired, either for green manure or as a smother crop, from 30 to 60 pounds of seed should be used.

Cultivation: Cultivation of velvetbeans during the early growing period will increase the yield sufficiently to more than pay the cost and should be continued until the plants begin to put out long runners, after which the ground will be covered so completely as to smother all weeds. When grown with corn, cultivation should be the same as for corn alone until the vines are so long that they are likely to be injured.

HARVESTING AND THRESHING

The time of harvesting velvetbeans depends largely on the variety and use to be made of the crop. When velvetbeans are to be fed whole or ground, to cattle, it is preferable to feed both hulls and beans. For this reason the quantity of beans threshed is ordinarily limited to those which are to be used or sold for planting purposes. When grown for seed, the entire crop should be harvested as soon as practicable after the pods mature. Immature or damp pods heat and mold when stored in bulk unless thoroughly stirred at frequent intervals. Because of the extensive tangled growth of vines, hand-picking is necessary. As pickers usually leave many of the pods, stock should be turned into the field after harvest to consume the vines and the beans not gathered.

Only well matured and thoroughly dried pods can be threshed without difficulty. If the quantity to be threshed is small, the pods may be sunned a few hours, put in an ordinary corn sack, and the beans beaten out with a club. For larger quantities, it is better to use one of the machines designed for the purpose and follow accompanying instructions.

Many factors, including soil fertility, cultivation, and weather conditions influence the yield of seed. On fairly rich soil the early varieties should produce 1,500 pounds of beans in the pods, or 1,000 pounds shelled, to the acre, and the late varieties 2,000 pounds in pods or 1,300 pounds shelled; 3,000 pounds in the pod is not an unusual yield.

DISEASES AND INSECTS

The velvetbean is notably free from disease or insect enemies. Bacterial spot, leaf spot, and southern blight and root rot are occasionally present and cause some injury. The velvetbean caterpillar is the only insect which causes serious injury to the velvetbean. For further information on diseases and insects, see chapter IX.

UTILIZATION

The vigorous growth of velvetbeans, together with their large yield of seed which may be gathered or allowed to remain in the field without much injury during the autumn and winter, permits this crop to be utilized in a number of different ways. As an annual summer green-manure crop it is one of the best. Its value as feed for stock is quite generally recognized in the South, where large quantities are used for this purpose. The value of velvetbeans as a winter pasture, either for carrying cattle through the winter or for fattening them, is well established.

Meal: In the manufacture of velvetbean meal the beans and pods are ground or rather crushed, either alone or with other feeds, by especially designed machinery. Although no standard of fineness has been established, a meal of the fineness
of corn meal is preferred, especially in the manufacture of mixed feeds. Some mills kiln-dry all beans before grinding, a practice which adds to the cost of manufacture but is necessary early in the season in order to keep the meal from spoiling.

Hay: Velvetbeans are seldom used for hay because of the difficulty in handling the long tangled vines. When used for this purpose it is necessary to cut the vines before many of the pods mature in order to save the leaves which shatter rapidly on the approach of maturity. The hay is coarse and rough at best, and is not relished by horses and mules. Yields of 2 to 3 tons per acre may be obtained.

Silage: Velvetbeans, particularly the early varieties, and corn have been used to some extent for silage. Most of the vine growth of the early varieties is wrapped about the cornstalks, and little trouble is experienced in cutting the corn with corn knives and in running it through the silage cutter. Silage made from this mixture turns black after it has been in the silo for a short time, because of the juices in the velvetbean plants, but this condition apparently does not impair its keeping qualities or feeding value. Corn-and-velvetbean silage is as palatable as corn silage, and dairymen who have fed silage made from the mixture prefer it to corn silage.

Pasture: The most important use of the velvetbean is as a grazing crop for cattle and hogs in the autumn and winter. On sandy soils, the leaves, vines and pods do not decay readily and often furnish feed until early spring. It is usually better to delay grazing until the crop is well-matured or killed by frost, as the leaves will be off the plants at that time and the corn may be gathered with less difficulty. The amount of grazing afforded will, of course, vary with the growth of the crop and the quantity of corn that is not gathered.

As velvetbeans are very high in digestible protein, great care should be exercised in feeding them to livestock, especially at first. After the stock become accustomed to the beans they should be kept in the field for only a short period each day until the crop is somewhat reduced, as excessive consumption is a waste of concentrated feed. In addition to wasting concentrated feed, overfeeding sometimes has a laxative effect similar to that caused by feeding too much cottonseed meal. For these reasons and because better gains will be obtained, velvetbeans should be fed in combination with other feeds. This is accomplished when cattle and hogs are pastured on corn and velvetbeans, as some corn will be overlooked in picking and the stover contains a relatively high proportion of carbohydrates.

Soil improvement: The velvetbean is one of the best soil-improving crops both for naturally poor soils and for those on which yields have decreased markedly. The ability of this plant to make a profitable growth on land so poor that most legumes do not thrive on it, places the velvetbean among the important crops for the South. In addition to adding at a minimum cost large quantities of vegetable matter to the soil, thus making it more retentive of moisture, the nodules on the roots collect a large amount of nitrogen from the air. The nitrogen is left in the soil when the crop is turned under and the plants decay. Even though the crop is grazed, much of the nitrogen in the plants consumed by the stock will be returned to the soil in the manure.

A smothering crop: When late varieties of velvetbeans are planted without a supporting crop they produce such a dense growth of vines that weeds, persistent grasses, and in many cases tree sprouts are smothered. The Florida Station planted a freshly plowed field of strong Bermuda-grass to velvetbeans. The following year this field was planted to cassava, and it remained entirely free from Bermuda-grass.

VELVETBEAN HIGHLIGHTS

1. The velvetbean, a summer annual, has become an important factor in the development of the livestock industry and as a soil-improving crop in the Southern States.

2. The development of early varieties has
made possible the culture of velvetbeans throughout the Cotton Belt north to the Ohio River.

3. Velvetbeans will grow on poor soils but respond to fertilizers applied at time of planting as for corn.

4. No artificial inoculation for velvetbeans seems necessary since the organism that inoculates velvetbeans is the same that inoculates cowpeas and lespedeza which are well distributed throughout the South.

5. As the feeding value is not seriously reduced by exposure in the field during the winter months, velvetbeans are valuable for grazing from late fall until early spring.

6. A mixture of velvetbeans and corn silage is regarded as a better feed than silage from corn alone.

7. The seeds of the velvetbean have a high feeding value and are of importance as a concentrated feed, while the leaves and vines afford good roughage.

8. Velvetbean meal ground, pods and seeds together, makes an excellent, coarse, high-protein feed.

9. Because of economy in handling, and the very small loss in feed value in the winter grazing of velvetbeans, this practice is largely replacing the picking of beans for grinding.

10. For soil improvement, especially on sandy soils, the velvetbean is one of the best crops, giving heavy yields at low cost.

Chapter reference numbers: 1


Soybean: DEL-2; KAN-30; MISS-3, 10; MO-17; OHIO-5, 46; PA-2; PR-1; RI-7; VT-18; VA-6; US-175-180, 249.


1 The reference numbers given here refer to references which are given in full by State, U.S.D.A., and Miscellaneous, on pages 682 to 724, and which are cross-referenced by author on pages 725 to 731. Citations in the text are indicated by abbreviation and number in parentheses.
The genus *Lotus* is represented in the United States by three cultivated forage species, *L. corniculatus*, *L. tenuis*, and *L. uliginosus* (*L. major*). In addition to these, there are some 40 native species (including those of the strictly North American genus *Hosackia*) all but one of which (*L. Helleri*) are native to the western United States.

These lotus-trefoils should not be confused with the native lotus water-lily (*Nelumbo lutea*), or with yellow trefoil (*Medicago lupulina*), commonly referred to in this country as black medic, or with the hop-trefoils (*Trifolium* spp.), commonly called hop-clover. The name “deervetch” is sometimes applied in literature to species of *Lotus*, but the name is not in common use for any of the cultivated species.

**BIRDSFOOT TREFOIL**

(*Lotus corniculatus* and *L. tenuis*)

**INTRODUCTION**

Birdsfoot trefoil, like some other plants to which little attention has been given in the United States but which have been well known in Europe for a century or more, has come up for special consideration in very recent years. Even though birdsfoot trefoil has been known and used in Europe for a long time, it has not come into general use as a single crop for pastures. However, in the regions to which it is adapted, it has been included in many of their pasture mixtures.

In the United States, birdsfoot trefoil came into practical use some years ago in eastern New York and western Oregon. It is now being grown in a limited way in a number of central and northern States with much success.

While birdsfoot trefoil is a valuable plant for hay in perennial meadows, its principal use seems to be in permanent pasture mixtures where it stays green and produces excellent feed during hot summer months when so many other legumes ordinarily used for this purpose dry up, and where some other short-lived legume like red clover can be used to supply feed for the first year or two until the birdsfoot trefoil becomes established. It is also usually longer-lived in competition with grasses than other legumes and does well under soil conditions where most of those legumes would not thrive.

The final answer as to whether it will increase in value and use as a forage crop and occupy a really important place among other pasture legumes will be given when the rather extensive experiments now being conducted by the Forage Crops Division and the Soil Conservation Service of the United States Department of Agriculture, in cooperation with the State agricultural experiment stations, are much farther along than they are now. Under certain conditions, some other legumes offer strong competition for a leading position as a pasture crop in mixtures with the usual pasture grasses.

**DESCRIPTION**

The root system of birdsfoot trefoil consists primarily of a strong taproot with numerous branches that extend out almost at right angles to the main axis and
form a dense mat in the upper region of the soil. The long, tapering, usually forked, primary root is surmounted by a dense crown of stems. Three-year-old plants dug from row seedings at Turkey Hill, near Ithaca, New York, showed an over-all depth of rooting of 3.5 feet; alfalfa a few feet away reached a depth of 5.5 feet. The alfalfa possessed a much less extensive root distribution. In native

Narrowleaf birdsfoot trefoil.

stands of birdsfoot trefoil in eastern New York, roots have been found to a depth of 6.5 feet in several instances.

The stem varies from prostrate to somewhat erect, depending upon the variety. The height, or over-all length of the stems varies greatly. The erect and narrow-leaved types on poor soil may be from 6 to 12 inches, while on soil of high fertility the stems may exceed 3 feet in length. The branches at the surface of the ground or those covered with soil usually do not root as in big trefoil.

The leaves are borne alternately along two sides of the stem. They vary greatly in size and shape in the different forms within the species. Each leaf consists of five leaflets, a terminal and two opposite lateral leaflets situated at the apex of the leaf petiole and two opposite leaflets at its base.

The flowers are borne in a cluster consisting of a whorl or umbel of 5 to 9 short-stalked flowers borne at the apex of a long stem. The flowers are yellow in color, and may have a reddish tinge when fully developed. The color range is from a deep orange, almost red, to a pale lemon-yellow. This color variation depends upon the strain or variety and the stage of flowering.

The seed-pod or fruit is a straight cylindrical legume about one to two inches long and one-eighth inch thick, brown to grey-brown when ripe, and covered with a coarse net-work of veins. It terminates abruptly in a fine point. When ripe it snaps open, rupturing along both margins and twisting the two halves into spirals.

Since the growth of the plant is indeterminate, flowers and fruits (seed-pods) of all stages of development may occur on the same plant though this is not general. This feature, along with the sudden rupturing of the pod and releasing of the seed at maturity are what make the saving of a large proportion of the total seed product of the plant difficult.

Species of birdsfoot trefoil: The cytological and morphological studies of Tome and Johnson (Iowa-24) show that the two forms of birdsfoot trefoil, commonly known as broadleaf birdsfoot trefoil and narrowleaf birdsfoot trefoil, and which have generally been considered as varieties of Lotus corniculatus, should be considered separate species.

The names which apparently belong properly to these two species are Lotus corniculatus for the broadleaf species, and L. tenuis for the narrowleaf, which have frequently been referred to in literature as L. corniculatus arvensis and L. corniculatus tenuifolius. Each of these species probably comprises two or more regional varieties.

The broadleaf birdsfoot trefoil (L. corniculatus) has obovate to elliptical leaf-
BIRDSFOOT TREFOIL

lets at least half as wide as long, and the narrowleaf birdsfoot trefoil (L. tenuis), has linear or linear-lanceolate leaflets. The roots of the narrowleaf form are more shallow than those of the broadleaf, which may be correlated with its adaptation to moist, fertile soils, while the broadleaf form is better adapted to the dryer, less fertile soils. The flowers are smaller in the narrowleaf than in the broadleaf.

In addition to these differences in gross morphology, cytological studies have shown that L. corniculatus has 24 somatic chromosomes, and L. tenuis only 12, and that there are other cytological differences in both structure and fertility reactions to each other.

ADAPTATION

Climate: The States in which successful experimental stands or naturalized growths of birdsfoot trefoil have been observed are California, Oregon, Idaho, Washington, Minnesota, Wisconsin, Nebraska, Missouri, Illinois, Iowa, Indiana, Ohio, Michigan, New York, Vermont, Pennsylvania, Maryland, Virginia, and North Carolina. With the exception of California, these are northern or central States. The most promising results have been obtained to date in New York, Ohio, Indiana, Illinois, Iowa, Missouri, California, and Oregon. In all of these States, except Oregon and California, broadleaf birdsfoot trefoil (L. corniculatus) is best adapted and has given best results. In Oregon and California the narrowleaf (L. tenuis) has been generally grown but the growing of the broadleaf is increasing in Oregon for both forage and seed production.

Soil: Birdsfoot trefoil is not too exacting as to soil requirements and does well under a variety of soil conditions. The broadleaf makes good growth on sandy and light gravelly soils as well as on heavier clay loam and has been observed growing in soils with moderate amounts of alkali. In the Catskill section of eastern New York it is growing on poor gravelly loam soils of recognized low-productive capacity for local standard crops. It is considered rather drought-resistant. In the Pacific Northwest and in New York, the narrowleaf strain usually is found growing on the heavy, fertile, rather moist soils. It is not particularly drought-resistant but will stand average drought conditions and is equal to most other crops in this respect.

In Europe the drought resistance is frequently referred to by claims of its striking power to withstand dry conditions and maintain itself where other plants could not survive. In France, good results were obtained on a poor rocky slope over a period of nine years.

Limited trials indicate that the slender narrowleaf species from eastern New York is harder than the commercial seed from Oregon, which is also mostly the narrowleaf strain. Soil adaptation as well as climate may be a factor in this last observation.

In tests at the U. S. Regional Salinity Laboratory, Riverside, California, narrow-
leaf birdsfoot trefoil showed outstanding salt tolerance. In one experiment comparisons were made with big trefoil, red clover, alsike clover, Ladino clover, and strawberry clover. Of these, both big trefoil and strawberry clover are considered salt tolerant. However, birdsfoot trefoil gave the largest all-season yields of any species on the low, medium, and high salt plots, and was the only one to give a large yield on the high-salt plot and this was 60 percent of that of the low-salt plot.

Alfalfa is regarded as comparatively tolerant to salt. When compared under similar conditions, birdsfoot trefoil produced over 50 percent more green weight than alfalfa in both the no-salt and the salt plots, and a larger relative yield in the salt plot.

**ESTABLISHING A STAND**

**Sowing the seed:** Experimental results and experience of growers in both Europe and the United States have indicated that stands of birdsfoot trefoil and big trefoil are sometimes difficult to obtain. A thorough preparation of the seedbed seems to be very essential. A very firm seedbed and shallow sowing are most important. The seed should be sown as shallow as possible and still insure enough moisture for germination and in no case over 
\[ \frac{1}{4} \text{ inch deep.} \]

Broadcast sowing and rolling to press the seed into the soil and firming the seedbed so that moisture will be near the surface and in contact with the seed, is perhaps the safest method to follow.

**Time of sowing:** In New York MacDonald (NY-28) states that for the most part seed is sown in the spring at the time of sowing the spring grain but that the seedlings from spring sowing may be severely injured in a very dry season. In the northwestern United States both east and west of the Cascade Mountains the best time for sowing is from April 1 to May 15, depending on the latitude and seasonal conditions. Pierre and Fuelleman state that the best results in New York, Iowa, northern Illinois, and northern Indiana have been obtained from early spring sowing. They also say that successful stands have been obtained in southern Illinois, southern Indiana, and at Elsberry, Missouri, by sowing in August when moisture conditions were right, but that late fall sowing was not satisfactory.

In California fall sowing seems to be preferred. In Oregon, good results have been obtained with spring sowing on top of one-half a normal sowing of fall-sown wheat. Wheat sown lightly as a companion crop has been much better than other cereals.

When late summer sowing is practiced, the use of scarified seed is recommended so as to obtain quick germination. Sowing at this time, when feasible, has the advantage of offering the rather weak seedling plants of birdsfoot trefoil less competition with weeds which are likely to be troublesome with spring sowing.

**Rate of sowing:** When sowing alone and a full stand is desired, birdsfoot trefoil should be sown at the rate of about 5 pounds of good seed per acre. Under favorable conditions and in mixtures with grasses, these figures can be reduced. In New York some growers use but two pounds of birdsfoot trefoil in a general mixture when the field is to be left down for a term of years. Also, no improvement in yield was obtained by sowing more than 5 pounds per acre with good seedbed preparation. This is equivalent to about 50 seeds per square foot. With time the stand will thicken by expanding growth and by resowing, and may displace some of the other plants in the mixtures.

**Mixtures:** In most cases it is desirable to grow birdsfoot trefoil in simple mixtures with grasses and other legumes rather than in pure stands. Most growers have followed this practice and, except when seed is the main interest, it is highly satisfactory. In pastures a mixture is to be preferred, and for hay both good yields and satisfactory quality can be attained by the use of locally adapted combinations. The best proportions of the different grasses and legumes will vary, which means usually only a small proportion of other legumes or none at all.
BIRDSFOOT TREFOIL

When grown for seed the choice of timothy as a companion grass is questionable, as it is practically impossible to separate the timothy seed from the birdsfoot trefoil. However, when early clipping is practiced, the timothy rarely heads a second time and little timothy seed is produced.

In New York, timothy, orchardgrass, Kentucky bluegrass, Canada bluegrass, bromegrass, tall fescue, tall oatgrass, ryegrass, red clover, Ladino clover, and alsike clover in mixtures with birdsfoot trefoil have given good results. In western Oregon, birdsfoot trefoil has been satisfactorily grown in combination with bentgrass, red clover, timothy, Alta fescue, and perennial ryegrass. In Iowa, Kentucky bluegrass, orchardgrass, and timothy seem to be the most compatible companions for birdsfoot trefoil.

When used in mixtures with grasses, it is usually best not to use other legumes unless a light sowing of red clover (two to three pounds per acre) is included to provide the legume portion of the forage the first year after sowing while the birdsfoot trefoil is becoming established. A heavy sowing of another legume might be detrimental to the development of the birdsfoot trefoil. The use of red clover is not a good practice where seed is to be harvested, because of difficulty of cleaning.

In some New York trials, timothy with birdsfoot trefoil outyielded all other grasses. Other grasses that were tried with birdsfoot trefoil were reed canary, perennial ryegrass, orchardgrass, bromegrass, and redtop. The perennial ryegrass and redtop almost or entirely killed out after the first year, leaving a practically pure stand of the legume. The orchardgrass and reed canarygrass maintained a satisfactory percentage of the grass in the second and third years.

Heath (Iowa-16) has reported the results of a four years' study of birdsfoot trefoil grown in combination with various grasses on a Clarion silt loam at the Soil Conservation Nursery at Ames, Iowa.

Observations showed the less competitive grasses such as Kentucky bluegrass, reedtop, orchardgrass, and timothy to be the most compatible to grow in association with birdsfoot trefoil. It is believed that a good stand of southern-type bromegrass, Alta fescue, or big bluestem may prove too competitive, unless controlled by clipping or grazing while the trefoil is in the seedling stage. Although timothy-birdsfoot-trefoil gave the highest total forage yields, the Kentucky-bluegrass-birdsfoot-trefoil association was rated first on compatibility. The phosphated plots yielded an average of 60 percent more forage than the unfertilized plots.

Other legumes tried in combination with the grasses were manna clover, medium red clover, alsike clover, alfalfa, white clover, Ladino clover, and black medic. The birdsfoot trefoil outyielded all except alfalfa for the entire period.

Inoculation: In districts where birdsfoot trefoil occurs naturalized, the plants seem to be well inoculated. Experimental trials, however, have shown that the plants do not become inoculated readily under all conditions, and that artificial inoculation is usually needed. It is recommended, therefore, that artificial inoculation be given to all new seedings. Cultures for birdsfoot trefoil will inoculate both the broadleaf and the narrowleaf birdsfoot trefoil but are ineffective on big trefoil, and vice versa, although parasitic nodules are formed. So far as is known, the bacteria from any other cultivated legume will not inoculate any of the Lotus-trefoils. Special attention, therefore, must be given to obtaining the proper inoculating culture.

Some commercial preparations include cultures for both species of birdsfoot trefoil and big trefoil together. It is preferable with the Lotus-trefoils, and probably with certain other legumes which require specific strains of *Rhizobium* for effective nitrogen fixation, to have in the prepared culture only strains that are known to be most effective on the particular variety or species. In any case, no parasitic nodule-forming strain should be present. In this connection it must be borne in mind that, whenever a legume becomes inoculated with a parasitic *Rhizobium* strain, it tends to resist the entrance of an effec-
tive strain to the roots of the legume host. In other words, the improved strain must “get there first” if it is to do the most good. This means that to get the best results from the introduction of an effective nitrogen-fixing strain introduced by a commercial culture, such strain should be applied to the seed at the time of sowing so as to have the nodules formed on the roots of the host plant most quickly.

Recently strains have been discovered or developed that in trials have inoculated all three cultivated species, but they have not been tested sufficiently to determine their adaptation or use in commercial cultures.

**Fertilizer and lime:** The sections in the United States where birdsfoot trefoil has come into use are more or less deficient in lime, indicating that soils low in this compound can produce the crop satisfactorily. The experience in European countries bears out this conclusion and supports the belief that this crop may have a place in at least limited areas where the lime content of the soil is insufficient for most other legume crops. It should be pointed out, however, that although birdsfoot trefoil does well on soils deficient in lime, it has been shown that under such conditions the use of lime often is beneficial and that the optimum requirement is probably not essentially different from that of such legumes as alfalfa, red clover, and Ladino clover. It has also been demonstrated that superphosphate and potash are beneficial. Robinson in the Empire Journal of Experimental Agriculture writes as follows: “The success of the crop depends to a considerable extent upon the supplies of potash and phosphates in the soil. Given a sufficiency of these two plant foods, the crop is capable of yielding well for a long time, periods of 9 to 20 years being not uncommon.”

**INSECTS AND DISEASES**

Several of the common insect pests of clover and alfalfa have been reported to occur on birdsfoot trefoil in Central Europe and Russia, although no serious injury by them has been mentioned. These insects also occur in the United States, but the only material injury by them reported in this country was one case by Montcith and Hollowell in which nursery rows were heavily infested with the potato leafhopper and showed injury similar to that caused on alfalfa by this insect.

Rhizoctonia is known to be a destructive disease of lotus-trefoils. It kills seedlings and sometimes older plants, and curtails seed yields. See chapter IX on Diseases and Insects.

**UTILIZATION**

**Hay:** Birdsfoot trefoil hay can be harvested and handled with ordinary farm machinery and is commonly cut with a mower and raked and handled the same as clover or alfalfa. Thin stands can be raked and handled quickly, but heavier stands require some time for proper drying.

In cooperative experiments at the Michigan Agricultural Experiment Station, yields of hay were obtained amounting to 2 tons per acre for the first cutting and 1,500 pounds for the second. Lime, phosphate, and potash were applied to these plots and no doubt increased the yield, but on poor, badly eroded, nearby areas receiving only lime, good growth had been made. At one of the substations in southern Illinois, a 2-year-old stand of birdsfoot trefoil yielded 3.81 tons dry weight per acre in 1929.

**Pasture:** Both the broadleaf and the narrowleaf strains of birdsfoot trefoil do well in pastures in sections to which they are adapted. The plants are palatable and nutritious and seem to be particularly well suited for growing with grasses. Being long-lived perennials, when once established in pasture mixtures they endure for a term of years. In Oregon, eastern New York, Iowa, Indiana, and Missouri, farmers are grazing birdsfoot trefoil and report entirely satisfactory results. The plants stand trampling and grazing well and livestock have done well on birdsfoot trefoil pasture.
European writers differ in some minor details regarding the value of birdsfoot trefoil for pasturage, but all agree that it is a valuable plant, as is evidenced by its inclusion in many of their pasture mixtures where it is adapted. Some of the features stressed by these writers are disease resistance, drought resistance, longevity, and the fact that it will grow under conditions where clover fails. It is also pointed out that birdsfoot trefoil furnishes succulent pasturage in middle to late summer at a time when most plants are making little or no growth. This latter characteristic appeals strongly to those in the United States who have used it for pasturage.

The composition of birdsfoot trefoil is usually given as about equal to that of alfalfa. It usually, but not always, contains prussic acid. Experiences in the United States indicate that this does not interfere with its feed value.

Referring to results obtained at the Indiana Agricultural Experiment Station, Mott (1nd-9) says: "Birdsfoot trefoil is the most prominent permanent-pasture legume recently introduced into the Corn Belt. It is a perennial legume with a deep root system, and it produces ample seed for its own reproduction in a permanent pasture. Birdsfoot trefoil appears to be as drought-tolerant as alfalfa and is able to compete with bluegrass in a permanent pasture. A seeding of birdsfoot trefoil and bluegrass made in 1940 has shown a steady improvement during the five years.

"This mixture has consistently produced faster gains and a greater quantity of beef per acre. In the drought year of 1944, the birdsfoot trefoil displayed a greater advantage over the other mixtures because of its tolerance to dry weather.

Single spreading plant of narrowleaf birdsfoot trefoil in bloom.

...
timothy, and 64 percent more than the bluegrass and clover.

Although birdsfoot trefoil has been tried extensively only a few years, the States of New York, Ohio, Indiana, Illinois, Iowa, Missouri, California, and Oregon have found it to be a valuable addition to their small list of satisfactory pasture legumes. The narrowleaf type is being extensively used in pasture mixtures under irrigation in the central valleys of California. Instances have been reported where these pastures have carried 20 sheep per acre for the entire pasture season.

Even with its two shortcomings of slow establishment and difficult seed harvest, birdsfoot trefoil has come to occupy a place as a long-lived legume in permanent pastures in the above States which cannot be filled by other legumes. In certain localities where it has not proved satisfactory so far, later investigations may show the reasons and pave the way for its satisfactory use as a pasture crop.

Erosion control: There are many thousands of acres in the country that are devoted to grazing, the soils of which are not well adapted to the production of such legumes as alfalfa, Ladino, red, or even alsike clovers. These lands may be either too low in fertility, have a high water table, or to too acid in reaction to allow the profitable production of these high-producing legumes. Birdsfoot trefoil, being a perennial legume and capable of good growth on some lands with these adverse physical char-

Root system of 2-year-old plant of broadleaf birdsfoot trefoil. Cluster of seed pods on rule.
SEED PRODUCTION

One of the major obstacles to the increased use of birdsfoot trefoil as a forage legume has been the difficulty of obtaining seed. Several early writers considered that the cultivation of this plant would never become an economic possibility because of the difficulty of obtaining seed at a reasonable cost.

Harvesting for seed: The seed ripens unevenly, and plants often will have both green and ripe pods at the same time. When ripe, the pods pop open easily and this results in a considerable loss of seed. In order to get maximum seed yields, it is necessary to watch the plants closely and to harvest when the maximum of seed is sufficiently mature. This will be when most of the pods are well browned and a goodly number have turned a dark violet color or black. The plants will still be green.

Cutting either with a reaper or a mower, with or without swather attachments, probably should be done at night or during damp periods, if possible. In the West, much of the harvesting is done at night. The cut material should be windrowed, then bunched, and later stacked or threshed, or combined from the windrow, depending upon facilities available. Where weather conditions will permit, the cut crop may be taken from windrow to thresher with large bunch rakes. The seed immediately after harvest should be watched closely to prevent damage, as the moisture from immature seed may cause molding.

Seed production in Oregon: Both the narrowleaf and broadleaf birdsfoot trefoil are grown for seed in Oregon, but the larger part of the production has been of the narrowleaf variety. Most of this is grown under irrigation in the Rogue River Valley, near Medford. The broadleaf variety which stands droughty conditions and also heavy grass competition in regions of high rainfall better than the narrowleaf, is gradually increasing in seed production in the Willamette Valley and along the Pacific Coast.

The first harvest of narrowleaf birdsfoot trefoil seed in Oregon, near Medford, was in 1940 by one grower who produced 4500 pounds of seed from 50 acres. Since then (1941-48) the average annual production in that area has been about 50,000 pounds with a maximum of about 70,000 pounds in each of the years 1944, 1945, and 1948, and a minimum of 16,000 pounds in 1942. The acreage harvested for seed during this 8-year period ranged from 150 to 1300 acres, and the yields from 54 to 156 pounds per acre.

The following information on harvesting has been supplied by Ben W. Tucker, County Agent, Medford, Oregon:

When harvest time approaches, the growers watch the fields as the seed ripens and gather seed pods which are then dried with oven heat to see if the field is ready for harvest. The desired stage for harvest is where the seed will not shrivel and just before the pods start to shatter in the field. These tests are generally made two or three times a day until the seed is ready for harvest.

When the field is ready to cut, tractor mowers equipped with windrow attachments are put into the field in the late afternoon when the humidity is high, and are continued in operation until heavy dew or humidity increases to such an extent that the mowers cannot be operated properly. Immediately behind the mower, buck rakes are started bucking up the windrows in large piles, and this is continued as closely behind the mower as is practical, until all of the crop that is cut and windrowed that day is in piles.

Within two or three days after the piles are made, the buck rakes are put into the field again and each pile is carefully moved onto dry ground, which means moving the pile only a few feet. Extreme care is used by the operator in forcing the buck rake teeth into the pile in the same place and on the same side from which it was previously operated, so as to disturb the pile as little as possible. This constant shifting of piles from one location to another is continued for perhaps five to seven times in as many days.
This prevents absorption of ground moisture, and enables the entire pile to cure better.

Some ten days to two weeks following the mowing and buck-raking of the crop, it is threshed with a stationary threshing machine. In front of and under the feeder a large canvas, usually 30 by 100 feet in size, is spread on the ground. Buck rakes are then used again to carefully move the pile of cured trefoil. After the load is elevated by the buck rake, the driving is carefully done to avoid shattering, and the pile is deposited on the canvas near the threshing machine. It is then fed by hand into the machine and the shattered seed is reclaimed from the canvas. Usually 10 to 15 percent of the total yield is reclaimed from the canvas.

Seed production in New York: In the first years of seed production in New York, the crop was harvested as hay and later threshed by the use of an ordinary grain separator. This was successful, but there was considerable loss by shattering during curing in the field and through subsequent handling of the crop. It was found impossible for a single farmer with limited help to harvest a large acreage, since the period of seed maturity before shattering is very short.

Birdsfoot trefoil seed was first harvested in commercial quantities in New York in 1937. By 1938, seed was grown in the region of Preston Hollow where the early recognized native stands occurred. Seed production has spread from this first center to embrace nearly a dozen counties located principally in the Hudson and Champlain Valleys, with only limited production in Central and Western counties.

In 1939 one farmer purchased a combine harvester for use in this work. The use of this equipment was found to be possible only after the drying of the seed crop in the swath or small windrow, since seed separation was not possible when the green crop was harvested directly.

During the 6 years (1937-42) the number of growers of broadleaf birdsfoot trefoil in New York increased from 3 to 30, the total acreage from 100 acres in 1937 to 366 in 1942, and the production from 2,625 pounds in 1937 to 16,822 pounds in 1942.

The total New York production of broadleaf birdsfoot trefoil seed in 1946 was 6,500 pounds; in 1947, 40,000 pounds, and in 1948, 120,000 pounds. The weighted average yield per acre for the 6-year period, 1937 to 1942, was 33.5 pounds per acre; for 1938 and 1939, 18 pounds; for 1940 and 1941, 38 and 37 pounds, respectively; for 1946, 46 pounds; and in 1948 about 100 pounds per acre. Individual yields of up to 300 pounds of clean seed per acre were reported in 1948.

During the five years (1939-43) from two to five growers produced seed of the narrowleaf variety, and the total production of that variety during this period was only 6,970 pounds. Use of the narrowleaf variety is becoming more prevalent for pasture purposes on the wet, heavy soils of several eastern New York counties. Only a very limited amount of seed, however, is produced.

The most outstanding feature of seed production in New York until recent years has been the low seed yields obtained. These are far short of European reports in which French authors agree that a yield of from 250 to 350 pounds per acre may be expected. These low yields can probably best be accounted for by the method of handling the seed during and after harvest. Improved harvesting methods and pollinating practices of the past few years have tended to increase the average seed yield and bring about an occasional yield of over 200 pounds per acre.

In order to determine more accurately the seed production capacity of this crop in New York, several sample areas were selected as representative of the stands. The yields per acre of the broadleaf variety obtained from these when practically all the seed was saved was very variable, ranging from 673 pounds from the fertilized area down to 312 from the unfertilized area, 282 from the waste area, 112 from poor, weedy meadow, and 43 from a sparse stand.

It is evident from these sampling results that appreciably greater seed yields
BIRDSFOOT TREFOIL

than those cited here may be obtained where less seed is lost in handling and where good culture and management are followed. In fields harvested for seed since 1939 at the Mt. Pleasant Research Farm of the New York Experiment Station, Cornell University, Ithaca, yields up to 350 pounds per acre have been obtained.

In New York pure stands are only occasionally met with, and when sown the problem of weeds and lodging may become great. In native stands used for seed production, associations with timothy and povertygrass are common. Plantings made for seed production in recent years are usually sown as pure stands.

In 1939 single plots of birdsfoot trefoil were sown at Mt. Pleasant in a preliminary trial for the evaluation of the most desirable grass association for seed production. Plantings were made with timothy, bromegrass, and orchardgrass at the rate of 6 pounds per acre for the birdsfoot trefoil and 10 pounds per acre for the grasses. Sweetclover was added at 8 pounds per acre and harvested early for hay in the first crop year, 1940. The plots were harvested for seed in 1941 and 1942, and the respective yields for these two years were: with timothy, dry matter 2,381 pounds and 5,602 pounds, seed, 42 and 100 pounds; with bromegrass, dry matter 2,514 and 5,330 pounds, seed, 50 and 94 pounds; with orchardgrass, dry matter 1,865 and 2,883 pounds, seed, 17 and 85 pounds.

Seed production in Minnesota and Iowa:

At the Soil Conservation Nursery, Winona, Minnesota, in 1947 on O'Neill sandy loam, a total of 1,479 pounds of clean birdsfoot trefoil seed was harvested from 7.5 acres, or an average of 197 pounds per acre. This field was sown in April 1945 at the rate of 10 pounds per acre, and was fertilized at the same time with 250 pounds of 0-20-20. Part of the field was sown alone, part with 3 pounds of redtop per acre, and part with 4 pounds of bromegrass per acre. The largest yield, of 242 pounds per acre, was obtained from the 1.5 acres sown in combination with redtop. That sown with bromegrass yielded 173 pounds, and that sown alone 153 pounds per acre.

An Iowa farmer (Iowa-16) in 1945 sowed 5 pounds of birdsfoot trefoil seed per acre on 2 acres of 18-year-old bluegrass pasture that had been limed 2 years previously. The soil was rather light and of low fertility. The pasture was thoroughly worked at time of sowing and 300 pounds of 20 percent phosphate was applied.

In 1946 the field produced 4 tons of good hay per acre. In 1947 it was cut for seed and produced 150 pounds of seed and 2 tons of straw per acre on the 2 acres. The straw was so green and retained its leaves so well that it really made good feeding hay. The Iowa station has reported seed yields of 171 pounds per acre in 1944 and 119 pounds in 1948.

Seed characteristics:
The seeds of birdsfoot trefoil are small, ranging from 375,000 to 450,000 seeds per pound, or a little smaller than red clover seed. In general, birdsfoot trefoil seed is solid light to dark brown in color. The weight of the seed is about 63 pounds per bushel. Seed germinates readily except for hard seed. Unless specifically scarified, about half the seed or more is likely to be hard. Under favorable storage conditions, it retains its viability through a long term of years.

Hard seed:
The question of hard-seed content is one of great importance in regard to birdsfoot trefoil, as with many legumes. Birdsfoot trefoil seed in commerce has an average germination frequently of not more than 50 percent. In New York, germination percentages of from 50 to 60 percent are common. In 1940, a crop cut and cured in the field for a period of 10 days resulted in an average germination of 7 percent. A similar area, cut at the same time, wilted, cocked over night, stacked for 18 hours to sweat, and then dried, gave an average germination of 81 percent. It appears that the different treatments either promoted hard-seed development in the first instance, or that the latter treatment had a softening or other effect on hard seed already present.
That the hard-seed content and the viability of the hard seed are affected by harvesting, handling and method of storage is apparent from the varying experience of seed producers. It is a common belief that combine harvesting results in a higher germination and less hard seed than other methods.

**BIG TREFOIL**

*(Lotus uliginosus)*

Big trefoil has been grown in a limited way in some European countries for more than a century, primarily for pasture, but in southern Europe it is also grown for hay and seed. It has been introduced into the United States, Australia, and New Zealand during the past 25 years. In the United States its culture so far has been confined largely to the Pacific Northwest. Clatsop and Clackamas Counties in Oregon have been the center of the largest production, and practically all the seed produced in the United States comes from there.

Big trefoil is often referred to in foreign literature as *Lotus major* and goes by this name rather commonly in some foreign countries and in the Pacific Northwest. It is not as well known or as widely distributed in the United States as the birdsfoot trefoil. Big trefoil has a decidedly different adaptation from any of the strains of birdsfoot trefoil.

**DESCRIPTION**

Big trefoil is a long-lived perennial with vigorous underground stems or rhizomes. It grows from 2 to 3 feet tall and in solid stands resembles fine-stemmed alfalfa. The stems are weaker than alfalfa and usually need the support of vigorous growing grasses. Instead of the stand thinning as it grows older and the stems getting coarser, the spreading underground rootstocks keep sending up new stems which maintain a solid growth of fine stems. The seeds of big trefoil are a trifle smaller than white clover and average nearly one million to a pound.

Big trefoil is only moderately variable. Two varieties are recognized, var. *glabrusculus* which is smooth or nearly so, and var. *villosus* which is hairy. The latter variety has been and still is more common but seed stocks of the former are increasing.

Big trefoil differs from both species of birdsfoot trefoil in several ways among which are (1) adaptation to a wet, poorly drained soil, (2) tolerance to brackish water overflow, (3) greater tolerance to soil acidity, (4) less resistance to drought and severe cold, (5) widely spreading underground rootstocks which with their fibrous roots form a dense mat near the surface of the soil, (6) smaller flowers in clusters of 8 to 14 instead of 5 to 9, as in birdsfoot trefoil, (7) shorter and smaller pods which taper gradually, instead of abruptly, to a point, (8) larger number of seeds in each pod, and (9) seeds less than half the size of the birdsfoot trefoil.

**ADAPTATION**

Big trefoil, from limited observations, appears to be less winter-hardy than birdsfoot trefoil. Plantings have survived and made good growth as far north as Massachusetts. It has become naturalized along the coast of British Columbia, Washington, Oregon, and northern California, and has shown up well in experimental plots in lowland situations in North Carolina, Georgia, and Florida.

It differs from birdsfoot trefoil in its soil adaptation. Big trefoil occurs naturally in wet soils, along ditches, and in shady situations. It is rarely found on hill lands and then only under conditions of high rainfall. It can be grown on soils of pH 4.5 to 6.0 and there is some indication that this range of acidity is preferred by big trefoil to soils more nearly neutral or alkaline.

On low lands big trefoil has the ability to withstand long periods of surface flooding after the plants are well established. Instances of it being covered by surface water for three months or more without damage to the stands have been observed, although practically no growth is made during the time it is submerged. Flooding with slightly brackish water for
short periods apparently does no injury to the plants.

On upland soils that remain relatively moist throughout the summer months, in the area where adapted, big trefoil is a very promising legume. On lands of low natural fertility, it has a very stimulating effect on the yields of grasses grown with it. Identical mixtures of grasses with and without big trefoil have shown that the legume and its effect on grasses increased the total yield from two to three times. Just how extensively this crop may prove adapted to various parts of the United States is not as yet definitely known. Lovorn in North Carolina and Ritchie in Florida report that preliminary trials look very well under certain conditions. Burton in southern Georgia reports it as being the most promising perennial summer legume in trials on the flat piney woods lands. Preliminary results in connection with pine forest grazing in southern Mississippi are encouraging.

ESTABLISHING A STAND

Preparation of seedbed: The preparation of the seedbed is a most important consideration in obtaining a stand of big trefoil. It is practically impossible to get the seedbed too firm or too fine. The use of a corrugated roller prior to seeding is a good practice, but use of a heavy corrugated roller after seeding puts seed in too deep. Many instances of failures to obtain stands of big trefoil can be attributed to loose seedbeds. Good stands have been obtained on cut-over timber lands by early spring sowing, without any seedbed preparation. Care must be taken, however, to control native growth by grazing, to prevent the shading out of the small seedlings of big trefoil. In Georgia, Burton obtained good stands without seedbed preparation on native pine lands, provided, proper mineral fertilizer was applied.

Dates of sowing: Big trefoil like many other long-lived plants does not establish itself rapidly. The seeds being small have little stored food; the seedlings start slowly and do not generally begin to develop underground stems or rhizomes until about a year after planting. Because of this slowness in getting established, early spring sowing is desirable, and along the Oregon coast the best time is from March 1 to April 1. As with birds-foot trefoil, sowing the seed of big trefoil in early spring on half a normal sowing of fall-sown wheat is usually successful. Fall sowing in the West has not proved successful as even light frosts tend to heave the young seedlings out of the ground. In the Southeast, early fall sowing has proved best. In North Carolina, Lovorn has found September sowing to be better than October or later.

Rate and depth of sowing: Experience indicates that 2 pounds of big trefoil seed per acre sown with adapted grasses gives satisfactory stands. When sown alone the use of 3 to 4 pounds per acre is desirable. The seeds are very small and if covered more than \( \frac{\sqrt{2}}{16} \) inch deep the sprout often will not reach the surface of the soil. Surface sowing under most conditions has given best results and is recommended.

Methods of sowing: Mixing grass seed with big trefoil before sowing usually aids in the even distribution of the small quantity of big trefoil seed. If care is taken, however, this small quantity may be distributed by the use of a carefully regulated wheelbarrow seeder (use care to plug or tape all small openings) or a Calhoun type broadcast seeder. In the Pacific Northwest the use of a cultipacker prior to sowing, then broadcasting the seed and allowing the wind and rain to cover the seed, has been satisfactory. When sown in mixtures with grasses, as is generally recommended, pasturing or clipping back may be needed to keep the grasses in check the first year. Pasturing 30 to 60 days after sowing has not proved detrimental to big trefoil.

Inoculation: Always inoculate big trefoil seed before sowing with the special inoculant prepared for this species. Many failures are attributable to a failure to inoculate with the special inoculant for big trefoil, as no other is effective. Yellow or sickly plants are an indication of ineffective inoculation. There are some
mixed cultures on the market which include the two special strains of bacteria for both birds-foot and big trefoil, and which may be used with either of the trefoils.

UTILIZING BIG TREFOIL

Big trefoil has shown more promise than any other legume for sowing on cut-over timber lands. These lands, which formerly grew fir, hemlock, and Western red cedar trees up to seven feet in diameter, are almost universally quite acid and there is no practicable way to apply lime because of the contour and the presence of logs and stumps. The acidity of these lands generally varies between pH 4.7 and pH 5.7. Ten-year-old stands of big trefoil on these lands have continued to improve and are competing successfully with the bentgrasses and fescues which comprise the principal ground cover. All seed of big trefoil sown on these lands has been sown on the surface during March without any seedbed preparation.

It is a common practice in the coastal section of Oregon for farmers to make multiple use of sown grass and legume areas. Where big trefoil is adapted, it fits into such a combination admirably. For example, a field of big trefoil and grass may be pastured in the spring, then allowed to grow up and be cut for silage in late May, and then be followed by a light hay crop or a seed crop, and finally pastured in the late fall. The use of grass-legume silage is definitely on the increase. Yields of silage have averaged about 10 tons per acre. Silage made from immature growth of mixtures of big trefoil and grass is very palatable and has in many cases been used as the exclusive forage ration for both dairy and beef cattle. This silage has averaged 12 to 15 percent crude protein on a dry matter basis.

When cut at an appropriate stage of maturity, hay made from big trefoil compares favorably with alfalfa hay. Analyses of dried big trefoil hay show it to contain an average of 17.5 percent protein, .58 percent calcium, and .29 percent phosphorus. The calcium content appears to be significantly lower than that of alfalfa hay. This may be explained by the ability of big trefoil to grow on more acid soils.

Compatibility with various grasses: Big trefoil, because of its vigorous spreading root system, has the ability to compete with many of the very vigorous grasses. Oregon workers report it has successfully competed with bentgrass, Alta fescue, Chewings fescue, and red creeping fescue.

Lovorn of North Carolina has tried it in competition with carpetgrass and after 7 years' trials, reports "Big trefoil is the most promising legume we have tried for use on lands infested with carpetgrass and where over-grazing may be a limiting factor in the use of other legumes." Burton in Georgia, after 2 years' trials with big trefoil and Coastal Bermuda-grass, thinks it may be a suitable summer legume to grow with Coastal Bermuda.

Ritchie at Gainesville, Florida, and Bair at the Everglades Station in Florida, report that big trefoil is promising in Florida on the low, sandy situations where most common legumes cannot be established. In these places, big trefoil will compete on even terms with the more vigorous grasses and furnish very desirable feed, and also furnish the stimulation to grasses that is commonly expected from legumes. Ritchie also reports that big trefoil is the only legume he has found that can be sown without seedbed preparation on the low wet lands growing wire grass, or on the low pine lands common to Florida. Fall-sown big trefoil dominated the grass the next summer. Warner at the Northern Florida Station is encouraged with his results with big trefoil sown on carpetgrass sod.

SEED PRODUCTION

Seed production of big trefoil in Oregon has developed in Clatsop County around Astoria, and in Clackamas County around Oregon City. Seed could probably be grown equally well on lowlands or other suitable locations, in the Coastal Region of Oregon and Washington, and the Willamette Valley.
Seed is not produced until the second year after sowing. Established stands are usually pastured or clipped once or twice to get rid of rank growth until about May 15, or sometimes as late as June 1, or cut for silage at that time and then allowed to grow for seed. If this is not done, the crop usually lodges badly and does not set seed so well. Good stands may produce seed for ten to twenty or more years after becoming established.

The seed is harvested when the first pods begin to shatter which is from August 10 to September 10. At that time the plants will still be blooming at the tips. It is necessary to watch the seed crop closely during the entire harvesting and threshing operation so as to avoid loss of seed by shattering. A few days or even hours delay or carelessness in a single operation may mean the loss of a large part of the crop.

In harvesting, care should be taken to handle the seed crop as little as possible. It is cut with a mower with windrow attachment. Sometimes a side delivery rake is used but it should be avoided as much as possible because it shatters the seed. Turning by hand is preferable when needed. The cured crop can be combined directly from windrow or gathered by buck rake and wagon and taken directly to thresher. The straw makes good feed because of the high percentage of leaves. Most of it is used in this way.

The yields of seed depend as much or more on care taken in harvesting and handling than on growing conditions. Large yields are the result of careful application of good practices. Growers say that 75 to 125 pounds of seed per acre are average, but that 200 pounds or more may be obtained under favorable conditions.

HIGHLIGHTS OF BIRDSFOOT AND BIG TREFOIL

1. Birdsfoot trefoil and big trefoil are long-lived perennials of known agricultural value in many parts of the United States, but much remains to be determined as to the soil and other environmental conditions most favorable for both species.
2. The several strains of birdsfoot trefoil, when well established, are adapted to a wide range of soil types and soil-moisture conditions. The narrowleaf variety is better suited to moist heavy soils, and the broadleaf to lighter, drier soils.
3. Big trefoil is adapted to moist, heavy, acid soils that are not necessarily well drained. In areas of higher rainfall, it is also proving adapted to better-drained soils.
4. Both birdsfoot trefoil and big trefoil are slow to establish and may be severely injured where unfavorable conditions exist during the year of sowing.
5. Both birdsfoot trefoil and big trefoil have a deep root system with profuse branching of roots in the upper soil zone. With big trefoil, the fibrous roots combined with wide spreading rhizomes form a dense mat in the surface soil.
6. After establishment, birdsfoot trefoil is unusually drought and heat resistant, continuing green and succulent when most vegetation under the same conditions shows serious damage.
7. The response of birdsfoot trefoil to fertilizer treatment is similar to that of the other common agricultural legumes. The minimum level for growth seems to differ, however, in that birdsfoot trefoil persists and produces at lower soil-fertility levels than other forage legumes.
8. The soil-lime requirement for the production of birdsfoot trefoil is less than that needed for alfalfa and sweetclover. Birdsfoot trefoil is somewhat acid-tolerant, but not nearly so much so as big trefoil.
9. For nitrogen fixation, birdsfoot trefoil and big trefoil each requires a special inoculant different from the other and from other common legumes.
10. Early spring sowing of both species has been found to be superior to fall sowing in both the northern and northwestern States and early fall sowing is best in the Southeast.
11. Both species should be sown on a very firm seedbed at a depth of from one-eighth to one-quarter inch. Very shallow sowing has given results superior to those from deeper sowing.
12. With good soil preparation and favorable growing conditions there is no advantage in sowing birdsfoot trefoil at rates greater than five pounds to the acre. A companion crop is not desirable.
13. With a very firm, well prepared seedbed and plenty of moisture, and surface or shallow sowing, two pounds of seed per acre of big trefoil is sufficient.
14. Birdsfoot trefoil and big trefoil normally give lower yields of hay than alfalfa on soils adapted to the culture of alfalfa. On many soils too poor or too acid for alfalfa, they are often more persistent and give larger yields of high quality forage.

15. Red clover normally gives larger hay yields than birdsfoot trefoil in the first harvest year but does not persist thereafter in appreciable quantity, while birdsfoot trefoil persists and produces as a perennial for many years.

16. Grasses or other legumes which are not compatible and offer excessive competition in mixtures with either birdsfoot trefoil or big trefoil are detrimental to the maximum production of these trefoils. However, the stem of both birdsfoot trefoil and big trefoil is weak. Sowing with a strong and supporting grass tends to prevent lodging.

17. Birdsfoot trefoil is especially well suited for use in a mixture with grass for pasture. It will withstand overgrazing, but maximum production cannot be expected under such conditions.

18. Neither birdsfoot trefoil nor big trefoil is recommended for sowing on land to be included in short rotations. They are too slow in establishment and the seed is too costly to be used in this way.

19. Birdsfoot trefoil and big trefoil maintain their green succulence for several weeks after other legumes are severely injured and defoliated by frost.

20. The palatability of birdsfoot trefoil and big trefoil compare favorably with that of other legumes of similar nature and stage of maturity.

21. Chemical analyses indicate that insofar as nitrogen, calcium, phosphorus, and lignin are concerned, birdsfoot trefoil and big trefoil do not differ greatly in nutritive value from alfalfa for hay and from white clover for pasture.

22. A number of promising new strains of birdsfoot trefoil have been selected. Selection and breeding are considered to be two of the most promising means of improving this crop.

23. The production of seed of both birdsfoot trefoil and big trefoil present one of the major problems regarding their extensive use as agricultural crops. However, some progress is being made in solving them.

24. The mature pod of both birdsfoot trefoil and big trefoil shatters readily, necessitating great care in handling the crop to prevent undue seed loss.

25. Birdsfoot trefoil seed from Europe has given satisfactory results where it has been tried. Stands obtained from European seed seem to be winter-hardy, though the longevity of such stands has not been thoroughly established. The European trefoil matures somewhat earlier and recovers more quickly after cutting. It would appear, therefore, that imported seed may help to supplement our short domestic supply.

26. Serious losses by insects or diseases of either of the species of birdsfoot trefoil or of big trefoil have not been reported in the United States. However, certain root-rots, such as Rhizoctonia have occurred in nursery stands. The general effect has been to reduce seedling stands, lower the vigor of mature plants, and seriously curtail seed production.

27. In general, the results of the studies and observations made to date indicate that birdsfoot trefoil and big trefoil, while little used so far in American agriculture, show enough desirable characteristics to warrant their further investigation and improvement. It is apparent that neither one can be expected to compete with such crops as alfalfa, red clover or Ladino clover for hay or pasture production on the better soils and under a short rotation system of farming. They do, however, present distinct possibilities for both hay and pasture production on soils and under conditions where most other legumes are not satisfactory.

28. Birdsfoot trefoil is proving to be a most superior legume for use with certain grasses in permanent pasture and on lands of relatively low fertility throughout most of the Corn Belt, the Pacific Coast States, and New York. It is especially valuable for use with Kentucky bluegrass and fills a long-felt need for a suitable legume to use with this grass in permanent pasture.

29. Big trefoil is proving to be a most satisfactory legume for pasture, hay or silage on low, wet, acid lands of the Pacific Northwest and the Southeastern States. It is especially useful for sowing on cut-over timber lands in Washington and Oregon, and in the Coastal Plains of the Southeastern States, in making some of these otherwise waste areas into productive pastures.

30. Birdsfoot trefoil is not a get-rich-quick crop. It hasn't the spectacular appeal of alfalfa but if one wishes a legume for permanent pasture and has the patience to wait a year or two for results, he prob-
ably will not be disappointed with birdsfoot trefoil.

**THIS CHAPTER**

The published works of MacDonald (NY-28), McKee and Schott (US-168), Howell (OREG-8), Hughes, Heath, and others in "Forage Notes" of Iowa (IOWA-16) and notes made by Howell on an extensive trip made in 1949 through many of the States where the Lotus-trefoils are being grown or are under trial, have supplied by far the larger part of the material used in this chapter on both birdsfoot and big trefoil. This has, however, been supplemented by information on birdsfoot trefoil obtained personally from the above-mentioned writers, from Mott of Indiana, Brown and Baldridge of Missouri, Dodd of Ohio, and Pierre of the S.C.S., Illinois, and from my own observations beginning with my first nursery trials of birdsfoot trefoil started in South Dakota in 1904. Also, the preliminary manuscript on birdsfoot trefoil was read by all of the above-mentioned agronomists, and certain suggestions of theirs incorporated in it before publication. The final complete manuscript was reviewed jointly by Howell of Oregon and Hughes of Iowa.

Chapter reference numbers: IND-2, 9; IOWA-7, 16, 22, 24; MD-8; NY-2, 28, 36; OREG-8; VT-13, 15; OHI0-11; US-77, 168; MISC-23, 32, 41, 60.

1 The reference numbers given here refer to references which are given in full by State, U.S.D.A., and Miscellaneous, on pages 682 to 724, and which are cross-referenced by author on pages 725 to 731. Citations in the text are indicated by abbreviation and number in parentheses.
CHAPTER XVII
SOUTHERN LEGUMES FOR FORAGE AND
SOIL IMPROVEMENT

Bur-clover, Lupines, Kudzu, Crotalaria, Alyceclover, Sourclover,
Black Medic, Roughpea, and Hairy Indigo

Among the most important legumes for the South for both forage and soil improvement are the lespedezas, vetches, Austrian Winter pea, crimson clover, soybean, and cowpea. There are a few others of considerable importance, and a number of relatively minor importance or of recent acquisition, among which are bur-clover, lupines, kudzu, crotalaria, alyceclover, hairy indigo, sourclover, black medic, and roughpea, all of which are covered in this chapter.

BUR-CLOVER
(Medicago species)

Bur-clover is a southern winter legume which is highly regarded because it so readily maintains itself with little or no resowing, and because each year it can be depended on to add humus and nitrogen to the soil without sacrificing the regular summer crop of the farm. For the South, especially, bur-clover is the cheapest legume that serves as a winter cover crop, thus preventing the washing of the soil. In addition to its value as a winter cover crop, it furnishes some pasturage and improves the soil. Many instances are reported in which the cotton crop has been materially increased each season by the use of bur-clover alone.

Bur-clovers are valuable agriculturally only where the winters are mild—in the United States in the cotton-growing area west of the Cascade and Sierra Nevada Mountain Ranges.

DESCRIPTION

Bur-clovers are annual legumes, much like ordinary clovers, but the small yellow flowers are in clusters of 5 to 10, and the coiled pods are commonly beset with spines, thus forming the so-called "bur." The branch roots are fibrous and do not extend very deep. Most of the plants are branched at the crown, and have 10 to 20 or more spreading or decumbent branches 6 to 30 inches long, which when in fruit are thickly beset with burs. Well-developed plants may contain more than 1,000 pods.

KINDS OF BUR-CLOVER

There are 35 or more species of Medicago in the group commonly called bur-clover. Some of these have smooth burs, while others have very hard and spiny burs. All of them are native to the Mediterranean region, although a few occur naturally as far eastward as Turkistan. Only two of these species are commonly cultivated in the United States, namely, the spotted or southern bur-clover (Medicago arabica), and the California or toothed bur-clover (M. hispida). Tifton bur-clover (M. rigidula) is a more recently introduced species that has been grown and distributed from the Georgia Coastal Plains Experiment Station, located at

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BUR-CLOVER

Tifton, Georgia, but has not yet become established commercially. Another species, little bur-clover (*M. minima*) has been naturally introduced in a number of places in the Southern States and is gradually spreading. It is comparable with spotted bur-clover in winter hardiness.

Spotted bur-clover in bloom.

Tifton bur-clover is the most hardy of all bur-clovers and usually will survive most winters as far north as Washington, D.C. It is readily distinguished by its hard, spiny, comparatively large bur, while little bur-clover is readily recognized by its very small and soft spiny bur.

The spotted or southern bur-clover is distinguished by the purple spot in the center of each leaflet. There are several varieties, one of which has been developed with spineless pods. Manganese bur-clover, selected by A. Lee Andrews of Lafayette, Alabama, is about 2 weeks earlier than the common Southern bur-clover and has a much larger spot in the leaf. The Giant Southern bur-clover is a strain of spotted bur-clover developed in the Delta Region of Mississippi.

California or toothed bur-clover has no outstanding features. It is readily distinguished, however, from the spotted bur-clover, which it most nearly resembles, by the lack of the large brown spot in the center of the leaflet and differences in bur characters. There are several varieties of California bur-clover with spineless pods.

California or toothed bur-clover.

A spineless species of *Medicago* closely related to the bur-clovers, known as button clover (*M. orbicularis*), has been grown in Wilson County, Tennessee, since 1936, and is considered valuable by the farmers of that section. The Tennessee Agricultural Experiment Station has had it under trial in various parts of the State, and reports that it continues to increase in popularity with middle Tennessee farmers and that the crop appears promising for Tennessee. It also is adapted to other parts of the South and to California but apparently has not become generally used or distributed outside of this one section of Tennessee.

In description, adaptation, culture, utilization, and value, button clover is similar to bur-clover. Button clover, however, is a much better seed producer than
either toothed or spotted bur-clover, often yielding more than twice the quantity of seed per acre. The spineless pods are also a desirable characteristic of button clover, especially for sheep grazing.

Other species with large spineless burs, as snailclover or snail medic (M. scutellata) and tubercled clover (M. tuberculata), have been tested to determine their value as compared with the spiny varieties. They grow well but are not as aggressive as spotted or toothed bur-clover.

ADAPTATIONS

Climate: All of the bur-clovers are normally winter annuals; that is, in the country to which they are native they germinate in the autumn, grow during the fall, winter and early spring, and mature early in the summer. They are thus primarily adapted to regions with mild, moist winters, and in this country maintain themselves naturally only in the Gulf Coast States and along the Pacific Slope. Northward from the States along the Gulf Coast, they succeed fairly well when the seed is sown in the spring, but are scarcely able to maintain themselves by volunteering from year to year.

On the Pacific Coast, especially in California, spotted bur-clover is abundant only along the coast. In the interior valleys it is scarce. In the latter areas, and especially on the foothill ranges, California bur-clover is one of the most abundant and most valuable forage plants.

In the Southern States spotted bur-clover is decidedly better adapted to the conditions than California bur-clover. The latter, however, appears able to maintain itself from year to year in the less humid portions of eastern Texas, and in parts of southern Oklahoma. There is also evidence to indicate that California bur-clover is destroyed in winter by temperatures that do little or no harm to the spotted bur-clover. The latter, therefore, is to be preferred in the Cotton States where California bur-clover cannot be so highly recommended. In the Pacific Coast area from Oregon south to Arizona and in the Great Plains area of eastern Texas and southern Oklahoma bur-clover is a valuable winter annual pasture plant and is especially well thought of throughout that region for its high feeding value.

Bur-clover may be pastured in North Carolina by the middle of February, and near the Gulf Coast it furnishes practically continuous winter pasturage. Few legumes will make more growth in that area during cool weather.

Soil: Bur-clover will succeed in practically all types of soil, but loams are most suitable. In the South the plants grow best in soils rich in lime, but they thrive well enough in soils low in calcium. As a rule it prefers moist, well-drained soils, but in California it grows vigorously in adobe soils, which are often poorly drained. Where the soil is very moist the plants mature much later than on well-drained land. The California Agricultural Experiment Station found that California bur-clover would grow luxuriantly in alkali soil containing 113 pounds of carbonate of soda to an acre in the top 30 inches. Apparently the plant is as tolerant of alkali as is barley. In general, bur-clover succeeds well in slightly alkaline soils, but not in those heavily charged with salts.

ESTABLISHING AND MAINTAINING A STAND

Time of sowing: Bur-clover should always be sown in late summer or fall. In the Cotton States the best time of sowing is in the months of August and September, when seed in the bur is used, but sowing as late as November may give favorable results, even as far north as South Carolina. Late sowing, however, is to be avoided whenever possible, as but little fall and winter growth is obtained from such plantings. Hulled seed germinates more readily than seed in the bur, so that where hulled seed is used the time of sowing may be delayed on an average from 2 to 4 weeks longer than if seed in the bur is used.

In California, where the summers are always dry, sowing may be delayed until just before the fall rains begin. If the sowings are to be made on irrigated land,
BUR-CLOVER

the best average date is about the first of October, since by sowing at this time only a single irrigation is ordinarily necessary; that is, the one made just before sowing. If the sowing is done earlier, a second irrigation may be necessary before the rains come; otherwise, the young plants are likely to be injured by drought. Manner and rate of sowing: Hulled seed may be sown by a grain drill with a press-wheel attachment, or by any method of broadcasting, about 15 pounds of seed being used per acre. A firm seed bed is essential, and especial care should be taken to cover the seed thinly. Under most conditions broadcasting will be found most satisfactory, but the seed should be harrowed lightly. Where moisture conditions are entirely favorable, good stands have frequently been obtained by merely scattering the seed on the surface, but whenever practicable harrowing is recommended.

When the seed is sown in the bur, broadcasting is the only practicable method. To obtain a full stand by this method, from 5 to 10 bushels of seed per acre are necessary, followed by a harrowing.

In the regions that are well adapted to bur-clover it is much more economical as a rule to begin with a light sowing and to depend in subsequent years on the volunteer crop, where this is practicable. Germination of the seed: Bur-clover seed in the bur retains its vitality for a number of years. Hulled seed deteriorates more readily but usually gives a high percentage of germination for 3 years or more. In all cases seed in the bur contains a high percentage of hard seeds, most of which do not germinate until the second year or later. Hulled seed usually germinates readily. On account of the high percentage of hard seed it contains, unhulled seed often gives poor stands, and for this reason hulling or special treatment to induce germination is recommended.

Treatment of hard seed: This difficulty of germination can be largely overcome by treating the seed in the bur with boiling water before it is sown. The following method is recommended: (1) Empty a bag of the burs into a tub of cool water and let them stand for 2 hours, stirring occasionally to loosen as much dirt as possible for inoculating the burs at the end of the hot-water treatment; (2) remove the burs from the tub of cool water, put them in a bag, and immerse for 5 minutes in a barrel of water almost scalding hot; (3) plunge the bag of burs for 1 minute in water kept boiling hot; (4) lift the bag of burs from the boiling water, and plunge first into a barrel of cool water. Sow the seed immediately or spread it out to dry as rapidly as possible in an airy, shady place. Inoculate the seed before sowing.

Inoculation of seed: On the Pacific Coast, where bur-clover is established practically everywhere, inoculation is not necessary. In the Cotton States, however, lack of inoculation apparently has often been the cause of failure in establishing bur-clover crops, especially where hulled seed was sown. Often when seed is sown in the bur there are enough bacteria in the dust on the burs to insure inoculation. It is desirable, however, in sowing bur-clover for the first time or wherever there is doubt as to the presence of highly efficient strains of bacteria for bur-clover, to obtain and use a commercial culture from a reliable source.

Fertilizers: Bur-clover does poorly on soils of low fertility. In establishing stands, except on very fertile soils, the use of liberal quantities of stable manure or commercial fertilizer is recommended. Usually phosphorus is the most essential fertilizer ingredient, and the use of 400 pounds of superphosphate per acre is all that is needed. In some cases potash is beneficial, and on very poor soils the addition of nitrogen will give increased growth. On very acid soils lime is essential.

Volunteer stands of bur-clover: One of the advantages of bur-clover over most other legumes is the fact that good stands can often be obtained from year to year without additional sowing of seed. On pasture lands, where once established, bur-clover will resow itself indefinitely.

On cultivated land the same thing is true, provided the land is not plowed
until some of the burs have ripened. However, for most summer crops as commonly planted it is impractical to allow the bur-clover to remain on the land so long. This is particularly true of corn and cotton. With these and other row crops, stands of bur-clover for the succeeding fall can be secured when the plantings of row crops are in wide rows (4 to 5 feet) which make possible the sowing of the current year's corn or cotton between the old rows that are left as "balks" in which the bur-clover can mature and be worked down later.

With rows of cotton 6 or 7 feet wide it is possible to interplant with cowpeas or soybeans after the matured bur-clover has been plowed down. The dried bur-clover plants should be turned under rather shallowly, because, if the seeds are buried deeply, the stand will probably be thin. On the whole, however, it is better to grow the seed in a separate patch, gather it when ripe, and then sow in the cultivated crop where desired. Under some conditions bur-clover seed will retain its vitality in the soil for 4 or 5 years, so that where it is once well established volunteer stands are common.

**UTILIZATION OF BUR-CLOVER**

**Bur-clover for pastures:** Bur-clover is utilized mostly as pasture for hogs, cattle, sheep and poultry. Farm animals do not eat it readily at first, but they soon acquire a taste for the plant and then eat it freely. In Argentina, where both the California and the spotted bur-clover occur, it is said that horses will eat the former quite readily but absolutely avoid the latter. No similar observations have been recorded for California, where the two species grow together.

When bur-clover is growing in cultivated lands, it is best not to pasture continuously, but to put the stock on the land for only a few hours each day, as this reduces very much the injury by trampling. Few cases have been recorded of bur-clover causing bloat, but where the growth is lush care should be exercised. Not only do animals eat the herbage, but sheep, especially, are very fond of the ripe pods and will lick them from the ground. Much of the value of range lands in California depends on the large crop of pods produced by the bur-clover, which remains in good condition for a long time. When the burs are abundant in the pasturage, sheep fatten very rapidly. The spines bother the animals only slightly, but the burs are eaten more readily when they have been softened by rain.

For permanent pastures in the South, a combination of bur-clover and Bermuda-grass is very satisfactory. The Bermuda-grass furnishes pasturage during the warm weather until further growth is stopped by frost, whereas the bur-clover begins to grow with cool weather in the fall and provides pasturage during the winter and spring. Where once established on such pastures it reproduces itself continuously. On Bermuda-grass pastures where bur-clover is not established, it is recommended that furrows be plowed through the Bermuda-grass from 5 to 10 feet apart and seed of bur-clover, preferably in the bur, be sown in these plowed furrows in September. Within a year or two the plants produced in these plowed furrows will produce seed for the whole pasture. Disking such a pasture in summer tends to stimulate the Bermuda-grass. Broadcasting about 1 bushel of bur-clover seed in the bur to each acre before disk ing the Bermuda-grass will usually give a stand of the bur-clover in a few years.

**Use as a cover and green-manure crop:** Bur-clover alone is commonly used as a green-manure crop in the orchards of California and is often so handled that good volunteer crops are obtained year after year.

In the South, undoubtedly the greatest value of bur-clover is the fact that it is the cheapest and most easily handled legume that can be used as a combination cover and green-manure crop. Even a growth only a few inches in height is sufficient to prevent to a large degree the washing of the land in winter and, when plowed under, to add sufficient humus and nitrogen to improve materially the following cotton crop. It is the most economical legume to use for this pur-
pose, as when once a stand has been secured and rows of the plants are left to seed it will volunteer from year to year. The same method can be used with corn or any other intertilled summer crop.

There is some difficulty in sowing bur-clover in standing cotton, as in the harrowing of the bur-clover seed some of the ripe cotton is pulled out of the bolls. For this reason, the harrowing should be done just after the pickers have been through the field, thus avoiding as far as possible any injury to the opened bolls. When or where there is objection to using the balk system just described, corn can be grown occasionally in rotation with the cotton. It is possible to have a good stand of bur-clover each year without annual sowing by allowing a bur-clover crop to mature seed once every 4 or 5 years, and in that year, after plowing the bur-clover under, planting a crop of late corn or grain sorghum as the season's cash crop. This is perhaps the most extensively used system in growing bur-clover with cotton.

Value as hay: Under favorable conditions bur-clover will make a dense stand 18 to 24 inches high. From such dense stands of bur-clover, yields of 2 or even 3 tons of hay per acre have been recorded. Unless the stand is very dense, however, bur-clover plants lie close to the ground, and mowing is very difficult. If bur-clover is to be grown for hay, it is preferably sown in mixture with oats or wheat, as with these grain crops the bur-clover plants tend to grow erect. Ordinarily about 5 bushels of bur-clover seed in the bur should be sown to the acre, together with 2 bushels of winter oats or 1½ bushels of wheat. For growing in this manner, however, hairy vetch is preferable to bur-clover, and even crimson clover will ordinarily give larger yields under such conditions than bur-clover. Bur-clover hay is not regarded very highly and is seldom used.

SEED PRODUCTION

California bur-clover: Most of the commercial seed of California bur-clover comes from California. Much of the seed is harvested as an impurity with wheat and other grain crops, from which it is separated at the mills and warehouses handling grain. Occasionally some seed is harvested from pasture lands where bur-burs in pure stands are often produced in abundance. The simplest method of harvesting is sweeping by hand with large stiff brooms. Ordinary mowers, self-rake reapers, combined harvesters, and specially devised suction machines have also been used. When the mower, reaper, or harvester is used, the crop must be cut before all the seeds are ripe, because the burs ripen unevenly and drop readily when ripe. As a consequence, a good deal of green material is harvested with the burs, which necessitates careful drying to prevent damage by heating and sweating. Furthermore, because of the half-prostrate habit of the plants, a large part of the crop is left on the ground.

The power suction machine saves all the seed, but the cost of operation is high. When this machine is used the burs are allowed to become perfectly dry, so that they are easily lifted from the ground by air suction.

When only a small quantity of seed is to be saved, the best method is to sweep by hand. When this method is used the seed is allowed to ripen thoroughly, and the vines are cut with an ordinary mowing machine and raked into windrows. The burs are swept together with large barn brooms and hauled from the field. The burs gathered in this manner are mixed with more or less gravel and other foreign substances, which must be removed before the seed can be satisfactorily hulled or used in the bur. This separation is accomplished by the use of handbarrow screens and an ordinary fanning mill regulated to blow the burs over; or, if running water is handy, a quicker and more satisfactory method is to throw the burs into the water. All heavy substances sink, and the burs and lighter substances are dipped from the stream. To facilitate separation, the channel of the stream should be narrowed in the shape of an open V, which aids in collecting the clean burs. To dip the burs from the water, a large handbarrow with
a bottom made of wire netting has been found satisfactory. The burs are spread on canvas to dry, after which they may be successfully hulled with an ordinary clover-huller.

Spotted bur-clover: Practically all the commercial seed of spotted bur-clover is grown in the Cotton States. Thus far the seed has been marketed only in the burl but hulled seed could easily be produced in commercial quantities should a demand for it develop.

On small farms, raking or sweeping the ripened pods from the ground is the common method used in harvesting spotted bur-clover seed. It is best to allow the burs to become perfectly mature or dry before harvesting. At this time the vines can be raked with a horserake without previous cutting, leaving the shattered burs on the ground. A subsequent raking with a hand rake usually will be necessary in order to remove trash that slips between the teeth of the horserake. When the pods are not perfectly dry, care must be exercised in curing, as otherwise the piles will heat, with consequent injury to the seeds.

On large farms, specially constructed suction machines are used for gathering or harvesting the dry burs from the ground, and this is the source of most of the spotted bur-clover seed on the market.

Yield and weight of seed: Bur-clover seed closely resembles that of alfalfa. Formerly much of it was used to adulterate alfalfa seed, but this practice is now rare, because of the enforcement of pure seed laws. The two kinds of bur-clover may be distinguished by their seeds as well as by their burs.

The average yield of hulled seeds in California is from 300 to 500 pounds per acre. The seeds weigh about 60 pounds to the bushel. One bushel of clean, dry burs weighs 6 to 12 pounds and contains 2 to 4 pounds of seed.

From a good stand of spotted bur-clover the average yield of burs per acre in the South is about 500 pounds, but yields of 1,200 or even 1,500 pounds per acre are recorded. One bushel of spotted bur-clover seed in the burl weighs from 6 to 14 pounds. One hundred pounds of the clean burs contain 30 pounds of seed. The yield of clean seed per acre is therefore 150 to 360 pounds, or about half the yield of California bur-clover seed secured in California.

DISEASES AND INSECTS

Bur-clover is not troubled with injurious diseases, and the only insect that does any serious damage to it is the clover-seed chalets fly, which also attacks other clovers and alfalfa. The quantity of seed thus destroyed is considerable. In California probably 10 percent of the early-maturing bur-clover seed is destroyed, and as much as 75 percent of the late seed. In the South the loss is probably not so great. No practical way of controlling this insect in bur-clover is known. It does no harm to the herbage. For further information, see chapter IX, on Diseases and Insects.

BUR-CLOVER HIGHLIGHTS

1. Bur-clovers are winter annual legumes and are used successfully for pastureage and green manure under mild climatic conditions, such as exist on the Gulf Coast and Pacific Slope.

2. Bur-clovers are valued particularly because they readily maintain themselves with little or no resowing and because each year they can be depended on to add humus and nitrogen to the soil without sacrificing the regular summer crop of the farm.

3. Bur-clover requires moderately fertile soil and when grown on poor land should receive an application of 400 pounds per acre of superphosphate or complete fertilizer high in available phosphorus, and where the soil is acid, an application of lime.

4. Bur-clover affords excellent pastureage and at low elevations on the range lands of California is one of the principal pasture plants.

5. Bur-clovers should be sown sufficiently early in the fall so that the plants will become well established before winter.

6. Bur-clover seed should be hulled and scarified or given the hot water treatment to make the hard seed germinable before sowing to insure good stands.
7. Inoculation of bur-clover is essential in the Southern States except on lands that have grown it successfully. Most soils in the areas of the West where bur-clover is grown seem to be well inoculated.

8. Bur-clover may be broadcast or sown with a drill, 5 or 6 bushels of seed in the bur being used for broadcasting or 15 pounds of hulled seed for drilling.

9. Where bur-clover succeeds in the South and can volunteer from year to year in cultivated land, it affords one of the best and cheapest winter cover crops to sow in corn and cotton.

10. When bur-clover is harvested for seed the burs are allowed to mature and drop to the ground, and are then swept together with barn brooms or harvested with special harvesters.

11. Spotted bur-clover yields from 150 to 350 pounds of hulled seed per acre, and California bur-clover yields from 30 to 500 pounds.

12. Bur-clover is relatively unpalatable, especially for horses and mules, but all animals on bur-clover pasture soon acquire a taste for it.

13. Bur-clover makes a small growth, especially on poor soils, but its ability to grow in cool weather makes it valuable.

14. On western ranges the burs of bur-clover sometimes become entangled in the wool of sheep and lower the market value of the wool. On cultivated land this can be avoided by sowing spineless varieties.

LUPINES

(Lupinus species)

Lupines have been known for some two thousand years, and for the past two hundred years or more have been commonly used in central European countries for soil improvement and to some extent as feed for livestock. Of the many species recognized, white lupine (Lupinus albus), yellow lupine (L. luteus), and blue lupine (L. angustifolius) are the annuals most used commercially. In New Zealand and Western Australia, lupines have been used satisfactorily during recent years as feed for sheep, although they contain an alkaloid that is poisonous to many animals.

In the United States several other species have been planted experimentally in the past fifty years by a number of experiment stations, but with little success. Extensive commercial plantings, chiefly of blue lupine, are now well established in Florida, Georgia, Alabama, and Louisiana. Lupines make excellent winter growth and heavy seed yields and are valuable as a winter cover crop to conserve soil fertility and to supply the nitrogen so much needed in crop production.

Field of blue lupine in bloom, early in April.

The commercial acreage of lupines has been made up almost entirely of a high alkaloid strain of the so-called blue lupine, Lupinus angustifolius L. This is used as a winter cover crop for soil improvement and for the production of seed for further plantings. The success in growing the high alkaloid variety suggested the possibility of using seed of a nonalkaloid or sweet variety as feed for livestock, since a good seed crop in late spring when concentrate feeds are scarce
would fit well into any scheme of livestock production. One nonalkaloid strain has been on the market since 1947.

DESCRIPTION

The lupines cultivated in the United States for soil improvement and forage are annuals of upright growth and coarse stems. The blue lupines attain a height of 2 to 3 1/2 feet, the yellow 1 1/2 to 2 1/2 feet, and the white 1 1/2 to 4 feet. The flowers of the yellow lupine are clustered in long upright racemes, and the blue in short racemes. Both are large and showy. The characteristic palmately compound leaves with about 7 leaflets are also attractive. Some perennial species of lupine are used as ornamental plants.

ADAPTATION

Lupines require cool weather for best development, and in the South commercial varieties must be grown as winter annuals. In the North they have to be handled as summer annuals and sown early in spring. Commercial plantings have succeeded in the United States in the Gulf Coast area only. White lupine has done best on alluvial soil in the lower Mississippi Delta, and blue lupine on Coastal Plain soils farther east. Commercial plantings of yellow lupine have not been successful, although experimental plantings in some instances have given good results. Some soils are known to be better suited for lupines than others, but much remains to be determined regarding limits in soil adaptation and whether the plants can be grown successfully in more northern latitudes.

Lupines differ in their adaptation to soils of different fertility levels. Yellow lupines do well on moderately acid light sandy soils of low fertility. Blue lupines succeed on neutral or slightly acid soils of at least moderate fertility. White lupines do best on fertile neutral soils.

SOWING THE SEED

Time of sowing: In regions with mild winters (15°F or above) seed should be sown from October 1 to November 15. Later plantings sometimes give good results. Sweet blue and yellow lupines volunteer some plants but cannot be depended upon to volunteer a full stand. The pink flowered strain does not appear to volunteer. Sowing in more northern latitudes should be made in the spring from April 1 to May 15.

Rate of sowing: Rates per acre to be recommended under average conditions when lupines are sown in close drills or broadcast are as follows: white lupine which has much larger seeds than the others, 160 pounds; blue lupine 60 to 75 pounds; yellow lupine 50 to 60 pounds. At these rates of sowing and with drills 8 inches apart, the seed in the drills would be from 3 1/2 to 4 1/2 inches apart. With favorable weather conditions and a good seedbed, these rates can be decreased about one-fourth.

Method of sowing: Sow shallow, 1 or 2 inches deep, and firm the soil with a cultipacker or by other means to insure contact of the seed and moist soil. A grain drill can be used or the seed broadcast and covered by disking. Seed can be sown in wide rows without reducing seed yields, and sometimes this may be desirable.

Inoculation: Inoculation of lupine seed is essential and usually it should be done every year. Recent experience in Florida indicates that inoculation is not necessary on land which has grown a well-inoculated crop of lupines the previous year. When the seed is well inoculated nodules are produced in great abundance. Commercial cultures are available and should be used at the time of sowing.

FERTILIZER AND LIME

The use of potash for lupines on sandy land has given negative results. Sodium nitrate has increased the yields but ordinarily it is not needed. Superphosphate has given good results, and 300 to 400 pounds per acre is recommended unless the previous crops in the rotation have been heavily fertilized, in which case small quantities or none may be needed. Superphosphate has injured stands when
LUPINES

applied in direct contact with the seed. Lime tends to reduce forage yields on land with a pH of 6 or more.

UTILIZATION

Green manure: In the South the comparatively large growth made by lupines during the winter months makes them an excellent crop for turning under for soil improvement. Where adapted, they make a heavier herbage yield than Austrian Winter field peas or hairy vetch and in this respect are superior to these crops. The average yield on good soils in Florida is around 35,000 pounds green weight per acre by March 15. Green weight yields of 40,000 to 50,000 pounds by this date are not unusual.

A large taproot and its smaller lateral branches furnish an abundance of unusually large nodules that in turn supply nitrogen to the soil. This, together with the large quantity of organic matter that lupines supply and the fact that this is produced early, makes the plant a most desirable soil-improving crop to precede cotton and corn.

Erosion control: The upright habit of growth and the comparatively few plants required for a stand make lupines less suited for use in soil-erosion control than smaller and more matting types of plants.

Feed for livestock: Lupines are used mostly for soil improvement and must be used cautiously for livestock feeding. Immature forage of some species is eaten by livestock without harm but a number of species of lupines are definitely poisonous, both in the green and dry state.

In the Gulf Coast area of the Southeastern States crops from fall-sown seed mature in May or early in June. In northern latitudes, crops from early spring sown seed mature in August.

The harvesting of lupines for forage can be handled with ordinary farm machinery. Under favorable conditions from one to three tons of hay per acre can be obtained.

The seed contains a higher percentage of poisonous alkaloids than any other part of the plant. The three species of lupines considered here normally have seed high in alkaloids.

Selected strains of nonalkaloid blue, yellow, and white lupines have been included in experimental plantings in the United States. Good growth and yields have been attained with nonalkaloid selections of the yellow and blue species, but only comparatively low yields have been obtained with the white species. It has been determined that varieties cross within species so that it is necessary to keep nonalkaloid selections isolated from high-alkaloid plantings. The possible value of nonalkaloid lupines for livestock feed is suggested and experiments to determine their feeding value are being carried on by the Florida Agricultural Experiment Station.

DISEASES

Lupines are subject to root knot (nematode), but suffer less damage than peas and vetch. Several fungus diseases attack lupines and sometimes do considerable damage. No definite control measures have been determined, but in Florida there has been less damage in the seedling stage from plantings made in November and December than from those made earlier. Selection for disease resistance is in progress. For further information on diseases and insects, see chapter IX.

SEED PRODUCTION

Acreage, production, and yield of seed: Statistical data on the acreage, production and yields of blue lupine seed in the United States are available for only the past 7 years (1943-49). This represents, however, the period of rapid development of the lupine seed growing industry from an estimated 1,000 acres in 1942 to about 5,000 in 1943, 8,000 in 1944, 15,500 in 1945, 37,000 in 1946, 58,000 in 1947, 38,000 in 1948, and 56,000 in 1949. The production of seed in pounds during this period was about 5 million in 1943, 7 million in 1944, 13.6 million in 1945, 37 million in 1946, 50 million in 1947, 26
million in 1948, and 54 million in 1949. The three States of Georgia, Alabama, and Florida have produced practically all of the commercial lupine seed, Georgia producing 60 percent, Alabama 22 percent, and Florida 17 percent of the total production during this 7-year period. The average yields of seed in pounds per acre for this period for these three States were 1,000 pounds for Alabama, 920 for Georgia, 725 for Florida, and 900 for all three States. Probably 96 to 98 percent of the total lupine seed production ordinarily has been blue lupine. The production of sweet lupine seed is slowly increasing, however; in 1948 with a total production of only half that of 1947, the percentage of sweet lupine was around 10 percent, and this was produced largely in Florida.

Harvesting seed: Harvesting of the seed should be begun before the plants are quite mature, and when a mower is used the crop should be cut while dew is on the plants. In yellow lupine ordinarily the seed shatters readily when allowed to mature. However, one strain of sweet yellow lupine holds its seed indefinitely without shattering. In blue lupine moderate shattering occurs but the white lupine retains its seed quite well. A combine can be used if the crop is mature. In threshing use a combine or a thresher adapted to peas or beans. Mature seed fails easily, making it possible for growers of small acreages to save seed for home use without special threshing equipment. Most species produce seed abundantly. In Florida 1,200 pounds per acre frequently has been obtained from blue lupines.

Effect of Temperature and Moisture on Germination of Blue Lupine Seed in Storage

The recent large scale harvesting of lupine seed in the South and long time holding of large amounts of field pea, vetch, and other seed in storage has brought to the fore the problem of maintaining seed viability under such conditions. High humidity and high temperatures, such as prevail during the summer months in the South, tend to decrease viability in most seed. Lupine seed seems to be particularly susceptible to such environment and many growers of this crop have experienced losses due to unfavorable conditions. Deterioration in field pea and vetch seed in storage has been less than with lupine, but the same general problem prevails.

McKee and Musil (US-161) have given some preliminary results from their study of this problem which show some of the effects of temperature and moisture content, and other factors, on blue lupine seed in storage. They show "conclusively that if either temperature or moisture is high, the other must be low of viability."
KUDZU

is to be maintained during the storage period.”

The percentages of moisture at various stages of maturity of pods were shown to be as follows:

- Pods and seed green, not fully developed: 82%
- Pods green, but seed fully developed: 66%
- Pods graying or changing color: 41%
- Pods straw color, partially dry: 29%
- Pods straw color, apparently dry: 18%

The point of importance is that seed in pods straw color and apparently dry still contained 18% moisture, and seed in pods that were straw color but not quite dry contained 20% moisture. It is at this stage of maturity that blue lupine seed is often harvested and unless care is taken in drying the seed immediately following harvest, deterioration is rapid.

The gain in moisture content of seed stored in a nearly saturated atmosphere increased with the temperature. At 20°C, in from one to six days lupines gained from 4.28 percent in one day to 15.69 percent in six days, while at 35°C the gain was from 11.51 to 33.95 percent.

At the end of a 7-day period blue lupine seed which had a moisture content of 10 percent at the beginning increased to 25 percent at 20°C and 44 percent at 35°C. The germination which was 92 percent at the beginning remained practically unchanged at 20°C, while at 35°C it went down to 16 percent.

Blue lupine seed stored under shelter at outside temperatures at Beltsville, Maryland, in 1945, showed a moisture variation during the summer season of 4.8 percent with a maximum moisture content of 14.8 percent for the season. Fluctuations were rapid and were directly correlated with atmospheric changes in temperature and humidity, often reaching 2 percent within 24 hours.

It is thus obvious that seed which takes up moisture rapidly, as is the case with blue lupine, must not only be dry at time of storage, but conditions of storage must be such as to maintain low moisture (and preferably relatively low temperature) if viability is to be maintained.

LUPINE HIGHLIGHTS

1. The lupines, a cosmopolitan group of legumes, known for 2,000 years, are represented commercially in the United States by three annual species, the white, yellow, and blue lupines.
2. The blue lupine is now well established in Florida, Georgia, Alabama, and Louisiana as a most valuable winter cover crop.
3. The important feature of the lupines in the Southeast is that they produce both forage and seed satisfactorily in the same localities so that seed for local sowing does not have to be shipped from distant points of production.
4. The common blue lupine is highly alkaloidal and not well suited as feed for livestock but is especially valuable for soil improvement. The average yield per acre is around 35,000 pounds green weight, and yields of 40,000 to 50,000 pounds are common in Florida.
5. Selected strains of non-alkaloid lupines are being tried in a search for a satisfactory strain for both soil improvement and livestock feeding. So far the sweet lupines have not been as productive as the alkaloid strains.
6. Large yields of blue lupine seed have been obtained in the South but the susceptibility of lupine seed to high humidity and high temperatures makes it necessary to dry the seed quickly and to maintain relatively low humidity and temperatures in storage to prevent deterioration.

KUDZU

(Pueraria thunbergiana)

Kudzu was brought into the United States from the Orient and exhibited at the Philadelphia Centennial in 1876. By 1946, 300,000 acres of it was planted on farms in this country. It is recognized as a valuable forage, a good crop in rotations for soil improvement, and an excellent plant for erosion control on hillsides and gullies.

Kudzu is one of the few perennial legumes adapted to the Southeastern States and useful both for forage and for soil improvement. The plant was of special
interest during World War II, since locally grown kudzu hay could be used to replace alfalfa or other hay that must be hauled long distances, thus releasing valuable shipping space for war materials. Kudzu also increases soil fertility and lessens the need for commercial nitrates.

Lack of adapted protective vegetation has been a chief obstacle in the development of adequate erosion-control measures in the Southeast. For hillsides and gullies kudzu is proving to be one of the best erosion-control plants in this region. It produces an abundance of forage and is adapted for erosion control in gullies where most other types of vegetation are inadequate.

DESCRIPTION

Plant characteristics: Kudzu is a coarse rapid-growing, long-lived, perennial viny plant having a comparatively large taproot and exceedingly long stems or runners that with age become woody at the base.

In the more northern part of its range the runners, or stems, kill back to the crown each winter but renew growth in spring from crown buds. In the South where winter temperatures are comparatively mild, the old runners, or vines, for at least a part of their length survive and renew growth the following season.

In the early stage of growth kudzu vines are soft and pliable and have a fuzzy or hairy appearance. The leaves are abundant, very large, and more or less circular. In general, they look like grape leaves.

The large purple flowers are produced in relative abundance late in the season and precede the clusters of densely hairy pods, which are about 2 inches long and usually contain few or no seed.

Because kudzu vines root readily at the nodes or joints when in contact with moist soil, new plants are formed which are the source of much planting material.

Seed characteristics: The seed of kudzu weighs between 50 and 60 pounds per bushel and has from 40,000 to 45,000 seeds per pound. It is not produced commercially in the United States but is available from Japan.

Kudzu plants set seed sparingly and apparently only where supported on trees, fences, or banks. Under such conditions a small quantity of seed will be produced each year.

Varieties: Individual plants of kudzu show wide variation in pubescence, leafiness, length of nodes, and vigor, but no strains or varieties of kudzu have been established commercially. Since kudzu is easily propagated or increased vegetatively, however, it would not be difficult to establish and maintain varietal strains. Some improvement in varieties could be accomplished by observing plants in foundation plantings grown from seed and selecting for propagation only those having desirable characteristics. Until improved varieties are developed, planting material should be taken from the best plantings possible.

ADAPTATION

Climate: Kudzu can be grown over an extensive area. It thrives in the humid Southeastern States and, when irrigated, grows reasonably well in the more arid climate of the Southwest. Although not entirely winter hardy in the northern part of the United States, it has survived in somewhat protected situations as far north as New York in the East, and as far as Lincoln, Nebraska, in the Great Plains area. In the Pacific Northwest it survives where the winters are mild and the summers cool, but growth is slow and slight.

In the Atlantic coastal area in the latitude of Maryland, kudzu survives the winters but does not produce so heavily as farther south. In the same latitude farther west the plants sustain more winter injury, and stands are more difficult to maintain. Kudzu is best adapted in the Eastern States south of Virginia and Kentucky and west to Arkansas.

Soils: Kudzu will grow on a wide range of soil types and under varied conditions, but it has its preferences. It does not make good growth on very light poor
KUDZU

sand or on poorly drained heavy clay. Unsatisfactory results have followed plantings on the poorly drained black lands of Alabama and Mississippi, and on poorly drained acid soils of lighter texture. Where rock, hardpan, or other unfavorable conditions exist just below the surface soil, it will not succeed. Kudzu grows best on well-drained loam soil of good fertility, but it can be grown on poorer soil by proper use of fertilizers and manure. On soils of low fertility liberal use of manure and a light application of superphosphate and potash about the plant when it is first set will go a long way toward insuring success. A complete fertilizer might be desirable on some soils.

PLANTING MATERIAL

Growing plants from seed: When kudzu seed is available, seedlings grown in nurseries for one year are satisfactory planting stock and can be handled more easily and at less expense than crowns.

Scarified seed usually germinates only 50 percent, and subsequent loss will so reduce the stand that only about a fifth of the germinable seed can be expected to become established nursery plants. Since kudzu seems to become well noded everywhere in the United States, artificial inoculation of the seed appears to be unnecessary. In the South toward the Gulf, seed can be sown at any time from April to June; farther north sowing should be delayed a week or two, depending upon the latitude.

Circumstances must govern the rate and method of sowing for producing plants in the nursery. When seed is plentiful, as much as 20 pounds per acre in double rows, 3 feet apart, will give satisfactory results. If seed is scarce, more plants for a given quantity of seed can be obtained by light rates of sowing—as low as 5 pounds per acre—but the number of plants per acre will naturally be fewer.

The seedbed should be thoroughly worked and well firmed; about 500 pounds per acre of superphosphate should be added at the time of preparation; the seed should be covered lightly; and the weeds should be controlled by hand or by cultivation. Plants intended for sale should be grown if possible in nematode-free soil. The vines should not be removed until after the plants have become dormant in fall.

Growing plants from cuttings: Both softwood (early growth) and hard-wood (mature wood) cuttings of kudzu can be rooted under favorable conditions, but such methods of propagation are not practical on the farm. Soft-wood cuttings require greenhouse or similar conditions, and cuttings of harder wood, although rooting under less favorable conditions, require some protection and a uniform moisture condition that is not found on most farms. The specialized nurseryman may sometimes use cuttings to increase planting stock, if he has insufficient crowns and seed for the purpose.

Data gathered from a series of experiments conducted at the Mississippi Agricultural Experiment Station in 1943 and 1944 (Miss-12) indicated “that kudzu can be established from vine cuttings if healthy, 1- to 2-year-old vines are used, and if the vines are properly treated and set in firm beds while the buds are still dormant, preferably in February.”

Plants from existing stands: Under general field conditions kudzu runners root readily at nodes that are in contact with moist soil, and this is the common source of increased planting material. The starting of new plants at the nodes is largely dependent on soil conditions. When the soil is packed and hard, the nodes develop roots very slowly, if at all; but when the soil is loose and moist, they form roots readily. A shovelful of dirt thrown on the nodes of the runners will often greatly facilitate the formation of new plants. About 10,000 plants, or crowns, can be harvested from an ordinarily well-established kudzu planting of 1 acre, and under ideal conditions, twice that number can be obtained.

Very large crowns usually are not satisfactory for planting. Their bulk also makes extra work in handling and planting. Likewise, small plants should be discarded, as they are likely to be weak and are more exacting in planting requirements. The use of broken, bruised
crowns also should be avoided, as these are naturally weakened by such bruising and would be subject to decay. Best results with crowns have been attained by the use of 2-year-old plants of moderate size.

Care of planting stock: Seedling nursery stock and field-grown, vegetatively propagated plants and crowns should be left in the field or nursery row until time for permanent planting, to insure the plants being in the best condition at that time.

When a field is once established and is supplying material for limited new plantings, the handling of stock direct from the field is entirely practical. If, however, large numbers of plants are being handled for commercial sale it may be necessary, on account of limitations on time and equipment, to dig them before the planting season and store them for later use. If this is necessary, the plants should be stored in a cool, well-ventilated place and should be heeled-in in moist sphagnum moss or in soil that contains ample moisture but is not too wet.

FIELD PLANTING

Plan of planting: Circumstances should determine to some extent the width of row to use and the spacing of plants within the row. If it is desirable to have the ground covered quickly to prevent erosion or to insure an early income, spacing should be closer than when time of establishment is of less importance. When the field is to be left more or less permanently for hay or pasture, the relative width of row is less important than when the field is to be regularly planted or rotated to some other crop.

Date of planting: Kudzu may be planted at any time from December to April, the best time depending upon the latitude and the moisture content of the soil at the time. On well-prepared land with ample moisture, plantings can be made at any time during the dormant season. In the South the best time is in February and early in March; farther north planting should be done late in March and in April.

Setting the plants: For best results in setting it is important to protect the plants from drying during the process and to firm the moist, well-prepared soil about them to prevent drying after they are planted.

A spade, shovel, mattock, or similar tool can be used in digging holes and returning the soil around the plants. The holes should be deep enough to allow the roots to spread out to full length. The crown buds of the plant should be on a level with the ground surface and very lightly covered with soil.

CARE AND MAINTENANCE

Care of new plantings: For the first year or two after planting, kudzu should be cultivated to keep down weeds, to insure good growth of the plants, and to make the soil surface condition favorable for the pegging-down or development of new plants at the nodes of the runners. Covering the vines at the nodes with soil will insure rooting, greatly increase the number of plants, and help thicken thin stands. A cultivated crop, as corn, can be grown between the rows, so that a cash return may be obtained from the land the year the kudzu is being established.

Kudzu should not be cut the first year and should be cut only once the second year or grazed lightly, unless an unusual stand and growth have developed.

Maintaining stands: Kudzu will not stand frequent close clipping or heavy grazing. Stands are easy to maintain, however, when once established, if properly cut or grazed and fertilized.

The crop should not be cut oftener than twice each season and should never be closely pastured. One cutting in June or early in July and another in fall just before frost usually can be safely made. If one cutting only is made, this should be before August.

When the crop is being removed from the land it is necessary to supply fertilizer, particularly superphosphate and manure, in order to maintain high production. Sometimes working the soil by
plowing or disking is advisable to insure new plant establishment and more effective use of the fertilizer.

UTILIZATION

Feeding value of hay: Experimental data regarding the relative feeding value of kudzu hay are meager, but limited trials and extensive and favorable use indicate that it has a high feeding value. Kudzu makes a rather coarse hay but is moderately leafy and of good texture. Average good hay contains about 50 percent leaf; carefully handled and early cut hay will have as much as 60 percent. Under adverse conditions or with advance of season the growing kudzu plant seldom sheds its leaves in quantity as many other legumes do. It is therefore possible to defer cutting in rainy weather or when rushed with other work, without too seriously sacrificing the quality of the hay from loss of leaves. Kudzu leaves also are retained well after the crop is cut, and in this respect the hay is superior to that of most other legumes. The hay is palatable to all kinds of livestock and can be fed with very little waste.

Harvesting for hay: The heavy viny growth of kudzu makes it difficult to harvest, especially when a new stand is cut for the first time. The long vines are caught by the divider board of an ordinary mower, making it necessary to stop mowing. To overcome this difficulty the Alabama Agricultural Experiment Station has developed a specially made iron rider bar, which, when attached to the end of the cutter bar, divides and frees the vines as the swath is cut.

Kudzu stands should be 2 years old before being harvested for hay and should not be cut oftener than twice each season. The first cutting should be made in June and the second just before frost. Yields of 2 tons per acre can be expected from good stands on fertile soil.

Value as pasture: Kudzu makes good pasture, and cattle make as large season gains on it as on any other kind of plant. At Tifton, Georgia, during an 8-year period, gains per steer ranged from 1.25 to 1.62 pounds per day, and from 74 to 346 pounds per season. The average seasonal gain was 237 pounds. The acre gain per season for the same period ranged from 124 to 346 pounds with an average of 243. Kudzu can be pastured from May until frost, or even later.

Management of pasture: Kudzu plants should not be grazed until the third year. If they are grazed the second year, it should be very lightly. When once well established, fields of kudzu will withstand continuous grazing if pastured lightly, but for maximum production a field should be divided into two or more pastures and grazed alternately or in rotation. In fall, rye or oats or a winter legume, as crimson clover, bur-clover, or vetch, should be seeded in the kudzu pasture to prevent loss of plant food by leaching during the winter months and to supply late-winter grazing. It is considered desirable to delay spring grazing to around June. Too early grazing reduces vitality of plants. Delaying until June 1 does not reduce the total feed obtained from grazing.

Value for silage: Good silage can be made from kudzu. For best results kudzu and grass should be used in a mixture containing about 60 percent moisture. The total moisture content of the kudzu plants at time of cutting is about 75 percent. This means that the kudzu must be handled as rapidly as is possible. Although no data from feeding trials with such silage are available, cattle readily eat good kudzu silage.

Soil improvement: Kudzu has been used but little in rotations. Crops following a kudzu planting, however, have been greatly benefited and continue to give heavier yields for several years. When corn is grown between the strips or rows, it is possible to let the vines extend into the corn rows and thus establish the kudzu during the season in which the corn is grown. In this manner a short rotation can be established and increased yields, as well as improvement in the soil fertility obtained.

When land that is suitable for growing corn, cotton or other standard crops has been occupied by kudzu for a term of years, the kudzu can be plowed under,
greatly to the benefit of subsequent crops.

**Erosion control:** Kudzu is being used for erosion control through the Southeast in ways in which no other plant seems to be equally satisfactory. Its coarse, vigorous, rapid growth makes it useful in places where it is difficult to establish most grasses and other legumes.

On steep areas in cultivated fields too steep for cultivation and which never should have been cleared, kudzu solves the erosion problem in the field, reduces terrace maintenance, protects more productive land from silting and washing, and produces forage.

Kudzu is an excellent plant for use in the control of small gullies in fields or sections of fields that are so badly eroded that they are no longer fit for cultivation. These areas of waste land are a burden upon the rest of the farm as they do not produce sufficient crops to pay their share of taxes and other expenses. Soil material and gravel washed from these areas cover valuable lowlands and often render them unfit for the production of farm crops. The subsequent silting of streams also causes destructive overflow of floodwater on lowlands and reduces the water-storage capacity of reservoirs above dams. This can be corrected effectively with kudzu. See illustration in chapter IV of kudzu used for forage and erosion control.

Kudzu can be established more cheaply on highway banks and railway fills than most other types of vegetation used. One row along the top of the bank will, if properly prepared, fertilized, planted, and cultivated, cover the road bank and ditch with a dense growth of vines and completely control erosion within 2 or 3 years. This type of planting is much less expensive than sodding with grass. Kudzu has the further advantage that it can be established more easily than grass on rather steep slopes.

**DISEASES AND INSECTS**

Few diseases have been reported as attacking kudzu but it is susceptible to nematodes which cause the diseased conditions commonly called root knot. There is no record of stands of kudzu having been killed by nematodes. However, they are serious pests, and kudzu plants dug from infested areas should not be planted on land where no nematodes are present.

Grasshoppers seldom do serious damage to kudzu. They sometimes eat the leaves to such an extent that the foliage is somewhat ragged, but unless grasshoppers attack kudzu late in the fall, the plants usually produce a new crop of foliage before frost. Another insect that frequently attacks the leaves of kudzu is the locust skipper butterfly whose caterpillars feed on the leaves. Serious injury from this cause is uncommon. Kudzu is also one of the favorite foods of the larvae and adults of the white-fringed beetles (*Pantomonas* spp.). For further information, see chapter IX on diseases and insects.

**KUDZU HIGHLIGHTS**

1. Kudzu is grown successfully for forage, erosion control, and soil improvement throughout all the Southeastern States.

2. Kudzu is a coarse, rapid-growing perennial vine that will cover quickly the steepest slopes, gullies, banks and railway fills, and effectively control soil erosion.

3. Kudzu will produce large yields of nutritious forage equal in feed value to other legumes, in locations which would otherwise be unproductive, and at the same time control erosion.

4. New fields of kudzu can be established with rooted runners from old fields, with cuttings, or with seedling plants from plant beds.

5. Kudzu makes good, easily handled hay, good pasturage, increases soil fertility, has no serious diseases, and reduces soil erosion.

6. Kudzu should not be cut or grazed until well established.

7. Kudzu pastures should be grazed moderately or rotated for maximum production.

8. Kudzu should not be cut for hay more than twice a season, and the second cutting should be delayed until shortly before frost.

9. Steep slopes in cultivated fields can be made productive and erosion can be controlled with kudzu.

10. Steep banks on roadways and railway fills
can be effectively and attractively maintained with kudzu.

11. Deep, irregular gullies, large or small, can be built up and stabilized with kudzu.

12. The area of arable land on farms with irregular and steep slopes can be maintained and materially increased through use of kudzu.

13. Eroded fields, too far gone to be reclaimed otherwise, can be redeemed with kudzu.

CROTALARIA

(Crotalaria species)

The first crotalaria introduced into the United States came from Brazil in 1899, but it was 30 years later before the crop was recognized as having agricultural importance.

The ability of the various species to grow on soils of low fertility and the fact that they do not harbor nematodes makes them especially valuable for use for soil improvement. Their ability to seed well and to volunteer from year to year under southern conditions insures a good soil-improving crop at low cost.

No figures on the acreage of crotalaria in the United States are available, but from general information it seems probable that several hundred thousand acres are being grown for soil improvement. Because the various species tested make more growth in light sandy soil than most other plants, harbor no nematodes, and are well noduled with nitrogen-producing bacteria, they are especially useful in the South, where nematodes are abundant and sandy soils predominate.

Thousands of acres of crotalaria are sown for cover and green manure in tung groves. It is also sown extensively in connection with peanuts, truck crops, and corn. Sowing crotalaria in spring in small grain and allowing it to continue after the grain has been harvested is one of the best soil-improving practices.

While the principal use of crotalaria in this country has been for soil improvement, the value of the non-poisonous species for forage has been recognized. It is possible that this use should be extended.

DESCRIPTION

Of the large number of species of Crotalaria only a few have been brought under cultivation. These are upright summer annuals or short-lived perennials. The stems are coarse; the central stem is upright and branches quite freely, except in very thick stands. The leaflets are borne singly or in threes in the axis of the leaf and vary in shape from linear to broad ovate. The plants in general are leafy, bloom freely, and set seed in abundance. The yellow flowers are showy and the seed pods as a rule are quite conspicuous. The seed color varies from straw-yellow through brown to black.

The species having forage value are C. intermedia, C. mucronata, and C. lanceolata. These are also used as cover crops. Another, a poisonous species, C. spectabilis, is used for cover.

ADAPTATION

Climate: Most species of Crotalaria are tropical or subtropical in their require-
ments, and in the continental United States they are treated as summer annuals. Warm temperatures with moderate humidity seem to favor their growth. In experimental work with a number of species, a temperature of 28° F. has been the minimum that growing plants have withstood frost injury.

Experiments indicate that some of the introduced species can be grown farther North than others. Some have matured seed as far north as Maryland, while other species have failed to mature in Maryland. Under irrigation in the Southwestern States, several species have made fair growth whenever stands have been obtained, but the establishment of stands is somewhat difficult. Sowing must be done after the weather is warm, and quick drying and baking of the soil at that time interferes with seedling emergence.

Soils: Crotalaria is much better suited to poor sandy soils than most crops, and it is for such situations that it has attracted special attention. On more fertile soils it makes correspondingly better growth, but other crops can be grown there. Experience has indicated that crotalaria needs a well-drained soil and is not adapted to heavy clay. It will make good growth on most soils of the Coastal Plain region of the Southeastern States.

ESTABLISHING A STAND

Seedbed preparation: Since seed of crotalaria is comparatively small, thorough seedbed preparation is necessary for the first sowing to insure a prompt and good stand. Subsequent stands, which will be largely volunteer, can be assured by ordinary cultivation or disking to check other plant competition and by putting the ground in reasonably good tilth.

Fertilizer and lime: Crotalaria will grow at a comparatively low soil-fertility level and has been used especially on sandy soils of low productivity. Continued production on such soils, however, will necessitate the addition of fertilizer for crops following crotalaria. When a heavy crop is desired, even though the crotalaria is to be used for green manure, fertilizing with superphosphate and potash is recommended. On acid soils a moderate quantity of lime has benefited crotalaria, and its use in addition to the fertilizer is necessary for the best production.

Sowing the seed: For maximum growth on prepared seedbeds, sowing the seed should be done after all danger of frost is past, about the same time as corn planting or a little later. Earlier sowing is advisable in oats or other small grain. When sown early under such conditions, the seed becomes covered and is ready to grow by the time the weather is warm. Sowing can be done broadcast or drilled. In drilling the rows can be close, as with small grains, or wide as with corn and sorghum. Rows can be wide when seed is limited or it is desired to control weeds by cultivation. They also may make seed harvesting by hand easier. Use of a combine in harvesting will be facilitated if the time of sowing is delayed, so as to reduce the height of the plants.

The rate of sowing varies with the different species, depending upon the size of the seed; 8 to 12 pounds broadcast or 2 to 3 pounds in 3½-foot rows for C. lanceolata; 10 to 15 pounds broadcast or 2 to 4 pounds in rows for C. intermedia; 10 to 20 pounds broadcast or 3 to 4 pounds in rows for C. mucronata; 15 to 25 pounds broadcast or 4 to 6 pounds in rows for C. spectabilis.

Wherever sown in the United States, crotalaria has made good growth and developed many nodules, so that artificial inoculation does not seem necessary.

DISEASES

Diseases have caused more or less damage at times to all the species of crotalaria that have been used in experimental plantings. Among these are anthracnose, stem canker, southern blight, gray mold, damping off, and a virus disease. No widespread epidemics of disease have ever been reported in farmers' plantings, however, and crotalaria can be depended upon to produce as regularly as any other crop.

While there are no specific remedies
Crotalaria

for the diseases of crotalaria, they can be largely avoided by thoroughly plowing under the old plants, thereby reducing the quantity of infectious material carried over from one year to the next. For further information on diseases see chapter IX.

UTILIZATION

For soil improvement: Crotalaria is used most extensively for soil improvement. The species grown for this purpose in the United States are C. spectabilis, C. mucronata, C. intermedia, and C. lanceolata. Other species have been used in other countries, but the ones named are preferred in the United States. C. mucronata was the first species to be grown extensively, but it gave way to C. spectabilis, which the growers prefer to all others for soil improvement because its less woody stem makes it easier to turn under and handle with the light plows and other implements available in the South. However, it is poisonous so should not be used for forage.

When crotalaria is used as a green manure crop, the quantity of nitrogen needed and the time it is to be available must be kept in mind to determine at what stage to turn it under. If a maximum quantity of nitrate is desired immediately, as for truck crops, the crotalaria should be plowed under in its early stages of growth when the nitrogen is high and decomposition rapid. If, however, the nitrate is not needed at once, as for late winter use by trees in orchards, the mature crop should be worked into the soil before the time of tree growth in the spring.

Use as a forage crop: No species of Crotalaria is used extensively as forage. Though experimental work has been too limited to determine the relative palatability or feed value of the different forms, it is known that animals will eat both the poisonous and nonpoisonous species, though not readily. Poisonous species are eaten only when other feed is very scarce. The only species that has been used to any important extent in feeding trials is C. intermedia. C. mucronata is the form most used by stockmen for grazing. Experiments with C. intermedia have been largely with silage.

C. mucronata has been used for pasture in open woodland that is too cut up or filled with stumps to be readily cultivated and on poor sandy land that will not grow other plants satisfactorily. For such situations, this species has value and should receive more attention. C. lanceolata, C. intermedia, and other species should be used in the same way. The volunteering ability of these species, together with good seeding habits and hard seed, reduces maintenance cost to a minimum by making sufficient seed continuously available.

Crotalaria, because of its coarse fibrous texture, is not likely ever to have much use as a commercial hay crop. When cut early (before bloom), a fair quality forage can be produced. Mature plants are difficult to cut because of the woody texture of the lower part of the stem. Cut material allowed to dry in the swath loses much leaf and, when put into windrows before it is dry, it cures very slowly on account of the coarse stems. At best, it is difficult to harvest and even more difficult to cure.

The most satisfactory use of crotalaria for forage has been as silage. When cut green and put into the silo, it can be handled satisfactorily with an ordinary threshing machine and silage cutter. More than 30 tons of green forage per acre have been reported for C. spectabilis.

Tests of crotalaria indicate that the various species are relatively high in protein, averaging about 17 percent when cut early, but decreasing to about 10 percent with advance toward maturity. A change in composition with development is important in connection with both feeding and fertilizer value of crotalaria. The fiber content is high and increases to as much as 47 percent at maturity.

While crotalaria is recognized as only a second-rate forage, its feeding value is increased with increase in protein and it should be pastured or cut during the early stages of development, when protein content is highest.
Use in rotations: On poor lands that cannot be cropped every year one can afford to grow crotalaria in the years the land does not produce a cash crop. Land with a stand of crotalaria will produce volunteer crops in succeeding years with proper management and thus reduce the cost of sowing. When crotalaria is sown in small grain and grown following the harvesting of the grain, allow the crotalaria to mature some seed each year to induce volunteering, or mature a full crop occasionally.

Crotalaria grown with corn should be sown several weeks before the corn is laid by, or it may be volunteered from a previous crop. In most seasons this allows enough time for some seed to mature and insure volunteering. In experimental plantings increased yields of corn and other crops have followed the use of crotalaria in rotations and interplantings, with maximum increases equaling 100 percent.

SEED PRODUCTION

Crotalaria seed is harvested with combines and mowers and by hand-picking. Some species ripen seed fairly uniformly, and these are best suited for handling with machinery. Species that ripen unevenly or through a long period must be harvested by hand to obtain a maximum quantity of seed.

Of the species mentioned here, C. spectabilis and C. lanceolata are perhaps the easiest to handle for seed. Some other species are more difficult because of being very large and coarse. Late sowing will reduce the size of plants to some extent and still permit seed setting; the smaller plants make harvesting easier. Crotalaria is not difficult to thresh when dry, but it will give trouble when harvested before fully mature. The threshed seed must be dried artificially or spread thinly on shed floors to dry naturally. Special crotalaria threshers have been built, but ordinary threshers, properly adjusted, will hull the seed satisfactorily. The average seed yields of the species grown commercially range from 300 to 500 pounds per acre.

CROTALARIA HIGHLIGHTS

1. Crotalaria is a warm weather summer annual crop introduced first from Brazil.
2. Crotalaria is primarily a soil-improvement crop. Only non-poisonous species should be used for forage.
3. The outstanding advantages of crotalaria are: (1) it grows on sandy soil, (2) it does not harbor nematodes, (3) it volunteers readily, (4) it produces quantities of high-fertilizer-value green manure, (5) it produces good crops of seed, and (6) it increases yield of subsequent crops.
4. The outstanding objections are (1) the poisonous character of C. spectabilis, (2) lack of adequate discrimination by livestock between poisonous and non-poisonous species, and (3) lack of palatability of any species for forage.

ALYCECLOVER

(Alysicarpus vaginalis)

Although alyceclover first came to this country back in 1910 as an immigrant from Asiatic tropics, it did not gain much in popularity until the past half dozen years. In 1938 there were only about 2,000 acres in Florida. The acreage in both Florida and Mississippi is known to have been greatly expanded since then, besides the other acreages scattered throughout the Gulf Coast plain. Where it is adapted, it is considered one of the best hay plants in the South. It curing readily because of its high percentage of dry matter amounting to as much as 42 percent.

Alyceclover can be harvested during a wide range of time—from September 15 until frost comes in November, and the best hay curing weather in that section usually comes during that time of the year. When properly managed it remains green and succulent and provides green grazing during the hot dry months of August often and into September.

Description: Alyceclover is a low spreading summer annual, but in thick stands the stems are more nearly erect and attain a length of 2½ to 3½ feet. The stems are branched moderately and are moderately leafy. The leaves are simple and vary greatly in shape but are broadly ovate and about an inch long. The
ALYCECLOVER

flowers are rosy or pale purple and borne in racemes of 6 to 12 flowers each.

Adaptation: Alyceclover is a native of the tropics of Asia, and has spread naturally into some of the warmer parts of Africa and America. It was introduced into the United States in 1910 where it has made good growth in Louisiana, Mississippi, Texas, Georgia, and Florida in experimental trials, and in commercial plantings in Florida and Mississippi. It likes sandy loams best and does not tolerate wet lands. It is not sensitive to lime. In Florida (Fla-7), however, it is stated that clay soils are preferred because root-knot is not as injurious on them as on sandy soils. On heavy, poorly drained soils, alyceclover seed will germinate but the seedlings will die when they reach a height of 2 to 6 inches. Good drainage, internal and surface, is a prerequisite to the growing of alyceclover.

Sowing the seed: Alyceclover should be sown on a well prepared seedbed, from late spring to July. Sowing in May and June has given good results in Florida and Mississippi. This makes it well adapted as a crop to follow a seed crop of oats, crimson clover, or rough peas.

It would be advisable to use newly cleared land, as such land is low in nematode population and better results may therefore be expected; also, on new land weeds do not compete seriously. Crop land contaminated with root knot and weeds is not recommended. A good seedbed will help in eradicating weeds. A late spring disking is generally necessary to incorporate the volunteer seed crop and to control weeds for growing hay crops in subsequent years.

Sow at the rate of 10 to 15 pounds of seed per acre, followed by a cultipacker, covering the seed only lightly, not over one-half inch deep. A lighter rate of sowing may be sufficient for pasture use. Scarified seed should be used, but machine-hulled seed is generally sufficiently scarified to give satisfactory germination. Artificial inoculation of seed, apparently, has not been necessary in the southern United States.

Fertilizers: The Mississippi Agricultural Experiment Station has conducted trials in a number of localities in the State to determine effects of various fertilizers on yields of alyceclover. No consistent increases in yield have come from the application of commercial fertilizers. At Poplarville, applications of phosphates apparently increased yields by one third, but applications of potash gave insignificant results. At Raymond, no material increases resulted from applications of either phosphates or potash. Seed yields there average about 350 pounds per acre, but range from 200 up to 600 pounds per acre.

In Florida (Fla-5) "good stands of alyceclover were obtained irrespective of fertilizer treatment, but hay yields were greatly increased when certain fertilizer mixtures were applied. On the Norfolk fine sand, 1,090 pounds of hay per acre were produced without fertilizer, as compared to 2,820 to 3,920 pounds when supplemented with lime, superphosphate and potash mixtures. Eighteen hundred and fifty pounds of hay per acre were produced without fertilization on the Arredonda fine sand, as compared to 4,370 to 5,560 pounds of hay per acre when limed and treated with superphosphate and potash mixtures."

From all these trials of alyceclover with various fertilizer applications, it appears probable that applications of 200 to 400 pounds of 20 percent superphosphate and 50 pounds of muriate of potash on poor soils will usually give profitable returns in both forage and seed production.

Diseases and insects: Alyceclover is very susceptible to root knot (nematodes) which often destroys the crop. It should not be grown on land to be used later for crops that are not only susceptible but are likely to be injured by nematodes. Alyceclover has not been seriously damaged by diseases or insects.

Utilization: Alyceclover makes good hay and pastureage and serves well as a cover crop for soil improvement. It is used primarily as a hay crop, but may be used for light grazing. When harvested for hay, it should be cut when in early bloom with an ordinary mower, and raked as soon as drying permits. It dries readily and can be baled the day following har-
vesting. Alyceclover is not as yet used generally in regular rotations, most of the acreage being interplanted in tung tree groves.

At Natchez, Mississippi, alyceclover has consistently outyielded annual lespedeza on eroded hills; yields have averaged 2½ tons of hay per acre for alyceclover and 2 tons for Kobe lespedeza. Kobe made a cleaner, brighter hay than did alyceclover, but feeding trials showed the two hays equal for maintaining beef cattle during the winter.

At Holly Springs, results obtained on thin, eroded Grenada soil show that alyceclover responds to fertilization on this soil. Without fertilization the yield was 3947 pounds of hay per acre, with 40 pounds P'O the yield was 4352 pounds, and with 25 pounds K'O added to the P'O the yield increased to 5566 pounds per acre. These yields average approximately the same as the yields obtained with annual lespedezas.

Alyceclover may be expected to produce highest yields during the first year it is planted on any one field. Tests conducted on sandy soils show a large hay yield reduction in the second and third years' crops, due to nematode injury.

In Louisiana (La-3) alyceclover hay is reported to be equal to lespedeza hay of the same quality in the feeding of milking cows. “The chemical analyses of the two feeds showed that the alyceclover hay contained approximately 2½ percent more protein than did the lespedeza hay; yet, milk yields and body-weight changes showed no significant differences between the two feeds. Carotene analyses of the two kinds of hay showed alyceclover to contain approximately 50 percent more.”

Seed production: When alyceclover is cut early for hay a second growth will produce a seed crop. It matures in late fall—October to November. When well ripened this crop can be harvested with a combine, otherwise, it should be cut with an ordinary mower and put in stack for threshing. In 1947 in Pearl River County, Mississippi, alone, over 2000 acres were harvested for seed, and over 100,000 pounds of seed was offered for sale. Seed yields there average about 350 pounds per acre, but range from 200 up to 600 pounds per acre.

Alyceclover retains its viability for 2 or more years under favorable conditions, but new seed only should be used as far as possible. Although only a few tests have been made, it seems that the new seed, unless scarified, gives low germination for several months after harvest. No particular difficulty, however, has been encountered in getting stands in field plantings, and apparently by sowing time the previous seed crop germinates satisfactorily.

ALYCECLOVER HIGHLIGHTS

1. Alyceclover was introduced into the United States from Asia in 1910 but did not begin to be popular until about 1940.
2. Alyceclover is a summer annual legume which has become well adapted to much of the Gulf Coast and is grown in a large way in Florida and Mississippi.
3. Though primarily a hay crop, alyceclover makes good pasture and serves well for soil improvement.
4. Alyceclover likes sandy loam best and does not thrive on poorly drained, cold, wet, heavy soils.
5. Artificial inoculation apparently is not necessary in its area of adaptation.
6. Fertilization increases forage production in some places, while in others no consistent gains from the application of fertilizers are apparent.
7. Returns from fertilizer applications are variable, but it appears probable that applications of 200 to 400 pounds of 28 percent superphosphate and 50 pounds of muriate of potash on poor soils will usually give profitable returns in forage and seed.
8. Alyceclover seed, machine-hulled or scarified, should be sown from late spring to July, on well-prepared soil, at the rate of 10 to 15 pounds per acre.
9. Alyceclover is very susceptible to root knot (nematodes) and should not be grown where crops susceptible to or injured by nematodes are to follow, or have been grown before.
10. Yields of seed average about 350 pounds per acre but range from 200 to 600 pounds.
SOURCLOVER
(Melilotus indica)
Sourclover is a native of the Mediterranean region. It was found as an escape in the southwestern United States as early as 1830 and was being used extensively as a green manure and cover crop in that region late in the century. It is generally adapted to most soils of that region and to the delta lands of the Mississippi River. It suffers little from insects or diseases. It is mostly a volunteer crop in grain fields of southern California and Arizona and is not ordinarily grown independently of other crops as a seed crop. If the present practice in that region of spraying to kill weeds in grain crops is continued, the production of sourclover as a by-product of grain production will be greatly reduced.

Description: Sourclover is a winter annual in mild climates. The plants are upright, branch little in thick stands, but are much branched when grown as single plants. The stems are medium size, about like alfalfa but somewhat harder. The leaves are three-parted and fairly abundant. One early-maturing strain has been selected by the California Agricultural Experiment Station.

Sowing the seed: After the usual preparation of a firm seedbed, the seed should be sown broadcast or drilled in early fall (September 1 to October 1), at the rate of 15 to 20 pounds per acre and should be covered lightly. Since it has a high percentage of hard seed, sourclover seed should be scarified to insure best germination. Unscarified seed several years old will usually germinate well if it has been kept in good storage. The seed of sourclover weighs about 60 pounds to the bushel, and there are about 275,000 seeds to a pound.

Inoculation: Inoculation usually is not needed in sections where the crop is commonly grown. The seed should be inoculated in those sections where the plant does not occur naturally and the crop is being grown for the first time.

Fertilizer and lime: Fertilizers are not used ordinarily in California, Arizona, and Louisiana, where sourclover is used as a winter cover crop. Superphosphate would be the fertilizer most likely to be needed. Sourclover has a comparatively high lime requirement which limits its use as a winter cover crop in the southeastern United States.

Uses: Sourclover is used as a winter green manure and cover crop in annual rotations. In some places it is used for pasture but is not relished by livestock. It is not desirable as hay as cattle do not relish it and it tends to scour them. The yield per acre of green matter is about 10,000 pounds.

Seed production: The seed of sourclover shatters easily, so the crop should be cut when about half the seed is mature. With fall sowing the seed crop matures in June. It may be combined direct, or it may be windrowed and combined from windrow. The larger part of the commercial seed, however, is saved as a waste product from other crops. Where harvested solely for seed the yields are usually about 200 to 300 pounds per acre.

BLACK MEDIC
(Medicago lupulina)
Black medic, or yellow trefoil, a near relative of alfalfa and bur-clover, is widely distributed in the South, but seldom occurs in great abundance. Seed often is included in mixtures for pastures, which has resulted in its spread. Plants from seed that have reproduced in the South for a term of years will make a larger growth than those from seed produced in other areas. In experimental plantings, plants from seed produced from naturalized adapted strains have made more vigorous and larger growth than those grown from imported seed and seed from general commercial sources. Naturalized adaptation has long been recognized, but not until recently have experimenters taken advantage of it to improve this crop.

Description: Black medic is a winter annual or biennial, growing 3 to 16 inches
tall. The stems are rather small and fairly leafy, procumbent, but ascend in thick stands. The leaflets, \( \frac{1}{4} \) to \( \frac{3}{4} \) inch in length, are hairy and a minute point is generally present at the apex of the central vein. The flowers are yellow and the seeds are borne in kidney-shaped pods which turn black when mature. The plant stays green and continues growth much later in the spring than most winter annuals.

Adaptation: Black medic is adapted throughout the United States on reasonably fertile lands not distinctly acid, and fairly well supplied with moisture. The many varieties differ rather widely in their climatic adaptation. Imported seed is generally poorly adapted in the United States.

Sowing the seed: Black medic is sown broadcast or drilled in early spring in the North, and fall in the South. Although it may be sown alone, it is generally sown in mixtures. Since the seed is small (325,000 to a pound), sowing at the rate of from 7 to 15 pounds per acre is ample when sown alone, and 2 to 5 pounds in mixtures. It should be sown on the heavier textured soils or on sandy soils with favorable moisture conditions, but not subject to flooding. More lime is needed than for white clover.

In the eastern part of the United States inoculation of the seed is essential on soils where black medic has not been grown previously. Inoculating cultures employed for alfalfa and bur-clover can be used, but those specially prepared for black medic are preferable.

Utilization: Black medic is especially useful in grass mixtures for pastures and green manure. It is seldom cut for hay, but yields on fertile areas of 2 to 3 tons per acre may be expected. When sown in the fall, black medic furnishes grazing principally from February to May, at which time it sows itself and dies.

Mooers of Tennessee (Tenn-11) says: "Black medic is another early-spring legume the seed of which, under field conditions, germinates in both fall and spring. The plants resemble hop clover, but are coarser, more vigorous, and long-lived. Plants from spring-germinating seed will live through the following summer and winter. The blooming period is longer than that of hop clover and the seeds, which are abundant, are borne in small, black, partly coiled pods instead of open heads as with hop clover. The Station’s trials of black medic indicate some difficulty in getting stands on prepared land, probably because the seed required scarification in order to germinate quickly. Under natural conditions affording mulch, it perpetuates itself readily. It has a much higher lime requirement than hop clover, but possibly less than alfalfa to which it is closely related. Wherever it thrives, black medic is a valuable constituent of the spring and early-summer pasture. In fact, its good qualities would seem to justify its more extensive use.”
ROUGHPEA

(Lathyrus hirsutus)

Roughpea is also known as wild winter pea, caley pea, and singlealty pea. It is a native of south Europe and southwest Asia. The date of its introduction into the United States is not known, but it has long been established as an escape in the southern half of the United States wherever moisture conditions are favorable.

There are no definite figures available as to acreage of roughpea, but it is known to have increased rapidly in recent years. It has been estimated that there are 100,000 acres in pastures in Alabama, and smaller acreages in other Gulf States. Under the Agricultural Conservation Program in 1946, there were over 150,000 acres in Mississippi, over 30,000 each in Alabama and Louisiana, and over 11,000 in Arkansas. Roughpea volunteers readily when once established. It has no serious diseases, and root knot is not serious.

Description: The plants are winter annuals with weak stems and decumbent growth, except in thick stands where they are ascending. They have somewhat the general appearance of the sweetpea, the leaves having one pair of long, narrow leaflets and terminating with a coiled tendril. The lavender flowers are usually borne in pairs on a long stem and are fairly conspicuous. The seed pods are rough or hirsute, and the seed is round and characteristically tuberculate. There are about 14,000 seeds in a pound, and a bushel weighs about 55 pounds. The plants mature at or before wheat harvest, make slow or little growth in winter, and grow rapidly in late winter and spring.

Sowing the seed: From September 15 to October 15 is recommended as the best time for sowing in the Cotton Belt. Use 20 to 40 pounds or more seed per acre and sow broadcast or closely drilled. Bennett (Miss. Farm Res. 6(9): 8, 1943) says that for seed production there is little need for sowing more than 30 pounds per acre, regardless of fertilization and that a greater seed yield is obtained when 200 to 400 pounds of 20 percent superphosphate per acre is applied. Roughpeas volunteer persistently after once established. They may be sown with a late maturing variety of oats to facilitate harvesting for seed.

Soils and fertilizers: Superphosphate is beneficial on most soils according to limited experience. Use about 200 pounds of 20 percent superphosphate or about 100 pounds of basic slag. The fact that roughpea grows quite readily in many parts of the South suggests it needs but little lime. It is not exacting as to soil but grows best on good fertile loams.

When seeding for the first time, inoculating culture should be applied.

Uses: Roughpea is used for pasture, hay, and as a winter cover crop. In most parts of the South it makes much less winter growth than Austrian Winter field peas or hairy vetch, and is accordingly inferior to these crops as green manure to precede cotton or early planted corn. Its most general use is for pasturage. It is a weed in grain fields. Toxic injury to livestock grazing roughpeas when in full
bloom or nearing maturity has been observed in Alabama and Louisiana so that caution is advised when grazing nearly mature plants or feeding hay containing plants with well developed seed.

When harvesting for hay, the use of an ordinary mower with windrow attachment is recommended. The machinery used for vetch or field peas can be used. A yield of 10,000 pounds green weight per acre may be obtained with good stands and growth. This is equal to about two tons of dry hay per acre.

Seed production: Roughpeas are harvested for seed the latter part of May or early June in the extreme South, and correspondingly later farther north. They can be cut with an ordinary mower. The use of a swather, as in cutting vetch, is helpful. They may be either shocked, or windrowed for threshing with a pickup combine. Stationary threshers also can be used, by slowing down the cylinder and removing concave teeth. Roughpea seeds heavily and produces up to 1,000 pounds or more per acre. Average yields, however, are much less, probably around 600 pounds per acre.

Roughpea has a very high percentage of hard seed and retains its viability for a long period of years. Scarifying is required to insure prompt germination and good stands with a minimum amount of seed. There are about 14,000 seeds in a pound and the weight is about 55 pounds per bushel.

Seed has been harvested in Alabama, Mississippi, and Louisiana the past few years from cultivated plantings and from the wild. It was earlier available as a waste product from Missouri grain fields.

**Hairy Indigo**

*(Indigofera hirsuta)*

Hairy indigo, recently introduced into the United States in experimental work, is native to tropical Asia, Australia, and Africa. Small commercial plantings have been made in Florida where it is now used for grazing, hay, and silage, and as a soil-improving crop. It is a good legume to use in rotations for soil improvement and as a companion crop for grasses in permanent pastures. It will make a good growth and mature sufficient seed in Florida to volunteer a satisfactory crop in corn after the last cultivation.

No insects or disease have yet been observed to be serious. The plants are highly resistant to root rot.

**Description:** Hairy indigo, an annual summer legume, is sensitive to cold and is killed by the first hard frost. It grows into a shrubby type of plant having medium to fine stems which become woody as the plant approaches maturity. The leaves are compound, being made up of several small leaflets, and resemble those of vetches except that they are covered with short hairs and are larger in size. The seeds are crowded into cylindrical pods and develop into small cubes resembling very small dice. The plants grow from 4 to 7 feet in height and often 5 to 7 feet in diameter. When planted to a heavy stand the plants form a dense thicket which is difficult to pass through. Heavier seed yields have been obtained from thinner stands.

Two distinct types are recognized, one a large, late-maturing strain, and the other a smaller type which matures about one month earlier. There are sufficient hard seeds which do not germinate after falling to the ground in the autumn to insure a good volunteer crop the following spring.

**Adaptation:** Hairy indigo is adapted to the Coastal Plain area from Florida to Texas. The late strain matures seed in November and, therefore, is adapted to the south half of Florida. The early strain, which matures in October, is adapted farther north, possibly not farther, however, than the southern half of Georgia.

Hairy indigo has a comparatively low lime requirement, grows fairly well on moderately poor sandy soil, but does best on fertile sandy loams.

**Sowing the seed:** Hairy indigo may be sown from March up to the last of May. Early sowing is preferred. Sow in a well-firmed seedbed at the rate of 3 to 5 pounds of seed per acre in close drills, or 6 to 10 pounds broadcast. The smaller amounts are recommended when the crop is grown for seed, and the larger
amounts when grown for forage or green manure.

**Fertilizer requirements:** Fertilizer studies have not been made in detail, but it has been noted that appreciable growth increase has resulted from applications of superphosphate and potash. Three hundred to five hundred pounds per acre of an 0-14-10 or 0-10-10 fertilizer, or its equivalent of phosphate and potash, are suggested.

**Inoculation:** Hairy indigo has been inoculated naturally wherever grown. Special high efficiency strains of nitrogen-fixing bacteria may be developed in the course of investigations now being conducted.

**Forage production:** Hairy indigo when cut for hay can be handled with ordinary farm equipment. It should be cut when still young (2½—3 feet) and handled as other common hay crops. Yields of from 1 to 2 tons of dry hay can be expected. If cut 8 to 10 inches high in August before blooming time, a second growth may be expected.

If the crop is to be used for grazing, it should be grazed when in an actively growing condition. If it is grazed or cut before the stems become woody new growth will appear, and a second or even a third grazing may be expected.

Hairy indigo is often sown on the surface on established pastures in the spring and the seed tramped into the soil by livestock. During the summer the animals browse the indigo with the grass. If the grazing is properly managed, enough seed of the indigo will be reproduced to volunteer a crop the following season.

**Seed production:** Because of the recent introduction and use of hairy indigo, seed production has not become fully established in definite localities. The late strain is in rather general production in Florida, but the early strain is just coming into use. Approximately 86,000 pounds of hairy indigo seed was produced in Florida in 1946. For seed production it is sown either in 3-foot rows at 3 pounds per acre, or broadcast at 5 pounds per acre.

For best results in seed production, the fields should not be cut for hay or pastured prior to seed harvest. Some seed is produced in fields cut early with high stubble or grazed moderately. The harvest period for seed is when most of the seed pods are mature and before they have shattered.

Although seed may be harvested by cutting seed-branches by hand, seed producers use one of two methods in harvesting seed. In cases where the plants are exceptionally large they may be cut with a mowing machine, allowed to dry in the swath or windrow, then run through a stationary grain thresher. Combines are usually used for harvesting and are successful if the stand is not too heavy. The yields of seed range from 100 to 300 pounds per acre. Seed sets abundantly but matures in late fall on the large strain, and three or four weeks earlier on the smaller strain.

Seed produced in experimental plantings has contained a small amount of hard seed and much seed that is of low germination. A pound contains about 200,000 seeds; a bushel of hulled seed weighs about 55 pounds. Seed of the earlier strain is smaller than seed of the late strain. The first seed was offered for sale in the United States in 1945.

**This chapter**

The material in this chapter on southern legumes came from a number of sources; that on bur-clover is largely a revision of McKee's "Bur-clover Cultivation and Utilization" (US-148), reviewed by Madson of California, Sturkie of Alabama, and McKee of the U.S. D.A.; that on lupines is largely a revision of McKee and Ritchey's bulletin on lupines (US-163), supplemented by McKee and Musil's (US-161) observations on effects of temperature and moisture on germination of blue lupine seed in storage, and was reviewed by McKee and Ritchey; that on kudzu is from McKee and Stephen's bulletin "Kudzu as a Farm Crop" (US-169), supplemented by material from Bailey's bulletin "Kudzu for Erosion Control in the Southeast" (US-12), an... was reviewed by McKee and Stephens; that on alycoclover and hairy indigo came mostly from published material by McKee and Ritchey (US-147 and 164 and FLA-5 and 15), and was reviewed by them; that on black
medic, roughpea and sourclover came mostly from McKee (US-151, 154 and 155), and was reviewed by him; and that on crotalaria was largely from McKee, Ritchey, Stephens and Johnson (US-165), and was reviewed by McKee and Ritchey. Material on a number of legumes was obtained from Blaser et al (FLA-7), Mooers (TENN-11), and Hoover et al (US-115).

Chapter reference numbers: ¹

Lupines: ALA-17, 32; TEX-55; US-115, 161, 163; MISC-6.
Alyceclover: LA-3; FLA-5, 6; US-115, 147.

Kudzu: ALA-5, 18, 25, 33; ILL-11; MISS-12, 17, 18; SC-2, 4, 7; TEX-2, 40, 52, 54; US-12, 169, 184; MISC-5, 19.

¹The reference numbers given here refer to references which are given in full by State, U.S.D.A., and Miscellaneous, on pages 682 to 724, and which are cross-referenced by author on pages 725 to 731. Citations in the text are indicated by abbreviation and number in parentheses.
Part III

SPECIAL CROPS—GRASSES
No other grass in the United States has a history of production and use equal to timothy. It is one of the earliest grasses to be introduced into the United States; it is the easiest to grow and obtain a satisfactory stand; it is one of the easiest to handle and cure for hay; it is the first grass upon which standards for hay were developed, and altogether, today it is the nearest "foolproof" of any known grass over the very large area in the United States to which it is adapted.

For feeding horses and mules, of which there are still substantial numbers, no other hay has been found so generally satisfactory as timothy. The cost of the seed is less than that of most meadow and pasture grasses and it can be sown more readily with the implements used for sowing clover and alfalfa. Although alfalfa produces hay superior to timothy in yield and in percentage of protein, timothy grows well on many soils on which alfalfa, or even clover, cannot be produced without a considerable investment for lime or drainage. Timothy is very extensively grown for hay in mixture with clover, and alfalfa can be more readily grown on some soils not naturally suited to it if it is sown in mixture with timothy. As a pasture grass, timothy is more palatable to livestock than many other grasses, and the recent increased interest in pastures has created an interest in the possibility of developing varieties of timothy especially adapted for use in pasture mixtures.

There are few grasses, if any, adapted to such a wide variety of conditions and so generally useful, either when grown alone for hay or when grown in combination with a compatible legume such as alfalfa, Ladino clover, alsike clover, or red clover for either hay or semi-permanent pasture. Timothy, therefore, still is a very fitting associate to legumes and other grasses of higher protein content and contributes to the worth of such combinations through its other valuable qualities. One must "know" timothy to know hay at its best.

In districts not well adapted to legumes, grasses continue to occupy an important place. In meadows, the one most universally grown is timothy. Many reasons may be given for this choice. Among the most important are: (a) palatability, (b) relatively low cost of establishing a stand and harvesting, (c) infrequent failure of new stands, (d) maintenance of stand under favorable conditions, and (e) high rank among the grasses in productivity.

Hay made from timothy and other grasses is not so rich in protein and minerals, particularly calcium and phosphorus, as that made from legumes, but unfortunately, the areas in which the clovers and alfalfa can be grown successfully are more restricted than are those in which timothy and some other grasses are adapted.

According to the United States census reports, timothy, alone or in mixture with clover, was grown in the United States in 1909, 1919, 1929 and 1939 on 34,288,000, 30,290,000, 29,867,000, and 18,543,000 acres, respectively. This decreasing acreage over this 30-year period was due in large part to the reduced number of horses and mules and consequent loss of a large proportion of the city
market for hay, in part to the inroads made by legumes and other grasses, and in part to changing farm practices. Another factor was the decreasing acreage in farm land in some parts of the United States where timothy is an important crop, as timothy acreage was planted to other crops.

However, since the 3-year period from 1937 through 1939, which represented the bottom of the decline in acreage and which averaged 18,724,000 acres with an average production of 25,540,000 tons of hay, there has been a slight increase in acreage and production up to 1945-49 which averaged for the 5 years 22,470,000 acres with an average production of 30,400,000 tons of hay. This represents an increase of 20 percent in both acreage and production above the 3-year low of 1937-39. Several factors may be responsible for this partial comeback in acreage and production, among which probably of importance are the increased interest in grassland agriculture and a re-evaluation of timothy.

ORIGIN AND HISTORY

About ten species in the genus *Phleum* are known, timothy being the only one under cultivation. They are all native to northern Europe and Asia with one exception. This one, a native of North America, is *Phleum alpinum*, alpine timothy, a grass that occurs throughout the mountainous regions in the western United States, and in the East as far south as the White Mountains of New England.

While timothy is of European origin, it was in the United States that it was first brought under cultivation. The early history of the crop in this country is somewhat obscure, but mention of it in colonial days is not uncommon. In New England, it was first found growing on the banks of the Piscataqua River in New Hampshire sometime during the seventeenth century by John Herd (or Hurd); hence the name “herd’s grass” which still persists in parts of New Hampshire. The name “timothy” is said to have been derived from Timothy Hansen, who obtained seed from New England or New York and introduced it into Maryland, and possibly into some of the other southern colonies about 1720.

Sometime after 1740 an early agriculturist, Jared Elliott, sent seed from Connecticut, under the name of herd’s grass, to Benjamin Franklin. In a letter dated July 16, 1747 Franklin wrote that the grass sent to him “is grown up and proves more timothy”—indicating that it had become fairly well established as a hay crop in Pennsylvania at that time. From then on the crop increased in use and importance and has received more attention from agriculturists than any other grass.

DESCRIPTION

Timothy is usually a short-lived perennial grass, well adapted for cultivation as a forage crop in cool, humid regions. The smooth stems, or culms, are commonly 2 to 3 feet high, stiffly erect, somewhat bulbous at the base, forming small to rather large clumps.

Timothy differs from most other grasses in that one (sometimes two) of the lower internodes of the stem become swollen into an ovoid body, popularly known as a “bulb,” more correctly as a haplocorm. It forms in late spring of the same year in which the shoot elongates. By late autumn, or possibly, in some instances, by the following spring, it has become dry and dead.

In any meadow, in mixture with shoots which produce heads there are, in proportions which vary under different growing conditions, other shorter, leafy shoots, each having a haplocorm and culm, but no head. They also complete their growth in one season.

The leaves are from a few inches to nearly a foot long in larger plants, about ¼ inch wide, rather firm, gradually narrowed toward the tip. The heads are dense, cylindric, commonly 2 to 5 inches long, ¼ inch thick, rather bristly. The numerous crowded spikelets are about ½ inch long, strongly flattened, the margins fringed with stiff hairs. The seed (caryopsis) is very small, usually remaining enclosed within the glumes.
ADAPTATION

Climate: Timothy is well adapted to the cool, humid climate of the Northeastern and Northcentral States, and also to the mountain valleys of the Rocky Mountains and the coastal region of the Pacific Northwest. Throughout the area to which it is adapted, it is more extensively grown for hay, either alone or in mixture with clover or alfalfa, than all other grasses combined.

Soils: Timothy is adapted to a considerable range of soil reactions but is adversely affected by high acidity to about the same degree as corn. Natural moisture conditions in most soils containing carbonate accumulations are often inadequate. It is rather sensitive to deficient moisture conditions during the early summer period when it is producing its seed-bearing spike. Fairly good drainage is required. Good crops of timothy are produced on many eastern soils at a relatively low fertility level, although yields are improved by manuring and fertilization. Nitrogen is especially beneficial in the top dressing of timothy hay lands where timothy is grown alone.

In the Northcentral States, corn, oats, and hay (largely timothy) form the common rotation, so that the principal hay-producing soils are also important for corn and oats. In sections farther north where climatic conditions are relatively unfavorable for crops other than the grasses, and where topography and stoniness interfere with tillage, hay is grown in a longer rotation, and the soils become important primarily for the production of this crop.

CULTURE

Time and method of sowing: Timothy may be sown either with the grass-seeding attachment on a grain drill, or with a hand seeder. The seed is small and should be covered not more than half an inch. Deeper sowing reduces materially the percentage of emergence. If sown on the surface of a loose, recently tilled soil, usually the first rainfall will cover the seed so that it will germinate. When sown very early in the spring on fields of winter grain, the alternative freezing and thawing of the soil helps cover the seed so that germination and growth can take place.

When timothy is sown alone or with winter wheat or some other fall-sown
cereal, it should be sown in the fall, since seedlings started at this time are less likely to be injured by dry weather during late spring or early summer than are seedlings from spring sowing. If clovers or alfalfa are to be sown with timothy, they should be broadcast on the surface of the soil in the early spring. Fall sowings of the legumes may be made in the southern part of the timothy belt, provided they are sown sufficiently early to become established before cold weather.

Rate of sowing alone and in mixtures: From 3 to 5 pounds of timothy seed per acre is recommended for fall sowing, or around 7 to 10 pounds for spring sowing. When sown in mixture with timothy, red clover or mammoth clover should be sown at the rate of 4 to 6 pounds per acre; alsike clover, 2 to 3 pounds; and alfalfa, 6 to 8 pounds. When all three legumes are sown together in mixture with timothy, the following rates are recommended: red clover 2 to 4 pounds per acre; alsike clover, 2 pounds; and alfalfa, 4 to 6 pounds.

In seven out of nine tests made by the Ohio Agricultural Experiment Station, the yields of hay from split sowings (2.5 pounds in fall, 7.5 pounds in spring) were greater than from 10 pounds of timothy sown in either the fall or the spring. In the nine tests, there was not much difference between the average yields from the split sowings and those produced by 2.5 or 5 pounds of timothy sown in the fall.

In the New England States and in some other parts of the timothy-growing area, redtop is sometimes sown in mixture with timothy, and on heavy, wet soils, this is a good practice. Timothy is very commonly sown with clover—medium red, mammoth, Ladino, or alsike—in order to get a hay with higher protein content and to better maintain soil productivity. On soils where the clover is subject to winter-killing, both alsike and medium red should be sown. On moist, fertile, well-drained soils, the addition of from one-fourth to one pound of Ladino clover to any timothy mixture is desirable for either hay or pasture, whether other clovers or alfalfa are included or not.

Wherever alfalfa is adapted, it can be sown in mixture with timothy and clover. After the clover has disappeared from such a mixture, the meadow will continue to produce crops of timothy and alfalfa. When alfalfa is thus grown in mixture with timothy or other grass, it is not as subject to winter injury as when growing alone. This is probably due to the mulch-like effect of the grass, stubble, and leaves.

**Fertilization:** Timothy quickly responds to applications of nitrogen in the form of nitrate of soda, sulphate of ammonia, and as a component of other fertilizers. In meadows where fertilization is to be continued for 2 years or more, the efficiency of the nitrogen carrier is increased by applying it in combination with superphosphate, or with superphosphate and potash on soils known to be deficient in potash.

Superphosphate and potash applied without nitrogen, especially on soils deficient in nitrogen, usually have little or no effect on the growth of the timothy plants. On soils deficient in these elements these fertilizers encourage the growth of volunteer clover plants, and in this somewhat indirect way the application of these mineral fertilizers may bring about an increase in the hay crop in timothy meadows since timothy in association with a legume grows more vigorously than alone.

Results from experiments conducted in Ohio indicate that applications of soluble nitrogenous fertilizers are more effective in increasing yields when made at rates not exceeding 200 or 300 pounds per acre of nitrate of soda or its equivalent. Applications of nitrogen on timothy made about April 15 have produced somewhat larger average yields than those made earlier or later. Where cyanamide is used, it should be applied about a month earlier than the optimum date for the more soluble nitrogenous fertilizers.

In experiments in which farm manure has been applied on a preceding corn crop, the yields both of mixed timothy and clover in the first year's hay crop, and of timothy in the second year's hay crop, have been increased substantially.

At North Ridgeville, Ohio, the addi-
tion of 80 pounds of muriate of potash to the annual application of 240 pounds of superphosphate and 120 pounds of nitrate of soda gave an average increase of 216 pounds of hay per acre over the 10-year period 1918-1927, but there was no increase over the first 3-year period, an average of 174 pounds over the second 3-year period, and an average of 435 pounds over the last four years, inclusive. This shows the cumulative effect during the last years of the experiment.

At Wooster, Ohio, in a 7-year experiment, neither 0-14-6 nor 20 percent superphosphate applications of 200 and 140 pounds, respectively, changed the yields of hay materially, but the applications of 50 pounds, 200 pounds, and 400 pounds of nitrate of soda along with 200 pounds of 0-14-6 gave respective average increased yields of 417 pounds, 786 pounds, 1,786 pounds, and 3,026 pounds per acre over the 7-year period, and the recovery of the nitrogen applied in the hay produced was, respectively, 37 percent, 50 percent, 55 percent, and 59 percent. Except with the 400-pound application of nitrate of soda which increased the percentage of protein in the hay by an average of nearly one percent, the percentage of protein in the hay produced through applications of nitrate of soda was not consistently altered. In fact, the fluctuations were so wide both ways that the average results may not be indicative either way.

Lime: Timothy is commonly regarded as more or less indifferent to the reaction of the soil. This is probably due to the fact that it will usually continue to give a pretty good account of itself on land that has become too acid for the profitable growth of many crops, particularly legumes like red clover and alfalfa. Evidence is accumulating, however, to the effect that the yield of timothy may be materially modified by the reaction of the soil. At Wooster, Ohio, the results obtained indicated that the higher the acidity the greater the reduction in yield.

**UTILIZATION**

**Timothy hay:** Timothy and clover hay constitute one of the major groups of hay in the United States. In 1925 the acreage of these two crops, half of which was sown to the two in combination, made up 58 percent of the total tame hay acreage. In 1945 this had declined to 37 percent, but even with this reduction they still occupied nearly 22 million acres which is about one-half more than either alfalfa or wild hay, the former of which had increased during this period from 10.8 million acres to 14.8 million, or a percentage increase of 37 percent.

The superiority of timothy in yield over other grasses in northern Ohio is illustrated by its performance on the farm of the Ohio Agricultural Experiment Station at Wooster. Over a period of twenty years during which the yields of eight most-used grasses were taken in comparative trials from 12 to 16 years, timothy ranked first with an average of 5,309 pounds of hay per acre which was 44 percent larger than the average of the other seven grasses and 24 percent larger than its nearest competitor.

**Feeding value of timothy hay:** As compared with clover, alfalfa, or hay made from any other legume, timothy, a non-legume, is relatively low in protein and also in minerals, especially calcium or lime. However, the deficiency in protein may be corrected by the use in the ration of a somewhat larger quantity of some high-protein concentrate, and the deficiency in calcium, which is not serious may be corrected by the addition of a small amount of a high-calcium mineral. If fed in this way, and if the timothy has been cut at the proper time and cured under favorable conditions, very satisfactory results may be obtained in feeding livestock.

Timothy is considered the standard roughage for horses and mules and is especially valuable when free from dust. The clear timothy hay is preferable for light horses, work horses, and mules, while a mixture with clover or alfalfa when cut early is a more satisfactory roughage for dairy and beef cattle.

In some of the feeding experiments conducted in earlier years with timothy, more or less unfavorable results were obtained, due in part, apparently, to the
use of a poor quality of hay. Quality is dependent in large measure on the cultural, harvesting and curing methods employed. Timothy cut after it has passed out of bloom usually contains less than 6, and not infrequently, less than 5 percent of protein. If cut in early bloom or even in full bloom, it may contain 6 to 7 percent of protein. If cut when the heads are appearing, or if heavy applications of a nitrogenous fertilizer are used, the air-dry timothy hay may contain 8 to 9 percent of protein. The latter percentages are higher than those of most other grasses but are considerably less than those found in alfalfa, clover or other legumes. Timothy hay of the best quality, however, may exceed even alfalfa in net energy value. It is also a valuable source of certain vitamins.

**Early cutting recommended:** After timothy has just passed the stage of full bloom there is only a very slight gain in yield of hay; even after the time of early bloom, the gain is not very great. Since there is a constant decrease in the percentage of protein, there is consequently a gradual decrease in the yield of protein per acre after it has passed early bloom. The greatest value per acre, as represented by the largest yield consistent with a high quality of hay, is obtained by cutting when the timothy is in early bloom. Cutting at this stage is highly recommended. Good quality hay cannot be produced from timothy cut in late bloom.

On farms where there is a large acreage of timothy and it is not possible to harvest the entire crop at the proper time, it is better to harvest some of the crop too early rather than too late. If adaptable varieties are available, it may even prove practical to grow on the same farm an early (Marietta), a medium (ordinary), and a late variety (Lorain or Hopkins), of timothy, in order to extend the time during which a high quality of hay may be obtained.

In the timothy-growing areas of the United States much hay is not cut until the seed is nearly mature. It may be that when timothy is harvested at this time rather than at an earlier date, there is less competition with other farm work, such as cultivating corn, harvesting wheat, or cutting clover hay. However, it should be recognized that this delay occasions a serious loss in the quality and value of the hay.

**Effect of stage of cutting on quality:** A change in the quality of the hay occurs as the season advances. The percentages of the most valuable constituents, including the two carbohydrates classified as the nitrogen-free extract and the fat, and also the protein, gradually decrease, while the less digestible and less valuable crude fiber increases.

Timothy hay contains all of the known vitamins, with the exception of C. Of these vitamins A, present in hay in the form of carotene, is of special importance in the feeding of roughage-consuming animals. It, like most of the vitamins, is present in greater quantities in early cut than in late cut and in well cured than in poorly cured hay.

Timothy, like other kinds of hay, is graded largely on the basis of its color as a visual indication of relative feed value. At successively later stages of development, as increasing numbers of green leaves, stems and heads change to straw color or become brown, the feed value declines and the United States grades which may be assigned to the hay gradually become lower.

**Effect of timothy on succeeding crops:** When an unfertilized timothy sod is plowed, the following crops are usually smaller than when a leguminous crop is plowed under. This decreased yield following timothy is now known to be largely due to the deficiency of available nitrates in soil that has produced a grass crop. The bacteria and other soil organisms that cause the decay of roots, stubble, or other plant parts, and transform them into humus, require for their own growth activities such a large part of the available nitrogen that an insufficient amount remains for the growth of the succeeding crop. If a nitrogen-carrying fertilizer is applied to land that has produced timothy, the yields of the cereal
crops produced in the timothy rotation and in the clover rotation become more nearly alike.

**Timothy pasture:** Timothy ranks high among the grasses in respect to its palatability. Tests show that if various kinds of grasses are available, stock will usually graze the timothy before redtop, orchardgrass, or even Kentucky bluegrass. Where timothy grows well, it is commonly included in the mixture of grasses and legumes sown in permanent pastures. For a time the timothy may constitute a large proportion of the pasturage, but as the pasture becomes older, the timothy tends to produce less and less, and to be gradually replaced by some other grass such as redtop, colonial bent, Canada bluegrass, Kentucky bluegrass, or some other species that is more tolerant to overgrazing.

When timothy is grown in mixture with red clover in a crop rotation, the timothy may be cut for hay the first year after the clover has disappeared, but if continued longer is likely to be pastured. If alfalfa also is sown in the mixture and the soil conditions are favorable, a grass-legume hay mixture may be harvested for more than one or two years, and, if desired, the later growth each year may be used for pasture.

**Silage:** Timothy has not been used extensively for silage, but like many other grass and legume meadow crops, appears to have great possibilities. Dr. C. F. Rogers of the Ohio Agricultural Experiment Station, in his experiments has found that if the grass is well compacted in the silo, it will make excellent silage if it contains 25 to 35 percent dry matter. He goes on to say, “Hollow stems of timothy make compaction difficult in the 30—40 percent of dry matter range. Added acids are now of questionable value, and sugar alone has less effect than molasses. Legumes mixed with timothy make a better silage than timothy or legumes alone, as much from the palatability as from feed value.” Both legumes and grasses are most palatable when in the early blossoming stage, but they remain in good ensiling condition until the early part of their seed formation and filling.

At the New Jersey Agricultural Experiment Station (NJ-13), on soils which had been well fertilized with a nitrogen-carrier in both years, and also with superphosphate and muriate of potash in the second year, the average yield in 1935 and 1936 of timothy for silage was 11 tons per acre, compared with 13 tons of corn silage from land fertilized with manure and superphosphate. The report of this work states that “yields of green timothy of between 9 and 13 tons an acre compare favorably with average acre yields of silage corn. Timothy need not be planted annually, and it needs no cultivation. When cut at an early stage of growth and ensiled, it produces a silage higher in protein than corn silage.” The silage made from timothy was produced at a lower cost per ton than that made from corn. The New Jersey Station further states that “the carotene content, which is provitamin A, is high. In fact, timothy silage contains more carotene on the dry basis than does the best dehydrated alfalfa hay which is fed during the winter months.” (See chapter on silage crops for further information on meadow crops for silage.)

**Erosion control:** There is much less erosion on soil producing timothy or other grass than on soil producing grain or cultivated crops, and in crops following timothy the tendency to erosion is greatly reduced by reason of the very numerous fibrous roots of the timothy plant that have been added to the soil.

**IMPROVED VARIETIES**

Though no improved timothy varieties were available at the close of the last century, at the present time there are a number that are available commercially in the United States among which are Shelby, Huron, Marietta, Lorain, Itasca, and the recently developed Welsh pasture strain of which limited quantities of seed have been imported from Great Britain. In other countries, additional varieties have been introduced.
Shelby: The Shelby, an early-maturing variety grown in southern Indiana for many years, apparently is the result of regional selection on the farm of William Zoebel of Shelbyville, Indiana, producer of the variety. Little or none of the seed is shipped away from the vicinity. Many farmers of the district who do not produce their own seed, purchase seed of Shelby timothy if it is available. This variety has not attained wide distribution or popularity beyond this district.

Itasca timothy: Itasca timothy is a synthetic variety developed by the Minnesota Agricultural Experiment Station. It is composed of six inbred lines as follows: one from Minnesota commercial seed, two from Cornell No. 1620, and three from Cornell No. 1777. In Minnesota it is superior to commercial timothy in hay production, about equal in seed production, and matures at about the same time.

Marietta: Another variety developed in Ohio from selections made by Evans (Ohio-14) was the Marietta. Among the selections made were a group that were distinctly earlier in blooming than common timothy, yet leafier, higher in protein content, more resistant to leaf diseases, more productive of hay, and with ability to retain the green color in the leaves until later stages of development than does common timothy.

Three of the best of these earlier strains (F.C. 11901, F.C. 28,096 and F.C. 28,185) were chosen for compositing and increasing under the name Marietta, the name implying adaptation to southern Ohio. Early strains of timothy tend to be more productive than late strains in southern Ohio. In fact, late strains do not head out well there, for they react unfavorably in the shorter summer days that occur in southern as contrasted with northern Ohio.

The base strains entering into Marietta have been widely tested in Ohio and in adjacent States. Even in northern Ohio these strains have out-yielded common timothy by 5 percent, while at Lexington, Kentucky, 38 percent higher yields were obtained. Intermediate gains have been found in southern Ohio where these early strains also contain a higher percentage of protein than common timothy.

As a seed producer, Marietta is far superior to common or later strains in the southern half of Ohio.

Marietta heads, blooms, and matures 4 to 7 days earlier than common timothy, but its leaves tend to remain green as late as those of common timothy. It arrives at a stage suitable for cutting for hay at more nearly the same time as alfalfa or medium red clover. It tends to make more late summer or early fall growth than does common timothy.

In the autumn of 1945, a clonal nursery of plants propagated vegetatively from the original plants of each of the selections of which Marietta timothy is composed, was established on the U.S. Soil Conservation Nursery at Zanesville, Ohio. Foundation seed, available to growers of registered seed of Marietta timothy, is produced in this nursery.

The parental selections are multiplied vegetatively in order to maintain their genetic identity. Vegetatively reproduced plants of all of the base selections are then grown in an isolated plot and the seed harvested as a composite is termed “Foundation Seed.” This seed is then sown in isolated fields for the production of “Registered Seed,” which in turn may be used for planting fields eligible for the production of “Certified Seed,” which may then be used for sowing in meadows to be used for hay production.

Huron: The Huron is a late-maturing variety developed in Ohio. The plant from which this variety originated was found growing along a road in northcentral Ohio in 1911. It was later distributed to agricultural experiment stations in other States, but has recently been displaced by Lorain which has proved to be a better late variety than Huron.

Lorain timothy: The varietal name Lorain is adopted from the name of Lorain County, where the Timothy Breeding Station was located, at North Ridgeville, Ohio, from 1915 to 1935. This variety was originally composed of F.C. 15167, the type selection of Lorain timothy.

Prior to 1946, all seed sown in meadows of this variety was composed of 15167
TIMOTHY

alone. Another selection, F.C. 28147, recently has been added. Its stems are slightly longer than those of F.C. 15167 and the plants of these two selections have practically the same periods of blooming and maturing. In northern Ohio, the Lorain variety is approximately 10 or 12 days later than ordinary timothy and about 16 or 17 days later than Marietta timothy. Lorain timothy is well adapted in the northern half of Ohio (Ohio-14).

Hopkins: The very late Hopkins timothy has been named after Dr. A. D. Hopkins, who did some of the earliest work in timothy breeding conducted in the United States. This variety, developed during the cooperative timothy breeding program conducted in Ohio, has been introduced recently. It is composed of the type selection F.C. 28119—the result of 8 generations of selection—and of F.C. 28352, which represents 6 generations of selection. Hopkins timothy, in northern Ohio, blooms about 14 or 15 days later than ordinary timothy, and 3 or 4 days later than the Lorain variety. In field plot tests conducted in 1940, 1941, 1942 and 1944, F.C. 28119, one of the components of Hopkins timothy, produced an average yield 343 pounds greater per acre than that produced by ordinary timothy grown under the same conditions.

Samples of hay produced by F.C. 28119, collected on five dates in the late spring and early summer of 1944, contained an average percentage of protein approximately 35 percent greater than that contained in samples of ordinary timothy collected on the same dates (Ohio-16).

TIMOTHY SEED PRODUCTION

Seed acreage and production: The acreage harvested for timothy seed each year for the 4-year period 1944-47 was about 1.6 percent of the total acreage of timothy and clover harvested for hay. For the 10-year period before that (1934-43) it was 2.4 percent. The total production of timothy seed in the United States for each of the census years 1909, 1919, 1929 and 1939 was, respectively, 130 million, 116 million, 63 million, and 75 million pounds. Of these quantities the seven States of Iowa, Minnesota, Missouri, Illinois, Ohio, Wisconsin and Indiana, named in the order of production, produced altogether in those four years, 106 million pounds or 82 percent of the total seed production in 1909, 107 million or 92 percent in 1919, 60 million or 95 percent in 1929, and 65 million or 87 percent in 1939.

Except for the decennial census figures...
on acreage and production of timothy seed, no annual figures are available prior to 1919. The average for the nine years, 1919-27, was 676,000 acres with a production of 108,360,000 pounds of seed (thresher-run); for the ten years, 1928-37, it was 473,000 acres with a production of 77,805,000 pounds; and for the 10 years, 1938-47, it was 408,000 acres with a production of 64,350,000 pounds. In 1948 there was a big drop in both acreage and production to 128,700 acres and 18,200,000 pounds of seed. The production for 1949 is estimated (December 1949) at 37,160,000 pounds of seed which is more than double that of 1948, but only 58 percent of the 1938-47 average.

The two 10-year periods (1928-37 and 1938-47) represent a gradual decline in both acreage and production of about 30 percent and 40 percent, respectively, below the first period. The second period included the very low production of 12,015,000 pounds in the drought year 1934, which was more than offset by the very high production of 192,420,000 pounds the year following.

Yields of seed: The average annual yield of timothy seed in the United States from 1919 to 1947, based on estimated total acreage and production in the United States, was about 160 pounds of thresher-run seed per acre. It is recognized, however, that average yields in certain surplus-producing areas especially adapted to timothy seed production would very likely be larger than the average for the whole United States. Maximum yields as high as 500 pounds or more are said to have been obtained but no accurate records of the sizes of the fields and of the yields obtained are available to support these statements. Yields of seed, like those of hay, are usually higher when the rainfall during the spring months is normal or somewhat above normal.

Imports and exports: Since a surplus of timothy seed is commonly produced in the United States, the quantity imported is usually negligible. The drought of 1934, however, which caused a great reduction in the seed crop of that year to the smallest on record, 12 million pounds, necessitated the importation of substantial quantities from Canada and European countries.

The quantity of timothy seed exported is often considerable, though not usually more than a small percentage of the total crop. From 1884, the earliest year for which records are available, to the last prewar year of 1940, the quantity of timothy seed exported annually ranged from a low of about 2,000,000 pounds in 1888 to a high of more than 27,000,000 pounds in 1910. The average exports for the 10 years 1922-31 were 14,400,000 pounds, and the average for the remaining nine prewar years 1932-40, were only 6,080,000 pounds. Most of these exports were to the Provinces of Ontario and Quebec, Canada, though much seed was also exported to Europe, largely to Great Britain, Germany, France, and the Netherlands.

During the war period (1942-47), the Government purchased for export over 35 million pounds or an average of nearly six million pounds a year.

Conditions affecting seed production: Weather conditions often determine whether a timothy field shall be harvested for hay or seed. Sometimes excessive or frequent rainfall delays harvesting a crop intended for hay until it has become nearly or quite mature, and for this reason it is harvested for seed.

The price also is a factor. When the market for timothy seed reaches a comparatively high level and the price of hay becomes relatively low, some of the timothy acreage originally intended for hay is likely to be harvested for seed.

Although the total income from an acre of timothy seed may be relatively small, the cost of production is correspondingly low. The income from a meadow used for seed production may be increased somewhat by the value of the threshed or headed hay and by pasturage during late summer and fall.

Method of harvesting: Much of the timothy seed crop of the United States is harvested with binders, in much the same way as wheat or oats. The sheaves of timothy are placed in shocks, each shock usually containing from 5 to 8 sheaves, arranged in a more or less circular form.
A less common method is to place the bundles in two paired rows. Sometimes the tops of the shocks are bound together, either with timothy stems or with binder twine.

In localities where combine harvesters and threshers have been used for cereal crops, these machines have come into common use for harvesting timothy seed. In Iowa, northern Missouri, and southern Minnesota where timothy seed production is general, combines are now generally used for harvesting timothy seed. Since timothy must be dead-ripe before a combine will harvest it properly, combined seed is usually well-matured. The timothy stems may be cut off relatively high, just below the heads, in much the same way as with a header. Because of increased weathering of timothy allowed to remain in the field until more mature for combining, and the higher moisture content and greater percentage of hulling of combined timothy seed, the resulting seed is usually poorer in color, lower in germination, and of generally lower quality.

If a hay crop is to be taken after the seed crop has been harvested, the field should be mowed as soon as possible, since the green leaves remaining on the plants dry rapidly.

Time of harvesting: The average date when the harvesting of timothy seed begins in northern Missouri, which is about the southern limit of the area of its commercial production, is about July 21. The average date when the first seed is harvested in southern Minnesota is about August 5. In any particular locality, most of the seed is harvested within a week or ten days after harvesting operations begin.

The largest yields of seed are obtained if the crop is harvested after most of the seed has matured but before much shattering has occurred. At that time seed may be shattering from the extreme tips of 10 to 20 percent of the earliest heads, although there will still be some immature seed on small heads growing on short stems. If, however, harvesting is delayed until these late heads mature, the seed on the larger early heads begins to shatter, or may be lost altogether.

Threshing the seed: Timothy must first become well dried before being stacked or threshed, or the seed may be injured as a result of heating. The threshing of timothy seed requires a considerable amount of skill on the part of the man operating the machine.

Experiments indicate that timothy seed can be completely and satisfactorily threshed if the speed of the cylinder does not exceed 800 to 900 revolutions per minute and the teeth of the concave do not come into mesh with those of the cylinder more than one-fourth of an inch. Under these conditions, hulls are removed from about 11 percent of the seeds. When the speed of the cylinder is increased to 1,050 revolutions per minute, and the teeth of the concave and cylinder are in mesh 1.5 inches, the proportion of hulled (hull-less) seeds is increased to about 34 percent.

Timothy seed is much lighter in weight than the seed of most cereals. If there is a very strong current of air through the machine, a large proportion of the timothy seed may be blown out with the straw and chaff and the yield reduced thereby.

If the seed is to be elevated and collected in bags from the spouts as with grain, then fine sieves must be substituted for or placed below those used for wheat or other cereals. If the quantity of timothy to be threshed is small, a canvas all which the seed falls may be placed under the machine. Timothy seed which may have grown as a volunteer crop in mixture with winter wheat or rye may be collected in this way.

Recleaning the seed: By using some of the modern types of seed cleaners it is possible to remove most if not all of certain weed seeds which could not be separated from the timothy by means of a fanning mill. Usually the seed grower does not have expensive seed-cleaning machinery on his farm, so, if he wishes to sow some of the seed produced on his farm, he should avail himself of the services of a processor or seedsman to do the recleaning for him.
In certain parts of the timothy-seed producing area, redtop grows in many of the meadows. Where large quantities of timothy with a mixture of redtop, even in small proportions, are harvested, the aggregate quantity of redtop seed re-cleaned from it to be marketed as such may be quite large.

It is difficult to remove the seed of alsike clover completely from timothy seed. Alsike mixed with timothy, however, usually is not objectionable and may even add to the value of the seed. The market for timothy and alsike seed mixed is not usually good and the price to be obtained is usually lower than that of the same quantities of pure seed of either of the two kinds.

Production of improved varieties: Although the same methods may be used in the production of seed of improved varieties as in the production of ordinary timothy seed, some special precautions should be observed. When a meadow is sown with a new variety for the purpose of seed production, care should be taken to sow the seed on land free from other timothy plants, and before harvest time it is well to mow two or three swaths around the outer border for hay so there will be no danger of harvesting seed from plants of ordinary timothy which may be growing along adjoining fences or meadows. Precaution should be taken, also, when the seed is threshed, that no seed of any other variety of timothy is in the machine to become mixed with that of the improved variety.

Timothy meadows are rarely fertilized for seed production, although yields of seed may be increased by the application of nitrogenous fertilizers. The use of fertilizer is not likely to be profitable, except when seed of a new variety for which there is a good demand is being produced, or when the seed is high in price.

Germination: After timothy seed has become mature and has been harvested, some time may elapse before a satisfactory percentage of it will grow. During this interval, what is known as the after-ripening process occurs. Timothy seed usually attains its maximum germination in about three or four weeks after it is harvested, when nearly 100 percent should germinate. It may retain its initial germination for one or two years after which the viability gradually decreases. Timothy seed sometimes retains nearly its original germination for four or five years if kept in a dry, cool place.

In most lots of timothy seed a portion of the seed has been hulled and occasionally this is a large proportion of the total, especially in combined seed. It has been shown that within a few months after harvest the seed without hulls grows as well as that with hulls, but that the hulled seed loses its viability more rapidly than the seed with hulls. The value of seed a year or two old may depend to a considerable extent, therefore, on the proportion of hulled seed present.

Impurities in timothy seed: There are three classes of impurities in timothy seed: (1) inert matter, such as particles of sand or broken pieces of heads and stems; (2) crop seeds which consist of seeds of other crops than timothy, and (3) weed seeds.

The first group of impurities is usually of but slight importance where the percentage is low, except as it affects the appearance of commercial seed. The importance of the third group depends upon the kinds of weed seeds that occur. There is a long list of weed seeds which may occur in timothy, those most commonly present being buckhorn, common plantain, curled dock, and red sorrel.

The seeds of some weeds differ so much in size from those of timothy that, even though they grow in the timothy meadow, they are quite readily removed when the seed is cleaned. On the other hand, it is very difficult if not impossible completely to separate the seeds of some other weeds from those of timothy.

Standards of quality for timothy seed: There are no official standards of quality for timothy seed. The three factors of purity, germination and total weed seed content enter into most sales contracts.
Other crop seeds, noxious weed seed, and color are also considered. The highest quality timothy seed offered by the best seedsmen and the one that usually carries their highest trademark brand, has an average purity of about 99.5 percent and a germination of 92 percent, and is free from noxious weed seed. The Government requirements on war contracts during World War II were 99 percent purity, 90 percent germination, and not more than 0.5 percent weed seed, with tolerances allowed. Qualities of seed below these requirements are evaluated on the percentage of each of the factors entering into consideration without any fixed standard.

The legal weight of timothy seed in all or nearly all States is 45 pounds per bushel. There are about 1,100,000 to 1,300,000 seeds per pound.

TIMOTHY HIGHLIGHTS

1. For more than two centuries timothy, a native of Europe, has been the leading hay grass in the United States. Like some other plants of European origin, it has reached its highest state of development and use in the United States.

2. In spite of the rapid decline in production of timothy, the standard horse hay, from 1910 to 1930, because of the reduction in horse population and the greater popularity of certain other kinds of hay for other farm animals, it has retained its position as the foremost hay grass in the United States.

3. The recovery of timothy in popularity in more recent years is attributed to a fuller recognition of its intrinsically valuable qualities for hay, pasture, silage, and erosion control.

4. Timothy is at its best in New York, the third State in the United States in total hay production (first in 1946). New York produces more timothy and clover hay (16 percent of the total United States production) than any other State, with Wisconsin, the first State on all hay production, a close second on timothy and clover hay.

5. During the past 15 years, Iowa has produced more than half the total United States production of timothy seed, Missouri, Ohio, Minnesota, and Illinois following with a 12-year average of 15, 13, 10 and 7 percent, respectively, of the total United States production.

6. Timothy has a wide range of adaptation, but in certain areas other grasses and legumes have largely replaced it for both hay and pasture.

7. Though timothy will tolerate soils with some acidity, there is evidence that yields of hay decline as the acidity increases.

8. Three to five pounds of timothy seed per acre sown in the fall with winter grain or seven to ten pounds sown in the spring with oats usually give greater yields than either larger or smaller rates of sowing.

9. Nitrogen applied in inorganic forms is more quickly effective than in organic forms. When nitrogen is applied with superphosphate and potash, the yields per acre of both hay and protein are increased. The latter constituents applied without nitrogen are usually not effective, unless the soil is already well supplied with available nitrogen.

10. The relatively low protein content of timothy hay when cut in full bloom or later, as compared with some other grasses, has often given it unfavorable consideration as a feed for livestock. However, timothy cut not later than early bloom and properly cured, compares favorably in protein content and feed value with other hay grasses.

11. Morrison (NY-30) says of timothy—"when early cutting is combined with nitrogenous fertilization, the hay often contains twice as much protein as late-cut hay from land deficient in nitrogen" and that such hay "can successfully be substituted for legume hay in feeding dairy cows during the usual winter feeding periods."

12. Considered from the point of view of both yield and quality of hay, the best production is obtained from cutting timothy hay when in early bloom, and from timothy-clover mixtures if cut when clover is in half to full bloom.

13. Experience in using timothy in mixtures with clovers and other legumes to improve both yield and quality of hay paved the way for the numerous grass-legume mixtures for hay and pasture that are in use today.

14. Timothy and red clover grown in com-
combination produce more and better hay than either one grown alone.

15. United States grades for timothy and timothy-clover mixed hays were the first United States grades for hay to be established.

16. At Wooster, Ohio, over a 20-year period, timothy averaged larger yields of hay than any of eight other standard hay grasses.

17. Where adapted, timothy is usually included in pasture mixtures because of its easy establishment and high palatability, but in permanent pastures it is gradually replaced by other grasses better adapted to growing in mixtures.

18. Silage of high protein and carotene content and otherwise of excellent quality has been produced from timothy cut in early stages of growth, at a lower cost per ton than corn silage.

19. The numerous fibrous roots of timothy are effective in reducing soil erosion.

20. The first organized efforts to improve timothy were started by W. M. Hays of Minnesota in 1889, and A. D. Hopkins of West Virginia in 1894, and later by T. F. Hunt of Ohio and New York.

21. The greatest advance in our knowledge of timothy during the past four decades has been brought about through the work at the Timothy Breeding Station established in Ohio, in cooperation between the United States Department of Agriculture and the Ohio Agricultural Experiment Station. The outstanding achievements at that station for the past 50 years have been accomplished under the direction of Morgan W. Evans who has contributed more than any other one man to our present-day knowledge of timothy.

22. Early varieties of timothy, such as Marietta and Shelby, for use in the southern part of the area of timothy adaptation and late varieties, such as Lorain in the northern part, have been developed and limited quantities of seed are available.

23. The outstanding superior attributes which establish timothy's continued popularity in the United States as a hay and pasture grass are:

(a) Ease of sowing timothy seed either alone, or with clovers, alfalfa, or other small-seeded legumes and grasses,

(b) Ease of establishing a stand of timothy, or timothy and clover mixed, under a wide range of soil and weather conditions,

(c) The usually relatively low price of timothy seed and the small quantity required per acre,

(d) Ease of cutting, handling, curing and storing timothy and timothy-clover mixed hay on the farm,

(e) Ease of baling, preparing for market, handling and grading timothy and timothy-clover mixed hay at market centers,

(f) Value of timothy hay as feed for horses and mules, and of timothy-legume mixed hays as feed for beef and dairy cattle,

(g) Excellent seeding habits of timothy which are not equaled by any other cultivated grass.

(h) Large yields of high-germinating seed possible of production almost anywhere that timothy can be grown,

(i) Ease of handling and storing timothy seed on the farm and of cleaning it with the regular types of equipment, and

(j) The usual ready market for both timothy and timothy-clover mixed hay and timothy seed the year round.

24. What, therefore, is the future of timothy and timothy-legume mixtures? Though the superior producing abilities of timothy and timothy-legume mixtures for both hay and pasture, especially in the Northeastern States, and their intrinsic value as feed for hay-consuming farm animals in all kinds of competition, have been clearly demonstrated, it is probable that timothy will never again reach its early twentieth century pinnacle of production because of the great reduction in numbers of horses and mules and the introduction and use of competing grasses and legumes.

THIS CHAPTER

The larger part of the material in this chapter was drawn from the published works of Morgan W. Evans (OHIO-14, 16, 18 and US-59, 62, 63), and Evans, Welton and Salter (OHIO-20). The research work of Evans, who has contributed more than any other one man to our knowledge of timothy, permeates all timothy literature of the past 30 years, on which one must depend for most of his information. Mr. Evans not only has carefully reviewed the manuscript for this chapter, but has made many valuable sugges-
tions which have been incorporated in it. The acreage and production statistics came from Edler and Kuzelka of B.A.E. In addition to Mr. Evans, the manuscript was reviewed by M. A. Hein of the U.S.D.A., D. C. Smith of Wisconsin, F. S. Prince of New Hampshire, and J. B. Washko of Pennsylvania.

Chapter reference numbers: MO-15; NJ-9, 13, 24; OHIO-14, 17, 20, 36; VT-4, 5, 18; WVA-4, 5; WIS-36, 37; US-58-66, 190, 204.

1 The reference numbers given here refer to references which are given in full by State, U.S.D.A., and Miscellaneous, on pages 682 to 724, and which are cross-referenced by author on pages 725 to 731. Citations in the text are indicated by abbreviation and number in parentheses.
CHAPTER XIX

ORCHARDGRASS

(Dactylis glomerata)

Orchardgrass, or cocksfoot as it is called in Great Britain and some other parts of Europe, is just now coming to occupy the place among leading forage grasses that it truly deserves. It is only in recent years that the State agricultural experiment stations have come to recognize its potentialities, especially as a pasture crop, and have undertaken extensive research with it with a view to breeding specially adapted varieties, to discovering compatible grasses and legumes to sow with it for best results, and to developing farm practices under which it can be used most efficiently as a pasture crop. In the newer pasture research programs of a number of States in the general area to which orchardgrass is adapted, this grass is being given a prominent position. At the U.S. Regional Pasture Laboratory for the Northeastern States, it occupies a most important place in their research programs.

The demand for taller and more rapidly growing grasses in grassland agriculture has brought out the importance of orchardgrass. Its toughness, leafiness, and ability to stand relatively poor soil and climatic conditions in the humid temperature regions of the United States are widely known. When properly managed, it has many fine qualities, but unless good practices are followed these fine qualities are lost. During the past five years, much of the doubt about it has been overcome and its merits have been admitted.

Orchardgrass is a long-lived perennial. Its typical bunch-type of growth produces no stolons, hence this grass never forms a complete sod as does bromegrass. Its tendency to form coarse bunches is one objection which should be of no consequence because this factor may be lessened by careful grazing management and by sowing orchardgrass with a legume such as red clover, Ladino clover, or alfalfa.

Good results have been obtained with an orchardgrass-Korean lespedeza combination in those regions where this kind of lespedeza is adapted. Both the grass and the legume will thrive on soils of medium fertility, though both of these plants of course respond to fertilizer. The bunch-type of growth which was much disliked in former times makes orchardgrass an ideal companion for Korean lespedeza. Both plants thrive during the summer months and thus extend the pasture season on land that would not maintain a growth of clover or alfalfa.

The strong and weak points of orchardgrass can best be seen by comparing it with timothy, redtop, and bromegrass. Orchardgrass is better adapted and more productive in the southern range of the timothy-growing region than either timothy or bromegrass. It will stand more heat, drought, and a lower soil fertility. Bromegrass and timothy are more resistant to winterkilling but neither is equal to orchardgrass in summer production of leafy pasturage.

Orchardgrass is one cultivated grass that can be sown in the spring with or without a nurse crop, with a reasonable assurance of obtaining a satisfactory stand. Spring sowing of orchardgrass, in fact, is generally better than fall sowing,
while in the establishment of bromegrass and timothy, fall sowing is almost necessary for best results.

Bromegrass is one of the most tempting grasses to livestock, while orchardgrass is low in appeal when allowed to mature. However, livestock graze orchardgrass readily in the early spring, and also later in the season if it is grazed sufficiently to keep it from becoming coarse and unpalatable, and if it does not have to compete at that season of the year with lush growth of other more palatable grasses and legumes.

It is highly important that local or domestic strains of orchardgrass be developed. Experience has shown that strains from foreign sources may not be adapted to our climatic conditions and, also, that when strains are moved to entirely different environments, the superior characteristics may be lost. At the present time, we do not have improved strains of orchardgrass in commercial production.

The common orchardgrass that has been so long coming into popular use, but which has now proved that it has a place in grassland farming, not only for hay and pasture, but also for silage and turf, will continue to increase in value and popularity only with the development of better strains and seed supplies, especially adapted for such uses.

DESCRIPTION

Orchardgrass is a tall-growing, perennial bunch grass that produces neither rhizomes nor stolons, but reproduces readily from seed. It is a rather coarse plant and, if left for seed, the stems become very coarse, fibrous, and unpalatable. It is readily distinguished by its large circular bunches, folded leaf-blades, and compressed sheaths, also by the peculiar form of its flower heads. The shape of the head has suggested the common English name of cocksfoot. Its ability to grow in the shade of trees is responsible for the name orchardgrass.

A good stand of orchardgrass equals timothy in sod density during the first year or two after sowing, but later the stand diminishes and the surviving plants stool and form distinct clumps. Individual plants are known to live 8 years, and some of them probably live much longer. Under some conditions many plants are relatively short-lived so that a progressive deterioration of the stand sets in 2 or 3 years after sowing.

In late March or early April orchardgrass begins to make a vigorous growth which is not checked by high summer temperatures as early as that of Kentucky
bluegrass. No other pasture grass in the area to which orchardgrass is adapted, with the possible exception of the tall fescues, makes so much growth from early April to early July. In normal seasons, it also makes considerable growth in late summer and fall.

This grass is about a month earlier in maturity than timothy. In the principal orchardgrass seed-producing States, the heads begin to appear about the first of May, then bloom late in the same month, and the seeds usually mature from June 15 to 20.

ADAPTATION

Climate: Orchardgrass is grown to some extent in nearly every State in the Union, and quite commonly in the region east of Kansas and Nebraska, and north of Alabama and Georgia. It attains most importance, however, in the North Atlantic States, eastern Corn Belt States, Tennessee, North Carolina, Virginia, West Virginia, Maryland, Missouri and Kentucky, and seems thoroughly adapted to a variety of soils in these States.

Orchardgrass is not so winter-hardy as bromegrass or timothy; therefore, it is not so well adapted to the northern Corn Belt as these two grasses. But conversely, it will thrive under higher temperatures and more humid conditions than either bromegrass or timothy. Well established plants withstand any cold weather that is likely to occur in the Central States, but plants weakened by continuous overgrazing are badly heaved by the alternate freezing and thawing on wet soil.

Soils: Orchardgrass grows well on light soils of medium fertility as well as on moist heavy land. It can be used to advantage on poor to medium fertile soils where a shade-tolerant and somewhat acid-tolerant grass is desired. It is also useful, with adequate liming and fertilization, for resowing with adapted legumes on old worn-out soils of the Eastern States.

Adaptability of strains: Commercial American-grown orchardgrass seed produced in the areas of largest production in northern Kentucky, northern Virginia and southcentral Missouri is generally adapted to those seed-producing areas and to others in the United States not far removed from the latitude of seed production, but does not seem to be so well adapted to more northern latitudes.

American-grown seed has not generally proved so well adapted to the English climate as the Danish seed, and in general the Danish strains and those from Aberystwith, Great Britain, tested at our agricultural experiment stations, have not generally shown adaptation to United States conditions. The difference in latitude, causing a material difference in length of day, is probably an important factor in this lack of adaptation of commercial American-grown seed to England, and of most Danish and English strains to conditions in the United States.

ESTABLISHING A STAND

Preparation of seedbed: Best results are obtained if a good seedbed equal to that required for the successful production of wheat is prepared for orchardgrass. If it is to be sown on rough, stony, or cut-over land where tillage is not feasible, it should be broadcast in February or early March. Where such land is covered by a heavy growth of grass and weeds or leaves, burning should precede sowing. If the land is not too rough and the brush cover is not too dense, the broadcast seed should be harrowed in with a brush drag, or a spring-tooth, disk, or an A-type harrow. Without good seedbed preparation, however, satisfactory stands of orchardgrass will be obtained only in unusually favorable seasons.

Time of sowing: In the southern portions of the Corn Belt States, orchardgrass may be sown with winter wheat immediately after the Hessian fly-free date, October 10 to 15. Sowing done in late August or early September, either without a companion crop or with winter barley or rye, will usually succeed throughout this zone. In the northern half, however, orchardgrass should be sown only in the spring, preferably in late March or early April, because the seedlings are easily killed by low temperatures.
Rates of sowing: The rates of sowing orchardgrass seed vary greatly throughout the region of adaptation depending upon several factors: (1) the geographical location, (2) the use for which the crop is intended, whether for hay, pasture, turf, or erosion control, (3) whether sown with or without a companion grain crop, (4) whether sown with other grasses or legumes as part of a grass or grass-legume mixture, (5) the time of sowing, whether in the spring or fall, and (6) whether used in a short rotation or for permanent meadow or pasture. Certain general rules, however, are applicable. In the southern part of the region higher rates of sowing are used than in the North, e.g., in the South one might sow 15 to 20 pounds of orchardgrass seed with 10 pounds of Korean lespedeza, while in the North under other similar conditions 5 to 8 pounds of orchardgrass seed with comparably smaller quantities of clover or alfalfa seed might be used.

If the orchardgrass is to be used primarily for pasture and remain as such for several years, even though it might be cut for hay during the first season or two, it should be sown in a mixture and usually at a somewhat heavier rate. Where the land is to be turned permanently to grass, a part of the orchardgrass might well be replaced in the seed mixture by such other grasses as timothy, bromegrass, redtop, or Canada bluegrass. Some redtop should be included in the mixture if the soil is wet or low in fertility; the poorer the soil, the larger the proportion of redtop. Whatever relative proportions of orchardgrass and other grasses are used, Korean lespedeza, Ladino clover, alfalfa, or other suitable perennial legume should be included in the seed mixture.

Companion crops: Better stands usually result if orchardgrass is sown without a companion crop, but it is difficult to sow the unmixed seed either with hand or horse-drawn sowing equipment because of the light, chaffy nature of much of the seed that is available, although well-cleaned seed can be sown rather successfully with hand or field drills. It is usually advisable, therefore, to mix the orchardgrass seed thoroughly with the heavier seed of wheat, winter barley, rye, or oats, and sow the mixture with a grain drill. In order to avoid placing the grass seed too deep, it is essential that the seedbed be firm and the drill set to sow as shallow as possible.

When orchardgrass is sown with oats, not more than one bushel of oats per acre should be used, and the oats either should be pastured in April and May, or cut for hay when the kernels are in milk to the soft-dough stage. If the oats are allowed to stand until the grain is mature, the young orchardgrass will in most seasons be so severely injured that few plants will survive.

If the wheat or winter barley with which orchardgrass is sown is to be harvested for grain, early maturing varieties should be used. Moderate grazing of the fall-sown companion crops during April, or pasturing them completely during April and May will usually benefit the young orchardgrass. The grain crop with which orchardgrass has been sown should never be pastured when the ground is soft.

Fertilizer and Lime: On any except very poor soils, an orchardgrass-lespedeza mixture will succeed without soil treatment. On most of the land that will be sown to this mixture or to other orchardgrass-legume mixtures, however, profitable returns will result from the application of moderate amounts of phosphate and lime. The grass will benefit indirectly from the applied phosphate and limestone which also will increase the productivity and nitrogen-fixing activity of the legume. Phosphate should be applied at the rate of 200 to 300 pounds per acre of 20 percent superphosphate, or its equivalent, and agricultural limestone at the rate of 2 to 3 tons per acre, depending on the degree of soil acidity. The limestone should be worked into the soil before sowing the grass, but the phosphate can be applied at the time of sowing if a drill with a fertilizer attachment is used. If such a drill is not available, the phosphate also should be worked into the soil ahead of the sowing operation.

Jones, Smith, and McVickar (Va-10)
summarized the results of their experiments with nitrogen applications to orchardgrass in northern Virginia in 1946, as follows:

1. Seed yields increased as nitrogen was added, up to 100 pounds per acre. Above this rate serious lodging reduced the amount of seed that could be harvested.

2. Hay production was encouraged by use of commercial nitrogen. Yield from the no-nitrogen treatment was 1,099 pounds per acre compared with 5,099 pounds from the plots receiving 488 pounds Calnitro (100 pounds nitrogen) per acre. As the amount of nitrogen increased, the advance in protein content of orchardgrass hay was as noticeable as the yield increase.

3. The use of commercial nitrogen influenced the aftermath growth of the orchardgrass following seed production; not only was the growth much heavier where nitrogen had been used, but the protein content of the grass also increased markedly.

Brown reports the effects from the application of nitrogen fertilizer on seed yields of old stands of orchardgrass at Fulton and Columbia, Missouri, as follows:

"When applied at a heavy rate (between 300 and 400 pounds an acre) in late September to 5-year-old orchardgrass growing on fertile soil, ammonium nitrate increased the seed yield from 169 pounds an acre (check) to 285 pounds an acre (treated)."

"In another test on 3-year-old orchardgrass growing on less fertile soil, ammonium nitrate applied September 25 at the rate of 200 pounds an acre increased seed yields from 110 pounds (check) to 192 pounds (treated)."

UTILIZATION AND MANAGEMENT

Hay: Orchardgrass is sometimes grown as a hay crop, although timothy is usually preferred for this purpose because it can be established at less expense and with greater certainty and ease. Furthermore, timothy reaches the hay stage a month later than orchardgrass, at a time when the weather is more favorable for hay making. The one distinct advantage that orchardgrass has over timothy for hay is the much larger second growth which can either be cut for hay or pastured off.

The quality of the hay will be much improved if the seed is sown at a heavier rate so that it makes a thick stand. Its value is also increased by the addition of one or more legumes such as Ladino, red or alsike clover, alfalfa or lespedeza. Also, the addition of another grass such as timothy improves the hay quality.

Orchardgrass should be cut for hay when the plants are fully headed and before they bloom. If cut earlier the yield is less, if cut later the quality of the hay is lower and the danger of crowding out the Ladino clover is increased. In a favorable season a second crop of hay that is finer in quality than the first may be obtained. The first crop usually lacks palatability because the seed stalks are usually present and partly mature when cut. Since the yield of the second crop ordinarily is no more than half that of the first cutting, it is usually utilized for pasture.

Orchardgrass grown alone will give an average hay yield of from 1 to 2 tons of field-cured hay per acre. When grown with clover or alfalfa, yields of 2 to 3 tons can be expected. Timothy and bromegrass will give a higher hay yield, but in the region where orchardgrass is adapted and over much of the region in the Cornbelt and Northeast where timothy and bromegrass are being recommended, orchardgrass will equal or give a larger yield of late growth at the end of summer and into the fall. This is the period when pastures are short and when barn feeding cuts income from livestock and livestock products.

Pasture: The principal use of orchardgrass is as pasture, and as such, it is rarely used alone but in mixtures with other grasses and legumes. As with most other pasture grasses, one or more legumes should always form part of the mixture.

Fall-sown orchardgrass for pasture should be allowed to grow to a height of 4 to 6 inches before grazing starts the
following spring, and the pasturing of spring-sown grass should be restricted throughout the first year. Even if the pasture as a whole is lightly grazed, certain spots will be eaten to the ground and the stand of grass there seriously injured if the livestock is left on the pasture too long.

After the first year, grazing should begin in the spring as soon as the grass is growing vigorously and should be continued throughout the spring and early summer at an intensity that will prevent most of the grass from heading. The young growth is palatable to both cattle and sheep. This moderately heavy grazing is necessary to maintain throughout this period the high quality of the early grass and reduce the competition offered by the grass to the early development of the legume. If the livestock is unable to keep the grass eaten down, it should be clipped before heading has progressed very far, because the seed stalks will become coarse, fibrous and unpalatable if left too long. These clippings can be made into hay if the quantity justifies the cost. In the fall it is again grazed with relish by cattle and sheep. The aftermath of a hay or seed crop also makes good pasture.

Spot grazing which results in severe injury to the over-grazed areas and in a waste of feed in the undergrazed areas can be prevented only by rotation grazing. Therefore, where it is feasible, and the water supply will permit, the pasture should be cross-fenced into three nearly equal divisions and the livestock moved in regular rotation from one division to another at intervals of two weeks. This can be done cheaply with electric fences.

With summer rainfall abundant and well distributed, and with lespedeza in the mixture, much summer pasture of fine quality will be obtained. If, however, even short periods of dry weather accompanied by high temperatures occur, the grass will rapidly exhaust the supply of soil moisture and the growth of lespedeza will be severely retarded. Therefore, lespedeza grown in one-year rotations with small-grain crops should be available as supplementary pasture from early July to early October.

The principal function of the lespedeza grown with orchardgrass is to provide the grass with nitrogen which the lespedeza, as a legume, can extract from the air and make available to the grass. If the lespedeza and grass should make considerable growth during the summer, this growth can be pastured during late August and September. The orchardgrass must, however, be protected from grazing during October and early November in order to allow the grass to store food reserves that have been depleted by the heavy spring grazing. For this period a field of winter barley or rye sown in late August will supply good pasture in normal seasons. Orchardgrass will not long endure continuous, heavy grazing in both spring and fall. The accumulated fall growth need not be wasted, since it makes good winter feed, and it can be pastured without injury to the grass after cold weather has checked further growth.

Silage: The practice of making grass silage has further shown the value and usefulness of orchardgrass. When grown in combination with legumes, such as red and Ladino clover, orchardgrass will produce a maximum tonnage of high-quality silage early in the season. If this early growth is cut, after the orchardgrass heads but before it flowers the orchardgrass will not crowd the Ladino clover so severely, and its rapid recovery will produce plenty of high-quality, summer pasture at a time when permanent pastures are usually dormant.

Turf: Orchardgrass has a limited use for turf. One of the limitations is that it will not withstand frequent mowing below four inches. Under continuous mowing at the four-inch height for a period of 4 to 5 years, it has produced a desirable though coarse type of turf at the Beltsville Turf Gardens. One of its advantages is that it can be sown in the early spring with a high degree of success. Fall sowings conversely do not result in as good a stand. Its drought tolerance commends it for certain types of ground cover, particularly on the non-used or little-used areas of air fields.
Being strictly a bunch-grass, it will not withstand traffic nearly so well as the types of grasses which are able to spread and thus maintain and repair themselves. However, at the four-inch height of cut, the turf is smooth as contrasted to a very undesirable, bunchy ground cover when it is mowed only once a year. When mowed closer than 4 inches it becomes invaded with weeds of different kinds.

There has been virtually no work done with different strains of orchardgrass as to their adaptability and purposes. This work is in progress at a few stations. In some States, it is included as a standard part of the State highway commission sowing mixtures. The obvious advantages of orchardgrass for certain coarse, little-used types of turf and ground covers, has been overlooked by many.

Where orchardgrass is to be used for a rough type of turf, a minimum sowing rate of 15 to 20 pounds to the acre should be observed. Sowing at low rates per acre will result in a more tufted, bunchy, and undesirable ground-cover. It is doubtful that the rate of 25 pounds of seed to the acre should ever be exceeded.

VARIETIES

There are no superior new strains or varieties of orchardgrass in commercial production in the United States today. There are imported strains such as Brage and S-143 that are being increased to a limited extent. A 3-year pasture test at the U.S. Plant Industry Station at Beltsville, Maryland, which included these strains, has shown that they have not maintained a uniform stand or desirable mixture with Ladino clover, especially when they have been compared with strains that have been developed from selection and breeding of material originating in our old fields of Maryland, Virginia, Pennsylvania, and a few other States. The strains from European sources do not have as good recovery or growth during mid-summer months. Oftentimes they are not so winter-hardy. They are later maturing and more leafy.

S-143 originated from the Welsh Plant Breeding Station, Aberystwyth, Wales. The original introduction was leafy, low growing and quite winter-hardy. It is a very sparse seed producer and later maturing than common orchardgrass.

Brage originated in Sweden and the parent material is quite leafy, winter-hardy, and tall growing for hay or silage. It is more resistant to leaf-spot disease and the leaves stay green longer than do those of the commercial strain. It is a good seed producer. It has not appeared quite so persistent as the commercial strain in the southern region of the orchardgrass belt.

SEED PRODUCTION

History of seed production: The earliest commercial production of orchardgrass seed in the United States was in Kentucky and Virginia, and these two States still produce 85 percent of the total, the larger part of the remaining 15 percent being produced in Missouri. This does not mean, however, that the climate and soil of other sections are not equally adapted to the production of orchardgrass seed.

When new varieties are developed specially adapted to sections in other latitudes, it is probable that seed production will develop either in those sections or others in approximately the same latitude. This is because of the sensitiveness of orchardgrass to length of day which makes seed production of such varieties more likely to be unsuccessful in latitudes removed from areas of primary adaptation. Further experimentation is necessary on this feature of orchardgrass seed production before definite conclusions can be reached. The development of special seed-drying equipment may be a factor in developing seed production in the more humid areas where new varieties of orchardgrass are being developed.

Large quantities of orchardgrass seed were supplied by the United States to European countries, mostly to England, during World War II. From the United States production of the 3 years, 1942, 1943 and 1944, England was supplied over 15,600,000 pounds of orchardgrass seed, or over 5,000,000 pounds a year,
which is considerably more orchardgrass seed than was consumed in the United States during that period. This war effort was made because Denmark, which was the regular source of the much-needed imports of orchardgrass seed for England's use, had been cut off by the war, and because orchardgrass (cocksfoot) was so important a crop in livestock production in Great Britain.

Seed-production statistics: The total annual production of cleaned orchardgrass seed in the United States has varied greatly during the past 25 years, from a low of 2,030,000 pounds in 1925 to a prewar (before 1941) high in 1931 of 5,124,000 pounds, and a high for the 25-year period of 8,134,000 pounds in 1949. The 9-year annual average (1941-1949) of 6,400,000 pounds of orchardgrass seed was nearly double the earlier 10-year (1925-1934) average of 3,289,000 pounds.

The average annual production of cleaned seed during the 8 years (1940-1947) in each of the three largest producing States was approximately 3,150,000 pounds in Kentucky, 2,250,000 pounds in Virginia, and 660,000 pounds in Missouri. Based on statistics, the overall yields per acre of orchardgrass seed have averaged about 13 bushels of thresher-run seed which is equivalent to about 130 pounds of clean seed. According to estimates of growers and buyers in areas of surplus seed production, the average yields range from 180 to 225 pounds, with occasional maximum yields of from 450 to 600 pounds per acre.

Sowing for seed production: A common practice for getting orchardgrass into seed production is to sow about 25 pounds of seed along with red clover and take a hay crop the first year. Seed is harvested in following years, and the remainder pastured or removed as hay. Some growers are having good success using sweet clover or alfalfa with orchardgrass. Seed yields of 25 bushels per acre have been reported from orchardgrass in 3-year-old stands with alfalfa, following which 1 ton of high-quality hay per acre was obtained.

Harvesting for seed: Orchardgrass is ready to harvest for seed when the heads are yellow, although the culms and leaves are still green. When ripe, the seed shatters easily. The seed crop can be harvested either with the ordinary grain binder or the combine harvester. If the combine is used, the machine should be set to cut the grass just as high as possible without passing over too many heads. At best, considerable green material and some immature seed will be included so that precautions must be taken to prevent the heating of seed in storage.

The grain binder should be set to cut the heads with just enough straw to make bundles. Losses from shattering can be reduced by cutting during the early part of the day while the heads and straw are still damp. If the seed crop is cut high, as recommended, the lower part of the plants can be cut for hay as soon as the seed crop is out of the way. A hay crop harvested in this manner will not, however, equal in quality hay cut before the bloom stage.

If orchardgrass is harvested with a binder, the bundles should be placed in small shocks for curing, which requires 2 to 4 weeks. Seed harvested and cured in this manner will not require as much care in drying to prevent heating after threshing as seed harvested with a combine-harvester or seed that is threshed from the shock before curing is complete. Seed may sprout before threshing, however, if exposed to long-continued wet weather.

If the seed is stored in large bulk immediately after threshing, it is quite likely to heat. To prevent this, the seed should be spread and dried before storage in large bins, or it may be stored in bags. Combine-harvested seed will usually require more drying than seed cured in the shock.

Since orchardgrass seed is light, it is necessary to reduce the air in threshing to prevent blowing over excessive quantities of seed. As a result, in the threshed seed there is much chaff and other trash which should be removed with a fanning mill before the seed is marketed or stored.

Seed cleaning: Orchardgrass seed is one
of several grass seeds which requires more care and elaborate equipment for cleaning than most other forage seeds. The only cleaning that can be done on the farm is to superficially screen or “scalp” the seed to remove straw and other coarse material. Care should be taken in doing this not to remove parts of the panicles containing good seed, and not to blow out good seed.

It is so difficult to estimate the percentage of clean seed in thresher-run orchardgrass seed that buyers and sellers are likely to miscalculate the percentage and estimate either much more or much less of clean seed than there actually is in a thresher-run lot. Because of the difficulty of accurately sampling thresher-run seed for the purpose of buying or selling, it is far better to base calculations on seed that has gone through one or more cleaning operations to remove as much as possible of the coarse, worthless material.

Weeds in orchardgrass seed: Orchardgrass seed grown on well drained land which has been properly limed and fertilized should be relatively free from weeds. Experiments in Virginia (Va-10) show that applications of nitrogen to orchardgrass fields eliminated most of the weeds by encouraging the growth of the orchardgrass. Practically no wild onions, the bane of the orchard grass seed producer, were present in fields so treated. Since this is a simple remedy for weeds, and the fertilizer gives commensurately greater returns in yields per acre, in addition to the greater salability of the seed, it is a short-sighted policy of certain seed growers not to use larger quantities of nitrogen fertilizer on their fields.

The delivery of orchardgrass seed containing large percentages of weed seeds and inert matter to processors makes it necessary for them to dock such seed much more than the actual percentage of weed seeds and inert matter present, because of the loss of good seed in the removal of such foreign material, and the costs of labor, time, and the elaborate cleaning equipment necessary to process such seed. The extra cost, where it is possible to do this, to clean orchard grass seed of 85 percent purity up to 90 or 95 percent or more by removal of weed seeds and inert matter, may shrink the seed from two to five times as much as the actual quantity of weed seeds and inert matter removed from the original uncleaned seed, in addition to the expense of processing which with orchardgrass is more than with most other forage seeds.

**ORCHARDGRASS HIGHLIGHTS**

1. Orchardgrass is recommended for use in pasture mixtures on poor, medium, or fertile soils over the entire area of its adaptation.
2. Orchardgrass is acid-tolerant and can be used on soils where bluegrass and other grasses will not thrive.
3. On erodible soils, orchardgrass serves the dual purpose of a forage and erosion-control crop.
4. Orchardgrass is best grown in mixture for pasture.
5. As a grass for use in shaded locations, orchardgrass is superior to most of our commonly used grasses.
6. Such legumes as Ladino clover, Korean lespedeza, red and alsike clover, alfalfa, birdsfoot trefoil, and sweetclover are all suitable for use with orchardgrass.
7. Other grasses suitable in pasture combinations with orchardgrass are tall oatgrass, timothy, redtop, bromegrass, tall fescues, Kentucky bluegrass, and Canada bluegrass.
8. Though primarily used for pasture, orchardgrass is very satisfactorily used for hay, silage, turf, and control of soil erosion in its region of adaptation.
9. When sowing in mixtures with such small-seeded grasses as redtop or bluegrass, the size of the seed makes it necessary to use a larger volume of orchardgrass.
10. Orchardgrass is generally rather slow to start growth, and, under some conditions, small-seeded, rapid-growing grasses tend to crowd it out, unless the proper proportions of seed in the mixture are used.
11. Where orchardgrass is best adapted, it is one of our most persistent grasses. Once it is established, a single plant occasionally lives 8 years or longer.
12. Orchardgrass should be grazed or cut for hay when young and not allowed to become coarse, tough, and unpalatable.
13. Orchardgrass fields heavily fertilized with nitrogen are usually almost weed-free. For seed production, therefore, nitrogen should be applied freely. Nitrogen appli-
cations also increase yields and protein content of hay.  

14. Use seed of adapted strains of orchardgrass from approximately the same latitude for either forage or seed production.  

15. Eighty-five percent of the commercial orchardgrass seed produced in the United States comes from Kentucky and Virginia, and most of the remaining 15 percent from Missouri.

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This chapter

Little has been published relating to the more recent research on orchardgrass. The material used in this chapter was taken largely from the writings of Brown (MO-3), Fuelleman (ILL-6), Jones, Smith and McVickar (VA-10), Mooers (TENN-11), and Piper (US-200), which has been supplemented by personal interviews with agronomists, and observations made in States located in the orchardgrass area. Seed statistics were supplied by Edler and Kuzelka of the B.A.E. The manuscript was reviewed by Hein and Edler of the U.S.D.A., Brown of Missouri, and Sprague of the Northeast Regional Pasture Laboratory.

Chapter reference numbers: 1 ILL-6, 18; KY-4; MINN-19; MO-3; NY-22; TENN-11; VA-10; US-54, 77, 115, 204; MISC-47, 48.

1 The reference numbers given here refer to references which are given in full by State, U.S.D.A., and Miscellaneous, on pages 682 to 724, and which are cross-referenced by author on pages 725 to 731. Citations in the text are indicated by abbreviation and number in parentheses.
CHAPTER XX

BLUEGRASSES

(Poa species)

The bluegrasses constitute a large group which is best known by the standard species, Kentucky bluegrass, (Poa pratensis). This species and Canada bluegrass (Poa compressa) are the only ones in general cultivation in the United States, and both were introduced from Europe. Hitchcock (US-93) has described 64 native and introduced species of Poa in the United States.

The bluegrasses are of great importance because of their forage value, some species being cultivated for pasture and others forming a large part of the harvested forage. The most important is Poa pratensis, commonly known as bluegrass. In the cooler parts of the United States it is cultivated for lawns and as the standard pasture grass in the humid regions. P. compressa, Canada bluegrass, is cultivated for pasture in the Northeastern States and Canada, especially on poor soils. P. trivialis and P. palustris, are occasionally grown in meadow mixtures but are of little agricultural importance. P. arachnifera, Texas bluegrass, has been used in some parts of the South for winter pasture. P. annua is a common weed in lawns and gardens. P. bulbosa is cultivated about Medford, Oregon, and elsewhere. With very few exceptions the bluegrasses are palatable and nutritious and are often the most important grasses in some parts of the country.

KENTUCKY BLUEGRASS

(Poa pratensis)

Kentucky bluegrass or “bluegrass” as it is frequently called, is, with the possible exception of timothy, the most widely known grass in America. A native of the Old World, it occurs over very much of Europe and Asia and was probably first brought to this country by early colonists in mixtures with other grass seed. Its wide distribution gives mute testimony of its adaptation to the soils and climate of the northern half of the United States and to the mountainous regions and cool localities farther south.

Kentucky bluegrass is principally used for lawns and pastures. It does not generally give heavy yields as a hay grass and is seldom used for that purpose. It is frequently found in hay mixtures, however, even though not sown, as it is very aggressive, particularly on fertile, well-drained soils of the Northern States and appears spontaneously under such conditions.

With reference to the feed value of bluegrass Morrison (NY-30) says: “The fact that bluegrass is one of the richest of grasses in protein helps explain the fondness for it shown by stock. Before heading out in the spring, bluegrass usually contains nearly 20 percent protein, if dried to a hay basis. This is actually a larger proportion of protein than in alfalfa hay cut at the usual hay stages. Also, when the grass is kept actively growing by proper fertilization and management of the pasture and is not permitted to head out, the percentage of protein will be nearly as high later in the season. On the other hand, bluegrass in blossom or at the still later stages of growth is low in protein and high in fiber. While bluegrass is much less nutritious at the later stages of growth, it is then grazed more readily by stock than most other mature grasses.”
DESCRIPTION

Kentucky bluegrass is a dark green, perennial, sod-forming grass with smooth, soft, shiny leaves 2 to 7 inches long, and characterized by a distinct boat-shaped tip. The stems are 1 to 2 feet in height and usually numerous in a tuft. The inflorescence is a pyramid-shaped panicle about 2 to 8 inches long. The branches of the panicle are commonly spreading and whorled in groups of three to five. The spikelets are 3- to 5-flowered and are located mainly at the ends of the branches. Flowering is early in this species, taking place in May and June.

The root system of Kentucky bluegrass is extensive and finely branched. The mixture of roots and rhizomes in the upper two inches of soil under an old stand of this grass forms an extremely dense, resistant sod. The depth of the root system is variable, but it apparently is largely confined to the upper few inches of soil.

Sprague (NJ-22) in New Jersey experiments performed on 5-year-old sod during the months of April, May and June, showed that nearly 60 percent of the total weight of roots in the upper 9 inches of soil were in the top inch. The percentages of roots in the remaining 8 inches of soil in these experiments were, respectively, 21.7 percent, 7.5 percent, 5.5 percent, 3 percent, 2.2 percent, 1.7 percent, 1.5 percent, and 0.6 percent. If the percentage below nine inches decreased at the same rate, relatively few roots extended below the first nine inches of soil. He also showed that the weight of roots in the upper two inches of soil was about two-thirds greater during May and June than in April.

ADAPTATIONS

Climate: Bluegrass, even though introduced from the Old World, is very widely distributed throughout the United States and Canada, except in arid regions. It is found in all States but is not common in the Gulf States. It occurs at all altitudes below alpine regions. Bluegrass is especially adapted to growth in the cool, humid climate of the northern half of the United States and finds its major distribution in this region. Bluegrass is a sun-loving plant, but does well in semi-shade during the hot summer months.

Soils: Bluegrass occurs on moist, well-drained soils, in meadows, pastures, fields and open woods. It is neither acid nor alkali tolerant but prefers soils of high fertility and medium texture.

The conditions of chemical fertility for best results are rather exacting. Large amounts of nitrogen must be available during the periods of most active growth, particularly in the spring, early summer, and autumn. Kentucky bluegrass is frequently associated with white clover, a nitrogen-fixing plant. Nitrogen fertilization, however, is generally needed, as the usual irregular occurrence of the white clover does not furnish sufficient nitro-
gen for maximum production of either forage or seed under present farm practices. Phosphorus is important, particularly for associated legumes, and soils must be either naturally rich in this element or maintained at a reasonable level of phosphorus availability by farm practices. The soil should be well supplied with calcium. The most desirable pH range is probably 5.8 to 8.2. The chief areas of successful bluegrass grazing are still confined to soils developed from calcareous material.

SOWING THE SEED

Best results will be obtained by sowing bluegrass pastures on a well-prepared, firm seedbed, with a grass drill, or a grain drill with grass-seeder attachment. The seedbed should be plowed at least a month previous to sowing. If a drill is not available, the seed can be distributed with a broadcast seeder or spread uniformly by hand and then covered by a light harrowing. Early fall sowing has given the best results, both for pastures and lawns. Sowing can be done any time after the middle of August to two weeks before killing frost, provided moisture is plentiful in the soil. If spring sowing is necessary, it should be done as early as weather conditions will permit. A nurse crop is not necessary and not usually desirable, except on sloping land where it is used to reduce erosion, because bluegrass is so slow in establishing itself. Finally, the use of high-quality seed will help to insure a good stand and early establishment.

The rates of sowing bluegrass seed vary widely, depending upon the use for which it is intended, and other factors. Except for lawn purposes and special strains for seed production, it is almost always sown in mixtures where from 3 to 20 pounds may be used per acre with other grasses and legumes. For lawns it is sown alone or with redtop at the rate of 3 to 5 pounds per 1,000 square feet.

FERTILIZATION

An application of fertilizer containing 16 pounds of nitrogen, 48 to 64 pounds of phosphoric acid, and 25 to 50 pounds of potash per acre in advance of sowing is recommended, if the land has not been fertilized recently.

Wisconsin agronomists (Wis-2) have shown that applying nitrogen fertilizer to permanent bluegrass or "Junegrass" generally is a good way to pep up pastures at a profit, but is not the most profitable way in the long run. Nitrogen fertilizer has a certain appeal in that it brings quick results, making it unnecessary to do long-range planting. Applied in the spring, nitrogen helps solve that year's pasture problem where the farm operator neglected to solve it the most profitable way by establishing legumes and bromegrass in previous years.

A four-acre bluegrass pasture, treated with 125 pounds of ammonium nitrate to the acre in the early spring, yielded 4531 pounds of dry matter to the acre. A similar untreated pasture yielded only 2,734 pounds. The increase from a modest amount of nitrogen thus was nearly 66 percent.

A moderate amount of ammonium nitrate increased bluegrass yields by 80 percent at Fort Atkinson, but calcium cyanamid increased them only 18 percent, and ammonium sulphate about 19 percent. The latter two fertilizers did not return an appreciable profit.

That growing legumes along with grass results in bigger and more economical yield increases than can be obtained by nitrogen-fertilizing bluegrass has also been found to hold true in Madison, Wisconsin, trials.

ABSORPTION OF MINERALS BY BLUEGRASS

Beeson, Gray, and Adams (US-17) have shown in an experiment with 15 grasses to determine the relative absorption of phosphorus, cobalt, manganese and copper, that Kentucky bluegrass absorbed the largest quantities of all these four elements except manganese. The most significant result in this test is probably the fact that Kentucky bluegrass in duplicate tests ranked higher than all of the other 14 grasses in its absorption of phosphorus, with an average of 35 percent. Orchard-
BLUEGRASSES

grass and Johnsongrass were also in the high phosphorus group with averages of 30.6 and 30.5 percent phosphorus, respectively.

FACTORS AFFECTING GROWTH AND COMPOSITION

Brown (Mo-6), in the course of an intensive four-year study of bluegrass in Missouri, made certain observations as to the factors, such as air, soil temperatures, rainfall and soil moisture content, which influence the growth and composition of Kentucky bluegrass and the seasonal operation of those factors, some of which he summarizes as follows:

"Kentucky bluegrass swards one or more years old made very little top growth until the average soil temperature at the ½-inch depth rose above 50° F. The rate of herbage production increased rapidly in April and usually reached a maximum during the first half of May at an average soil temperature of 60° to 64° F. The period of maximum herbage yield was also the period when reproductive shoots elongated and inflorescences emerged.

"Herbage production by bluegrass that was mowed semi-monthly began to decrease in late May and reached a minimum in July at an average soil temperature of 80° to 82° F. Irrigation reduced but did not prevent this midsummer decline in herbage production by Kentucky bluegrass. With adequate supplies of soil moisture and available nitrogen, herbage production increased to a second but smaller peak during late August at an average soil temperature of 74° F.

"Top growth declined during September and remained quite small during October, although the mean temperature during the latter month was almost the same as that during the first half of May when herbage production was at a maximum.

"Seasonal variations in herbage production were influenced by temperature, soil moisture, length of day, age of the grass sward, applications of sodium nitrate, semi-monthly mowing, and the quantity of roots and rhizomes in the sod.

"Spring, when semi-monthly average soil temperatures ranged from 40° to 75° F., and fall, when they ranged downward from 70° to 50°, were the more favorable periods of the year for root and rhizome development by dense swards of Kentucky bluegrass after the first year. Root development was larger during early spring (March 6 to May 20) when semi-monthly average soil temperatures were 40° to 60°, than during late spring and early summer (May 20 to June 30), when average temperatures ranged between 65° and 75°.

"Rhizomes increased more in weight from May 20 to June 30 than earlier, probably because of the longer photoperiod rather than because of the higher temperature. Both roots and rhizomes either made little gain in weight or actually lost weight during July and August when average soil temperatures were usually above 80° F.

"Root growth by Kentucky bluegrass was more rapid during the first autumn and winter following a September sowing than during any subsequent period. No rhizomes developed before spring, and their development was slow during the first spring and summer. Rhizome production was most rapid during the second summer in a sparse stand of irrigated bluegrass.

"Larger yields of herbage resulted from cutting Kentucky bluegrass once or twice annually at hay stages than from semi-monthly mowing at either the 1-inch or 2½-inch level. Smallest yields were obtained from plots mowed semi-monthly with the cutter bar set 2½ inches above the ground.

"Clipping bluegrass semi-monthly to a height of one inch had little or no effect on the quantity of roots in the upper 6 inches of sod, but repeated close mowing did reduce materially the quantity of rhizomes by retarding their development during the spring and by increasing the rate of their depletion during summer. During the autumn, rhizome development in the 1-inch cut plots was practically equal to that in the 2½-inch and hay-cut plots.

"The sugar and starch content of blue-
moderately pastured before stripping usually yields only from one-half to two-thirds as much seed per acre as ungrazed pastures, but gives the extra return from pasturage. A choice between the practices of grazing, or not grazing, before stripping should depend chiefly on the season, price outlook for seed, kinds and amount of weeds present in the grass, and the needs of the farmer for spring pasturage.

BLUEGRASS IN THE NORTHEAST

Since bluegrass has been frequently referred to disparingly as a pasture grass, particularly since some of the larger and coarser grasses such as bromegrass, the tall fescues, and orchardgrass, have recently come into prominence as pasture grasses, Brown and Munsell (Conn-13) conducted experiments and made observations in Connecticut in an effort to more properly evaluate Kentucky bluegrass. Following are some of their observations and conclusions:

Their paper presents "the results of four experiments involving comparisons of Kentucky bluegrass with other grasses common to the Northeast. In two experiments, the plots were lawnmowed 4 to 1 inches and in the other experiments mowed three or four times each season as early cut hay. In three of the four experiments, Kentucky bluegrass and the other grasses were in pure cultures, receiving nitrogen at 28 pounds three times each season, and also sown with Ladino clover.

"By both systems of harvesting, the quantity and quality of forage from Kentucky bluegrass were practically equal to orchardgrass, Rhode Island bentgrass, and timothy. The seasonal distribution of forage production was not appreciably different from the other grasses.

"The high level of soil fertility required by Kentucky bluegrass has been mentioned as one of its disadvantages. Unless one is attempting to grow crops which will exist on a low plane of fertility and accept the correspondingly low quantity and quality of forages produced under such conditions, this point seems to have little weight. In the experiments conducted at Storrs, Connecticut, Kentucky bluegrass has thrived where the soil was favorable for red and Ladino clovers or timothy. Alsike clover and members of the Agrostis genus (redtop, bents, etc.) will grow fairly well where the soil is too acid and wet for Kentucky bluegrass. Redtop and the bents will also survive with less easily soluble phosphorus in the soil than is required by Kentucky bluegrass. Farm experience in Connecticut appears to indicate that orchardgrass is superior to Kentucky bluegrass on sandy soils.

"The slowness with which Kentucky bluegrass becomes established is another disadvantage. When sown in the spring with clovers, little bluegrass will be found in the crop that year. Even with late summer sowing, the hay or pasture is likely to be mostly leguminous during the next season. In many cases, this will also result with other grasses. Where Ladino clover is the legume sown with Kentucky bluegrass, the difficulties of harvesting or grazing it the first season, when little grass is present, are likely to be realized.

"Ladino clover maintained its stand as well when sown with Kentucky bluegrass as with any of the grasses usually grown in this region for hay or pasture. Kentucky bluegrass has maintained much better stands than any of the other grasses.

"The most favorable characteristic of Kentucky bluegrass as a grass for livestock farms in the Northeast is its ability to maintain good stands under almost any kind of management or weather conditions, provided a reasonable level of fertility exists in the soil. In this respect, none of the other common grasses equal it. For this, if for no other reason, Kentucky bluegrass should be given serious consideration when sowing land which one does not care to till again for many years."

The above conclusions have been reached in connection with investigations made in Connecticut but are probably equally applicable over a rather large area of bluegrass production where comparable conditions may prevail.
BLUEGRASS LAWNS

Kentucky bluegrass is a very beautiful grass for lawns, particularly when grown on fertile soil, and is well suited for this purpose because of its excellent sod-forming habit and its dark shiny-green color. It should be the basis of all lawn mixtures for the Northern States on naturally fertile soil or soils improved by fertilizing. Kentucky bluegrass cannot be considered a shade-loving grass but it will stand moderate shade and ordinarily under such conditions, with ample moisture, will compete with crabgrass almost to the complete elimination of the latter. An abundant supply of phosphorus in the soil is essential to its growth, and potassium and nitrogen must also be plentiful. The presence of lime is not so important unless the soil is very deficient in lime.

Kentucky bluegrass lawns are exceptionally attractive in the spring and fall and remain more or less green throughout mild winters in the Central States when properly managed and fertilized. Unless watered liberally during exceptionally hot, dry periods of the summer, the grass becomes dormant and turns brown. At such times it should not be cut close and care must be observed in supplying water, as crabgrass may be encouraged which will compete with the bluegrass.

Bluegrass is often sown in mixture with other grasses in lawns, but if a bluegrass lawn is desired and the conditions are favorable for bluegrass, it is usually better to sow it alone. A commonly-used mixture consists of Kentucky bluegrass 15 parts, and redtop 3 or 4 parts. If white clover is desired, one part may be added to this mixture. If a pure grass lawn is preferred, the white clover should be omitted. The sowing rate usually recommended is 3 to 5 pounds to each 1,000 square feet of lawn, but under favorable conditions with a well-prepared seedbed and uniform distribution of seed, a much lower rate is ample.

The practice of sowing Kentucky bluegrass and redtop for lawns in mixtures in the above proportions is common, but Erdmann and Harrison (Mich-11) report that their experiments show that both common ryegrass and redtop inhibit the growth of Kentucky bluegrass and Chewings fescue and that "mixtures containing the quicker starting, more aggressive grasses have only one desirable point in their favor, namely, that of quicker ground cover. Once this quick cover is accomplished, the coarser grasses react unfavorably in the establishment of a desired turf." Therefore, "where quick cover is not essential, sowing an adapted, desired turf grass alone would result in a more satisfactory turf than a mixture which includes the coarser, more aggressive nurse grasses."

Bluegrass lawns are often established by sodding where immediate results are desired. It is usually preferable, and more permanent results are likely to be obtained by sowing the seed, if conditions are favorable as to moisture and time of sowing, and sufficient time can be allowed for the establishment of the newly-sown grass.

SEED PRODUCTION

Areas of production: The early establishment of Kentucky bluegrass in Kentucky and its becoming so readily adapted to the limestone regions of the State naturally made Kentucky the primary source of seed supplies and gave the present well-known United States name to a grass introduced from Europe. Later, Missouri came into production of Kentucky bluegrass, and for some time these two States produced the major portion of the bluegrass seed in the United States. The former Missouri area, now a part of what is known as the Western District, has gradually extended mostly northward and westward so that it now includes also parts of Kansas, Iowa, Nebraska, South Dakota, North Dakota, Minnesota, Wisconsin, and Illinois. The Western District in recent years has usually produced seven or eight times as much bluegrass seed as is produced in the three States of Kentucky, Indiana, and Ohio.

There have been many discussions as to the relative value of Kentucky bluegrass seed produced in different States of
production, but no experimental evidence is available on the adaptability or winter-hardiness of the seed from the different States. One factor which varies somewhat, however, in the different areas of production is that of weed seed. In some areas certain noxious weed seeds seem to be more prevalent than in some of the other areas. Since most of these seeds can be removed readily with modern cleaning equipment, this does not constitute any large obstacle to the use of seed from a particular area.

The extending of bluegrass stripping areas especially in the Western District from Missouri up into the States of Iowa, Nebraska, North Dakota, South Dakota, and Minnesota, has caused the development of the highly specialized seed contractor and stripper who owns or leases a large number of seed strippers which operate through the entire season of seed stripping, beginning in central Missouri and ending in northern Minnesota and North Dakota, and even up into Canada. These specialized operators strip and cure the larger part of the Kentucky bluegrass seed in the Western District.

Quantity of seed harvested: The total quantity of cured bluegrass seed harvested has varied considerably during the past 25 years, ranging from a low for that period of 4,200,000 pounds in 1928 to a high of 77,000,000 pounds (or 46,370,000 pounds clean seed) in 1937. The average for the 10 years (1939-48) of 36,800,000 pounds of cured seed was one-third larger than the previous 10-year (1929-38) average of 27,600,000 pounds. The total production in 1947, 1948, and 1949 was 63,500,000, 32,700,000, and 46,900,000 pounds, respectively, of cured seed.

The average production of cured seed in the Western District, which includes portions of Iowa, Kansas, Minnesota, Missouri, Nebraska, North Dakota, South Dakota, Wisconsin, and Illinois, for the 8 years (1940-47) was 34,500,000 pounds, or over seven times the average of 4,800,000 pounds harvested in the three States of Kentucky, Indiana, and Ohio during the same period.

Stripping bluegrass seed: Bluegrass seed should be stripped as soon as the head has turned yellow or brown and the seed is firm. The stripping season is comparatively short, usually lasting less than two or three weeks in any State or general area. The height of the season in Kentucky and Missouri is usually reached during the second or third week in June when a large percentage of the total crop of these States is harvested. For any particular locality the stripping season will seldom extend for more than a week. After the seed has reached the stage of maturity that allows it to be easily stripped from the standing plant, a rather short period intervenes before it begins to shatter. The amount of shattering is greatly increased by heavy rain or hail, and seed crops may even be lost completely through these unfavorable conditions.

Fearing the loss of some or all of the seed crop, the farmer or contractor who has large acreages to strip, often starts stripping too soon. This results in a decreased yield due to the unharvested seed, and gives a poor quality of seed that sells at a discount under seed stripped at the proper stage.

Stripping machines: Most of the stripping is done with machines known as strippers or headers pulled by tractors (usually) or horses. Hand stripping is practiced in a very limited way, and is confined generally to the most productive spots of grass, such as may be found in orchards and on unmowed lawns.

Two types of strippers are commonly used, one (in Kentucky) with three sickle bars mounted on a revolving frame, and the other (in the Western District) with a cylinder containing large nails or spikes, which revolves at a fairly high speed. The seed heads (and some undergrowth) are thrown beneath and behind the revolving frame or cylinder into a box, which is emptied manually when filled. The seed heads are then put into large bags and the latter are hauled to the curing yards, or less frequently, to sheds, barns, or warehouses for curing inside.

Several companies manufacture stripping machines which sell at the present time at about $125 to $600 each, depend-
ing upon the type and material used. The old comb-type stripper is still used by some farmers in Kentucky, but only a very small percentage of the total crop of bluegrass seed is harvested with this stripper because it is less efficient than modern strippers.

The acreage that may be stripped with a machine varies much, but the average is 8 to 10 acres a day. Under normal conditions a machine is used in one locality ten days or less each season, making a total of 100 acres or less for a machine in any one locality in a single season. Some contracting operators in the Western District often cover almost the entire range of production from South to North, so the same machines may be in operation for a full month or more. Concerns manufacturing the so-called "western" strippers make them so they can be "knocked down" and transported easily from place to place.

Curing the seed: The seed with the chaff commonly termed green seed is hauled immediately after stripping to the curing yard or shed. Curing may be done in the open or inside a building or shed, provided it is well ventilated. In Kentucky tobacco sheds or warehouses are sometimes used, but most of the seed in that State and nearly all the seed in the Western District is cured outside. An area of smooth ground, well sodded, with sufficient slope to insure good drainage, makes an excellent site for a curing yard. It should be mowed with a lawn mower and raked clean before the green seed is spread on it.

The green seed is piled in small windrows running in the direction of the slope. The windrows should be about 15 or 18 inches high and should be dressed down on the sides with a pitchfork and made as narrow as possible so as to turn water and permit free circulation of air. These windrows should be turned frequently, usually four or more times daily, to prevent overheating and to hasten drying.

The curing process should be continued until the seed and chaff are thoroughly dry and show little or no tendency to heat or mold. Under favorable weather conditions and proper attention, only two or three days are ordinarily required to complete the curing in small windrows. Two or more of the small windrows may then be thrown together into a large windrow or rick and the seed allowed to stand undisturbed until ready to be put into sacks. Frequent examinations should be made of the seed, however, to make sure that it is keeping properly and not heating.

The more frequently the seed is turned and exposed to the drying influence of the sunshine and air, the better the quality of seed produced. Green seed of apparently rather poor quality may be greatly improved so as to command a good price if properly handled; and green seed of excellent quality may be ruined by improper handling in curing.

Care should also be exercised to avoid overheating of the green seed before it reaches the curing yard or shed. Garman and Vaughn (Ky-14) found that green seed left in sacks for three hours reached a temperature of 120° F. to 145° F. Tests have shown that the germination of the seed is lowered greatly by a temperature of 140 degrees F. Probably under average conditions in the Western District the green seed may remain in sacks for more than three hours without danger of serious injury. But the results obtained by the Kentucky Station emphasize fully the necessity of prompt delivery to the curing yards and of frequent stirring and turning of the green seed.

In summarizing their investigations on curing bluegrass seed in Kentucky, Garman and Vaughn make the following suggestions which are as applicable today as they were when made in 1916:

1. Seed should not be gathered when green. In Kentucky the seed is usually at its best from about June 15 to June 20. The heating of immature seed while curing is excessive and its germination even under the most careful handling is not as good as that of well-ripened seed.

2. Seed must never be permitted to heat above 122 degrees F., since prolonged heating even to this temperature
lessens the value of the seed. Seed allowed to heat to 140 degrees F., even for a short time, is worthless.

3. To reduce the difficulty of keeping seed from heating, warehouses and other buildings used as curing places should be provided with both side and top ventilation, and ricks should be about 18 inches high. High temperatures and inferior seed are generally found in bags and large ricks.

4. Seed should never be left in the bags overnight, and ought in all cases to be spread out soon after stripping.

5. Out-of-door curing has its advantages over curing in barns and warehouses. However, curing sheds can be built so as to permit almost as free circulation of the air in the ricks as occurs in the open, and at the same time have the advantage of warehouse protection from rain.

6. Very weedy pastures should be avoided as a source of bluegrass seed. The comb-strippers, which are still used to some extent in the Kentucky area, gather excessive quantities of weed seed.

Yield of seed: The yield of green seed per acre varies from 2 to 30 bushels, with an average of about 5 to 7 bushels which is the equivalent of 35 to 50 pounds of clean seed. The average yield of cured seed for the 16 years (1932-1947) in the Kentucky district was 6.9 bushels and in the Western District 5.6 bushels, or an overall average for the United States of 5.8 bushels, but yields of 12 to 15 bushels are not uncommon. A few farmers and contractors have reported occasional yields of 20 bushels or more of cured seed per acre.

The legal weight of Kentucky bluegrass seed is 14 pounds per measured bushel, but the standard of quality for negotiating contracts is usually 21 pounds per measured bushel. Kentucky bluegrass seed cleaned to the highest quality by modern equipment may have a test-weight of 24 to 30 pounds per bushel.

Losses in weight of seed: The loss in weight of curing and cleaning seed varies greatly with the condition of the crop at harvest, and the amount of foreign material present. The loss of weight during curing ranges from 25 to 60 percent with an average between 35 and 50 percent; the loss in weight from threshing cured seed ranges from about 30 to 75 percent, with an average loss of 50 to 55 percent by weight. Hence, a bushel of 14 pounds of green seed will thresh out on the average 3½ to 4 pounds of clean seed weighing 21 pounds to the measured bushel, or stated in other terms, 100 pounds of green seed will yield 25 to 30 pounds of clean 21-pound seed.

Marketing of bluegrass seed: The seed is sold by the farmers in one of three conditions, (1) freshly stripped seed commonly known as “green” seed, (2) cured seed or “dry rough,” and (3) the standing unstripped crop. Those who make a practice of leasing land for stripping purposes often have many large crews operating at different places during the stripping season. These professional strippers or contractors lease on the basis of a specified sum per acre or for an entire field or boundary, or per pound or bushel; or they may strip on shares. The price paid per acre for stripping privileges varies widely in different localities the same year or from year to year.

The prices paid for acreages depend upon the estimates made by the contractor and the farmer as to what yields of seed will be obtained from the particular acreage. This has to be based upon long experience in handling Kentucky bluegrass and the knowledge of what fields under certain conditions will produce. Hot winds, rains, hail storms, or other agencies may change conditions in particular fields in a very few days' time, so there is always much of a gamble in making these estimates and contracting for acreage at specified prices.

Contractors are usually also buyers of cured and uncured seed, and have one or more curing yards or sheds located at convenient places to handle the crop bought green from farmers. Also, regular buyers are located in some of the conveniently located towns in the bluegrass areas. Prices paid by contractors or buyers vary widely, depending on the trend of the bluegrass market, and on the quality of the seed.
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CANADA BLUEGRASS

(Poa compressa)

In the United States Canada bluegrass occupies a minor place as compared with Kentucky bluegrass. Where the climate and soil conditions are favorable to the latter, it will be grown instead of Canada bluegrass, as there is no doubt that the Canada bluegrass is definitely inferior to Kentucky. However, it has its place and is of more value under certain conditions than some writers care to admit.

Description: Canada bluegrass is a hardy perennial grass, producing an abundance of creeping rootstocks by which it forms a close turf. It rarely attains a height of more than 24 inches, usually growing from 6 to 8 inches high. It is dark blue in color and resembles Kentucky bluegrass to which it is related. The characteristics readily distinguishing this grass from the latter are its compressed stems which long remain green, the single shoot at the end of each rhizome, and the close, narrow panicles. It also develops about two weeks later than Kentucky bluegrass.

Adaptation: Canada bluegrass was introduced from Europe and is now found commonly throughout almost the entire Kentucky bluegrass region, especially in the New England States, New York, Pennsylvania, West Virginia, and Ohio. In Canada it is rather important, especially in the southern part of Ontario, in the region bordering on Lake Erie. In this section some quantities of seed are produced and exported to the United States.

Canada bluegrass will grow on any kind of soil that will support Kentucky bluegrass and will thrive on some stiff clays and thin gravelly soils where the latter will make but little growth. It is decidedly aggressive, and under conditions that are not favorable for Kentucky bluegrass it excludes the latter almost completely.

Uses: The value of Canada bluegrass is almost entirely as a pasture grass, since it does not grow to a sufficient height to give a profitable yield of hay. The hay which it does produce, however, is of good quality and considered by horsemen better than timothy, especially for race horses. The hay is very heavy and requires a smaller bulk than ordinary hay to make a ton. It is said to produce a slightly laxative effect when fed to stock.

As a pasture grass Canada bluegrass possesses considerable value. In western New York, where the fattening of cattle for market is an important industry, it is a common opinion among the leading
stockmen that good pastures of it are better for this purpose than pastures of Kentucky bluegrass. These stockmen consider it to be more nutritious than the latter when grown under conditions such as exist in that section. It is also valuable as a pasture for dairy cows.

For lawns and golf links and similar purposes, Canada bluegrass can be used to advantage under conditions too dry and otherwise not entirely favorable to Kentucky bluegrass in mixtures with the latter.

ROUGH BLUEGRASS

*(Poa trivialis)*

Rough bluegrass is a native of northern Europe and is one of the abundant and valued pasture grasses of that region. It was early introduced into the United States, probably in mixed seeds, and now occurs generally from the Atlantic to the Pacific. It is common southward as far as Virginia and Missouri.

Rough bluegrass is best adapted to cool, moist soils. In shady places it thrives better than any other turf grass and makes exquisite lawns. During the hot weather of midsummer the grass suffers severely and apparently disappears in open places but again grows actively with the coming of fall. In Canada and the northern tier of States, it remains green all summer; farther southward it becomes dormant in midsummer, except in shady places.

Rough bluegrass spreads by stolons or creeping branches on the surface of the ground. Unlike Kentucky bluegrass, it has no underground stems. The leaves are apple-green in color, giving a very pleasing effect. Even in severe winter weather the leaves remain bright green, while Kentucky bluegrass leaves become very dull in color.

Rough bluegrass is a valuable pasture grass northward, especially on moist lands. It should be more generally used, though it seems to be spreading rapidly by purely natural means. For shady lawns it is far superior to any other grass. In Europe it has been called the "queen of the pasture grasses." The peculiar green color of northern European lawns and pastures, so different from that of Kentucky bluegrass, is largely because of the abundance of rough bluegrass.

In the United States rough bluegrass is used in lawn grass mixtures for shady places. Wherever Kentucky bluegrass is the major component, rough bluegrass is often either added to the mixture or made an important part for use in shady places.

Seed has been produced in abundance in Europe, mostly Denmark. One bushel weighs about 18 pounds. For use on pasture, it is best combined with other grasses. For lawns it should be sown at the rate of 2 or 3 pounds to 1,000 square feet.
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SANDBERG BLUEGRASS
*(Poa secunda)*

Sandberg or western bluegrass is common throughout the northern Great Plains, but the area of major distribution is in the Intermountain Region and Pacific Northwest. It is a perennial bunchgrass that supplies a major part of the range forage during the early spring and remains dry and dormant the rest of the season. It is very drought-resistant and comes up and persists on semi-desert land where other native grasses have disappeared. Growth and seed production take place during the early season when moisture conditions are favorable. The excess leafage produced at this time remains palatable throughout the season, and this plant therefore contributes to the carrying capacity of many of the ranges of the Northwest.

Sandberg bluegrass produces a fair amount of seed; with proper management the stand can be maintained indefinitely. Trials made thus far under controlled conditions indicate that it is difficult to establish this grass from seed. Stands can be established, however, if proper cultural techniques are used.

BIG BLUEGRASS
*(Poa ampla)*

Big bluegrass is the largest of the native bluegrasses found in the intermountain zone of the Pacific Coast States. It was a component of the Palouse bunchgrass prairie. It is a tall tufted grass that is remarkably drought resistant. Many ecotypes occur. They have been isolated and studied, one strain proving to be more generally adapted to wide variations in soil and climate than others. It has been released as Sherman big bluegrass.

This grass makes an excellent hay that is at least as palatable as timothy and smooth brome. It has remarkable root-producing ability, and is planted alone or in mixture with crested wheatgrass in semi-arid areas. The seed is large and is ordinarily produced in abundance, but since the plant reproduces only by seed, it is necessary to adopt range-management practices that will permit natural seeding to take place.

The grass or the mixture is used in rotation with grain for erosion control and improvement of soil structure. It is used in mixtures with alfalfa in rotation with cash crops in some sub-humid areas of the Pacific Northwest. Seedings of big bluegrass have been successful on burned over timber lands. Big bluegrass may be used for pasture after it is completely established. Overgrazing and severe trampling are injurious to native stands of this grass and without proper protective grazing, a range will deteriorate rapidly. The plants in new seedings are pulled up by grazing animals. When the stands are more than two years old, they are sufficiently well rooted to stand grazing.

Nevada bluegrass *(Poa nevadensis)* is closely related to big bluegrass. Meadows
of this grass occur at elevations above 5,000 feet in eastern Oregon and Nevada. These meadows have, for many years, been cut for hay by the ranchers.

**TEXAS BLUEGRASS**

(*Poa arachnifera*)

Texas or plains bluegrass is an important grass on sandy pastures in the eastern part of the southern Great Plains. This dioecious species starts growth extremely early in the spring, goes dormant in midsummer, and renews vigorous growth in the fall. It spreads rapidly by underground stems and makes a fairly dense sward where moisture is plentiful or grazing not too severe. Because of its high palatability and active growth when other plants are dormant, overgrazing has caused its virtual elimination except in the protection of sage and other shrubs, where it still retains the nucleus for rapid recovery.

**BLUEGRASS HIGHLIGHTS**

1. The bluegrasses constitute one of the most important groups of grasses. Kentucky bluegrass, with the possible exception of timothy, is the most widely known grass in America.
2. Kentucky bluegrass is probably naturalized over a larger area than any other introduced grass. It occurs naturally in pastures, along roadsides, and waste places, without sowing.
3. Canada bluegrass, the only other bluegrass in general cultivation, occupies a minor place as compared with Kentucky bluegrass and is definitely inferior to it, but is of value under certain conditions unfavorable to Kentucky bluegrass.
4. For permanent pasture, there is no other grass, native or introduced, so well adapted to so large an area as Kentucky bluegrass.
5. When sown for pasture, Kentucky bluegrass is usually sown with other grasses and legumes at the rate of 3 to 20 pounds of bluegrass seed per acre.
6. Kentucky bluegrass may be sown at almost any time that soil moisture and temperature conditions are right, but early fall sowing is preferable over practically its whole area of adaptation except where cool summers are the rule.
7. Kentucky bluegrass does well with nitrogen fertilization for both pasture and seed production, but this should be balanced with phosphate and potash for permanent growth and should be applied only where and when the moisture supply is adequate.
8. It is usually better for Kentucky bluegrass to get most of its nitrogen through an accompanying legume, along with the other benefits from the legume, than to apply nitrogen fertilizer, except in special cases.
9. Kentucky bluegrass likes limestone soils but usually does well on otherwise fertile soils without lime, but the presence of an adequate supply of phosphate is important.
10. Kentucky bluegrass furnishes most palatable pasture in spring and fall, but dries up during hot, summer months with low moisture and soil temperatures over 80 degrees F.
11. For all-summer pasture in most areas adapted to bluegrass, annual or biennial pasture crops should be sown to supplement the Kentucky bluegrass in midsummer.
12. The old-time closely-grazed, neglected bluegrass pasture is now obsolete on modern farms. Where bluegrass is used it is given the same attention and fertilization as are given to other crops, and the grazing is regulated to the optimum conditions for pasture maintenance.
13. Most nursery-selected and tested strains of bluegrass when grown under field conditions so far have not shown marked superiority over commercial bluegrass.
14. Stripping bluegrass pastures for seed has not had a detrimental effect on forage production but rather has appeared to be beneficial in many cases.
15. Under favorable moisture conditions good bluegrass, moderately pastured before stripping, usually yields from one-half to two-thirds as much seed as ungrazed pastures.
16. Kentucky bluegrass becomes established slowly from seed in pastures so does not show up much the first year.
17. Kentucky bluegrass will survive and maintain fairly good stands on fertile soils under almost any kind of management or weather conditions, and will recover quickly when more favorable conditions are established.
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18. Kentucky bluegrass is the classic lawn grass over a large part of the country because of its beauty, its sod-forming habit, its continued recovery from close cutting, and its ability to survive under almost any conditions. Extreme heat and crabgrass are two of its worst enemies.

19. For lawn or other turf purposes, Kentucky bluegrass is usually sown at the rate of 3 to 5 pounds to each 1,000 square feet of area, but under favorable conditions and uniform distribution, a much lower rate is adequate. Unless a quick cover is desired, it is best to sow alone without any other strong, quick-growing grasses, such as redtop or rye grass, being sown with it. White clover, if desired, may be added in proportion of one part clover to five parts bluegrass.

20. The average annual harvest of Kentucky bluegrass seed the past ten years has been about 37,000,000 pounds, or about one-third larger than the average of the previous ten years.

21. The Western district of bluegrass seed production now produces 7 to 8 times as much seed as the older Kentucky district.

22. The average yield per acre of cured Kentucky bluegrass seed for the past 16 years was nearly 7 bushels in the Kentucky district, and 5.6 bushels in the Western district, or an average for the United States of 5.8 bushels per acre.

23. Kentucky bluegrass seed is mostly harvested by large power strippers operated in large numbers in producing areas by large contractors who not only contract acreages but also buy green and cured seed from farmers.

24. Much care is required in curing seed in yards and sheds to prevent spoilage by heating and resulting loss in germination.

25. The stripping, curing, cleaning, storing, and marketing of Kentucky bluegrass seed is altogether one of the largest field seed projects handled almost entirely by a highly specialized seed industry.

This chapter is a digest of material from many sources. The published material used is largely from Hein (US·83), King (MO·16), Whitman and Stevens (ND·15), Brown (MO·6), Brown and Munsell (CONN·13), Garman and Vaughn (KY·14), and Ahlgren et al (WIS·2). The section on seed production was prepared largely from material in the Missouri and Kentucky bulletins, supplemented and revised by Geo. C. Edler of B.A.E. who, nearly every year for over 30 years, has covered the areas of bluegrass seed production during the seed harvesting season and has issued the U.S.D.A. seed crop and market reports on bluegrass. The preliminary manuscript was reviewed by Brown of Missouri, Fergus of Kentucky, Hafrichter of the Soil Conservation Service, Sprague of the U.S. Regional Pasture Research Laboratory, and Edler. The final manuscript was reviewed by Hein.

Chapter reference numbers: 1 CONN·13; KY·1, 4, 14, 16, 28, 29; MD·1, 10; MICH·11; MINN·14, 20; MO·6, 16; NJ·22; ND·15; OHIO·15; PA·16, 18, 21; TENN·11; VA·4; WIS·11, 25, 34; US·33, 77, 83, 89, 115, 119, 183, 204, 217, 267; MISC·13, 59.

1 The reference numbers given here refer to references which are given in full by State, U.S.D.A., and Miscellaneous, on pages 682 to 724, and which are cross-referenced by author on pages 725 to 731. Citations in the text are indicated by abbreviation and number in parentheses.
Grasses of the brome genus are found mostly in the North Temperate Zone. About 43 species are native to the United States. Some of our most important forage species belong to this genus—and also some of our most troublesome weeds. Most bromes are highly palatable—even the weedy bromes, during their period of most active growth. Smooth brome is by far the most useful of the bromegrasses as a forage crop and has become in recent years one of the outstanding forage grasses in the United States, particularly in the midwestern States.

Leaf blades of the bromes are characteristically flat, and the edges of the sheath grow together to form a tube. The seed heads are usually more or less open and spreading, forming panicles. The tip of the rather rigid lemma is notched into two teeth, between which the awn arises.

SMOOTH BROMEGRASS
(Bromus inermis)

Smooth Brome, more commonly known as "bromegrass," is one of the more productive, nutritious and palatable forage grasses in the Central and Northcentral States. Because of its outstanding performance during the drought years of 1934 and 1936, interest in this grass was greatly stimulated. Many bluegrass pastures in this area were seriously damaged or completely killed during that period when bromegrass survived. Bromegrass is now being sown by farmers in all sections of this large area, mostly in combination with alfalfa, many farmers growing it for the first time. The rapid expansion in acreage during the past 10 to 15 years reflects the increased appreciation of the value of this grass for pasture and hay, and as a soil-conserving crop.

Bromegrass has been known to botanists for nearly 200 years but its value as an agricultural crop was not appreciated until comparatively recent times. Stébler and Schroeter stated in 1884 in their publication "The Best Forage Plants" that bromegrass had been grown experimentally at Magocs, Hungary, for a period of thirty years, but was only then beginning to be used on farms as a pasture crop.

Bromegrass (Bromus inermis) is known by a number of common names: brome, awnless brome, smooth brome, Russian brome, Austrian brome, and Hungarian brome. It is a native of Europe, occurring naturally from France eastward into Siberia and China.

So far as can be determined from the available records bromegrass, presumably of Hungarian origin, was first introduced into the United States about 1880 by the California Agricultural Experiment Station. By 1884 the California Station offered packets of seed to farmers and others for trial plantings. In 1896 the United States Department of Agriculture distributed 603 packets of bromegrass seed of Russian origin to experimenters in 43 States. Among other early importations by the United States Department of Agriculture was one in February, 1889, from the Penza Province in the Volga River region of Russia, where it was reported to flourish with an annual rainfall of less than 13 inches. A large share of these early importations was distrib-
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uted throughout the midwestern States. There were many other importations of bromegrass from Russia, but they did not find continued favor in the southern portion of what is now the bromegrass-growing sections of the United States. These Russian types were adapted to the northern Great Plains, while the Hungarian type was found best adapted in the latitude of Kansas and Nebraska.

The early importation and distribution of bromegrass led to the natural development of regional strains, such as the Lincoln, Achenbach, Fisher, and Elsberry strains now produced in Nebraska, Kansas, Iowa, and Missouri. These were presumably derived from the original California importation because that type is known to have been widely distributed in the Midwest prior to the importations from Russia.

DESCRIPTION

Bromegrass is a long-lived perennial, as is clearly evidenced by the fact that some fields in the westcentral and northcentral States are now 25 to 50 years old. Newly established stands spread rapidly by means of rootstocks to produce a heavy sod which is less dense at the soil surface but considerably deeper than that produced by Kentucky bluegrass. Under favorable conditions it tends to crowd out other species of vegetation. The marked drought resistance of bromegrass together with its tolerance to heat, make it better able to continue growth during the hot summer period than Kentucky bluegrass.

After two or three years in solid stands, bromegrass is likely to develop a "sod-bound" condition. The plants become stunted, yellowish in color, and yields of forage and seed are reduced. This condition is due largely to a lack of available nitrogen. It occurs under favorable as well as unfavorable moisture conditions but its effects are no doubt intensified by prolonged periods of drought.

The seasonal growth habits of bromegrass are similar to Kentucky bluegrass in that it starts growth early in the spring and reaches peak production in June, after which it falls off somewhat until cooler weather returns in the autumn. Mature plants vary in height from 2 to 4 feet, depending upon the variety, the fertility of the soil, and the supply of available moisture.

The seeds are borne on rather large spreading panicles from 4 to 6 inches in length which emerge from the boot in early or middle June. These panicles, as they emerge from the boot, elongate until they extend well above the upper leaves of the plant and of the alfalfa, with which the crop usually is grown. The seed is ripe and ready to harvest in the Central States by early or mid-July, by which time the panicles have lost their green color and become dry and gray to brownish in color.

Bromegrass seeds are flat and relatively large, light and chaffy. Commercial seed usually weighs 14 pounds per bushel. Seeds of smooth bromegrass are easily eaten by domestic livestock when properly prepared.
distinguishable from those of the wild or annual types, which are awned and have the edges rolled in, instead of being flat.

Bromegrass seedlings may be identified by their long, narrow, hairy leaves, which usually are gently twisted in a clockwise direction. If a seedling is carefully removed from the soil with a knife and examined, the seed usually is found attached to the base of the stem and may serve as a means of identification. As the plant becomes older, the first or lower leaf sheaths wither and die; the new leaves are broader and less hairy. A slight growth constriction may occur on these leaves, forming a configuration resembling an “M” or a “W.” This characteristic, however, is not always evident. Inability of growers to identify bromegrass seedlings often has resulted in indecision as to the need for making another sowing.

ADAPTATION

Climate: Bromegrass is especially well adapted to a dry or semihumid, cool climate. At the same time it does relatively well under moderate conditions of heat during part of the year. It has proved best adapted to those areas in this country in which the native vegetation was the tall or medium-tall grasses. In recent years bromegrass has come into prominence in the central and eastern Corn Belt States and is being used extensively for both pasture and hay. It is ordinarily recognized as one of the best of the introduced grasses for the prairie provinces of Canada, south through the eastern part of the Northern Great Plains, and into the Northcentral and Central States.

It is used for pasture in combination with alfalfa and other legumes in the northeastern United States because of its high palatability and other desirable traits, but in much of this region orchardgrass is preferred because of its greater productivity, even though of lower palatability.

It is also well adapted to the Palouse area of eastern Washington and adjacent Idaho, and to the irrigated valleys of northern Washington where it is used primarily with alfalfa or Ladino clover.

Soils and moisture: All of the major soil types in the region to which bromegrass is adapted are suitable for bromegrass. The best soils are the deep silt loams, but bromegrass also does well on light sandy soils. Since it requires a readily available supply of nitrogen, the soil should be fertile. Soils low in nitrogen may need a heavy application of nitrogen fertilizer. Bromegrass possesses some degree of tolerance to alkali, but is surpassed by western wheatgrass in this respect. Short periods of flooding are withstood in a satisfactory manner and the grass will emerge through a considerable deposition of silt.

ESTABLISHING AND MAINTAINING A STAND

Rates of sowing and mixtures: Mixtures and rates of sowing may vary greatly. The region, soil type, and use of the crop all are factors which influence the mixture and rate to be recommended. Where the crop is to be used for hay, the proportion of alfalfa to bromegrass should be greater than where the crop is to be grazed. Ten to 12 pounds of bromegrass and 4 to 6 pounds of alfalfa is a good mixture when the crop is to be pastured or harvested for seed, whereas for hay, about 10 pounds of alfalfa and 6 to 8 pounds of bromegrass is to be preferred. In regions where alfalfa is particularly
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...as well adapted, the sowing rate for alfalfa may well be less than in other sections where it is not so well adapted.

Both sweetclover and red clover are used with bromegrass in short rotations in which the grass is not continued for more than one year after the year of maximum production of the legume or two years after the year of sowing both grass and legume.

When sweetclover is grown in association with bromegrass for pasture, a good mixture is about 8 pounds of sweetclover and 8 to 10 pounds of bromegrass per acre. The use of red clover or alsike clover is recommended when the soil is inclined to be acid, as they are more tolerant to this condition than either alfalfa, Ladino clover, or sweetclover. Red clover, like sweetclover, is quick to develop, will provide some grazing the year of sowing, and assure full production the following year. A good mixture for pasture consists of 8 to 10 pounds of bromegrass and 6 of red clover. If the soil is not acid alfalfa or Ladino clover may replace a part of the red clover.

Methods of sowing: Bromegrass seed is light and chaffy and difficult to sow with the ordinary mechanical seeders. It is helpful to have good, clean seed free of sticks or chaff. Some types of grain drills equipped with an agitator in the seed hopper work satisfactorily. Mixing the seed with oats or cracked corn facilitates feeding through a drill. The main caution to observed with the drill is to set it very shallow or to remove the spouts and allow the seed to be broadcast on the surface. Failure to obtain a satisfactory stand has often been traced to covering the seed too deeply.

Drill sowing is decidedly preferable to broadcasting, but where drilling is not feasible, the seed may be broadcast. In either case, special emphasis should be given to having a firm seedbed and packing the soil after sowing.

For broadcasting the endgate seeder is generally available and may be used. One method is to pour the bromegrass seed into the hopper from a bucket just about as fast as it is being broadcast. If the hopper is filled, seed will "bridge over" and fail to feed through. The proper rate of pouring can be determined with a little experience. Another procedure is to mix the bromegrass with oats. The use of a grain companion crop, however, is not advised for dry areas. When used, the oats help greatly in working the seed through the opening, and being heavier than bromegrass are distributed about twice the distance of the bromegrass. It is necessary, therefore, to make the lands only about half the usual width. In adjusting the broadcaster, the rate of sowing the oats, therefore, is reduced to one-half the usual rate to allow for the overlapping. The alfalfa may be sown separately or at the same time, when a grass seeder attachment is available. Since alfalfa seed distributes itself about the same distance as oats, the seeder should be adjusted at half the required rate to compensate for the double sowing.

Small acreages can be sown most easily by hand, but when this is done it is well to go over the field twice, at right angles, to insure an even seed distribution.

Depth of sowing: The seed of bromegrass, as well as all small-seeded grasses and legumes, should be covered to a depth of only 1/4 to 1/2 inch. The bromegrass seedling has a rather weak shoot which has difficulty in pushing its way through the soil. Ordinarily, harrowing or rolling after broadcasting the seed will cover it sufficiently. For dry situations, the experience of farmers indicates that a somewhat deeper sowing may be more satisfactory. When sown very shallow, light rains may germinate the seed, but the surface soil dries out before the roots have penetrated deep enough to maintain the seedlings.

Spring sowing: Spring sowing of bromegrass and alfalfa (or other legumes) should be made as early as weather and soil conditions permit, which, in the Central States, is usually late March or early April. Sowings made at this time generally follow corn in the rotation and are made with oats as a companion crop. The advisability of using small grain and the method of handling it will depend upon the farmer's own experience in getting stands, and the area in which he lives. A light sowing of oats will often...
make it possible to obtain a crop on the land while grass is being established, and at the same time check severe weed competition, which often is more detrimental than that of the small grain. The sowing rate for the oats preferably should be not more than 6 to 8 pecks per acre. In some places, where lack of moisture may be the limiting factor, best results are reported when spring sowings are made without a companion crop.

Late summer sowing: Wherever conditions favor sowing in late summer, this is best done as soon after August 15 as moisture conditions permit. This usually is not before September 1, but the earlier the sowing is done after this date, the better for winter survival and satisfactory production the following year. Late summer sowing is generally done following a small grain crop. Early preparation of the seedbed is a factor of extremely great importance. Ordinarily the seedbed is prepared by periodic disk ing to control weeds followed by harrowing and rolling prior to sowing. Plowing usually is not desirable because of the excessive loosening and drying of the soil. When disked, some protection against erosion is afforded by the stubble which is left partially on top of the ground. When the disk ing method is used it should be started soon after small grain harvest to keep weeds under control, in this way conserving soil moisture. A finely pulverized and well-compacted seedbed is equally as important following disk ing as following plowing. On sloping land, all tillage operations including disk ing, harrowing and rolling, should be performed on the contour.

Great difficulty has been encountered in establishing grasses and legumes on infertile, steep slopes. A procedure which has had some success in such situations is to sow in late summer following second-year sweetclover. The sweetclover enriches the soil and provides a good protective mulch in which to sow the grass seed. Soil moisture conditions generally are good following second-year sweetclover. Initial steps in seedbed preparation should be started before the sweetclover stems rot off at the base. The heavy top growth is broken down by repeated working with a heavily weighted disk set to cut nearly straight. The objective is to cut up the stems, leaving them largely on top of the ground. The bromegrass seed is broadcast in this mulch and covered by light disk ing and rolling.

Bromegrass also can be established in old alfalfa fields which have begun to thin. This is a rather difficult process and is ordinarily not recommended. The high nitrogen level of the soil undoubtedly contributes much to its success. This can be done in late summer or in the very early spring following treatment with a spring-tooth harrow.

Fertilization and lime: The beneficial effect of liming acid soils and the use of phosphate fertilizers is associated primarily with the efficient production of legumes, such as alfalfa and sweetclover. Applications of lime preferably should be made at least 6 months in advance of sowing. Lime requirements are determined by a simple soil test. The legumes in the mixture respond well to the application of phosphate fertilizer on many soils. Applications of the phosphate are best made at the time the alfalfa-bromegrass seedbed is being prepared so that it will be thoroughly worked into the soil. If not done then, and the soil fertility is low, good results have been obtained from the use of a 10-20-0 fertilizer at time of sowing. Rates of application usually are from 200 to 300 pounds per acre of 20 percent superphosphate or its equivalent.

Manure, applied as a top dressing immediately after sowing is very helpful in insuring a good stand. This is particularly true on thin, eroded spots in a field where difficulty has been encountered in obtaining stands.

Field care: The newly established stand should be managed so as to obtain maximum development of the seedlings. Early removal of the small grain companion crop, either by grazing or cutting for hay, is helpful. If the bromegrass was not sown with oats and weeds are prevalent, the field should be clipped to reduce weed competition. Close grazing in the fall is very harmful to new stands.

Neither bromegrass nor alfalfa can
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withstand grazing as closely as is customarily practiced with Kentucky bluegrass. Severe overgrazing has prevented many stands from ever attaining satisfactory production. A good rule to follow is never to graze closer than shoe-top height. Difficulty with spotted grazing is often encountered, however, when such a procedure is followed. When two or three pastures are available good results are obtained when the livestock can be rotated from one to the other, allowing a good recovery following each grazing period.

The autumn season is the best time to “rebuild” the vigor of grass. This is done by allowing growth to accumulate through the fall season. It is at this time that grasses store food materials in the roots for growth the following spring. If, because of close grazing, the grass is not permitted to develop these food reserves the next season’s growth is materially reduced. Meadow aftermath and stubble fields frequently can be used for pasture while bromegrass is given an autumn rest.

Maintenance of alfalfa in bromegrass: Maintaining alfalfa in bromegrass has been something of a problem in semi-permanent and long rotation pastures. It has been clearly demonstrated that bromegrass does not drive out the alfalfa, as is generally believed. Rather, bacterial wilt thins the stand of alfalfa, which may be hastened by overgrazing, and bromegrass simply takes over the space vacated by the alfalfa.

In an experiment at Ames, Iowa, to determine the effect of cutting treatment on the relative stand of bromegrass and alfalfa, a stand was established using approximately 8 pounds each of bromegrass and alfalfa. During the next two years one series of plots was cut four times per season while another series was cut only two or three times per season. Separations of the forage into the two components showed that the more frequent cutting resulted in a more rapid increase in the percentage of bromegrass, with a corresponding decrease in alfalfa than when the forage was harvested at the normal hay stage. These data indicate that the more frequent or more severe the harvest treatment, the more rapidly the grass will increase at the expense of the alfalfa.

With either cutting treatment, however, a satisfactory stand of both the alfalfa and the bromegrass remained at the end of 3 years. When seed of the new wilt-resistant alfalfa varieties becomes generally available it would appear possible to maintain alfalfa in bromegrass-alfalfa mixtures successfully for 5 or more years.

Renovation of stands: An unproductive field of bromegrass too steep to plow for a clean-tilled crop can be improved by the introduction of such legumes as sweetclover, alfalfa and red clover. It is important that the sod be well torn up before sowing the legume. This can be done with such equipment as a weighted disk, a springtooth harrow, a field cultivator or a plow, in order to work the sod thoroughly, to reduce the competition of the grass while the legume is re-established.

It usually is desirable to do part of the tillage to subdue the grass in the late fall after the bromegrass has been grazed rather closely. If the soil requires lime,

Alfalfa-bromegrass mixture.
it should be applied before these tillage operations. If seepy areas are present in the field in the early spring, these usually can be sown with fair results without further disk ing. The legume is sown in the early spring after additional disk ing or springtooth ing. On low-fertility soils, 200 to 300 pounds of 20 percent superphosphate, or its equivalent, should be applied and mixed with the soil during these tillage operations. Following sowing, the field should be harrowed and rolled to cover the seed and firm the soil. Heavy disk ing greatly reduces seed and forage yields in this first season. However, where legumes are sown in grass, the disk ing greatly improves the stands by reducing the competition of the grass. The legumes do not increase yields the year they are established but may be expected to in subsequent years. Grazing should be carefully controlled the year the seedlings are established to allow for maximum development of the legumes.

It is possible also to increase greatly the returns from sodbound bromegrass by top dressing in the early spring with nitrogen fertilizer. The application of 150 pounds per acre of ammonium nitrate on sod-bound bromegrass was found to more than double the yields of seed and forage in Iowa.

UTILIZATION

Pasture: Bromegrass sown in mixtures with legumes, and properly managed, provides excellent rotation pasture. The value of such pasture in livestock production can hardly be overemphasized. Bromegrass-legume combinations provide an economical source of protein for livestock.

The length of the rotation may vary, depending upon the kind of soil, the steepness of the slopes and the forage needs. On extremely erodible soils, pastures should be left down for as long periods as possible, plowing only when the legumes grown with the grass need to be re-established.

For pasture, bromegrass may be sown in mixtures with sweetclover, red clover, Ladino clover, or alfalfa, singly or in combination. On a non-acid soil sweetclover and Ladino clover may be expected to give a large production and to persist by sowing through a period of years. If the crop is to be harvested as hay for a year or more before it is grazed, alfalfa is much to be preferred. Red clover is better suited on soils inclined to be acid, but red clover is likely to persist for so short a period that the grass will soon become sod-bound and unproductive.

The greatest production usually is not obtained in the first season after sowing. This fact makes the use of bromegrass-legume mixtures questionable for rotations in which the grass is to remain down for one year only. A number of farmers, however, are using bromegrass-alfalfa mixtures in four and five-year rotations of corn-oats-meadow-meadow or corn-corn-oats-meadow-meadow. It seems likely that the use of bromegrass in such rotations in regions where bromegrass is particularly adapted will become increasingly popular as seed supplies of the better adapted varieties become plentiful.

The inclusion of bromegrass with alfalfa will materially reduce the erosion hazard. Bromegrass has the ability to thicken and fill in as the alfalfa thins out.

It has been observed, also, that grass grown in mixture with a legume may be expected to reduce the loss of the legume by soil-heaving during the winter, especially on the more impervious soils where heaving losses may present a serious problem. On some farms meadows are turned into pastures as soon as the proportion of alfalfa to bromegrass is reduced to the point where the bloat hazard ceases to be important.

Hay: The time to cut bromegrass-alfalfa mixtures for hay should be determined by the stage of growth of the alfalfa. In the Central States three cuttings ordinarily may be harvested, each being made when the alfalfa reaches the early, or approximately one-tenth to one-quarter bloom stage. A top growth of 8 to 10 inches should be present when the stand goes into the winter.

A hay crop of fair quality can be harvested from fields following the harvest of a bromegrass seed crop with a combine. The bromegrass seed heads extend
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well above the alfalfa. The alfalfa and
the leafy portion of the grass, although
somewhat too mature to make the best
quality hay, is nutritious and is relished
by horses and other mature livestock.
The bromegrass-alfalfa field after seed
harvest may be utilized also to provide
good pasturage at a time when other
pastures are likely to be unproductive.

Silage: The silo is a good place to con-
serve excess bromegrass-legume pasturage
which may be available during spring
seasons of lush growth, or when the
weather conditions are unfavorable for
curing hay. Silage of this kind is high in
both carotene and protein content, pro-
viding a feed particularly attractive in late
winter. Some dairymen, however, prefer
using it as a part of a midsummer ration
when pastures may be dry and unpalat-
able.

For good preservation the moisture
content of the bromegrass and alfalfa
should be about 65 percent when it goes
into the silo. The safest procedure is to
use a conditioner. From 40 to 60 pounds
of molasses per ton of green forage has
given good results. About 125 pounds
of ground shelled corn or 150 pounds of
corn and cob meal per ton also is a satis-
factory conditioner to mix with the grass
and legume silage. The fresh cut grass-
legume forage is likely to contain about
70 percent of moisture. It is not an un-
common practice to put the grass-legume
mixture into the silo without using any
conditioner, but when this is done it is
important to allow the material to wilt
well in the field after cutting, to chop it
finely, and to pack it well in the silo.

Erosion control: Grassed waterways are
essential to good land use on rolling land
subject to erosion. The spreading root
system of bromegrass, together with the
surface protection it affords, makes this
good an excellent one for use in water-
ways and terrace outlets that are nor-
mally well drained.

Probably the best time to establish
bromegrass in waterways is when the field
or watershed is sown to a small grain
crop such as oats. In some areas, water-
ways are difficult to establish by the
sowing of grasses because of continuous
washing. Here it may be helpful to first
grow a stabilizing crop, such as broadcast
corn, sorghum or Sudan, which should
be dead or killed by tilling before sowing
the bromegrass. The bromegrass seed
can be drilled into the stubble of the
stabilizing crop in late August or early
September. The bromegrass should be es-
tablished in the waterways before any
terraces are constructed so there will be
some place to "dump" the water.

The rate of sowing bromegrass for
waterway and terrace outlet seedings
should be nearly double the normal rate,
or about 25 pounds per acre. This is
because of the need for a quickly devel-
oped, heavy sod under conditions that
are often unfavorable for establishment.

Field borders often contribute little in
the way of actual production and they
also present an erosion hazard because of
the necessity of cultivating in one direc-
tion only. These difficulties may be large-
ly overcome by sowing a 15- or 20-foot
border of bromegrass-legume mixture
around the entire field, the crop from
which may be harvested or grazed later in
the season. Subsequent management of
brome waterways and field borders is im-
portant. Proper mowing and fertilizing
are required to maintain them in useful
condition.

Weed control: The establishment of
bromegrass in fence rows will also, in
time, largely control the weeds which
usually flourish there. State and Federal
highway administrators are adopting the
practice of sowing roadsides as a means
of decreasing maintenance costs by con-
trolling roadside gullies and weed growth.
Bromegrass-legume mixtures are excel-
lent for this purpose, and in many cases
high maintenance costs are reduced after
their establishment because farmers mow
the roadsides for the hay crop. Some
farmers are sowing roadsides adjoining
their farms, not only to improve the ap-
pearance, but for the hay which can be
obtained.

Nearly every farm has a few waste
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expense, but weeds on these areas may add many times to the cost of maintenance of adjoining fields in later years. In such situations bromegrass may serve a useful purpose in controlling weeds.

**VARIETIES AND STRAINS**

Two types of bromegrass: Since bromegrass introductions into the United States have been from two major sources, Hungary and Russia, it is not surprising that two rather distinct types are now found in this country. The Russian type has found its place in our Northern States and Canada, while the type from Hungary and France has been found best adapted in the Corn Belt. It is now grown extensively in Illinois, Iowa, Nebraska, Missouri, and Kansas, as well as in surrounding areas.

The two types differ slightly in appearance. Northern bromegrass spreads less vigorously by underground rootstocks and is, therefore, more of a "bunch type" in appearance. Seed heads of northern bromegrass are more open and erect, but this difference is not always clearly apparent. Seed of northern bromegrass is darker in color and less chaffy than that of the southern types, and is, therefore, more attractive to the seed trade. It is more easily drilled because of the lack of chaffiness and this appeals to growers. For this reason, it has been easy to sell northern bromegrass seed in the southern part of the bromegrass region in spite of the fact that it is not the best bromegrass for that latitude. Extensive tests at the Nebraska, Kansas and other experiment stations have shown that the performance of northern bromegrass under conditions which exist in the southern Corn Belt, is entirely unsatisfactory.

Southern bromegrass, on the other hand, has never become widely used in the Northern States. It is fully winter-hardy as far north as North Dakota and is adapted to southern Minnesota, but northern growers have usually preferred the types with less vigorous rootstocks because they have felt that the rapidly spreading southern types grow so vigorously as to crowd out legumes and other grasses in pasture mixtures. Furthermore, the southern types tend to become "sod-bound" more quickly than do the northern types under northern conditions.

**Northern varieties:** Strains of bromegrass which do not develop as extensive a rootstock system as common brome, have been selected in Canada, North Dakota, and other northern States. These strains are referred to as "non-creeping" brome. A non-creeping strain, "Parkland," which is somewhat less aggressive than common brome, has been developed in Canada, and seed of this strain is available on the market. It is claimed that Parkland brome is somewhat finer-stemmed and more leafy than common brome, but it has seemed to be less vigorous and not as productive when grown in the States. (ND-15)

Martin bromegrass, a variety developed at the Minnesota Agricultural Experiment Station, is a combination of 21 clonal lines selected from seed collected in 1936 from an old brome stand in Martin County, Minnesota. Under Minnesota conditions Martin is intermediate in habit of growth between southern strains and Canadian brome.

Manchar bromegrass was released by the Washington and Idaho Stations in 1946 for use in the Palouse area of eastern Washington and northwestern Idaho, and the irrigated valleys of northern Washington. Like Martin brome, it is intermediate in habit between the northern and southern strains of bromegrass. It is a tall-growing type with leaves well up the culms; the plants are vigorous and slow in forming swards. It has more seedling vigor than the true southern-type smooth bromes such as Achenbach, and because of its semi-bunch habit it doesn't compete so vigorously with alfalfa.

Strain 404, developed at Mandan, North Dakota, and now under test there, has been found to be more adaptable and higher in protein in all stages of growth than Lincoln but is not a high yielder or aggressive.

**Southern varieties:** There are four southern varieties of bromegrass—Achenbach, Fischer, Lincoln, and Elsberry, which have performed so much alike in most comparative trials in the Central States.
that there seems to be little basis for a choice among them. Any one of the four would appear to be considerably superior for most uses in the Central States to the Canadian or Northern type.

Lincoln originated from several old fields in Nebraska that were found by plot tests to be of similar type and superior productiveness. These foundation fields are thought to have been derived from the earliest plantings in the State of the seed of Hungarian origin. Two of these original plantings, still in existence, were made prior to 1898.

Achenbach is the name given by the Kansas Station to a variety increased from a field on the farm of Achenbach Brothers, Washington County, Kansas, known to have been in production for more than 40 years.

Fischer bromegrass is from an old field established by E. A. Fischer on his farm near Shenandoah, Iowa, in 1917, with seed purchased from Ohio. It shows considerable uniformity in plant type, is tall, leafy, persistent, and a good seed producer in Iowa.

Elberry was selected from among a number of other bromegrass strains obtained from various sources and tested in the Soil Conservation Service Nursery, Elberry, Missouri. Its performance there was the best of those tested. The original seed came from northwestern Missouri or southwestern Iowa.

Among other strains now under test are two from Nebraska. Nebraska 36 is a selection of the Lincoln type which shows much refinement in plant characters over Lincoln and is outstanding in forage production and in large production of high quality, heavy seed. Nebraska 44 is a synthetic which has been tested at Nebraska and is now being increased for further trial. It also shows superiority in both forage and seed yields.

From the field tests made at the University of Nebraska of bromegrass strains obtained from Canada, North Dakota, Nebraska and Kansas, Newell and Keim (Neb-17) state that "on the basis of their origin and performance, the strains tested were placed in two general groups here referred to as northern and southern types.

"The strains of southern type produced more vigorous seedlings under short days of fall and early spring, were more tolerant of drought and heat, possessed more vegetative vigor, and were more productive under the conditions of this test than the strains of the northern type.

"Southern strains produced a larger percentage of their total forage in early spring than the northern strains. Under the conditions of this study, the designations "early" and "late" are thus suggested for the strains of southern and northern type, respectively. The southern or early strains are preferred in the region served by these tests, since the relatively low production of late-producing strains may be further curtailed by recurrent spring and summer droughts.

"The results of this study show that variations in bromegrass similar to the variations in other cross-pollinated crops, occur from farm to farm as well as between regions. These variations appear to have resulted from the selective effects of environmental factors operating both before and after the introduction of this grass into the United States."

At the University of Wisconsin, Ahlgren et al (Wis-2) have reported the observations made by them of a study made, in cooperation with the United States Department of Agriculture, of 12 bromegrasses obtained from various sections of the United States and Canada.

"The study suggests it may be possible to select strains which will be more suitable than most of those grown at present. At least two or more strains probably will be needed, since no single strain appears to do best in all parts of Wisconsin.

"Among the findings were these:

1. Southern types of bromegrass began growing much earlier in the spring than northern types, and in general were more vigorous.

2. Northern bromegrass recovered better following grazing or mowing, compared with southern types.

3. In the total yield of alfalfa-brome-
glass mixture produced, differences among the various strains of bromegrass were rather small. Where bromegrass grew vigorously there was less alfalfa, and in plots seeded to slower-growing bromegrass the alfalfa produced enough extra yield to help make up the difference.

"Although alfalfa tends to make up for some lack of vigor in bromegrass in seedings one and two years old at Madison, this does not necessarily mean it is unimportant what strain of bromegrass is used. There may, for example, be marked differences in the length of time the alfalfa will last, and in the productivity of the mixture in later years.

"In brief, if alfalfa-bromegrass mixture is to be grown as efficiently as it can be, it will be necessary to determine over a period of years which strains of brome are best adapted to the soil and climate in various sections of Wisconsin, and then concentrate on growing those strains."

At the University of Minnesota, Thomas and McPherron (Minn-21) have reported the results of their experiments on bromegrass from 1944 to 1948. Data are given on three-year average forage yields of 16 brome strains at seven locations in Minnesota. Southern bromes are clearly superior in forage production in the southern part of Minnesota and appear to be as good or slightly better in the northern part. In comparable trials for seed production the northern bromes appear to be superior to the southern. The northern area represented by the tests is lower in temperature and rainfall than the southern.

At each of four southern Minnesota locations over a 3-year period, Lincoln, Achenbach, and Fischer, the three highest yielders, averaged about 50 percent greater forage yields than the average of the three lowest which include Canadian Commercial, South Dakota Commercial, and a Canadian selection. At each of three northern Minnesota locations, Lincoln and Achenbach outyielded the other 14 varieties or selections, but the average yield of these two varieties was only 32 percent greater than the average of the two lowest, and 12 percent greater than the same Canadian Com-
mmercial which was one of the lowest-yielding in the tests at the four southern Minnesota locations.

Seed yields were obtained from six locations with varying numbers of years from one to four. Only four strains were included in this study. Considering Canadian Commercial as 100 percent, the other three yielded as follows: Martin, 91 percent; Parkland, 80 percent; and Fischer, 63 percent.

At Wasco, Minnesota, in other trials, forage yields of brome-alfalfa mixtures from two cuttings were also obtained. In these tests, 6 pounds of Ladak alfalfa were sown with Martin, Fischer, and Canadian Commercial brome at the rates of 8 pounds and 4 pounds per acre for the brome. For comparison Ladak alfalfa was also sown alone at 8 pounds per acre. There were no very substantial differences in total yields from the two cuttings of the different combinations, but in the third season the stand of alfalfa from the 3 varieties averaged 15 percent greater with the 4-pound sowing of brome than with the 8-pound sowing, and the stand of grass average 8 percent less with the 4-pound sowing than with the 8-pound.

Where alfalfa was sown alone the stand of alfalfa was 63 percent, and the remaining growth was weeds. It is interesting to note in the report of these trials the almost total absence of weeds and bare ground in the brome-alfalfa mixtures as compared with an average of over 3 percent weeds and over 5 percent bare ground in similar trials with alfalfa-timothy mixtures at 4 and 2-pound rates of sowing for the timothy, and 35 percent weeds and 2 percent bare ground where alfalfa was sown alone.

SEED PRODUCTION

Although bromegrass-alfalfa mixtures are primarily sown for forage, a large percentage of the bromegrass seed crop in the Central States is harvested from such mixtures. Highest yields of seed are produced from relatively new stands in which both bromegrass and alfalfa have become well established. Often in the first crop year, the alfalfa will predominate and the
bromegrass seed yield under such conditions will be light. In wet seasons, however, the grass may grow rapidly and produce an excellent seed crop the first year. Old fields, from which almost all of the alfalfa has long since disappeared, produce low yields of bromegrass seed. In many instances, the more profitable yields of seed would be obtained if more recent seedings, still containing a good stand of alfalfa, were harvested.

Sowing for seed production: Since most bromegrass seed is produced from fields that are grown primarily for forage, no special methods of sowing in such cases are followed. However, a few growers producing seed of improved varieties have adopted the method of sowing bromegrass in rows varying from 24 to 30 inches apart. When row-spaced in this way, sowing in the spring with a nurse crop is complicated and difficult. The method of row-planting the crop recommended in Michigan is to mix bromegrass and oats in equal parts by volume, plug necessary holes in the drill properly to space the rows, and sow in early August.

In Michigan a mixture of 5 to 7 pounds of bromegrass and 6 to 8 pounds of alfalfa per acre, either drilled or broadcast, has proved satisfactory for bromegrass seed production, as well as for hay or pasture. If bromegrass is sown in rows 28 inches apart for seed production, from 2 to 2½ pounds of seed will be required per acre. If rows are 28 inches apart and ½ bushel of oats is mixed with each ½ bushel of bromegrass seed, each acre will require approximately 4 pounds of oats.

Fertilization for seed production: If sown with alfalfa, the field should be fertilized as required to meet the needs of the alfalfa. If bromegrass is sown alone for seed, a complete fertilizer or one high in phosphorus and potash such as an 0-20-20, 0-14-14, or similar analysis, applied at the rate of 300 to 400 pounds per acre, may be desirable. Nitrogen should be applied annually as a top dressing in early spring.

Bromegrass requires readily available nitrogen in the spring, and if this element is lacking, a low yield of seed results. When grown in mixture with alfalfa, the bromegrass utilizes the nitrogen supplied by the alfalfa. When grown alone, the nitrogen must be applied as fertilizer unless the soil is already rich in this plant food element, as on muck. When the nitrogen supply is excessive and conditions are favorable for rapid growth, the bromegrass lodges and prospects for a good seed crop are materially reduced.

In the Michigan trials bromegrass, grown in rows and cultivated, produced twice as much seed per acre as that grown in broadcast plots when no fertilizer was applied. Nitrogen applied either in fall or spring was beneficial, but too much nitrogen caused lodging and substantial reduction in yields. Lodging was very severe on plots receiving 800 pounds of fertilizer in early spring, and some plots receiving 400 pounds per acre lodged severely. When lodging was not a factor, 200 pounds of ammonium sulfate per acre on cultivated plots, and 400 pounds per acre on broadcast plots, were the most practical rates of application. When lodging was a factor, the 200-pound rate was best for both row and broadcast plots.

Bromegrass grown in combination with alfalfa produced an average of 174 pounds of seed per acre, as compared with 121 pounds per acre for bromegrass grown alone in broadcast plots, or an increase of 44 percent for the four-year period. Bromegrass grown in rows and cultivated averaged 222 pounds per acre, as compared with 121 pounds per acre for bromegrass that was broadcast, or an 83 percent increase for the four-year period.

Harvesting the Seed Crop

Estimating yields of seed: It appears doubtful whether it is profitable to harvest fields that yield less than 100 pounds per acre. Yields of more than 300 pounds per acre are often obtained, and frequently yields of more than 500 pounds are obtained. Experiences with other crops help very little in estimating seed yields of smooth bromegrass. The two characteristics which best indicate seed yield are number of heads per unit area, and the amount of lodging. Under a given climatic condition, maximum yields are obtained from stands showing numerous
heads with dense undergrowth of shoots and leaves, with no lodging. Old stands that have become sod-bound and lack nitrogen fail to produce many heads. Frequently under those conditions, the heads will also be small and few tillers will be produced.

Fairly accurate estimates of seed yields may be obtained by counting the number of heads per square yard and assuming one pound of seed per acre for each head per square yard. Of course, this method requires care in measuring the square yards and making enough counts to give an average of all conditions in the field. Estimates based on this method were more nearly accurate at medium yields than when yields were either low or very high.

**Noxious weeds:** The most noxious weed in bromegrass is quackgrass. Looking for the quackgrass before the bromegrass is headed out is useless because the two plants are not easily distinguished. After heading, the two plants can be distinguished readily. If quackgrass is found, no attempt at rogueing will be satisfactory because some plants will be missed. Attempts to miss the quackgrass by driving around the weed area will help but very little, for when such patches are skipped there are usually smaller areas harvested which contaminate the seed. In three-fourths of the States, quackgrass is a noxious weed by law and seed containing it is limited in sale, if not excluded. There is no commercial method of removing quackgrass seeds from bromegrass because the two are very much alike in size and shape. If the field contains other noxious weeds, such as Canada thistle, perennial sow thistle, or wild carrot, which cannot or will not be rogued out previous to harvest, it is also advisable to use it for pasture or hay rather than for seed.

In the semiarid regions of Kansas and Nebraska, quackgrass is not a serious problem, but both chicory and dock are troublesome. The latter, however, can be controlled with 2,4-D. If either of these weeds is allowed to mature the bromegrass should not be harvested for seed.

**When to harvest:** It is often difficult to determine just when the crop is ready to harvest. Examination of samples of threshed seed indicates that in many instances the harvest was delayed too long. When such is the case, some of the seed is lost by shattering and the harvested seed is frequently of lower quality. Under similar threshing conditions, seed is often a darker, duller color, hulls are looser and more frayed, and usually a higher percentage of the seed is dehulled.

Bromegrass does not ripen from the ground up but ripens in the kernels and panicles first. The base of the plant remains green long after harvest and can be utilized for hay or pasture. As the crop ripens some of the heads will show a purple color. This color develops before the crop is ready to harvest for seed and changes to a brown color as ripening progresses. For binder harvest, the crop normally should be harvested before all of the purple color disappears. At harvest, most of the seeds will be brown and the branches of the panicle yellow. At this stage, many of the stems turn yellow for several inches below the panicle.

**How to harvest:** The crop may be harvested with a binder or by combine. The latter is preferred, especially if the bromegrass is in a mixture with alfalfa. When a binder is used, the stubble should be left as high as possible so that much of the green base can be left out of the bundles. The crop should be shocked in long narrow uncapped shocks to cure before threshing.

If the crop is not lodged badly, a combine is very satisfactory for harvesting bromegrass seed. The cutter bar may be set high enough to miss almost all of the alfalfa and most of the green leafy base of the bromegrass plants. Combining from the standing crop is much more satisfactory than any attempt to combine from windrows. This is especially true if the crop is in mixture with alfalfa. As soon as the seed crop is removed from the field, the stubble may be cut for hay or pastured.

**threshing bromegrass seed:** Bromegrass seed may be threshed with an ordinary thresher or combine with only minor changes. An examination of several com-
commercial samples of threshed seed, however, indicates that a more careful study of the methods of threshing and more experience are needed, as threshed samples have ranged from approximately 60 percent to 97 percent purity, even when weed seeds and other crop seeds were not a problem.

**How to handle threshed seed:** Threshed seed that is tough (too high in moisture content) will heat and spoil in storage. Such seed must be dried in some manner before storing. If space is available, it can be spread on a clean floor for a few days and shoveled often enough to prevent heating. When the seed is of low purity and contains pieces of green leaves and stems, one “run” over a fanning mill will reduce the bulk from 25 to 50 percent and remove most of the green material. A few growers have corn dryers available on their own farms or in the neighborhood which could be used to advantage. Only seed of reasonably high purity should be placed in dryers. It is poor economy to dry the impurities which are often higher in moisture content than the seed, and space in the dryer may be at a premium. Seed containing only a slight excess of moisture can be placed in loose mesh bags and stood in a dryer with sufficient space around each bag to permit circulation of air. Seed should not be packed into the bags. If the seed is more than slightly tough, arrangements should be made to spread the seed in a thin layer rather than to dry it in the sacks. Under humid or semihumid conditions, bromegrass seed ordinarily should not be dumped into storage bins at time of threshing.

**Cleaning bromegrass seed:** Cleaning seed of smooth bromegrass is a major problem. The farmer-grower can do much to lighten the final cleaning process by careful threshing and scalping to remove much of the coarse material before delivery to the processor. The final processing, however, requires the best kind of cleaning equipment which is available only in fully-equipped processing plants.

Widespread variations in the purity of threshed lots of seed, possible contamination with quackgrass, and lack of space and suitable equipment for cleaning, are major factors which increase the difficulties of commercial cleaning of the seed. Bromegrass with a purity exceeding 90 percent may be cleaned in less than half the time required to clean a lot having a purity of only 70 percent. In any case, cleaning the seed is a slow job. Commercial dealers hesitate to clean or handle bromegrass that may contain quackgrass because the quackgrass cannot be removed.

**Acreage and production:** For the 8 years (1942-49) for which data are available on bromegrass seed production, the average acreage harvested for seed in the United States was 51,700 acres, and the average seed production was over 9,000,000 pounds of which by far the larger part (80 percent) was produced in Nebraska and Kansas. Nebraska also had the highest yields per acre with an average of nearly 200 pounds, while the national average was 175 pounds per acre.

Only a small percentage of the seed produced is certified. In 1941 slightly more than 250,000 pounds of smooth bromegrass seed was certified in the United States. In 1947 over a million pounds was certified of which more than half was Lincoln bromegrass certified in Nebraska, and about one-fourth was Achenbach certified in Kansas.

**BROMEGRASS HIGHLIGHTS**

1. Bromegrass, grown in association with alfalfa or other legumes, is one of the most valuable grasses for pasture, hay, and erosion control in the Northcentral and Central States.
2. Bromegrass can be grown successfully on many soil types but is best suited to the more productive soils.
3. Bromegrass will survive long periods of excess moisture or drought without loss of stand, but is not productive under very dry conditions.
4. Bromegrass soon becomes unproductive or “sod-bound” when grown alone, even on the better soils, because of insufficient nitrogen to maintain vigorous growth.
5. It is important that a legume be grown in conjunction with bromegrass. The bromegrass-alfalfa combination has become very popular over a large region.
and is one of the most valuable of all grass-legume mixtures. Yields of hay from this mixture are often three times those from bromegrass alone.

6. Varieties of the "southern type," Lincoln, Achenbach, Fischer, and Elsberry, are usually superior to northern strains of bromegrass in the Central States and as far north as the southern half of Minnesota.

7. In the northern States and Canada the Russian or northern type of bromegrass is more generally grown. Such new varieties as Manchar, Parkland, and Martin are proving superior to the general run of northern type brome in some areas.

8. Successful stands of bromegrass are obtained from sowing shallow on a firm, clean seedbed, either in early spring or late summer, when moisture conditions are favorable.

9. For pasture, sow 10 to 12 pounds of bromegrass and 4 to 6 pounds of alfalfa per acre. Red clover, Ladino clover, and sweetclover, either alone or in combination, may replace all or part of the alfalfa. For hay, somewhat greater yields may be expected by increasing the proportion of alfalfa to bromegrass.

10. In establishing stands of bromegrass the use of lime and phosphate to promote a vigorous growth of the accompanying legume is important. Alfalfa and Ladino clover are most useful in maintaining the supply of nitrogen so essential for keeping the grass in a highly productive condition.

11. Grazing should be managed in such a way as to maintain a growth of 6 to 8 inches in the pasture. Bromegrass will not remain productive when grazed as closely as is ordinarily practiced with Kentucky bluegrass.

12. Unproductive pure stands of bromegrass are greatly stimulated by the application of nitrogenous fertilizers or barnyard manure, or by sowing certain legumes in the grass after thorough disking in early spring to subdue the sod.

13. Seed of smooth bromegrass may be harvested from bromegrass-alfalfa mixtures or from pure stands of bromegrass.

14. Yields of bromegrass seed range from 200 to 700 pounds per acre for fields in their prime. Old stands yield considerably less.

15. When grown in pure stand strictly for seed production, bromegrass grown in rows 30 to 36 inches apart gives the largest yields of best quality seed.

16. Do not harvest for seed any field of bromegrass known to contain quackgrass, or any field from which other noxious weeds have not been removed, or any field so full of weeds of any kind as to produce a low quality seed or make harvesting unprofitable.

17. Combine bromegrass for seed when most of the seed is brown and some of the stems are yellow for a few inches below the panicle.

18. Do not store bromegrass seed that is not thoroughly dried or that contains portions of green stems or weeds. If the seed is tough, spread on a clean floor for a few days; turn with a shovel each day until well dried.

19. Bromegrass forage remaining after seed harvest may be pastured or cut and removed for hay.

20. Bromegrass seed may be "scraped" on the farm with a fanning mill if it is left trashy from the threshing machine, but because of the difficulty in cleaning such light, chaffy seed, it should be cleaned by a commercial seed-cleaning establishment to put it in shape for sale or for sowing.

RESUCUEGRASS

(Bromus catharticus)

Rescuegrass is a native of South America, and is particularly abundant in Argentina and Uruguay. In many sections of the United States, especially in the South and in the humid parts of the Pacific Coast, it is naturalized. Agriculturally it is most important in Australia which is the source of most of the seed supply. The seed is relatively cheap and as a rule of excellent quality.

Description: Rescuegrass is a short-lived perennial, usually living 4 or 5 years under favorable conditions, but in the extreme South it behaves as a winter annual.

It grows in tufts or bunches, often a foot in diameter and very leafy at the base. The stems are erect or nearly so, 2 to 3 feet high, and bear large open panicles. The large spikelets drop from the ends of long slender branches. On vigorous plants some panicles are a foot long.

The seeds of rescuegrass are large, nearly equal to oats in size. A bushel of seed weighs 14 to 16 pounds.
Adaptation: Rescuegrass will withstand the winter as far north as Washington, D.C., and Lincoln, Nebraska. Northward, however, the grass has never attained any agricultural importance. Rescuegrass is best adapted to humid regions with mild winters, springing up in the fall, growing through the winter, and maturing early in summer. In other words, it behaves as a winter annual in the regions where it is most valuable. It is distinctly a rich-land grass, growing vigorously on good soils but only meagerly on poor land. In view of these characteristics, rescuegrass has proved more valuable as a winter crop on strong soils in the South and on the Pacific coast.

Establishment and care: Rescuegrass is best sown in the fall when cool weather begins. If sown alone on prepared land, from 20 to 30 or more pounds per acre are used. In Australia, mixtures with alfalfa or red clover or Italian ryegrass are said to give excellent results. In Texas, bur-clover has been used mixed with rescuegrass to good advantage. If the grass is allowed to mature seed late in the season and is then plowed under, a summer crop of cowpeas or lespedeza may be grown, after which a good volunteer crop of rescuegrass appears. Even on permanent pastures, rescue grass volunteers well if it is allowed to mature some seed. On river-bottom lands subject to floods, rescuegrass maintains itself very well.

BROMAR MOUNTAIN BROMEGRASS
(Bromus marginatus)

Bromar is an improved strain of mountain bromegrass that is particularly suited for use in sweetclover-grass mixtures for pasture and green manure. It can be grown in crop rotations throughout the intermountain area of the Pacific Northwest, except in areas where the annual precipitation is less than 16 inches. It is well adapted to the cultivated soils of this area since Mountain bromegrass is a part of the native vegetation on the better sites. It seems to thrive with climatic conditions of a cool dry summer, and winter precipitation.

Description: Bromar is a short-lived perennial bunchgrass. It reaches maximum seed and forage production the second season after sowing; hence, it does well with sweetclover. Third- and fourth-year yields are low as Bromar plants lose vigor and die out after the second year under average use conditions. In comparison with commercial mountain bromegrass, Bromar is taller, more leafy, more disease resistant, and about two weeks later in maturity. Bromar has a more vigorous seedling stage and is earlier in spring recovery the second year. The seed is somewhat smaller and de-awns more readily than that of commercial mountain bromegrass.

Disease resistance: Bromar is highly resistant to head smut, showing 2.53 percent infection compared to 27.75 percent infection for the commercial strain. The resistance of Bromar is particular-
ly important from the standpoint of seed production, making unnecessary seed treatment of this grass to control head smut. Bromar is apparently resistant to stem rust, leaf rust, and leaf spot, but susceptible to stripe rust and to aphid injury. Aphid injury has been serious only on solid stands of Bromar sown without sweetclover. Abnormally wet weather during spring and early summer seems to favor increase of aphids to epidemic proportions.

**Preparation of seedbed:** The seedbed for pure stands of Bromar and Bromar-sweetclover mixtures must be well-worked, firm, and weed-free. Fall-plowed cereal stubble should be left rough over winter and then worked early in the spring to kill weeds, firm the seedbed, and retain moisture near the surface. Rolling with a cultipacker just before sowing will give the necessary firmness. Spring plowing is not recommended because moisture will be lost and it is difficult to prepare a firm seedbed. The seed of Bromar should not be covered with more than one inch of soil.

**Time of sowing:** Bromar should be sown in the spring as soon as a good seedbed can be prepared. Sowing later than May 10 has not given good results because the dry summer period will result in some loss of seedlings unless they are well established with roots below the plow layer.

**Rate of sowing:** When grown for seed production in rows spaced 30 to 36 inches apart, Bromar may be sown at about six pounds per acre. For pasture or green manure, Bromar is sown at ten pounds per acre with 5 pounds per acre of Spanish sweetclover. A better stand can be obtained by sowing the grass first and cross-sowing the sweetclover in order to reduce competition between the two species. Alternate rows of the grass and sweetclover have proven best for obtaining a high percentage of grass in the mixture. This type of sowing may be accomplished by plugging alternate holes in the grain box and the grass-seeder box so that alternate rows of Bromar and sweetclover are sown. Bromar should be sown with a drill as broadcasting has been unsatisfactory in most cases. Drilling with a hammer mill will aid in getting the grass seed through the drill.

**Yields of hay:** In trials at Pullman, Washington, Bromar was consistently higher yielding than commercial mountain bromegrass in second-year production from single-row hay plots sown four different years. In these four successive sowings Bromar exceeded commercial mountain bromegrass in yield by an average of 1,922 pounds of hay in second-year production. Considering second-season yields for all the hay and clipping plots together, Bromar produced 4,056 pounds of dry forage compared to 2,645 pounds for the commercial strain. The hay yields of both strains are very low for the third and fourth seasons after sowing. For this reason it is recommended that Bromar be used primarily with sweetclover in conservation seedings for pasture and green manure. Sweetclover is a biennial legume that is very productive in the second year. The vigorous seedling growth and the high second-season production of Bromar fit well with sweetclover for short rotations.

**Root system and soil erosion:** The grass in a Bromar-sweetclover mixture provides an extensive fibrous root system that is effective in controlling soil losses. The total yield of the Bromar-sweetclover mixture in the upper 8 inches of soil is about one-third root material, while only one-fifth of the yield of the sweetclover alone came from the roots. The fibrous grass roots decompose slowly in the soil, thus affording protection from soil loss through erosion for a longer period after being plowed down than would be realized from a pure stand of sweetclover.

**Use for pasture:** In trials of Bromar-Spanish sweetclover mixtures pastured by yearling steers for three growing seasons, the Bromar-Spanish sweetclover produced an average of 287 pounds of beef per acre per season contrasted with 219 pounds of beef for a comparable alfalfa-grass pasture. The average yield of hay from the Bromar-Spanish sweetclover pasture was 7,160 pounds of hay per acre and only 3,535 pounds per acre for the alfalfa-grass pasture. The Bromar made up 8 to 26 percent of the total yield.
in the sweetclover grass pastures. These results and experience in cooperative seed­
ings in other districts have led the Wash­
ington State Station to recommend the use of Bromar with sweetclover for pas­
ture in the Palouse region of the Inter­
mountain area.

Seed yields: Seed yields for the two
strains of mountain bromegrass were ob­
tained from second-year stands in rows
spaced two feet apart. Bromar was high­
est yielding in three out of four years.
The 1941 yield of Bromar was low be­
cause of aphid injury to the grass during
the exceptionally wet season. The com­
mercial strain of mountain bromegrass, being
about two weeks earlier in maturity,
escaped serious injury. The seed pro­
duction plots were given a maintenance ap­
lication of 200 pounds of ammonium
sulphate applied in the late fall. Third­
year yields from two different trials at
Pullman averaged 470 pounds per acre.
At least two seed crops may be obtained
from one sowing, provided that weeds arc
kept in check and the stand of grass does
not suffer severe winter injury between
the second and third year of production.
Over an 8-year period, the average head­
ing date for Bromar was June 6, com­
pared to May 26 for the commercial
strain, a difference of 15 days. Bromar
averaged ten days later in seed maturity
date, the average for 8 years being July
7, compared to June 27 for the com­
mercial strain. The later maturity of
Bromar is important because this grass
is used with sweetclover for pasture and
green manure. In pastures this late ma­
turity extends the period that the grass
is palatable.

CALIFORNIA BROMEGRASS

(Bromus carinatus)

California bromegrass is a vigorous,
short-lived native of the Rocky Mountain
and Pacific coast regions, closely related
to mountain brome.

The species is characterized by capacity
to produce large quantities of leafy for­
age that is relished by all classes of live­
stock. The mature foliage is harsh and
less palatable, a condition that is offset
somewhat by the fact that the seed heads
are palatable and nutritious.

This species would have extensive use
for revegetation if adequate seed supplies
were available.
Chapter XXII

THE FESCUES

(Festuca species)

The fescues compose a large genus of which there are about 100 species in temperate or cool zones. They vary in texture and growth. Some are annuals, some perennials; some are low and others are rather tall; different ones are fine, coarse, tufted, creeping, erect, and so on. Thus they comprise a versatile group of varying uses.

The annual species are weedy, but the perennials are excellent for forage and turf. The several species that are cultivated as pasture grasses can be classified as the broad-leaf and the fine-leaf species.

Of the broad-leaf species that currently are most widely used, meadow fescue (Festuca elatior) and tall fescue (F. arundinacea) are outstanding. Of the fine-leaf species, red fescue (F. rubra), Chewings fescue (F. rubra commutata), and sheep fescue (F. ovina) are perhaps the most useful.

Meadow fescue and tall fescue have been in use agriculturally in the United States for a half century, but neither has been given the prominence it really deserves. Meadow fescue is a standard grass in Europe, particularly in western Europe. In this country it has been considered a grass of minor importance in the northeastern United States west to the Great Plains and south to the latitude of Tennessee, and to a still lesser degree farther south and west.

MEADOW FESCUE

(Festuca elatior)

ORIGIN AND HISTORY

Probably the first introduction of meadow fescue into the United States, certainly the first to develop later into large-scale seed production, was by Fred Barteldes into eastern Kansas in the eighties. It is reported to have been grown first on a farm in Johnson County, Kansas. Since the original seed came from England, meadow fescue acquired the name locally of “English Bluegrass.” Thomas Coughlin, a farmer in that locality, obtained seed for growing on his farm, and from that original introduction the crop has been produced every year since then on the Coughlin farm and on many other farms in that area. During this 55-year period, probably more meadow fescue seed has been produced on the Coughlin farm than on any other farm in the United States, and in some years as much as several carloads of seed.

In times past, nearly every quarter section farm in the Kansas-growing district had a 15 or 20-acre field of meadow fescue for seed production which was also used for fall pasture after harvesting the seed. From a small beginning over a half century ago, the four counties of Miami, Johnson, Franklin, and Douglas in eastern Kansas, and in more recent years Henry and St. Clair counties in west-central Missouri, have been the chief sources of supply for meadow fescue seed in the United States.

Nebraska and Indiana also have seed-producing areas, but none is as large a producer of meadow fescue seed as the four contiguous counties named in eastern Kansas or the two counties in west-central Missouri. With Alta fescue and Ky 31 fescue, and other regional strains of tall fescue coming into prominence and demonstrating their general superiority over the original meadow and tall fescues in nearly every way, it is a ques-
tion whether these meadow fescue seed-producing areas in Kansas and Missouri will decline in their production of meadow fescue seed, or whether they will introduce one of the improved strains of tall fescue to take the place of meadow fescue, and thus retain their present prestige as important fescue seed-producing areas. Since the seed-producing areas in Kansas and Missouri were developed and sponsored largely by the seed industry to supply meadow fescue seed to Europe, their continuance as large producers of meadow fescue seed will depend largely on future European demand for such seed.

DESCRIPTION

Meadow fescue is a hardy, short-lived perennial grass attaining a height of 15 to 30 inches, or even more on rich land. It does not propagate by rootstocks or form a very heavy sod, neither is it inclined to be so bunchy as orchardgrass or tall meadow oatgrass. Its leaves are bright green and very succulent, and remain so almost throughout the growing season. Like timothy, redtop, and orchardgrass, it has excellent seed-producing habits. The seed is produced in abundance in much-branched or nearly simple open panicles similar to Kentucky bluegrass, although much larger and more easily harvested.

DISTRIBUTION AND ADAPTATION

Meadow fescue is a standard grass in Europe. In the United States, it is used as a forage crop in some portions of the New England, North Atlantic, and Central States, and on a small scale in the Southern States. It is of most importance in eastern Kansas and Nebraska, and in parts of Missouri and Indiana. So far as climate is concerned, it appears to be generally adapted to all of the above area, or about the same region as timothy. As to soil requirements, it prefers a rather heavy, moist soil but with good care and adequate fertilization it will do well on light soils or with only a moderate supply of water. For wet soils, few grasses are better adapted than meadow fescue.

ESTABLISHING A STAND

The preparation of seedbed, time, rate, and method of sowing the seed are much the same for meadow fescue as for the tall fescues which are given under that heading.

UTILIZATION

Pasture: Meadow fescue is used primarily for pasture, generally in mixtures. It is especially adapted for pasture use, as it is ready for grazing early in the spring and continues late into the fall. Its vigorous growth, though less vigorous than the tall fescues, will probably make it a more desirable companion crop for certain legumes such as Ladino clover than Alta, or Ky 31 fescue, because the latter are likely to become too competitive and drive out their leguminous companion. Meadow fescue makes luxurious late fall pasture, and stays green until hard freezing weather. This is true, whether used primarily for pasture or following the cutting of a hay or seed crop. This is of especial importance in Kansas and Nebraska where meadow fescue supplements the native pastures after they have dried up.

Meadow fescue is a very hardy grass after it goes through the first winter. It will stand heavy fall and winter grazing; in fact in Kansas heavy fall grazing seems to improve the next year's seed production. Meadow fescue is slow in getting established the first year, and like many other grasses, it will not persist under continuous grazing. In Kansas after the harvest of a seed crop around July 1, it seems to take a rest of a month or more before making its new fall growth. All in all, it appears that the advantages of meadow fescue as a pasture plant have never been as fully appreciated as the merits of the plant warrant.

Hay: Though meadow fescue has been recommended primarily as a pasture crop, its value for hay in mixtures with other compatible grasses or legumes should not
be overlooked. It makes a very good quality hay which is finer in texture than that of tall fescue or any of its varieties. It may be used in mixtures with timothy, redtop, orchardgrass, perennial ryegrass, and with medium red, alsike, or Ladino clover, and Korean lespedeza. Where it is necessary or desirable to pasture hay meadows in the fall, meadow fescue furnishes the palatable green basal growth so much desired for fall pasture. It does not reach its greatest productiveness so quickly as timothy but usually persists much longer. On average land where grown alone, a yield of 2 tons per acre is not unusual, and with proper treatment larger yields may be obtained.  

**Soil conservation:** In two ways meadow fescue plays an important part in soil conservation. In the Kansas area it has been consistently used to increase soil fertility in rotations where corn follows the grass crop and high yields of corn have resulted. It is also used extensively in mixtures to prevent soil erosion in waterways.

**SEED PRODUCTION**

**Acreage and production:** Since much of the seed production of meadow fescue has been for export to Europe because seed of satisfactory quality could be produced more cheaply here than in Europe where it is much needed for pasture for dairy herds, it may be desirable to maintain our acreage and production of the regular type of meadow fescue for this purpose until we know that the export demand for it has fallen off or is likely to be supplanted by the demand for one or more of the improved strains.

The production of meadow fescue seed has fluctuated rather widely over certain periods of years. During the first three years for which figures are available, 1919-21, production of clean seed averaged only about 500,000 pounds; during the following nine years, 1922-30, it was 1,760,000 pounds; during the nine years, 1931-39, it was 550,000 pounds, and during the last 10 years, (1940-49), it was about 1,336,000 pounds. The lowest recorded production was 150,000 pounds in 1938, and the highest 3,240,000 pounds in 1947. In years past, Kansas was the largest producer of meadow fescue seed, but Missouri has produced more seed than Kansas, during most of the recent years.

**Weed seeds:** For export as well as for domestic use, the weed problem in seed-producing fields is serious. The weed that is most troublesome is chess or cheat which cannot readily be removed from meadow fescue seed. Year after year some
of our seedsmen handling the largest quantities of meadow fescue seed have made special efforts to obtain from the best growers special lots of seed which they could clean to a high percentage of purity for use in sowing fields especially for seed production, but unless this is done continually and proper rotations followed, the fields become thoroughly contaminated with this weed.

**Fertilization for seed production:** Heavier fertilization is needed for seed production than for forage. Such heavy fertilization is probably also desirable for forage production, but it is necessary if good crops of seed are to be produced. The slogan for growing meadow fescue seed in Kansas is “If your soil is not good, make it good.” When sown for seed production, Kansas growers have found that phosphate applications at the time of sowing seem to be very beneficial. Experience there has shown that later applications of phosphates, especially the second year, do not bring results but that it pays to apply a top dressing of nitrogen fertilizer in the early spring.

**Harvesting seed:** Meadow fescue seed is usually harvested with a binder, then shocked and threshed, using a special riddle. The combine is often used to save labor, but because of the large quantity of succulent foliage likely to be present when the seed appears to be ripe, special care must be exercised if it is to be combined. It must be left in the field until very well ripened. The straw as well as the seed should be past the succulent stage. After combining, the seed should be dumped on a flat rack and left in the sun for a few hours to dry and stirred until the moisture is gone. If put in bags, these must be aired several days in the sun and turned several times before storing where there is good ventilation.

Where binders are used, a common practice is to pasture the fields after seed harvest; where combines are used, a hay crop is taken following the combine and the fall growth is pastured.

For seed production most fields are left for two or three years, but occasional fields that are relatively free from weeds have proved profitable for seed production for eight or ten years. Where the growers specialize on seed production and apply the best practices, yields as high as 600 pounds per acre are obtained, but the average is probably below 300 pounds.

Re-cleaned meadow fescue seed and the seed of the several strains of meadow and tall fescue weigh 22 to 27 pounds per measured bushel, and there are about 225,000 seeds per pound.

**THE TALL FESCUES (ALTA AND KY 31)**

*(Festuca arundinacea)*

**ORIGIN AND HISTORY**

The tall fescues, also introduced from Europe, and perhaps often called meadow fescue, are rather widely distributed in the United States but were not given much prominence until Oregon and Kentucky brought out the two strains, Alta and Ky 31. Tall fescue and meadow fescue are now usually considered by botanists as species. Tall fescue is the more valuable, but the seed has not been sufficiently plentiful until recently for general use. In Oregon the special selection of tall fescue known as Alta fescue has largely supplanted the original tall fescue. In Kentucky the regional strain known there as Ky 31 was discovered several years ago and is now making a remarkable record in both Kentucky and neighboring States.

Alta fescue and Ky 31 fescue are alike in general appearance and, so far as known, have not shown material differences in adaptation or resistance to disease. More extensive trials, however, in various sections of the country will be required to definitely determine their relative values. It would hardly seem probable that a regional strain of tall fescue like Ky 31, which has been developed through some fifty years or more of natural selection in one State, would be identical in all respects, particularly that of adaptation to soil and climate, to a selection from the same species though from a different source, made in a State some two thousand miles away under different climatic
conditions. What these differences are, if any, will show up in more extensive trials. For the time being and until the seed from the two sources has been thoroughly tested over the United States, it is probable that these two varieties will be known under these two names, depending upon source of seed and area of distribution; Alta fescue, perhaps more generally in the Northwest, Central and Northern States, and Ky 31 more gen-

![Kentucky 31 fescue grown for seed.](image)

erally in the South-Central, and South-eastern States.

From trials to date, these two varieties of tall fescue, in spite of their being coarser than meadow fescue, appear likely to supplant largely both meadow fescue and the original tall fescue since they have demonstrated in various trials greater hardiness and resistance to disease as well as greater productive capacity than the original types. This accounts for their increasing popularity in most of the areas of adaptation to meadow fescue. With the desirable traits of these two new strains combined with those of meadow fescue, it seems that this group of fescues should come to occupy a more important position among our pasture crops than heretofore.

**DESCRIPTION**

The tall fescues are similar to meadow fescue in about every way except that they are taller, have coarser foliage, a deeper root system, and are longer lived. They have numerous dark green basal leaves and comparatively few seed stalks. In Oregon Alta fescue attains heights of 3 to 4½ feet, with branched or panicle-type heads 4 to 12 inches long. The seeds are borne three to five in a spikelet, shortawned, about the size and shape of rye-grass seeds, distinctly veined on the back, and somewhat dark in general appearance because of a slight purplish tinge on the glumes or chaff and the dark purple color of the caryopsis or kernel.

The tall fescues in old stands develop a uniform sod. The roots of the plant are numerous, coarse, and normally penetrate to a depth of five feet or more in soils that are moist throughout their entire depth during at least a portion of the year. Alta fescue is one of the few grasses in western Oregon that remain green throughout the summer. Hay and seed fields produce considerable aftermath after harvest. Winter growth is almost continuous in western Oregon. Recovery is particularly rapid in the spring and after the first fall rains.

The tall fescues, like meadow fescue, grow slowly in the seedling stage and usually require one full growing season to become established. During this time the production of forage is small.

*Alta fescue: This strain originated from plant selections made at the Oregon Agricultural Experiment Station. All the tall fescue in use in Oregon at the present time is believed to be of this improved strain. We are indebted to Oregon for this variety, not only for its origin but also because that State is now the principal source of our seed supply.*

*The first sowing for seed-increase was made in 1932 at the Oregon Station.*
initial commercial seed harvest took place in 1936, and since then production has continually increased.

The extreme popularity of Alta fescue in Oregon is based chiefly on its excellence in pastures. The outstanding qualities of the grass are: high yields of palatable forage, a long-growing season, deep roots that allow the plant to utilize deep subsoil moisture for green growth throughout the summer, wide adaptations, and long life.

No definite information is available on the present acreage of Alta fescue for forage and seed production purposes in Oregon. Many fields have been sown for forage in which Alta fescue is included in mixtures with other plants. Most fields that are harvested for seed are used incidentally for forage after the seed is harvested. The estimated total acreage in Oregon for all purposes in 1945 exceeded 50,000 acres. It has increased rapidly since then so that the total acreage may have reached 75,000 or more in 1948.

Wide markets for Alta fescue seed are developing. Experimental results indicate that the grass is valuable as a forage plant under a great variety of conditions in both eastern and western sections of the United States. Alta fescue appears to thrive and out-yield meadow fescue, orchardgrass, and perennial rye-grass throughout the areas in which the latter three grasses are used. The future market for Alta fescue seed will probably be chiefly domestic.

Ky 31 fescue: This fescue is a local strain of tall fescue that has been growing in Menifee County, Kentucky, for over fifty years. The Experiment Station began testing it at Lexington in 1932. It has been in Extension demonstrations since 1939 and, at the present time, is growing in most of the counties of the State. Results of tests conducted by a number of the experiment stations of the Southern States, and the very successful growth of the grass in most of these tests and on farms indicate that Ky 31 fescue has a large place in southeastern agriculture. Ky 31 fescue is reported by some observers as not to have given entirely satisfactory results in the southern parts of the States along the Gulf Coast.

ADAPTATIONS

Climate: The tall fescues have wide climatic adaptations. Alta is winter hardy in Oregon but is not entirely so in all parts of the most northern States. It is generally adapted for forage production where the annual precipitation is 15 inches or above and where the elevation is not more than 5,000 feet. For seed production in Oregon the general requirements are a yearly precipitation of at least 18 inches and an elevation of not greater than 3,000 feet. Alta fescue seed production is at present centered in the Willamette Valley of western Oregon.

Ky 31 fescue has proved to be hardy through the Corn Belt and in the Southeastern States. It probably has a climatic adaptation similar to Alta fescue, but has not been tried extensively in the Northern States.

Soils: The tall fescues grow in a diversity of soils. They prefer fertile, moist, rather heavy soil, but will thrive in many soil types except those that are extremely light. The roots are able to penetrate dense subsoils. They will tolerate poorly-drained conditions and will survive in standing water for long periods during the winter when the plants are semidormant. Long submergence, however, during the growing season is likely to be injurious. The tall fescues are known to be tolerant of moderate alkali concentration when soil moisture conditions are favorable; they will thrive also in quite acid soils. Where the soil is fertile they are large producers of forage and seed. In soils of low fertility, forage growth is usually satisfactory but seed production is usually low.

The tall fescues are excellent soil improvers, especially for heavy lands, because of the action of the roots in "opening up" the soil below plow depth, and the large amount of organic matter that accumulates as a result of partial renewal of the root system each year.
CULTURE AND MANAGEMENT

Preparation of seedbed: Tall fescue makes slow growth during the first year; consequently, a clean seedbed is desirable for most rapid establishment. For fall sowing, spring-plowed and summer-fallowed land may be used, but the most common procedure is to prepare a seedbed on land that has grown a cultivated crop or a spring-sown grain crop. This practice eliminates many weeds. Shattered grain should be allowed to sprout and then be destroyed by cultivation before sowing the grass seed.

Tall fescue is sown in the fall following a fall-sown and summer-harvested crop, the stand may be considerably thinned or weakened by weed competition during the first year. Seedbeds for spring sowing should be plowed early in the spring and worked into a fine, firm, weed-free condition. On lands that are subject to blowing, excessive soil rolling is to be avoided. Soils heaved by frost are sometimes in fairly satisfactory condition for late-winter broadcast sowing.

Time of sowing: Tall fescue may be sown in either the fall or spring. Fall sowing is usually practiced in western Oregon under most conditions, except on cultivated hill soils that heave badly during frosty periods. Fall sowing may be done in eastern Oregon on soils that are not subject to excessive wind or water erosion. The period for fall sowing usually extends from September 10 to October 15.

Spring sowing is generally done during March, April, and May, and is often done on lands that heave or erode in the winter and in cold dry regions. Sowing in rows is almost invariably done in the spring.

Late summer or early fall sowing of Ky 31 fescue in the Southeast is desirable. Late fall sowing, especially on a loose seedbed, may cause the plants to heave and winterkill. Early spring sowing is also satisfactory. A well compacted seedbed is always important and the seed should be covered lightly.

Methods of sowing: Drilling is preferable to broadcasting because uniform stands are more easily obtained. Broadcasting the seed evenly, followed by light harrowing, is a satisfactory method of sowing. Under favorable moisture conditions the depth of the seed after sowing should not be more than one-half inch.

The tall fescues, especially for seed-production purposes, are usually sown without a nurse crop. Good stands are often obtained by fall sowing with winter barley or wheat, but thin or spotty stands often result when heavy growth of volunteer grain, vetch, or ryegrass occurs. Spring sowing with a nurse crop of spring grain is satisfactory with irrigation.

Sowing in rows: Sowing in rows has these distinct advantages over sowing broadcast: (1) Not more than one-half as much seed is required as when sown broadcast; (2) Higher yields of seed, especially for the first two or three years, are obtained from rows; (3) Row-sowing appears to be more favorable to the establishment of a companion legume crop; (4) Row-sowing in some cases appears to produce more pasture than solid fields.

In Oregon Alta fescue for seed production is often sown in cultivated rows 2½ to 3½ feet apart. This method is recommended for the production of seed of high purity and for maintaining high seed yields, particularly in dry regions and on less productive soils. Sowing in rows is usually done with single or multiple beet and bean planters, or ordinary grass seed or grain drills with all feed cups plugged except those placed at the desired sowing intervals.

Three methods of row-sowing have been used in Kentucky—(a) Mixing the seed with superphosphate and sowing through the fertilizer attachment of a corn planter, (desired row-spacing is obtained by sowing between original rows); (b) mixing seed and superphosphate and sowing through the fertilizer attachment of a grain drill, stopping up two or three out of each three runs; and (c) sowing the seed through the runs of a grain drill, stopping up two out of each three runs. On rolling or hilly land the rows should be on the contour.

Rates of sowing: The recommended rate for sowing tall fescue alone in solid stands for forage or seed on cultivated land is
FESCUES

10 to 25 pounds an acre. The lower rate is usually desirable for seed production. When sown for forage in mixture with other plants, the rate may vary from 2 to 16 pounds per acre. When sown in rows spaced three feet apart, three to five pounds of seed an acre are required.

Fertilization: In both seed and forage production the tall fescues respond well to liberal applications of nitrogen. Experimental data on the effects of various fertilizers on seed production are incomplete. Seed growers' observations and preliminary experiment-station trial data indicate that for increased seed production on some soils a combination of nitrogen and phosphorus is better than nitrogen alone. Experienced seed growers usually use at least 150 pounds per acre of 15 to 20 percent nitrogen fertilizer and enough phosphate fertilizer to supply 30 pounds or more of phosphoric acid. On many soils, applications of phosphorus and sulphur will materially aid the production and maintenance of companion legumes in forage plantings. Potash applications are apparently not generally needed on most Oregon soils where Alta fescue is grown.

Under Oregon conditions, nitrogen-carrying fertilizer is usually applied to Alta fescue in the late winter or early spring, or as soon as the grass begins to grow. Nitrogen is sometimes applied twice, either in the fall and early spring, or in the early and midspring. Phosphate fertilizers such as superphosphate may be applied in the fall, late winter, or early spring. Applications of fertilizers made after April 15 on unirrigated land are generally much less effective than February or March treatments.

Eradication: Tall fescue, though not an aggressively spreading grass, is quite tenacious when once established. The breaking up of tall fescue fields requires more effort than is needed for many other common grasses such as perennial ryegrass, Chewings fescue, timothy, and orchardgrass. Fall-plowed tall fescue may become partly reestablished during the winter in western Oregon. To break the sod successfully, eradicate the grass, and prepare the land for another crop, three successive steps are recommended: (1) shallow plowing of the sod three to four inches deep when sufficiently dry to kill the grass crowns; (2) thorough diskng at sufficient depth to chop up the turned sod; and (3) replowing about six or seven inches deep after all grass is dead, completely burying all dead and decomposing sod, followed by packing with a roller.

For breaking tall fescue sod, the prairie sod-breaker type plow is recommended. Any general-purpose plow with a rather long, gradually turning mold-board is preferable to the stubble plow.

A wide variety of crops may be used to follow tall fescue. Crops especially recommended for this purpose in Oregon are: Willamette vetch, Austrian Winter field pea, winter grain, red clover, alsike clover, spring grain, flax, or a cultivated crop such as field corn, or crops for cannerly use.

Pests: No serious diseases are known to affect Alta fescue in Oregon. Insects are seldom destructive. Certain rodents may damage newly-sown fields but are seldom destructive to old fields where the heavy sod discourages their burrowing.

UTILIZATION

Pasture: The tall fescues are often better suited for pasture than for hay because of their numerous basal leaves. They are heavy yielders of forage and have a long growing season. In comparison with ryegrass, the tall fescues make as much winter growth and produce considerably more spring, summer, and fall forage. The grass is quite palatable to livestock when the leaves are young and succulent and it is readily consumed when in that stage. The foliage has a tendency to become somewhat coarse, tough, and unpalatable with age. The tall fescues respond well to plentiful nitrogen in the soil which is usually supplied most economically by sowing in combination with an adapted legume. Depending on soil and location, alfalfa, common white, Ladino or alsike clover, or birdsfoot trefoil may be used as companion crops. Where legumes are not used in mixtures with the tall fescues, fertilization with nitrogen is generally...
necessary to maintain high forage production.

The tall fescues are better suited than most other grasses for growing in pure stands because of their long life and aggressiveness. The better practice, however, is to use one of them as a major component of a permanent pasture mixture containing one or more legumes. In practically all the pasture mixtures recommended for Oregon, Alta fescue is included as a major component of such mixtures.

The stubble remaining after removal of a seed crop usually yields considerable pasture that can be well utilized by cattle, horses, or sheep. Analyses of Alta fescue stubble sampled during midsummer have shown it to contain about 3.8 percent crude protein. Pasturing is usually discontinued in the late fall on seed-producing fields to avoid reduction of the following year's seed yields. Excessive winter pasturing may result in soil puddling and growth of weeds.

Hay: The tall fescues are high-yielding hay grasses, particularly on fertile bottom lands where leaf growth is extremely heavy. Seed fields are sometimes cut for hay when the prospects for a good seed crop are unfavorable. Hay yields on farms have ranged from one to two tons an acre. Experimental results show that higher yields may be obtained. Alta fescue has made the highest average hay yield over a six-year period of all forage grasses tested at the Eastern Oregon Livestock Experiment Station at Union. For the six-year period, 1936 to 1941, it averaged over 4 tons of hay per acre, while the other 11 standard grasses averaged approximately 2 tons per acre. In yields of green forage over a 4-year period, 1941 to 1944, Alta fescue was also at the top with a yield of nearly 12 tons per acre, while the other 11 grasses under trial averaged only 7 tons per acre.

Turf: The tall fescues (Alta and Ky 31) are coming to be used rather extensively for turf purposes on roadsides, airfields, athletic fields, and the fairways of golf courses. They are also used for cemeteries, parks, and home lawns, but for the latter purposes they are used mostly in mixtures with bluegrasses in lieu of the customary redtop or ryegrasses. A lawn mixture of tall fescue, Kentucky bluegrass, and red fescue in the proportions of 50-25-25 by weight, or including highland bent 50-20-20-10 are favorite combinations.

The tall fescues have several advantages for use as turf and a few disadvantages. They withstand clipping of one inch or less in good soils but allow weed invasion at this height. At 3 inches or higher, they form an excellent weed-free turf. They are broader-leaved and coarser than Kentucky bluegrass, the red fescues, and the bentgrasses, but if clipped and fertilized regularly, the foliage is finer and combines nicely in mixtures with the finer leaved turf grasses.

For turf purposes, on areas not to be intensively used, or used very soon, a sowing of 20 to 30 pounds of seed per acre may be sufficient, but for lawns for quick results, or for areas of intense wear, whether sown alone or in mixtures, a total of 80 to 100 pounds of sced per acre should be used. It should be sown very shallow in spring or early fall. Summer sowing is not recommended.

The tall fescues will do better than most other turf grasses on soils of low fertility, but where good turf is desired, heavy fertilization should be given. Two applications a year, early spring or late summer, of 800 pounds of 5-10-5, or 400 pounds of 10-6-4 are desirable. If soil phosphorus is high, use straight nitrogen.

Weed control: The tall fescues are believed to possess real possibilities as an aid in perennial weed control because of their deep roots, dense growth, long growing season, and general aggressiveness. No cases of actual weed eradication have been reported, but observations of good stands of Alta fescue established on areas infested with perennial weeds such as Canada thistle, wild morning glory, and quackgrass, have shown that the weeds were usually greatly reduced in growth and formed no seed, especially on lands that became short of moisture in the summer. These three weed plants have been practically eliminated from
lands that have been planted to Alta fescue at the Oregon Agricultural Experiment Station.

SEED PRODUCTION

Conditions most favorable: Only clean land should be used for seed production. The presence of Canada thistle, Russian knapweed, whitetop, quackgrass, and other noxious weeds in seed fields usually increases cleaning expenses or may make the crop unsalable because of the presence of noxious weeds. Other plants that are objectionable are: orchardgrass, tall oatgrass, ryegrass, and cheat.

The length of time a tall fescue field may remain in profitable seed production is variable. Well-managed seed fields of Alta fescue in Oregon have been known to produce six successive paying crops, but three to four profitable seed crops are usually obtained. On soils of low fertility, the period of profitable production is usually short. Heaviest production usually occurs in the first and second crops.

Little is known about the influence of irrigation on Alta fescue seed production. Pasturing of seed fields is often done in the late summer and fall. Pasturing during the late winter and spring is likely to be detrimental to the developing seed crop.

Harvesting and cleaning: Tall fescue seed is ready to harvest if a few seeds drop into the palm of the hand when the seed head is pulled gently between the thumb and forefinger. At this stage of maturity, most of the seeds will have reached the hard-dough stage, and the kernels will be dark purple in color. Ripe seed shatters easily. When the crop has reached desired stage of maturity, harvesting should be done as quickly as possible to avoid excessive seed loss by shattering.

Cutting may be done with a grain binder. The bundles are placed in medium-sized shocks to cure. Some seed growers equip their binders with removable pans placed beneath the draper rolls and a box in place of the bundle carrier to catch shattered seed. The cured bundles will drop much seed when being hauled to the thresher. The use of racks or slips with tight beds or canvas covers will save most of this shattered seed.

Threshing is usually done with the stationary thresher. The methods correspond closely to those used for perennial and common ryegrass. Adjustments of threshers for threshing the seed of the tall fescues are easily made. In general, the air vents should be opened slightly, the top screen in the shoe closed far enough to remove the straw, and both screens in the shoe set at a comparatively gentle slope. High cylinder speed and too many concaves may result in chopping the straw and dehulling the seed. When the weather is dry and the seed is well cured, the toothed concaves may be replaced by blanks. Sheets of burlap or canvas should be used to catch seed that may sift to the ground through openings in the thresher.

The seed may also be harvested with combines from windrow. Growers sometimes combine the standing crop if seed maturity has advanced so far that excessive seed loss by shattering would result if harvested by the usual method. Seed harvested in this way should be spread out on a tight floor in a well ventilated place and stirred occasionally until dry to prevent sweating or heating.

Equipment for cleaning tall fescue seed is similar to that used for ryegrass seed. Generally, seed of Alta fescue grown in Oregon under favorable conditions contains comparatively few weed seeds. The preliminary farm cleaning of such seed can be done with a properly equipped fanning mill. The final cleaning of this seed, as with all other grass and legume seeds, to make it suitable for sowing and to meet State and Federal requirements, should be done with special machines in a well-equipped processing plant. Crop seeds such as orchardgrass, tall oatgrass, ryegrasses, and Chewings fescue are very difficult, if not impossible, to remove from Alta fescue seed.

High quality seed should be free from noxious weed seeds, should be of high purity, and should have at least 90 percent germination. The seed usually weighs between 22 and 27 pounds per bushel. There are about 225,000 seeds per pound.

Acreage and production: The acreage of
Alta fescue for seed production in Oregon has increased rapidly since 1938. In that year only 70 acres were harvested. In the succeeding years up to 1946, the acres harvested in order were 150, 750, 1250, 1500, 2100, 3800, 5000, and in 1946, 7200 acres. In the same period, the resulting production ranged from 22,500 pounds in 1938 to around 1,200,000 to 1,500,000 pounds in 1946, though accurate figures are not available for 1946.

In December 1949, the crop of tall fescue seed for that year was estimated by the Bureau of Agricultural Economics at 6,900,000 pounds of clean seed. A survey by that Bureau showed that 4.4 million pounds of this total were of the Kentucky 31 strain, produced in Kentucky, and 2.5 million pounds were the Alta strain, produced in Oregon. The 1948 crop of tall fescue was estimated at 6.4 million pounds, of which 3 million pounds were Kentucky 31 fescue and 3.4 million pounds were Alta fescue. While no comparisons with previous years were available for Kentucky 31, the 1943-47 average of Alta fescue was 1,222,000 pounds.

Because of the generally favorable results obtained in observational trials of Ky 31 fescue over a large part of the southeastern region of the Soil Conservation Service, a program was started under which 5-acre plots were sown especially for seed production in 1945, 1946, and 1947 in practically all of the county soil conservation districts in 7 of the 8 States of the region. In Florida sowings were made in only 6 such districts, but the results so far in that State have been favorable. The seed produced from these 5-acre plots will be certified and used for further sowing in these States.

Yields in rows and solid stands: Most tall fescue seed is grown in solid stands. The cultivated row method is gaining in popularity with many growers. Experimental evidence indicates that highest seed yields are obtained where the rows are spaced between three and four feet apart. Growers usually use 30-inch spacing because their cultivating and harvesting machinery can be adapted to it easily. Experimental yields of Alta fescue seed grown in rows and in solid stands at the Oregon Agricultural Experiment Station at Corvallis over a period of five years averaged 346 pounds from rows two feet apart, 452 pounds from 3-foot rows, 476 pounds from four-foot rows, and 374 pounds from broadcast stands.

The row culture for seed production has certain definite advantages, in that higher seed yields are usually obtained, cleaner seed is usually produced, profitable seed production is usually maintained longer, and the seed crops can be grown under less favorable conditions than when grown in solid stands.

Yields of seed have varied from 50 to 1200 pounds per acre. The yearly average acre yield in Oregon from 1938 to 1944 varied from approximately 150 to over 300 pounds of seed per acre.

RED FESCUE

(*Festuca rubra*)

Red fescue resembles sheep fescue, but its leaves are bright green and it does not grow in tufts. It creeps by underground stems.

From the commercial standpoint, there are two distinct forms, red fescue and Chewings fescue. The first is a creeping grass, although this characteristic is rather variable, for some strains are more creeping than others. This may account for the use of the common name "creeping red fescue" in an attempt to make a distinction between strains.

Chewings fescue is cespitose or tufted and does not creep. It has been assumed by some that Chewings and red fescue had a common origin; that can hardly be true because both occurred in Europe and were described before they were of commercial importance.

Like sheep fescue, they are hardy, robust plants. They are used mainly for lawns and good turf and are especially adapted to shaded dry sites.

Much of the seed of both red and Chewings fescue used in the United States is produced here or in Canada. Large amounts used to be imported from Europe, Australia, and New Zealand. Several
new strains have been produced, but their general regions of adaptation have not been determined. These include the Illahee and Rainier strains from Oregon and the Olds strain from Canada.

In August 1949 the production of red fescue seed in Oregon and Washington for that year was estimated by the Bureau of Agricultural Economics at 1,040,000 pounds of clean seed. This is only about one-half of the 1948 crop of 2 million pounds, but much larger than the 5-year average of 658,000 pounds. Oregon's crop for 1949 was estimated at 940,000 pounds and Washington's at 100,000 pounds. The Oregon Chewings fescue crop for 1949 was estimated at 2.2 million pounds of clean seed, compared with 3.2 million pounds in 1948 and an average of 1.8 million pounds.

**SHEEP FESCUE**

*Festuca ovina*

Sheep fescue, probably a native of the Northern Hemisphere, is a bunchgrass that forms dense tufts with numerous stiff, rather sharp, bluish-gray leaves. It is adapted to about the same climate as bluegrass and can be grown in the most northern agricultural areas. It succeeds better than most grasses on sandy or gravelly soils. Cattle and sheep will graze fescue but it is not generally recommended for pastures—its greatest use is for making a durable turf on sandy soils. The commercial seed comes from Europe. The seed weighs 10 to 15 pounds per bushel. The usual rate of sowing is 25 to 30 pounds to the acre.

**FESCUE HIGHLIGHTS**

1. Both meadow fescue and the tall fescues (including Alta and Ky 31) are primarily pasture plants and furnish luxuriant green pasture from early spring to late fall.
2. The tall fescues differ from meadow fescue in being taller, longer-lived, deeper rooted, and in having coarser foliage.
3. Both fescues grow well on wet soils, even when poorly drained, but will also endure drought, especially the tall fescues.
4. They tolerate soils of low fertility but respond to high fertilization, both for forage and for seed. Fertile soils are required, however, for profitable seed production.
5. The tall fescues with their coarser foliage should be pastured when the leaves are
young and succulent; with age they become coarse, tough, and unpalatable.

6. The vigorous growth of the tall fescues tends to suppress weeds that are often troublesome in pastures.

7. The vigorous growth of the tall fescues also makes it necessary to study carefully the kinds and characteristics of other crops, especially legumes, to use with them in mixtures. In pasture combinations, including certain legumes, under favorable conditions for the tall fescues, the latter will dominate the pasture in a short time. The less vigorous growth of meadow fescue makes it more suitable in combinations with certain legumes.

8. The tall fescues, because of their extensive root systems, have demonstrated their ability to prevent soil erosion in waterways, and to form a dense turf on banks, road shoulders, hillsides, and on airports. Both Alta fescue and Ky 31 fescue have been used alone with great success on air fields.

9. Either meadow fescue or the tall fescues can be eradicated readily by plowing.

10. The dense penetrating fibrous root systems of both meadow fescue and the tall fescues, especially the latter, because of their greater depth, makes them especially good crops for rotations to prepare the soil for succeeding crops.

11. Both meadow fescue and the tall fescues are excellent seed producers, and seed can be harvested and threshed with standard equipment such as used for other grasses. If fields are kept free from certain weeds and other grasses, the seeds of which have similar characteristics to the fescues, there is no difficulty in processing seed from such fields to a high purity.

12. The fine-leaf fescues, red fescue, Chewings fescue, and sheep fescue, are used mainly for lawns and good turf, and are mostly adapted to shaded dry sites.

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**SPECIAL CROPS—GRASSES**

Little material has been published recently on meadow fescue, most of that used here being obtained directly from growers, dealers, and agronomists, and from older publications. On the tall fescues, especially on Alta and KY 31, much recent material is now available in experiment station literature. The material used in this chapter came largely from Ramp ton of Oregon (OREG-20), Ferguson and Johnstone of Kentucky (KY-20), Hoover et al (US-115), from field observations made by the writer at agricultural experiment stations, and from personal interviews with agronomists. The notes on their use for turf purposes came from Fred Grau, and on acreage and production statistics from Edler and Kuzelka of B.A.E. The manuscript was reviewed by Hein and Edler of the U.S.D.A.

**Chapter reference numbers:** KY-13, 18, 20, 27; MISS-21; OREG-9, 20; PA-11; US-77, 89, 129, 204, 269, 270.

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1 The reference numbers given here refer to references which are given in full by State, U.S.D.A., and Miscellaneous, on pages 682 to 724, and which are cross-referenced by author on pages 725 to 731. Citations in the text are indicated by abbreviation and number in parentheses.
Chapter XXIII

OTHER NORTHERN FORAGE GRASSES

Rye grasses, Redtop, Bent grasses, Reed Canary grass, Harding grass, Meadow Foxtail and Tall Oat grass

RYEGRASSES

(Lolium species)

The common name, ryegrass, is applied to a group of plants comprising two species of the genus Lolium. One of these, Lolium multiflorum, is known as Italian ryegrass, and the other, L. perenne, as perennial ryegrass. Selections and hybrids of these two species have received special varietal names, and seed is offered in the trade under such designations.

One of the outstanding characteristics of the true ryegrasses to the layman is the edgewise placement of the rather large solitary spikelets with the rachis or main axis of the spike.

The ryegrasses of the genus Lolium should not be confused with the wild-rye of the genus Elymus most species of which are also good forage grasses and of which Mandan wild-rye is an improved variety of Elymus canadensis. The name "Western ryegrass" is also sometimes used in the Northwest to designate slender wheatgrass (Agropyron trachycaulm).

DESCRIPTIONS OF VARIETIES

Italian ryegrass: Italian ryegrass is a hardy, short-lived grass, usually an annual. When sown in the spring, late summer, or early fall on fertile land it makes rapid growth and soon covers the ground, furnishing grazing in a remarkably short time. It is tender and very palatable to livestock and has excellent carrying capacity. The plants grow from 2 to 4 feet in height and make excellent hay. It generally is distinguishable from perennial ryegrass by the awn and stem characters and by the arrangement of the leaf in the bud. Awns are present on seed of Italian ryegrass and are usually absent on perennial ryegrass. The culm, or stem, of Italian ryegrass is cylindrical, whereas that of perennial ryegrass is slightly flattened; and the leaves of Italian ryegrass are rolled in the bud, whereas those of perennial ryegrass are folded. The plants of Italian ryegrass are yellowish green at the base, while those of perennial ryegrass are commonly reddish.

Commercial Italian ryegrass seed usually produces some plants that live into the second season. It is not definitely known whether these plants are long-lived Italian ryegrass or hybrids of Italian ryegrass and perennial ryegrass. Their characteristics, however, suggest they probably are hybrids. Selections from Italian ryegrass have been made abroad that persist 2 years, but these strains do not appear to any extent on the market in the United States. Westerwald ryegrass, a rapid-growing variety of Italian ryegrass, has been tested in several States, but has never become popular in this country.

Since Italian ryegrass is a heavy seeder if not kept closely grazed or mowed, many new plants appear from volunteer seeding. If moisture and fertility are sufficient for rapid growth, it may be cut twice during the season.

Italian ryegrass has many uses. It makes an excellent nurse crop for spring-sown permanent pastures and lawns, and gives a quick cover for early grazing in pastures.
When sown in combination with winter grains for temporary pasture it makes a desirable bottom grass and increases the length of the grazing season. Italian rye-grass is a most desirable annual grass for temporary poultry range. In the South it is used extensively for fall sowing on permanent lawns in order to furnish a green cover in winter. It also makes a fine temporary lawn. In the Northern States it is frequently sown on lawns in the spring, to be spaded up in late summer for a permanent lawn sowing in the fall. The cultural practices and rates and methods of sowing are the same as given for perennial and common rye-grass.

Perennial rye-grass: Perennial rye-grass, also known as English rye-grass, is a native of Europe and is quite similar in general appearance to Italian rye-grass, except for the characteristics described under Italian rye-grass. It was the first of all perennial grasses to be grown in pure culture for forage in England in the seventeenth century. Stands obtained from commercial seed of perennial rye-grass often disappear in 3 or 4 years, probably for the reason that they are from seed that is a mixture of perennial rye-grass with hybrid strains of the perennial and annual species, and the latter are usually short-lived.

Perennial rye-grass differs considerably from Italian rye-grass in quality. The general run of perennial rye-grass plants are very tough, and therefore the grass is unpopular for lawns as it does not cut easily with the lawn mower. The tough character of the foliage is not particularly noticeable while the plants are young, but becomes more noticeable as they become older. This is true especially during the hot, dry weather of July and August.

Several strains of truly perennial rye-grass are now advertised commercially, especially in England and New Zealand, and the seed is used extensively in sowing permanent pastures in those countries. These strains and many others have been tested in this country. The results indicate that most of them are short-lived, although some plants survive for a number of years. They are best adapted to regions with cool temperatures and ample moisture during the summer.

The main use for perennial rye-grass, although not extensively used in this country, is for permanent pasture mixtures. It starts quickly and furnishes early grazing while other longer-lived grasses are becoming established. The hot, dry weather of July and August affects the growth; and if the drought continues very long into September, the recovery is slow.

Common rye-grass: Domestic rye-grass, Oregon rye-grass, western rye-grass, native
ryegrass, and Pacific ryegrass are names also used to designate common ryegrass seed grown in the United States. Seed sold as pure Italian ryegrass may be just that, but more often it is a mixture with common ryegrass predominating.

Common ryegrass is also often referred to as the South American type of Italian ryegrass. In its conglomerate make-up, numerous types are present and the type prevailing in South American seed sometimes appears in varying amounts. There are many intermediate types resulting mostly from field crossing.

Common ryegrass is rather widely used as a forage, cover, lawn, and seed crop in the United States. In plant and seed characteristics it resembles Italian ryegrass very closely, although usually it does not grow so tall, the stems are somewhat stiffer and heavier, and the seeds are more hispid and plump with shorter and weaker awns.

Common ryegrass grows from 2 to 3 feet tall, is leafy and tender, and when used as pastureage is very palatable to all classes of livestock. Since it furnishes early grazing and acts as a nurse crop to the more permanent grasses that are generally slow in becoming established, it makes an excellent addition to a permanent pasture mixture.

It also gives very good fall, winter, and early spring grazing when sown alone. It is a heavy yielder and when properly handled gives a high grade of very palatable hay.

For lawns and putting greens in the Southern States it is very satisfactory, producing a rapid growth from sowing and making possible green lawns during periods when the southern permanent grasses are dormant or are frosted and brown. Used in this manner, it generally dies out in late spring or early summer as the permanent lawn grasses become vigorous.

**ADAPTATIONS**

**Climate:** Ryegrasses are not so winter-hardy as many other grasses, including timothy and orchardgrass. Perennial ryegrass is more winter-hardy than either common or Italian. In the United States ryegrasses are grown principally in the Pacific Coast States west of the Sierra Nevada and Cascade Mountains and in the southern humid States, although in many cases they are used much farther north. They are grown to some extent east of the Cascade Mountains in the Northwest, where ample moisture is available, and in other sections in the United States where climatic conditions are not too severe.

**Soils:** The ryegrasses have a very wide range of soil adaptability. In some sections they are considered wet-land grasses, although production usually declines as the drainage gets poorer. For most desirable production the ryegrasses require soils of medium to high fertility, although they will make growth equal to most grasses on soils of low fertility. On the latter soils heavier sowing is required since the ryegrasses do not stool so much as on more fertile land.

**CULTURE**

**Time of sowing:** The ryegrasses can be sown in the fall or early spring. In sections where winters are severe, spring sowing is desirable because of probable heavy winter injury to fall sowings. Where the winters are mild early fall sowing is advisable. Late fall sowing is usually successful, but severe freezing, especially when accompanied by soil heaving, may cause heavy plant loss. Spring sowing should be done as early as possible and is most successful in sections having cool summers and frequent rainfall.

**Rate of sowing:** When sown alone for forage or seed production, 20 to 25 pounds of seed per acre are sufficient. When sown with small grain for annual pasture 8 to 10 pounds per acre will furnish a satisfactory stand. When perennial ryegrasses are sown as part of a pasture mixture, 4 to 6 pounds per acre may be used. When used for sowing on established grasses to furnish green lawns for winter or when sown alone in spring or fall for a temporary lawn, 3 to 5 pounds per 1,000 square feet are used.

**Method of sowing:** The ryegrasses may be broadcast by hand or sown with an
endgate seeder and covered with a smoothing harrow, or they can be sown with a grain or grass-seed drill. In Oregon most of the seed is sown with a drill. When a grain drill is used it may be necessary to reduce the size of the seed outlets to prevent sowing too much seed. The seed should be covered with approximately one-half inch of soil.

When ryegrass is to be grown for forage or for seed production, a seedbed prepared as for small grains is desirable. Sowing for these purposes usually is made without a nurse crop, although in the Pacific Northwest when ryegrass is grown for seed production, the practice of sowing with winter oats is increasing. When sown with oats, which should be at the rate of 1 bushel of oats to 20 to 25 pounds of ryegrass per acre, there seems to be little or no reduction in the yield of ryegrass seed; a fair yield of oats usually is obtained, and harvesting, particularly binding, is easier. The two crops are harvested together, and the oats and ryegrass seed are separated with a fanning mill.

**UTILIZATION**

*Hay:* Ryegrass is generally cut for hay when the seed is in the soft-dough stage. The hay cures rapidly and when handled properly has a bright-green color. Because of its leafiness and medium-fine stems, it makes a high-quality hay that is considered excellent for horses and is fed successfully to cattle and to sheep. One crop of hay is obtained, and under favorable soil and moisture conditions considerable pasturage is produced after the hay crop is removed.

*Pasture:* Ryegrass makes very rapid winter and spring growth, and new stands often are ready to pasture in 3 months after sowing. Unless pastured too heavily, it can be used continuously until summer in the West, and until late spring in the South. Heavy pasturing is quite desirable as it keeps the grass in succulent condition and utilizes all the forage produced during its short productive period. At Beltsville, Md., in 1931 and 1932, sheep were grazed on common ryegrass, largely of the Italian type. As an average for the 2 years, the grazing season extended from April 25 to August 1, and 650 sheep-days grazing per acre were secured. In addition, approximately three-quarters of a ton per acre of field-cured hay was removed about June 15, because of lack of sufficient sheep to keep the grass down during the flush period of growth.

When necessary to remove hay from a grazed field, it is advisable to set the mower to clip at least 3 inches from the ground.

For pasturage, ryegrass is not often sown alone except for temporary use. Because of its rapid growth and its value in producing forage while other longer-lived plants are becoming established, it is used extensively in mixtures.

*Lawns:* Large quantities of common ryegrass and limited quantities of imported Italian ryegrass seed are used for lawns, particularly winter lawns in the Bermuda-grass sections. These are very satisfactory for sowing in the fall on other grass sod to maintain a green, pleasing appearance during the winter months, and do not offer any interference when other grasses and legumes are in good condition.

Because of the rapid germination and short time necessary to produce a green covering, both common ryegrass and imported Italian ryegrass often are used in lawn mixtures. When this seed is sown with long-lived grasses under lawn conditions, it seldom maintains itself for 2 years, although occasionally when the percentage of perennial ryegrass in common ryegrass seed is rather high, perennial ryegrass plants will remain for several years, but are not popular in lawns.

**SEED PRODUCTION**

Practically all the seed of common and perennial ryegrass is produced in the Willamette Valley in northwestern Oregon. Seed production is general in that area except on bottom lands which cause too heavy growth of foliage for seed production. With common ryegrass only one seed crop should be taken. A volunteer stand may be obtained the second year but
should not be cut for seed. With perennial ryegrass three crops may be taken unless the field becomes weedy or overrun with other grasses. Perennial ryegrass for seed production should not follow common ryegrass because of the danger of mixture with common ryegrass which is always a possibility even when precautions are taken. The most common weeds that are troublesome in ryegrass seed are buckhorn, Canada thistle, sheep sorrel, rattail fescue and St. Johnswort. In recent years a few counties in Kentucky have been producing a quantity of ryegrass seed—presumably common.

Harvesting practices are the same as for small grains. When cut with binders, stationary threshers are used for threshing. When the crop is cut with a header and windrowed, or when allowed to stand until mature, combines are used for threshing. As the seed shatters easily, larger yields may be secured by cutting with the binder or header when the seed is in the early hard-dough stage. Combining the standing crop when the seed is ripe enough to thresh satisfactorily sometimes results in rather heavy losses from shattering, but the best quality seed is obtained by allowing it to mature on the stalk. To prevent shattering, there has been a tendency to harvest the seed with a combine while it is still in a slightly immature stage. Such seed when sacked or piled in large quantities often heats and molds with the possibility of reduced vitality.

Seed yields vary considerably. On the better soils from 1,200 to 1,600 pounds of clean seed are obtained; average yields are 500 to 700 pounds an acre. Seed production on a large scale has been carried on in the Pacific Northwest for more than 20 years. The production there has shown a general increase from 12,900,000 pounds of common and 200,000 pounds of perennial in 1936, to 56,000,000 pounds of common in 1947 and 35,000,000 pounds in 1948, and 7,000,000 pounds of perennial in 1948, the average production of each for the 13-year period being 30,000,000 and 3,125,000 pounds, respectively.

A seed crop is never harvested after taking off a crop of hay but is sometimes harvested following a short pasture season which usually ends the middle or latter part of April. This practice may, however, reduce the yield of seed.

REDTOP AND BENTGRASSES

(Agrostis species)

The genus Agrostis which includes redtop and the bentgrasses is a large genus of grasses comprising over 100 species of which about 30 are found in the United States. Most of the species have considerable value as forage plants.

Redtop, (A. alba), however, is the only one of much prominence as a hay plant among them. It was early introduced into the American colonies and has been known under many common names, such as whitetop, fiorin, white bent, and herd's grass. As all of these names belong more properly to other grasses, they should not be used for redtop.

The popularity of redtop is due not so much to the quality of the crop as to the fact that it will grow on almost any soil that is adapted to hay or pasture, particularly on wet or acid soils; it offers less competition as a short-lived grass in mixtures with other grasses and legumes than common ryegrass in either pastures or lawns; the seed, like timothy, is easily handled, is easy to sow, germinates quickly, is easy to obtain a stand, and is relatively low in price; all of which are important if a crop is to retain its popularity.

The bentgrasses are not used to any extent for forage or erosion control but have been found well adapted for putting greens and in mixtures with other grasses for lawns.
REDTOP

*(Agrostis alba)*

**DESCRIPTION**

Redtop is a perennial grass, with a creeping habit of growth, which makes a coarse, loose turf. It matures at about the same time or a little earlier than timothy in Illinois and Missouri where the two crops are often grown for seed.

The leaves are about one-fourth of an inch wide and the stems slender. The loose, pyramidal, usually reddish panicle is very characteristic and the color readily distinguishes it from most other grasses that have a similar shaped inflorescence.

In both plant and seed characteristics, the several closely related species of *Agrostis* are so similar as to not always be readily distinguishable from each other, but the single-flowered spikelet will serve to distinguish them from most of the grasses of other genera with which they might be confused such as the blue-grasses and mannagrasses.

**ADAPTATION**

Though Redtop is found all the way from Canada to the Gulf Coast and from the New England States to the Pacific and has a wide climatic adaptation, it is primarily adapted to the cooler and more humid regions of the northeastern United States.

No other grass will grow under a greater variety of conditions than redtop. It is one of the best wet-land grasses among the "tame" species. It will grow on soils so very poor in lime that most other grasses fail. It is rather drought resistant and is often used for holding banks of drainage ditches and waterways, to prevent erosion.

**CULTURE**

Sowing the seed: About the same factors govern the sowing of redtop as do the sowing of timothy in the preparation of seedbed, and time, rate, and method of sowing the seed. Possibly more care should be taken to see that redtop seed is not sown too deeply. A firm bed with light soil-covering and plenty of moisture is required by redtop. It is sown either in the fall or early spring at the rate of 5 to 10 pounds of recleaned seed per acre when sown alone, or 3 to 5 pounds when sown in mixtures.

Because of its quick establishment, low cost, and lack of aggressiveness in association with other grasses and legumes, in certain areas where the hay is to be used...
on the home farm it is a common practice to add from 2 to 3 pounds of redtop as a filler in hay or pasture mixtures. This practice is followed whether or not redtop is considered a major component of the mixture.

**UTILIZATION**

**Hay and pasture:** As a hay crop on low sour land redtop will continue to be sown as before. It produces a fair quality of hay for home use if cut early and well cured. It is not a good hay to market like timothy, as it is in little demand if timothy and other better kinds and qualities of hay are available.

Because redtop, like alsike clover, is adapted to wet heavy soils where other more desirable grasses and other legumes will not thrive, the two make a good hay combination, maturing for hay about the same time and having about the same longevity.

Redtop and reed canarygrass may be used in combination, even though the latter is generally grown alone. In the Southcentral States where Korean lespedeza is adapted, it is also used in combination with redtop. So, regardless of the inroads made on the use of redtop as a hay and pasture plant in recent years by other kinds of grasses, and the market disfavor of redtop hay, it still occupies a place under certain soil and climatic conditions where other forage grasses would be of little value.

Redtop is one of the most useful lawn grasses in the more humid areas of central, northcentral and northeastern United States. It is very commonly used in combination with Kentucky bluegrass in the proportion of about one part redtop to 4 or 5 parts of bluegrass. Other grasses may be used with these two or they may be sown together without other grasses. Redtop germinates more quickly than Kentucky bluegrass and gives a lawn that can be mowed in a few weeks time if moisture and temperature conditions are favorable. Redtop usually is better for this purpose in lawn mixtures than common ryegrass, because it furnishes less aggressive competition with the Kentucky bluegrass or other constituents of a lawn mixture. Redtop should not be sown alone for a permanent lawn.

**SEED PRODUCTION**

Up to recent years redtop seed production was largely confined to Illinois, and this State is still the largest producer. During the past 10 or more years, however, Missouri has been increasing its production of redtop seed so that now it produces nearly half that of Illinois, or nearly one-third of the total U.S. production. A large part of the Missouri production and some of that produced in Illinois is grown in mixture with timothy. Because of the physical characteristics of these two seeds, they can be separated readily by the use of modern machinery so as to produce practically pure seed of each kind from such mixtures.

**Harvesting seed:** Redtop seed, to be of the best quality, should be allowed to ripen on the stalk but if allowed to remain longer than that, there is danger
of loss of seed through shattering. In Illinois and Missouri, this ranges from the last week in July to the middle of August, depending on the season.

Self-binders and threshers are used mostly in the important producing area, but in some localities combines have taken their place. Sometimes it is cut and cured in the swath and later combined with pick-up attachment.

**Acreage and production:** During the past 10 years (1939-48) there has been no general trend upward or downward in total United States acreage of redtop seed harvested. The lowest acreage in that period was in 1948 with 72,000 acres and a production of 4,100,000 pounds which was also the lowest. The largest acreage was in 1940 with 305,000 acres and a production of 18,300,000 pounds. The largest production and yield per acre combined were in 1945 when 22,300,000 pounds were produced from 274,000 acres based on a yield of 81 pounds per acre. The average acreage, yield, and production for this 10-year period (1939-48) were 240,000 acres, 66 pounds, and 15,860,000 pounds, respectively. Though redtop seed acreage and production appear to be declining in some counties of southern Illinois because of increased use of other grasses and of lime and phosphate and the relatively low acre income from redtop, this is probably being more than compensated for (except for the very low acreage and production in both States in 1948) by the increased Missouri acreage and production. The average yield per acre has also increased from 54 pounds per acre from 1922-33 to 66 pounds per acre from 1939-48.

**REDTOP HIGHLIGHTS**

1. Redtop is a popular grass but does not owe its popularity to the quality of the crop but rather to the fact that in the region of its climatic adaptation a stand can be established easily; it will grow on almost any soil that is adapted to hay and pasture, and the seed is relatively cheap.

2. The principal uses of redtop are (a) as a wet-land or sour-land crop, (b) as a part of pasture mixtures, (c) as an ingredient of lawn seed mixtures to give the lawn a quick start and early sod formation, (d) as a wet-land soil binder, and (e) as an ingredient of seed mixtures in erosion control on difficult sites.

3. Redtop and alsike clover, the grass and legume which will stand rough treatment and low, relatively sour land where most other kinds will not thrive, are suitable for growing together and can be used to make up a large part of pasture mixtures for growing under those adverse conditions.

4. In combinations, redtop is one of the very few grasses that are suitable for use with reed canarygrass. On the poorer land of the South, redtop can be used with Korean lespedeza.

5. In lawns redtop is generally sown with Kentucky bluegrass in proportion of one part redtop to 4 or 5 parts Kentucky bluegrass.

6. Redtop gives best results when planted on a well prepared, compact seedbed, and is usually sown broadcast in the fall.

7. Under normal conditions redtop should be harvested for seed not later than one week after blooming is completed, because of the danger of loss through shattering if harvest is delayed beyond that time.

8. The average yield of redtop seed per acre has increased in recent years from 54 pounds per acre from 1922 to 1933, to 66 pounds per acre from 1939 to 1948.

9. The ten-year (1939-48) average United States production of 15,860,000 pounds of clean redtop seed was 44 percent larger than the ten-year (1927-36) average of 11,000,000 pounds.

10. Until recent years, Illinois has produced practically all the commercial redtop seed crop of the United States, but for the past five years, Missouri has produced nearly 30 percent of the total.

11. Practically all of the redtop seed produced in Illinois comes from pure stands, but that produced in Missouri is largely grown in mixture with timothy. The two kinds of seeds can be separated readily in cleaning so as to produce practically pure seed of each.

**SPECIAL CROPS—GRASSES**

**(Agrostis species)**

The fine bentgrasses—colonial bent (Agrostis tenuis), creeping bent (A.
REDTOP AND BENTGRASSES

*palustris*), and velvet bent (*A. canina*)—have been found well adapted for putting greens and, in mixtures with other grasses, for lawns over much of the northern half of the United States. For many years they have made beautiful lawn turf in New England.

Of the many strains of creeping bentgrass, most of them must be started by planting pieces of the stolons or runners because no seed is available. Washington creeping bent and Metropolitan creeping bent were the first named strains; many different strains now available are being used on putting greens. Seed of Seaside bent, also classed as creeping bent, is commercially available.

Velvet bentgrass (*A. canina*) is a fine-leaf type commonly found in rather limited districts in old turf. It is propagated from stolons as are some varieties of creeping bent. Seed also is commercially available.

The bentgrass most generally used in lawn mixtures is commonly known as colonial bent (*A. tenuis*). It does not creep extensively; partly for that reason it needs less attention than the creeping bents. Astoria bent is essentially the same as the common colonial bent. Highland bent is classed as a variety of colonial bent but has a slightly different color and growth habit than the common colonial bent.
bent. All the colonial bents have given good results in lawn mixtures. They are affected by large brown patch, a fungus disease, and where they are grown alone they are likely to be injured by the disease.

Seed fields of colonial bent are extensively grazed after seed harvest in northwestern Oregon in the seed-producing area. This is done primarily to help in seed production. Pasture returns from such grazing are more or less incidental.

In August 1949 the harvest-time forecast of Oregon's bentgrass crop for that year was 1.2 million pounds of clean seed, 20 percent less than the 1.5 million pounds produced in 1948, but 7 percent more than average.

CANARYGRASSES

(Phalaris species)

The canarygrasses, both the native and introduced species, are widely distributed throughout the world, although those in the United States are not so numerous as those of most other genera.

The canarygrasses are annuals or perennials. Most of the ones found in the South are winter annuals; some of them occur in the North as summer annuals. The common name, canarygrass, probably had its origin from the fact that the seed of Phalaris canariensis has long been used as canary bird feed. Reed canarygrass (P. arundinacea), and Hardinggrass (Phalaris tuberosa stenoptera) are the only species cultivated for forage in the United States.

REED CANARYGRASS

(Phalaris arundinacea)

Reed canarygrass, while not a new grass in either hemisphere, is one of the latest to assume a role of increasing importance. In the United States it is found from the New England States westward to the Pacific Coast and as far south as Tennessee. The grass is native to the temperate portions of Europe, Asia and North America.

The cultivation of reed canarygrass probably began in Sweden about 1849, in England about 1824, and in Germany about 1850. Cultivation in the United States probably began along the North Atlantic Coast shortly after its early use in Europe. At the present time the Pacific Coast sections of Oregon, Washington, and northern California, and the Northcentral States, including Minnesota, Wisconsin, and Iowa, have the largest areas of this grass.

According to reasonably authentic records, it was first cultivated in the Coquille Valley of Coos County, Oregon, about 1855, and the original stand is still in existence. A majority of the fields on the Pacific Coast can be traced to this early sowing. In various sections of the northern Rocky Mountain States and in southern Canada considerable areas of reed canarygrass are found. The origin of the first fields in these sections is not known, but many of them are probably native.

An expansion of the acreage of this grass in many sections of the eastern United States is indicated by the increasing quantities of seed purchased. Much seed is also being grown in the Northcentral States. Reports indicate that successful stands are being obtained and that forage yields are high.

No diseases serious enough to attract any attention attack this grass, and at present it is troubled very little by insects. During occasional years when grasshoppers and cutworms are numerous, slight damage is done.

DESCRIPTION

Reed canarygrass is a rather coarse perennial 2 to 8 feet tall with leafy stems, usually stout enough to prevent lodging, tending to grow in dense tussocks or bunches 2 to 3 feet in diameter and
spreading underground by short, scaly rootstocks. The leaves of the ordinary variety are broad, smooth, and light green in color; the inflorescence is a semidense, spike-like panicle varying from 2 to 8 inches in length.

The seeds are obovate, blackish brown or gray in color, and slightly pubescent when first coming from the panicle, but rapidly becoming smooth in handling. The weight of the seed depends largely on maturity and cleanliness, but to some extent on the climatic conditions under which it is produced. Well-matured clean seed weighs 30 to 40 pounds per bushel.

The seeds mature from the top of the panicle downward and shatter very easily after ripening, especially if the weather is dry and warm. Good seed will test 95 to 98 percent purity. The purity is high because in general where reed canarygrass grows, few grasses or other plants are found whose seeds will get mixed with it. Germination varies from 20 to 90 percent; low germination is due partly to immature seeds and heating because of immaturity and presence of green material. These are always present as the result of early harvesting to prevent loss from shattering. Some of the seed germinates very slowly, which may be an additional reason for the difficulty in obtaining good stands. There are approximately 564,000 seeds in one pound.

Varieties: There are numerous variations in the ordinary variety of reed canarygrass. Several of these have been segregated and are being tested in sections where the grass thrives. A distinct strain was selected in Oregon several years ago. It differs from the ordinary reed canarygrass in its more upright growth, greater leafiness, stiffer stems, and better seeding habits. The seed shatters very little, and yields are larger and harvesting costs less because machinery can be used to better advantage. The seed averages slightly larger and is more pubescent than that of the ordinary strain. This strain has been designated as Superior reed canarygrass, and seed is being produced in commercial quantities.

A reed canarygrass is a synthetic variety developed by the Iowa Agricultural Experiment Station by combining 10 outstanding strains which had been the most vigorous and productive over a period of several years in trials involving a large number of strains from Minnesota, Oregon, U.S.D.A. and Europe. This variety has done well both on wet lands and on upland soils under Midwest conditions.

A variety with variegated leaves and botanically known as *Phalaris arundinacea picta*, commonly called ribbon-grass, is grown as an ornamental.

**ADAPTATION**

Climate: Reed canarygrass does best where the climate is moist and cool; but it is not sensitive to heat or cold, growing successfully where winter temperatures drop below zero and where summer temperatures occasionally reach above 100°F. Cool weather is especially desirable during the winter dormant period.
Soils and moisture: Reed canarygrass makes its best growth on fertile, moist, or swampy soils, is especially suited to swampy or overflowed lands of a sandy, mucky, or peaty nature, and makes an excellent growth on loams and clays of good fertility. The grass is not suited to salt marsh or alkali soils. Moving overflow is not detrimental to this grass during either the dormant or the growing season.

Although naturally a moist-or wet-land grass, it makes a very good growth on high, well-drained, productive soil if supplied with ample moisture for spring and early summer growth. The Superior strain is especially suited to such situations. Its moisture-loving habits make it adapted to irrigation in cool climates.

CULTURE

Seedbed preparation: Four kinds of seedbeds are used for reed canarygrass on the Pacific Slope. These are well-cultivated land, newly slashed and burned-over land, semicultivated land, and uncultivated land.

The most satisfactory stands are obtained usually on well-cultivated land. Seedbed preparation should be such that the soil is fine, firm, and reasonably free from weeds.

The next most satisfactory seedbed is brushland or timberland, newly slashed and burned over. Most land under these conditions is reasonably free from weeds, and the natural ashy seedbed is often as good as or better than can be prepared by machinery. On land suited to reed canarygrass along the Pacific Coast, it is very often used as the “breaking in” crop after slashing. The stands are allowed to remain until the stumps have decayed sufficiently to be easily removed by pulling. After the stumps are cleared off, the land may be used for other crops or the stand thickened by sowing in vacant spots.

Date of sowing: Both fall and spring sowings are successful on the Pacific Coast, but in the Central and Eastern States it is best to sow in the early spring. Where winter temperatures do not cause heaving of the young seedlings, and winter overflows do not occur until the seeds are germinated and the seedlings well established, late summer and early fall sowing on reasonably well-prepared seedbeds is satisfactory. On burned-over lands, fall sowing is better than spring sowing, as the land is in better condition, no further seedbed preparation is necessary, and the full value of the ashes is realized.

In general, in most of the reed canarygrass sections spring sowing is most satisfactory on cultivated lands. On these lands a longer sowing season is usually possible, and good seedbeds can more easily be prepared. Where these conditions exist, sowing may be done from February to June, depending on climatic and soil-moisture conditions.

Reed canarygrass seed germinates very slowly. Under ordinary temperature and moisture conditions it takes from 24 to 40 days for complete germination. This point must be considered in fall sowing. When sowing in the fall on land that may overflow, it is especially advisable to sow early so the seed will not wash away and the seedlings will be well enough established to resist washing or drowning out.

Rate of sowing: On well-prepared seedbeds where ample moisture is available for maximum germination and continuous growth, and the probability of plant loss is small, 4 to 8 pounds of good seed to the acre are used by many farmers and excellent stands obtained. Because of the high price of seed, the use of larger quantities to act as an insurance of good stands on land receiving little or no seedbed preparation is a practice of doubtful value. Thin stands gradually improve if the land is suited to the crop.

Method of sowing: Several methods of sowing are practiced. Fall sowing is nearly always made alone, either with a grass-seed drill or by broadcasting. The seed should be covered very lightly, not over one-half inch. Broadcast seed can be covered sufficiently with a brush drag or a spike-tooth harrow with the teeth inclined backward at an angle of 45 degrees.
Reed canarygrass is seldom sown in combination with other grasses. It has not been considered compatible with other grasses and legumes. Experiments have been conducted in the northern and Corn Belt States in the sowing of reed canarygrass with certain legumes such as alsike and Ladino clovers with some success, but because of the habit of growth of reed canarygrass, it has been suggested that the nitrogen needed by the grass may be supplied better through the use of nitrogen fertilizers than from a legume. Further research is needed on this problem.

Reed canarygrass may be sown with small grains, on land of good fertility and plentiful moisture supply. When sowing with a companion crop the seed may be sown with a grass-sowing attachment on the grain drill or broadcast either before or after drilling the grain. In order to cover as much seed as possible, it is advisable to give the field a light dragging or harrowing after either method of sowing.

In western Oregon and western Washington sowing alone in the spring usually gives the most uniform stands, but spring sowing is often done with a small grain on low, fertile soils plentifully supplied with moisture during the summer. Spring oats or barley are generally used. Usually after the grain crop is harvested the new stand of grass is large enough to furnish considerable fall and early winter pasture.

Fall sowing with winter grain is sometimes done if the land is adapted to both crops. Soils that are sufficiently well drained for growing fall-sown grains are of doubtful value for ordinary reed canarygrass unless irrigation is possible. The Superior strain appears much better adapted than ordinary reed canarygrass for sowing with winter grains in the Pacific Northwest.

Sowing of reed canarygrass in cultivated rows on rather dry upland has been successful in several sections. On low ground, cultivation to control weeds is practically impossible because of the pulling out of roots, so on mucky soils, solid stands should be obtained. The sowings made either in the fall or in the spring in rows 16 to 20 inches apart are cultivated the first year. This results in the establishment of a good root system and thrifty plants. During the second year the plants spreading by means of their root-stocks usually occupy most of the spaces between the rows, and an almost solid stand is obtained.

Small areas to be used as nurseries or seed plots may be planted vegetatively. The rootstocks grow very readily. Sods three to four inches in diameter, set two to three feet apart and two inches deep, should form a solid turf in a few years. It is good practice to cultivate the first season unless the rootstocks are planted close together on fertile, moist soil. This method may be useful where it is desired to propagate certain special strains.

**UTILIZATION**

Use as pasture: Reed canarygrass is primarily a pasture grass. Its long life, long grazing season, and the large quantity of very succulent, palatable forage produced make it a valuable pasture plant where it thrives.

Because of the type of land on which it makes the most growth, as well as its rapidity of growth, it is better suited to dairy or beef cattle than to sheep or other kinds of livestock. The rapid, rather soft growth makes it a somewhat washy feed. Many dairymen feed a ration of grain with a small quantity of concentrate to offset this characteristic and, as they say, “to give it more body.” On overflowed or low, rather swampy land in sections where winters are open, the pasture season is usually the time between flood periods, or as soon as the land gets firm enough to hold the stock. Along the Pacific Coast good stands on reasonably well-drained land furnish pasture for nine months of each year; on higher, drier lands the effective pasturing season is not so long. In sections where long winters occur the pasture season can usually be considered as extending from shortly after the last heavy frosts in the spring to the early heavy freezes in the fall.

Under Pacific Coast conditions one
acre of good reed canarygrass pasture on land well-suited to it and properly handled will furnish fresh feed for four dairy cows for seven months each year. For the best quality of pasture the grass should not be allowed to make excessive growth and get old or tough. It is one of the earliest grasses to begin growth in the spring and will withstand pasturing well if not grazed too closely or too long continuously. Reasonably close grazing improves the quality of the pasture.

Rotation pasturing is practiced by the more successful livestock men. This results in better utilization and a better quality of pasturage. Rotation grazing makes it possible also to use parts of the pasture for hay or seed production, if conditions are such that all of the areas cannot be pastured economically.

During the late spring overflows, this grass will grow in the water. Some farmers pasture it under these conditions. This is not desirable; it is detrimental to the soil and injurious to the grass.

Use as hay: The use of reed canarygrass for hay is increasing. During its early history it was considered of little value for hay because of coarseness, low palatability, and the large proportion wasted by livestock. These deficiencies were mostly the results of lack of knowledge regarding the proper methods of handling.

The best quality of reed canarygrass hay is obtained from thick stands pastured early in the season to retard the haymaking period and to produce leafier crowns and stems. The early season growth is usually very heavy and the stems coarse. During seasons of excessive late spring rains considerable lodging may take place.

Reed canarygrass should be cut for hay when approximately 25 percent of the early heads are in the blooming stage. It has a long heading season, and if the cutting time is delayed until the late heads are in bloom the hay will be coarse and stemmy.

The hay cures rather slowly on fertile, moist lands because the large stalks settle rather closely to the ground after cutting. Tedders are effective and often used to accelerate the curing of such heavy crops. On higher, drier land, curing is more rapid because of lighter crops and drier soils.

Reed canarygrass hay is nearly always shocked and allowed to remain until well-cured. It is dangerous to stack or mow this hay until it is thoroughly cured, because it heats very easily and rapidly, and loss by fire or decay may result.

Yields and quality of hay: In Wisconsin and Illinois average yields of from 2½ to 4 tons of field-cured hay to the acre are obtained; in Oregon somewhat larger yields are reported. In some sections where limited pasturing is practiced two cuttings a year are possible. Reed canarygrass is not a high-class hay grass generally, but its suitability to wet and overflowed lands makes it a valuable hay grass on such soils. On account of the high yields per acre the use of reed canarygrass for hay is considered profitable under such conditions, even though the palatability and nutritive value are not so high as in some other grasses.

When it is fed to dairy cattle, beef cattle, or sheep, a grain ration with a small addition of some concentrate, such as linseed, soybean, or cottonseed meal, results in more profitable use of the hay.

Use as silage: Reed canarygrass is being used in increasing quantities for silage. Prepared as silage, it is a palatable, nutritious feed. The yield is large, ranging from 15 to 25 tons to the acre. Its use for silage makes possible a cheap, succulent winter feed, in sections where other silage crops often do not grow well or are too expensive to use profitably. The silo is a means of saving the grass when it is difficult or impossible to cure it for hay. The making of reed canarygrass silage is most common at present in the Coos Bay section of Oregon. It is being fed to beef and dairy cattle with good results.

Comparative analyses of reed canarygrass forage with other forages indicate that as fresh feed it is practically equal to timothy and redtop and considerably better than winter oats. As hay, it has a lower feeding value than the other crops. As silage, it compares favorably with winter oats, corn, or vetch and oats.
The exceedingly heavy yields in many cases offset the differences in nutritive value when considered on the basis of the cost per ton of feed.

Fucleman (Ill-7) summarizes his recommendations for Illinois as follows: “Reed canarygrass is not recommended as a hay or pasture crop to replace those which have been proved economically useful in Illinois. It is, rather, a crop having a special adaptation for periodically flooded lowland with muck or peat soils, unadapted for the growing of other crops.

“Results from Illinois experiments have shown that reed canarygrass produces large yields of hay or pasturage, but that it is not relished by livestock after it becomes coarse and fibrous. This unpalatability can be eliminated in part by cutting the first crop for hay, or, if used as pasture, by keeping it grazed sufficiently close to prevent it from going to seed.

“Canarygrass may be used to prevent erosion, particularly in waterways, or along stream banks, where cutting or scouring occurs. Seeding is usually difficult, and the method of establishment used is that of cutting canarygrass sod up into small pieces and space-planting the sods. Although more expensive than seeding, it is sometimes the only feasible method of establishment.”

SEED PRODUCTION

Until 1924 most of the seed handled by dealers was imported from Europe. In recent years seed production of reed canarygrass has been developed along the Pacific Coast and in the Northcentral States. Along the Pacific Coast seed matures in late July and early August if the grass has not been pastured late or previously cut for hay. In the northern Middle Western States seed matures in late June and early July.

Method of harvesting seed: Grain binders or headers have been used successfully, particularly for the Superior strain, which shatters considerably less than does the lowland type. The binders are equipped with pans under the conveyors and bundle table and behind the sickle, to catch most of the seed that shatters. In the Middle Western States various machines have been developed for harvesting the seed. Some of the seed is winnowed and then combined from the windrow. It is occasionally combined from the standing crop but when this is done the seed must be dried immediately.

Much of the seed has been, and to some extent still is, harvested by hand. The heads are cut off near the base or stripped, put in tight cloth bags, and taken to curing racks or buildings for drying. During bright warm weather outside curing racks are used. These consist of a series of two or three shelves made of fine poultry netting arranged one above another. The ground underneath is covered by canvas to catch shattering seed. The newly harvested heads are spread on the racks to dry and an occasional stirring causes more rapid drying.

As soon as the seed is dry it is threshed out with a flail or a fork and cleaned, or it may be threshed with a stationary combine. Barn floors are often used for drying, and although it takes longer to complete the process, the danger of loss by rain is eliminated. It is very important that the threshed seed be spread evenly over the floor not to exceed 3 to 4 inches in depth, and stirred 4 to 6 times daily as needed the first three days to prevent heating.

Because of the varied soil and field conditions under which the crop is grown, the method of harvesting seed will be the one best adapted to the particular situation and will depend upon the ingenuity of the grower to select and devise the best equipment for the purpose.

Seed yields and production: The yield of seed is very variable, ordinarily running from 50 to 150 pounds to the acre. Large yields of 300 to 500 pounds are sometimes obtained. In a good field the average person will harvest from 20 to 40 pounds of seed per day by hand. Seed is produced commercially in Oregon, Wisconsin, Minnesota, and Iowa, and possibly in other States where the crop is grown. These regions are now meeting
the domestic demand to a large extent. No accurate data are available of acreage and production, either for forage or for seed.

At the Soil Conservation Nursery, Ames, Iowa, the following yields were obtained in 1947: broadcast, 57 pounds per acre; 15-inch rows, 136 pounds; 36-inch rows, 204 pounds; and 48-inch rows, 207 pounds per acre. Three field methods of harvesting were compared: (1) use of binder, shock, and thresher; (2) combine with a high-lift attachment; and (3) using a combine as a header, with high-lift attachment and elevator canvas removed. With the latter method, it was necessary to place an extra man on the combine to rake the heads away from the reel. One-tenth acre areas were harvested for comparison, with seed yields per acre in the order of the methods listed: (1) 100 pounds; (2) 204 pounds; and (3) 320 pounds.

A number of experiment stations are attempting to develop non-shattering strains, and the future seed prices will depend to some extent on the results of these efforts. Seed of the newer strains, particularly of the Superior and Forced strains, has sold at a substantial premium over that of the common reed canarygrass.

**REED CANARY HIGHLIGHTS**

1. Reed canarygrass, a well known grass, but one of the more recent to attain importance as a forage crop in the United States, is a native of Europe, Asia, and North America.

2. Reed canarygrass has a wide range of both climatic and soil adaptation in the North Temperate Zone but is most at home in a moist cool climate, and grows best on fertile, moist, swampy soils of a sandy, mucky, or peaty nature. It makes an excellent growth, however, on most loams and clays of good fertility, but is not salt- or alkali-tolerant.

3. There are many variations in reed canarygrass, so it is possible to select varieties for specially desirable traits. The variety Superior has better seed habits, shatters less, has lower harvesting costs, and the seed yields are larger than the ordinary strain. It also thrives on uplands as well as the low moist lands to which the ordinary strain is specially adapted.

4. Reed canarygrass is primarily a pasture grass. It furnishes abundant, succulent, palatable forage throughout a long season and over a long life period. Better pasture utilization is obtained from rotation grazing.

5. Reed canarygrass does not make a high-class hay but produces from 4 to 9 tons per acre of fair to good quality hay if made from thick stands, pastured a while in the spring to dispose of the early coarse flowering stalks, and cut before one-fourth of the early heads are in bloom.

6. Reed canarygrass does not compete with timothy, orchardgrass, bromegrass, or other general purpose forage grasses in palatability or nutritive value, but its suitability to wet and overflowed lands makes it a useful grass where the others would not give profitable returns.

7. The most satisfactory stands of reed canarygrass are obtained on well cultivated land which has had the usually recommended seed-bed preparation of a fine, firm soil, reasonably free from weeds.

8. Spring sowing at the rate of 4 to 8 pounds per acre is practiced in most reed canarygrass growing sections, but either spring or fall sowing is usually successful on the Pacific Coast.

9. Seed is produced in the Willamette Valley and Puget Sound areas of Oregon and Washington, and in Minnesota, Wisconsin, and Iowa, but there are no statistics of acreage and production available. Seed yields are variable, running most from 50 to 150 pounds per acre.

**HARDINGGRASS**

*(Phalaris tuberosa stenoptera)*

Hardinggrass is related to the well-known reed canarygrass but in its adaptation is very different from that species. It is presumed to be a native of the Mediterranean region, but actually it was first noticed in 1902 near the Toowoomba Botanic Gardens, Queensland, Australia, so that the actual source is unknown. It has been under observation by the California Agricultural Experiment Station since 1914.

**Description:** Hardinggrass is a tall, perennial bunchgrass, with a loose, branching, somewhat rhizomatous base. It
MEADOW FOXTAIL

resembles reed canarygrass in general appearance, growth, and cultural practices. The principal differences are the more compact seed head of the Hardinggrass and its less spreading rootstocks. Also, the seed of Hardinggrass shatters less freely and harvesting is easier. Adaptation and use: Hardinggrass is a winter grower but will not withstand severe frosts. It does not like severe competition the first year, but once established, it is very hardy. It is highly drought-resistant, but produces more forage under more favorable moisture conditions, and prefers heavy soils. It survives in California with 10 to 60 inches of rainfall. It is nutritious and palatable when young and has been used chiefly for grazing. It furnishes succulent feed in the winter before the annuals appear. It will stand severe grazing and recovers quickly, but will produce more forage with good management. Culture: An alfalfa type seedbed gives best results on arable land. A good stand is invariably obtained by broadcasting in brush ash. Where fertility is low, Hardinggrass will give remarkable response to fertilizers. The seed is sown from September to March in California at a depth of ½ inch to 1 inch, or it is broadcast on fresh ash. When planted in 36-inch rows, 2 pounds per acre of good quality seed will give a good stand. If drilled or broadcast, 5 to 10 pounds of good seed per acre should be used. Mowing or heavy grazing to remove excessive weed competition the first spring is essential. Mowing top growth from time to time will stimulate fresh growth. Seed production: Hardinggrass is a fair seed producer but shatters badly. This results in low yields when full maturity is allowed before harvest. When harvested at the somewhat immature stage, more seed is secured, but the germination may be somewhat reduced.

MEADOW FOXTAIL

(Alopecurus pratensis)

Meadow foxtail is a native grass of the temperate parts of Europe and Asia. It has been cultivated since about 1750 and is grown in Europe to a considerable extent as a hay grass for rather wet lands of high fertility. It was probably introduced into America in the latter part of the nineteenth century in northeastern United States and eastern Canada. During recent years it has assumed increasing importance in the Pacific Northwest, and in this region its use for forage is increasing as rapidly as seed supplies become available. It appears to have possibilities as a satisfactory forage grass in several sections of the northern half of the United States. Since most of the cultural and utilization information published about meadow foxtail in the United States and that given in this chapter is based on experience in the Pacific Northwest, some inquiries regarding meadow foxtail were made of agronomists in some of the Northcentral and Northeastern States where it would be supposed to be adapted. Some replies indicated that they had had no expe-
rience with this grass. There are probably other localities in the northern United States than those mentioned here where meadow foxtail would be suitable as a forage crop.

Thompson, Supt. of the N.E Minn. Exp. Sta., says he believes that this grass has a place in that district. Its virtue lies in its earliness. It is often three weeks in advance of timothy and is helpful in spreading the hay-making season for this reason. The yields are not particularly heavy.

Neither Colby of Massachusetts, nor Prince of New Hampshire, in their trials have found meadow foxtail to be a more useful grass for their purposes than timothy.

Meadow foxtail should not be confused with several minor-value or weedy grasses because of its common name. The word "foxtail" in particular is considered by many persons to be an indicator that it may be a grass of little value or possibly a pest. In reality, it differs widely from other grasses quite commonly referred to as foxtail in that its agronomic and utility value are high and there is no evidence whatever of weedy characteristics.

DESCRIPTION

Meadow foxtail is a long-lived perennial grass. The flowering stems are erect and usually about 3 feet high. The head is much like that of timothy. It starts growth very early in the spring and is about the earliest of all cultivated grasses. Where winter and early spring temperatures are relatively low, production of flowering stems is usually within a comparatively short period.

ADAPTATIONS

Climate: Meadow foxtail does best where the climate is moist and cool; however, it is not sensitive to heat or cold, as it grows successfully where summer temperatures occasionally reach 100° F. and where winter temperatures may drop below zero for relatively long periods. Where average mean minimum temperatures are 40°-50° F., meadow foxtail makes rather continuous winter growth. It is adapted to the moist cool climates of the southern part of Canada but is not suited to southern climates. It will withstand cold weather or frosts in early spring and summer, thus being adapted to high elevations where frost may occur any month of the year.

Soil: Meadow foxtail makes its best growth on fertile, moist, or swampy soils. It is especially suited to swampy or overflow lands of a mucky or peaty nature. It makes very good growth on loams and clays of good fertility when well supplied with moisture. It is being used extensively on diked lands near the Pacific Ocean in the Pacific Northwest. In the northern intermountain country of western United States good stands have existed.
MEADOW FOXTAIL

for many years on low wet lands that are quite alkaline.

ESTABLISHING A STAND

Preparation of seedbed: Most satisfactory stands of meadow foxtail have been obtained from sowing on well cultivated land or after burning over of newly cut-over or slashed timberland or brushland. The seedbed on cultivated land should be such that the soil is fine, firm, and reasonably free from weeds. Late spring, summer, and early fall preparation is usually most feasible. This will make possible early summer or early fall sowing. Most land that has been well burned over is reasonably free from weeds and the natural ashy seedbed is often as good as or better than can be prepared by machinery.

Time of sowing: Both fall and spring sowings are successful in the Pacific Northwest, but in the Northern and Northeastern States early spring sowing is best. On burned-over lands fall sowing usually results in better stands than spring sowing, as the land is in better condition, soil moisture is more plentiful, and no further seedbed preparation is necessary.

Meadow foxtail seed germinates rapidly. The seedlings are small and quite weak. As a consequence, fall sowing should be done as early as possible so that the young plants can make maximum development previous to any adverse climatic conditions and be in best condition to resist washing or drowning out when seedlings are on low and wet or overflow land.

Rate of sowing: On well prepared seedbeds or on burned-over lands where ample moisture is available, 12 to 14 pounds of good seed to the acre is used and good stands are obtained. When sown in combination with other grasses and legumes, from 3 to 5 pounds of meadow foxtail seed is usually used per acre. Meadow foxtail seed is extremely variable as to germination. Seed that germinates 80 to 85 percent is good. Seed germinating 90 percent or more is excellent and is occasionally available.

Method of sowing: Several methods of sowing are practiced. Most sowing in the past has been by broadcasting by hand for the reason that the seed is very light and fluffy and difficult to distribute evenly with either hand-operated or other types of machines. Recent improved methods of harvesting and processing have resulted in increasing the weight of seed per measured unit and in reduction of the bulk by removal of considerable of the hull and pubescence. This in turn has made the use of sowing machinery practicable.

Drilled seed should be covered very lightly, not more than \( \frac{1}{4} \) inch. Broadcast seed can be covered sufficiently with a spike-tooth harrow with the teeth inclined backward to an angle of 45°, or with a brush drag. Sowing on burned-over lands is practically always by hand or hand-operated machines. Covering of the seed on such lands is often not practicable because of stumps, logs, and other interferences.

On low, wet, and swampy lands meadow foxtail is usually sown alone as there are few other grasses that combine well with it under these conditions. On lands that are quite moist for most of the year, it is often sown in combination with ryegrass and redtop and white, Ladino, and alsike clover, or big trefoil.

INSECTS AND DISEASES

Meadow foxtail is attacked only to a limited extent by insects in humid climates. Occasionally slugs and cutworms do some damage. In dry climates grasshoppers, when numerous, do considerable damage, particularly late in the season when other forage has dried up and the meadow foxtail on moist soils is green and succulent. Occasionally aphids attack the green heads.

No troublesome diseases have been noted on meadow foxtail.

UTILIZATION

Pasture: Meadow foxtail is primarily a pasture grass. Its long life, winter hardiness, long grazing season, and very succulent palatable forage make it a valuable pasture plant where it thrives. It is not
as heavy a producer as some other more
vigorous growing grasses.
Meadow foxtail is one of the first
grasses to start growth in the spring.
In mild climates it makes rather con­tinuous growth throughout the winter.
Growth is rapid during the spring and
carly summer and holds up well during
late summer and fall where soil moisture
conditions are favorable. When soil mois­
ture is low, it goes into semidormancy
until conditions improve.

It is a palatable grass and produces a
higher percentage of basal leaves than
most other grasses. Livestock, particularly
cattle and sheep, usually graze it in pref­
cence to other grasses. In some respects
this is detrimental, as it may result in
overgrazing, reduced production, and
shortened life of plants.

Hay: Meadow foxtail is as yet seldom
used for hay, but its use for this purpose
in all probability will increase as the
acreage increases. Under favorable con­
ditions two cuttings may be obtained in
a season. Under exceptional conditions,
three cuttings may be obtained. It is best
cut either when in full bloom, or very
shortly afterward. At this time the stems
are very sweet, containing more sugar
than most other grasses. The hay is leafy
and very palatable and is consumed readi­
ly by all kinds of livestock.
The hay yields of meadow foxtail com­
pare favorably with those of several of
the grasses commonly grown in western
Oregon for this purpose. It does not
average as high as for orchardgrass, tall
meadow oatgrass, or timothy. Yields of
approximately 1½ tons per acre have
been obtained in the northeastern United
States and southeastern Canada.

SEED PRODUCTION

Until 1940 only very small quantities
of meadow foxtail seed were on the mar­
et. Some of this seed was imported and
the remainder was produced mostly in
western Oregon. Since 1940, seed pro­
duction in this country has developed
quite rapidly. Most of this production
has been in Oregon. This situation is
largely the result of harvesting the large
meadow areas in the southeastern part of
the State. The quantities of meadow fox­
tail seed produced in Oregon for the 8
years (1940-47) were, in order of year of
production, 7,000, 7,000, 10,000, 16,-
000, 21,000, 40,000, 50,000, and 65,000
pounds.

In humid sections seed is harvested by
hand-stripping and combining. Hand­
stripping requires that a field be gone over
several times and the ripe heads harvested
each time. Hand-stripped seed is usually
of higher quality than machine-harvested.
During recent years, some combine har­
esting has been done in the humid sec­
tions with relatively good success.

In dry regions of southeastern Oregon
where meadow foxtail occurs on wet lands
and seed maturity is relatively uniform,
harvesting is all done with combines. An
average day's harvest for a small combine
is from 450 to 600 pounds of reasonably
clean seed. Yields of seed vary from 25
to 300 pounds per acre with the average
at present approximately 100 pounds.

MEADOW FOXTAIL HIGHLIGHTS

1. Meadow foxtail is adapted to the moist
cool localities of the northern United States
and Canada. It makes its best growth on
fertile, moist or swampy soils, and stands
more overflow by brackish water than most
other grasses.

2. Meadow foxtail is used mostly in the Pa­
cific Northwest, but is probably adapted,
though little used so far, to other localities
in the northern tier of States.

3. Meadow foxtail is not a competitor of
timothy and orchardgrass where these are
adapted, but is of special value for pasture
on lands too wet for most common grasses
and legumes.

4. Meadow foxtail is one of the first grasses
to start in the spring and is three weeks
ahead of timothy for hay harvest.

5. As pasture or hay the feed value of meadow
foxtail is equal to or better than timothy,
though the yields are definitely less.

6. The seed is sown, mostly broadcast, in the
spring or fall, either alone at 12 to 14
pounds per acre, or in combination with
redtop or alsike, white, Ladino or straw­
berry clover or big trefoil at 3 to 5 pounds
per acre.

7. Meadow foxtail matures its seed unevenly
so some seed is lost in harvesting, and the
TALL OATGRASS

yields are variable. The average yield may be around 100 pounds per acre, but yields of 300 pounds per acre may be obtained.

TALL OATGRASS

(*Arrhenatherum elatius*)

Tall oatgrass, also called tall meadow oatgrass, is a standard grass in parts of Europe and is grown in this country to some extent in the Central and Northern States, and as far south as Tennessee. Kalm advocated its culture in 1747. It was cultivated in Massachusetts as early as 1807, and in South Carolina in 1821.

Its failure to attain any great importance in any locality is perhaps due largely to the fact that the seed is expensive and that it takes a large quantity per acre to secure a stand. Aside from this, the grass, though succulent, has a peculiar taste which stock apparently do not relish until they have become accustomed to it. It is probable that this quality should not long remain a serious drawback to the growing of the grass, as abundant experience proves it to be palatable and highly nutritious. It might also be corrected wholly or in part by selection and breeding.

Description: Tall oatgrass is a hardy perennial which grows 30 to 60 inches in height and produces many leaves. It does not propagate by rootstocks but tends to be bunchy. Seed is produced in open heads or panicles resembling those of cultivated oats, although the seed is smaller and much more chaffy.

An improved strain, developed in Oregon, is being increased under the name Tualatin. Its seed shatters less readily than that of common tall oatgrass; in the East it is somewhat shorter in growth and has narrower leaves.

Soils, fertilizers and lime: Tall oatgrass prefers well-drained soil, and seems to be especially adapted to light sandy or gravelly land. It does not grow well in shade.

It does best on a soil well supplied with lime, its response to liming being about the same as that of timothy, but less than that of red clover. Good supplies of all the mineral elements of plant food, especially phosphoric acid and potash, are essential to a high yield. In sections where commercial fertilizers have been found profitable, 300 pounds to the acre of 16-percent superphosphate, or its equivalent in other high-grade phosphate, and 50 pounds of muriate of potash are advisable. The application should be
made prior to sowing, and the fertilizer should be well worked into the soil.

If injury from aphids appears probable, an application of from 50 to 100 pounds per acre of nitrate of soda is advised. The nitrate not only produces increased growth, but apparently enables the plants better to withstand the attacks of the insects. Nitrate may be used to increase growth at other critical times, such as late fall when a seedling is in danger of making insufficient growth to go through the winter, or in early spring to give the crop a good start and to make a more profitable yield.

Sowing the seed: Spring sowing is usually satisfactory but in sections where there is a reasonable amount of moisture in autumn or late summer and where winters are not severe, best results will probably be obtained by sowing broadcast in September or early October, at the rate of 30 pounds of seed per acre. The coarse, fluffy seed does not feed evenly through a drill. A well-fitted seedbed is essential. After sowing, the seed should be covered by cultipacking or harrowing lightly.

Use: Tall oatgrass has never attained great importance in any locality, but it does have many desirable forage qualities. It can be used for pasture or meadow; it gives a heavy yield of hay which is quite palatable. It is being used in mixtures with sweetclover or other legumes in short rotations. It is rather well adapted to light soils in the northern latitudes. In the Intermountain Region, it is also used for hay and supplemental pastures.

Seed production: Its poor seed habit is a drawback. It produces abundant seed, but harvesting is difficult because the seed shatters before fully mature. The seeds ripen about a month after blooming. Since the seed ripens unevenly and shatters easily, it should be harvested as soon as the straw yellows, or as soon as any substantial proportion of the seed is ripe and ready for harvest. As in the case of orchardgrass, it may be cut high for seed and a crop of hay may be harvested afterwards. Yields of seed on good soil may run around 200 to 400 pounds per acre.

The seed is often of low viability. It weighs 10 to 16 pounds per bushel, and it takes approximately 150,000 seeds to weigh a pound. The usual rate of sowing is 30 to 40 pounds to the acre.

The larger part of the material on ryegrasses used here is a revision of Schoth and Hein's bulletin (US-231), and the manuscript was reviewed by both authors of that bulletin. The material on redtop was obtained largely from Burlison et al (ILL-4), and Piper (US-204), and that on bentgrasses from Hoover et al (US-115). The manuscript was reviewed by Fueledeman of Illinois, and Hein and Edler of the U.S.D.A. The material on red canarygrass is largely a revised rearrangement of Schooth's bulletin (US-229), supplemented by Holdman and Albert (WIS-28); and that on Hardinggrass is from Hoover et al (US-115), and from Madsen and Love of California. The manuscript of both was reviewed by Schoth of Oregon and Hein of the U.S.D.A., and that on red canarygrass by Wilse of Iowa. The material on meadow foxtail is almost entirely a rearrangement, slightly revised, of Schooth's bulletin (OREG-24). It was reviewed by Schoth and Howell of Oregon, and Hein of the U.S.D.A. The material on tall oatgrass is largely from Hoover et al (US-115). The seed statistics on the ryegrasses, redtop and bentgrasses are from Edler and Kuzelka of B.A.E.

Chapter reference numbers:

Ryegrass: MD-14; MICH-11, 19; OKLA-9, 18; OREG-10; US-35, 36, 77, 230, 231.

Redtop and bentgrasses: ILL-4; MICH-11; NJ-25; RI-11; US-34, 204, 208; MISC-4.

Canarygrass: ILL-7; IOWA-2, 9; MICH-13, 25; MINN-3; OHIO-14; WIS-28; US-77, 229; MISC-27.


Tall oatgrass: OREG-1; TENN-11; US-77, 115, 204.

The reference numbers given here refer to references which are given in full by State, U.S.D.A., and Miscellaneous, on pages 682 to 724, and which are cross-referenced by author on pages 725 to 731. Citations in the text are indicated by abbreviation and number in parentheses.
CHAPTER XXIV

THE WHEATGRASSES

(*Agropyron* species)

The genus *Agropyron*, most of the species of which are commonly known as wheatgrasses, is one of the most important genera of grasses for hay and other forage in temperate regions. The number of species is rather large, probably as many as 150, of which about 30 are native in North America, nearly 100 in Asia, and the rest scattered in other regions. In recent years, with the increased interest in grass and grasslands, a number of species, primarily from Russia and Siberia, have been introduced for trial in the United States. These species have been rather confused as their identity has not been satisfactorily established. Some introductions have remained unidentified and others have carried names which are obviously incorrect.

Among the most important native species of *Agropyron* now under cultivation in the United States are western wheatgrass (*A. smithii*), and slender wheatgrass (*A. trachycaulum*), both of which have come under cultivation only within the last 40 years. The most important single introduction into the United States is Standard crested wheatgrass (*A. desertorum*). Another introduced species, the intermediate wheatgrass (*A. intermedium*), shows promise of becoming important in much of the eastern Great Plains area, especially for use in mixtures. Probably the most generally known introduced species is quackgrass (*A. repens*) which is classified as a noxious weed or primary noxious weed in most of the central and northern states.

Some wheatgrasses form sod; others grow in bunches. The sod-forming species are particularly valuable for erosion control. Germination of the seed which usually is produced in abundance, is rapid, and the young seedlings may become established in competition with weeds and other grasses. This seedling vigor permits the sowing of wheatgrasses with a minimum of seedbed preparation. Often good stands have resulted when the seed was drilled in weeds or small grain stubble. Their ease of establishment and adaptation to many kinds of soils, moisture conditions, and extremes of climate, make the wheatgrasses of first rank for use in plantings that are intended to protect the soil.

Early spring growth, with high production of lush forage at the season when most needed by overwintering livestock, is another good characteristic of these grasses.

The wheatgrasses have been used extensively for revegetating depleted range and abandoned farm lands. They are unexcelled for this purpose in the areas to which they are adapted. Seed is generally available, and successful methods of stand establishment are generally known and readily applicable. Many thousands of acres of previously cropped farm land in the Great Plains owe their present economic usefulness for grazing to these hardy, nutritious grasses.

None of the group has any long period of domestication behind it—the first cultivation reported dates no further back than 1895—although several of the species have long been recognized as valuable range grasses, both here and abroad. Others may furnish valuable breeding materials.

It has been demonstrated that two
introduced species, *A. elongatum* and *A. intermedium*, will hybridize with common and durum wheats. Many promising possibilities are thus opened.

**CRESTED WHEATGRASS**

(*Agropyron desertorum* and *A. cristatum*)

Crested wheatgrass is one of the most valuable forage grasses of the northern Great Plains. Its high palatability and quality of forage produced, together with its great hardiness and drought resistance, combine to make it superior to most other grasses for this area, and without an equal for use in some of the more arid portions.

There are two species known as crested wheatgrass, the Standard (*Agropyron desertorum*), and the Fairway (*A. cristatum*). They are native to the cold, dry plains of Russia and Siberia and were introduced into the United States.

The first recorded introduction into the United States was made through the efforts of the United States Department of Agriculture in 1898, and the first recorded trial of crested wheatgrass in the United States following the introduction in 1898 was at the South Dakota State Agricultural Substation at Highmore, South Dakota, in 1906, as recorded by Dillman (US-50), but the possibilities of the grass did not attract much attention until after 1915, when it was sown in the northern Great Plains where it proved especially adapted.

By far the larger part of crested wheatgrass grown in the United States is Standard. In Canada, Fairway is more generally used and some of this variety is grown in North Dakota and Montana, and perhaps a little elsewhere. In this chapter, unless otherwise mentioned, the Standard variety is considered under the name “crested wheatgrass.” They are typical bunchgrasses, differing in this respect from western wheatgrass and bromegrass (*Bromus inermis*), both of which spread by underground rootstocks and tend to develop a uniform turf.

Crested wheatgrass. 

SPECIAL CROPS—GRASSES

**DESCRIPTION**

The taller Standard strain of crested wheatgrass, which is more generally grown in the United States, is represented by a wide range of types. Some plants are leafy and fine-stemmed, whereas others produce few leaves and have stiff and coarse stems. Head types are extremely variable, some being lax and others dense. The seeds of some plants have pronounced awns, whereas, those of others are awnless or nearly so. Strains now in process of development have extremely plump, awnless seeds with a test weight of over 30 pounds per bushel. Seeds with long awns are objectionable, as they have a tendency to hang together and do not feed readily through the drill. The Fairway strain has been used to some extent as a dry-land lawn grass, but it has a tendency to become bunchy as the plants become older. In western Canada, where the Fairway strain was developed, it is used
Crested wheatgrass has a longer productive life than slender wheatgrass or bromegrass and under northern Plains conditions has yielded well for 15 to 20 years or more. In comparable tests, bromegrass and slender wheatgrass have frequently yielded more than crested wheatgrass the first two or three years, after which the slender wheatgrass tends to die out and the bromegrass becomes sod-bound, whereas the crested wheatgrass continues to produce even under limited moisture conditions.

Comparison of Standard and Fairway crested wheatgrass: Standard crested wheatgrass (A. desertorum) and Fairway crested wheatgrass (A. cristatum) are two distinct species but are often referred to as two varieties of one species. The two species will not cross with each other. Fairway is a selection and does not break up into many forms as does the Standard. The plants of Fairway are finer-stemmed, more leafy, and tiller more than those of Standard. The upper surfaces of the leaves of Standard are sparsely pubescent on part of the plants while those of Fairway are covered with fine hairs on practically all of the plants. The Fairway plants are usually bright green in color, while those of Standard vary from dark green to grayish green. The heads or spikes of Standard are variable in size and shape, while those of Fairway are broad at the base and taper toward the tip. The seeds of Standard are larger, carry fewer awns and weigh more than those of Fairway. Fairway seeds carry more and longer awns than Standard.

The plants of Fairway are very uniform in height varying normally from 16 to 24 inches, and averaging approximately 22 inches. The roots penetrate the soil very much as do those of Standard, but there is generally more fibrous material in the upper layers of the soil.

ADAPTATION

Crested wheatgrass is able to grow at low temperatures and as a result makes earlier and more rapid growth than many other grasses with which it has been compared. The grass is extremely drought-resistant and has survived the most severe periods of dry weather. This characteristic is probably due to its extensive root system, which permits storage of abundant food reserves and ready utilization of water. Excavations have shown that the roots may penetrate to a depth of 8 to 10 feet. During hot, dry periods, the grass has the ability to become more or less dormant and protects itself from injury by this characteristic. With a favorable moisture supply, growth is resumed upon arrival of the cool days of autumn and continues until late in the season. Its ability to grow at low temperatures, combined with its efficient utilization of soil moisture, enables the grass to crowd out weeds where the moisture supply is limited. It is entirely resistant to all extremes of cold. No reports of killing of an established stand from either cold or drought have been made in areas where the grass is adapted.

Crested wheatgrass is especially well adapted to the northern Great Plains, where the temperatures are severe and the moisture supply is limited, and westward to the Sierra Nevada Mountains. In this general region it has proved particularly valuable for regrassing abandoned croplands, and has become the leading grass for use in the Northern Plains for pasture, hay and erosion control. Farther south, it has not given as good results except at altitudes of 5,000 feet or more.
In the area adjacent to the Plains on the east, other grasses are generally more satisfactory. Under the more favorable conditions of the Eastern States, it is not equal to timothy and other adapted grasses. See map for distribution of Standard crested wheatgrass (A. desertorum, not A. cristatum as shown on map).

The grass does well on productive soils of almost any texture ranging from light sandy loam to heavy clay; but it is not as tolerant of alkaline soil conditions as is western wheatgrass. It has done well on stony loams in the Judith Basin, Montana.

**UTILIZATION**

**Pasture:** In the areas to which it is adapted, crested wheatgrass fills a unique place as a pasture grass, and it is probable that its greatest usefulness will be for this purpose. The grass is especially valuable as a supplement to native range. It can be grazed almost a month before native range is ready and at a much lighter rate. When the native range is in the best condition for grazing, livestock can be taken off the crested wheatgrass and any grass remaining can be cut for hay. With favorable moisture in the fall, enough growth is made so it can again be grazed at that time, but it has little value for winter grazing. Utilization in the fall increases the grazing period considerably and it provides succulent feed in the early spring when it is so important for calving or lambing pastures. Young crested wheatgrass large enough for grazing has a high protein content (20 to 30 percent) both in the spring and in the fall.

In grazing tests conducted in cooperation with the Bureau of Dairy Industry at the United States Dry Land Field Station, Ardmore, South Dakota, crested wheatgrass for dairy cows proved superior to bromegrass, sweetclover, and native pasture. At the Judith Basin Branch Station, Moccasin, Montana, crested wheatgrass has given better returns as a dry-land pasture than bromegrass, sweetclover, or native grass, especially in years with less than 12 inches of annual precipitation or other adverse conditions. At Mandan, North Dakota, crested wheatgrass makes excellent early pasture and cattle make good gains on new growth. In common with other cultivated grasses, its grazing value decreases as it approaches maturity.

Crested wheatgrass is the most important grass for use in the crop-replacement program in areas where it is adapted. Many thousands of acres of abandoned plowed lands have been reseeded with excellent results. If mixtures of grasses are used, fifty percent or more of the seed in the mixture should be crested wheatgrass.

**Hay:** If the grass is to furnish a good quality of hay, it is advisable to cut it shortly after it comes into head or before blooming time. As the grass matures, it becomes harsh, and the protein content decreases rapidly and by the time the grass is mature may be as low as two or three percent. The hay dries readily, and with favorable weather can be stacked or stored soon after being mowed. Where the grass is adapted, yields have ranged from three-fourths of a ton to one ton of cured hay per acre over a period of years, with considerably higher yields in the more favorable seasons.

At the Northern Great Plains Field Station, Mandan, North Dakota, a seeding made in rows in 1915 returned its fifth highest hay yield in 1942, the twenty-seventh year of production. The highest yield was 3,550 pounds per acre in 1916, and the lowest was 146 pounds per acre produced during the severe drought of 1936. The average yield for the twenty-five years has been 1,675 pounds per acre.

**Erosion control:** The grass can be utilized very effectively for the control of wind and water erosion. Its tough fibrous root system especially adapts it for use in rotations. Because it is a bunchgrass, it is easily killed by plowing. The roots add a tremendous amount of organic matter to the soil, which is so important for good crop production, and water infiltration is increased. The grass is also useful for sowing rights-of-way along highways and for farm roadsides where a perma-
ent growth is needed to control coarse weeds.

**WESTERN WHEATGRASS**

*(Agropyron smithii)*

Western wheatgrass has several outstanding characteristics that make it exceedingly valuable for use both as forage and for erosion control. Its palatable, high-protein, early-spring growth make it especially relished by livestock. Its rapid growth and strongly creeping rootstocks produce a good ground cover and a rather heavy sod. Pure stands of this grass are not uncommon, especially on the heavy gumbo soils of old lake beds. By reason of its tall, grainlike growth, its seed can be harvested and cleaned easily and cheaply by the use of ordinary small-grain equipment. Further, the seed is relatively large and can therefore be sown rather deeply. Where there is little moisture, deep planting assures better germination and establishment. The tenacious, soil-binding habit of this grass makes it especially suitable for reestablishing grass on abandoned farm lands. This is borne out by the fact that on abandoned farms that were not clean-cropped too long, good stands of western wheatgrass have developed from rootstocks carried over from the time when the land was first plowed.

**DESCRIPTION**

Western wheatgrass is a native perennial, sod-forming grass usually growing from one to two feet tall under most northern Great Plains conditions, but which will grow to three or more feet high under favorable conditions. The leaves are usually from four to twelve inches long and less than one-fourth inch wide. The upper surfaces of the leaves are prominently ridged lengthwise and are very rough to the touch. The underside of the leaf is relatively smooth.

The leaf blades do not droop, despite their length, but are more or less stiff and erect. When the plant is drying, the leaves roll up tightly and assume a wire-like form which gives the plant the appearance of having a scanty foliage. The entire plant—stem, leaves and flower-head—is usually covered with a grayish bloom which, combined with the actual green of the plant, gives it a bluish green, distinctive coloration.

The flowering heads are from two to six inches long, spike-like in form, and usually there is but one spikelet at each joint of the rachis. The spikes are borne on tall, erect stems.

The extent of the underground parts of western wheatgrass varies considerably with the soil moisture. The long slender rhizomes usually lie between one-half and three inches below the soil surface; they grow rapidly, branch frequently, and are profusely covered with scale leaves. Under favorable moisture conditions the root system of this grass may extend to eight feet or more, while on the dry upland areas the depth of penetration may not be more than three or four feet. Un-
der dry conditions the surface absorbing portion of the root system is especially well developed.

ADAPTATION

Western wheatgrass is distributed widely over the United States occurring in all but the eastern and extreme southern sections. It is most abundant, however, in the northern and central Great Plains region. It is well adapted to a variety of soil conditions but makes its best growth on the heavier soil types where an adequate supply of moisture is available. In western North Dakota and South Dakota it is abundant in lowlands and frequently occurs in nearly pure stands on the “sagebrush” flats along watercourses. However, it grows in considerable abundance on the dry uplands in company with the grama grasses and the needlegrasses. Its height, growth and forage production are usually correlated with the available soil moisture. In alkali tolerance this species ranks among the first and is usually one of the major species found in the alkali soil areas of the western part of the Northern Great Plains. In recent years it has been demonstrated at Woodward, Oklahoma, that western wheatgrass can be used advantageously to lengthen the grazing season when used with native range.

UTILIZATION

Hay: The high quality of western wheatgrass hay has long been recognized. In the early days before the railroads crossed the Dakota prairies, it was in great demand by freighters, and early-cut well-cured hay brought a premium of ten to twenty percent over other prairie hays or timothy as feed for their horses. Almost pure stands of western wheatgrass can often be obtained by turning over prairie sod containing a well distributed portion of western wheatgrass and following with roller, disk or cultipacker over the plowed field, providing sufficient moisture is available following this operation. Especially good yields of hay are obtained from such stands and also from the stands of western wheatgrass on abandoned cultivated fields. Frequently such fields are dominated by nearly pure stands of this grass and may yield from one-half to three-fourths ton of hay per acre. Most operators prefer to have such fields from which to cut hay, rather than the native undisturbed sod which yields smaller amounts of forage. Where moisture conditions are favorable, even greater hay yields of this grass can be expected.

Pasture: In the Northern Great Plains western wheatgrass constitutes a substantial portion of the native pasture. Its growth begins relatively early, usually several weeks before the graminoids, and it does not mature until late in the season. Throughout its growing period it provides a high quality pasture forage, and also furnishes fair to good winter grazing.

Its palatability rating is high and it has excellent nutritive qualities. Chemical analyses of the grass cut in the early bloom stage indicate that the protein content is just as high as that of blue grama in the same stage.

Care should be taken to see that western wheatgrass is not grazed too closely. Too heavy grazing will reduce the forage yield, and may result in the death of many of the plants. Under heavy grazing, western wheatgrass largely disappears from the native prairie in western North and South Dakota.

Erosion control: Because of its vigor and rapidly-growing rootstalks, western wheat-
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grass can be readily transplanted and is, therefore, especially useful for sodding terrace outlets and channels as well as for sowing or sodding stream and reservoir banks as a protection against wave action. After the plants become established the long rootstocks and heavy root system effectively bind the soil by forming a dense sod and heavy vegetative cover. In gullies and terrace outlets, where the plants receive excess run-off water, the leafy top growth retains the soil particles carried in the run-off and so serves as an excellent de-silter.

SLENDER WHEATGRASS

(*Agropyron trachycaulum*)

Slender wheatgrass is a short-lived, perennial, native bunchgrass that has been brought into cultivation and is now quite widely used in the northern Great Plains and in Canada. It was the first native grass to be brought under cultivation in that area.

DESCRIPTION

Slender wheatgrass commonly reaches a height of 1 1/2 to 2 1/2 feet, and under favorable conditions, will grow taller. The dense bunches may be as large as 1 foot in diameter. The sheaths are usually smooth. Often the leaves and stem bases have a bluish or purplish bloom. The flowering stems are numerous, erect and quite coarse, sometimes reaching a height of 4 feet, but more commonly about 2 feet. The inflorescence is a slender, greenish spike on which the closely appressed spikelets are frequently set some distance apart. However, this species is highly variable and the spikelets may be close together on the axis. The spikelets are usually not awned, or if awns are present, they are rather short. The spike, more slender than those of the other common wheatgrasses, is quite characteristic of the species.

Primar wheatgrass: Primar is a new early-maturing, leafy, disease-resistant, rapid-developing variety. It is specifically adapted for use in sweetclover-grass mixtures in the Palouse area of the Pacific Northwest. In comparison with other slender wheatgrass strains, it is earlier in spring recovery, more productive in growth, and has coarser and more abundant leaves and stems. It is compatible with and has a growth rate corresponding to that of sweetclover. Primar is ten days earlier in seed maturity and grows 5 to 10 inches taller than Mecca slender wheatgrass.

Canadian varieties: Three varieties of slender wheatgrass—Mecca, Fyra, and Grazier—were developed by Canadian workers. They are all leafy, late-maturing strains particularly adapted to the western provinces and other summer rainfall areas. Most slender wheatgrass seed available today came from these three varieties.
ADAPTATION

Slender wheatgrass is distributed throughout the United States except in the southeast and southcentral parts. It has somewhat higher moisture requirements than western wheatgrass, and in the Dakotas is seldom found on the upland prairies, but it is common, though usually not especially abundant, on moist, well-drained soils throughout this area. While it is fairly well adapted to most soil types, it seems to do best on the lighter, loamy soils. It is a common constituent of the vegetation in river bottoms, on the alluvial soils along stream courses, and in open wooded or shrubby areas. In western North Dakota, it is found in some abundance on sagebrush flats.

Although this grass shows a high degree of drought resistance, it still does not compare with western wheatgrass or crested wheatgrass in this respect, and it is largely limited to soils with medium moisture conditions. In alkali tolerance, it is exceeded only by western wheatgrass among the common forage grasses.

In experimental trials at the Intermountain Forest and Range Experiment Station, Ogden, Utah, slender wheatgrass seed obtained from any part of the Central or Northern Great Plains has not proved suitable for resowing. The plants grown from locally-grown intermountain seed are long-lived and winter hardy, whereas, those grown from seed obtained from the Great Plains Region have failed to make permanent stands. The reason is not clear, especially as to winter hardiness, because the winters are more severe in the Great Plains than in the Intermountain Region.

UTILIZATION

Hay: Good yields of high quality hay are obtained from stands of slender wheatgrass for two or three years. After that, the yields become negligible. Yields from productive stands of one-half to over two tons per acre are not unusual, even in the drier sections.

The protein content of slender wheatgrass is lower than that of crested wheatgrass and bromegrass during the early part of the season; all three species are about on a par at mid-season, but at maturity bromegrass and crested wheatgrass have an appreciably higher protein content than slender wheatgrass. Thus, to insure the highest quality hay, slender wheatgrass should be cut at mid-season well before maturity. It is generally recommended that it be cut shortly after heading or just before blooming.

Pasture: This grass begins its growth relatively early in the spring and holds up well through the summer, if not allowed to mature. It is highly nutritious and palatable, but as the grass matures it becomes “stemmy” and is not grazed so readily. However, it cures fairly well on the ground and furnishes some forage for winter grazing. It is not as resistant to close grazing as western wheatgrass, but it will stand reasonably intensive use. Its chief disadvantage when used as a tame pasture is its short life. After the third or fourth year, productivity of the grass decreases greatly. Consequently, when used for pasture, it should be sown in mixtures with other grasses of longer life which will take over the stand as the slender wheatgrass dies out.

INTERMEDIATE WHEATGRASS

(Agrostypyron intermedium)

Intermediate wheatgrass was introduced by the Department of Agriculture from
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the Union of Soviet Socialist Republics, and was planted first at experiment stations in the northern and central Great Plains and the Pacific Northwest.

This wheatgrass is a perennial sod-forming grass having a vigorous root system similar to those of smooth brome and western wheatgrass. It grows erect and produces a heavy growth of basal leaves. The plants vary considerably in color, texture, leafiness, and disease resistance.

The plants begin growth in early spring and reach a height of 3 to 4 feet before growth ceases in midsummer because of scarcity of moisture. The return of moisture and cool temperatures in the late summer brings good growth recovery.

The abundant leafy foliage is relished by all classes of livestock. Plant growth is vigorous. Established seedlings tend to form a full sod somewhat less rapidly than those of smooth brome or western wheatgrass grown under like conditions of soil and moisture.

Tests indicate that intermediate wheatgrass is best adapted to those areas of the region discussed here where smooth brome does best, chiefly in the eastern parts of South Dakota and eastern and central Nebraska and Kansas. It may be used also in areas farther south and west. Because of some winterkilling in North Dakota further trials will be needed to determine its hardiness and adaptability in that State.

The main virtues of this grass are ease of establishment and high production of excellent pasture and hay. Its large seeds germinate rapidly, producing fast-growth seedlings. This tends to keep it free of root rot and seedling blight, the most serious diseases of grasses in the seedling stage.

Excellent seedling vigor permits relatively low rates of sowing. The seed-producing qualities of intermediate wheatgrass for two or three years after sowing are so promising that the quantity of seed needed for revegetation will no doubt become available in commercial quantities within the next few years.

The South Dakota Agricultural Experiment Station has grown a considerable quantity of a strain of this grass and distributed the seed under the common name Ree wheatgrass (SD-7).

BLUEBUNCH WHEATGRASS

(*Agropyron spicatum*)

Bluebunch wheatgrass, a native, perennial, drought-resistant bunchgrass, is found chiefly in the dry, open areas of the western United States. It is the climax herbaceous species of the native vegetation of the Pacific Northwest and Intermountain States where it forms as much as 60 percent of the vegetative cover in many localities. Its abundance, general distribution, drought-resistance, and dependability as range forage make it important in the two regions.

The vigorous plant growth starts rather early in the spring if enough moisture is available. The leaves are flat, rather lax, about ¼ to ½ inch wide and 6 to 10 inches long. The volume of forage produced is usually high and dependable. The leafage remains green throughout the growing season and is nutritious and palatable even after growth ceases, although the stems become wiry late in the season. Plants may reach a height of 4 feet. Seed heads are about 6 inches long; the fairly dense spikelets have prominent divergent awns.

Beardless bluebunch wheatgrass, (*Agropyron inerme*), is closely related to bluebunch wheatgrass and differs only in that it lacks the awned spikelets. Many stockmen prefer it for the reason that lack of awns makes the plants more palatable, especially during the late stages of growth.

Deferreng grazing until seed maturity, thus utilizing livestock for scattering the seed and trampling them into the ground, has been practiced to good advantage in some places. Many successful plantings have been made in revegetation work on range and farm lands in the Pacific Northwest.
ESTABLISHING A STAND OF THE WHEATGRASSES

Preparation of seedbed: The wheatgrasses, in common with many other grasses, are tender in the seedling stage and require favorable conditions for germination and early growth. A firm seedbed is essential to establishing a satisfactory stand. Grass seedlings are readily susceptible to injury from soil blowing. A protective cover should be established on soil that is likely to blow before sowing is undertaken. The general practice considered safest to avoid danger from soil blowing is to drill the seed directly into grain stubble, without previous tillage. Stubbleland provides a firm seedbed and makes possible sowing of large areas that otherwise could not be returned to grass because of expense involved or danger from soil blowing.

Clean grain stubble furnishes one of the best preparations for early fall sowing. Drilling the seed under such conditions permits the grass to make considerable growth before winter, and the stubble protects the seedlings from danger of soil blowing and catches snow to furnish moisture for early and rapid spring growth. Well prepared summer fallow can also be used to advantage as a seedbed, especially for early fall sowing, provided there is little or no danger from soil blowing. Summer fallow is best used for special sowing or for small acreages. The reserve moisture stored in the fallow usually favors more growth and stronger plants than any other preparation.

Corn ground that is protected from soil blowing affords a good seedbed. Grain stubble can be plowed and prepared for sowing. Such sowing should not be undertaken on soil that is likely to blow. In all cases it is necessary to prepare a firm seedbed, especially if the soil is worked to kill a crop of weeds just before sowing. A good rain just before sowing will usually firm the soil enough for a suitable seedbed. If a rain does not come at the right time, it may be advisable to pack the soil before sowing. Late spring sowing can be done on summer fallow under some conditions, but in some areas weeds are much worse in grass sown on fallow at this time.

Time of sowing: The most favorable time to sow the wheatgrasses varies with the locality, the moisture supply, and the abundance of grasshoppers. Young wheatgrass plants thrive best under cool growing conditions, such as occur during fall or early spring. Sowing both in fall and spring has been successful in the northern Great Plains. Within recent years fall sowing has met with greater favor and success than sowing at any other period. Early fall sowing can usually be done late in August or during early September, depending upon moisture conditions. Late fall sowing can be done any time from the middle of October until the soil freezes. Early spring sowing should be done as soon as field work can be started. Late spring sowing can be done during May.

The purpose of early fall sowing is to give the grass a chance to make a good fall growth before the soil freezes. Sowing at this time is dependent upon rainfall to afford favorable moisture conditions before sowing can be attempted. When such conditions occur, sowing should be done as soon as possible.

Late fall sowing is not dependent upon favorable moisture conditions at the time of sowing, as the seed is put into the ground late enough so that it will not germinate until early the next spring. Such stands are less subject to grasshopper damage than those from early fall or late spring sowing. Late fall sowing can be extended over a longer period than early fall sowing and is better adapted for larger acreages. It is especially well adapted to land that has been damaged by blowing but has a weedy cover. Seed sown at this time usually starts growth before it is possible to get into the field in the spring. The seed can be drilled into grain stubble or abandoned land that has a protective cover of weeds. This time and method of sowing has resulted in the regrassing of large acreages in the northern Great Plains.

Early spring sowing should be done
as soon as it is possible to get into the field, and can best be done in clean grain stubble or on protected corn ground.

**Method of sowing:** The wheatgrasses may be sown in close drills or in rows wide enough apart to be cultivated. Where the crop is to be utilized for hay or pasture, close drills are preferable. The seed should be sown with a grain drill and covered about one-half inch. When sowing in the early fall on fallow it may be advisable to sow the seed approximately an inch deep in order to place it in contact with moisture and below the surface layer which often dries out. A firm seedbed is essential to uniform shallow sowing. A single-disk drill has proved satisfactory for most sowing on a prepared seedbed, especially fallow, as it cuts through trash, and leaves the surface of the soil rough. A double-disk drill can be used satisfactorily, if the depth of sowing is watched closely and the seedbed is in good condition. A deep furrow disk-type drill (without chains) has been used extensively and successfully, especially for sowing abandoned land where the seedbed is firm and where it is necessary to cut through weed growth and trash. Broadcasting has not proved satisfactory in most cases.

The use of clean, heavy seed cannot be too strongly emphasized. Good seed of crested wheatgrass should weigh 22 pounds or more to the bushel, and of slender and western from 18 to 20 pounds. Seed of this weight will run freely through a drill without the aid of an agitator. Light chaffy seed will not feed through the drill readily even with the aid of an agitator.

If grown mainly for seed production, thin stands are gradually thickened by the ability of the wheatgrasses to volunteer. In cultivated rows for seed production, one to three pounds of good seed per acre is ample for single rows and two to four pounds for double rows 36 to 42 inches apart.

**Field care:** Ordinarily a closely drilled field of crested wheatgrass does not require any attention during the year it is sown. This is also true of other wheatgrasses. In a favorable season a light crop may be produced, but it is usually advisable to permit the grass to stand so that it will make enough top growth to catch snow the first winter and the loots will have an opportunity to build up additional food reserves. This vegetative growth should be mowed and removed the following spring. It is not advisable to burn the old growth. The seedlings are small and difficult to see; therefore, it is advisable to leave a sown area undisturbed the first season, even though there does not appear to be a satisfactory stand. As a general rule, weeds should not be clipped on a new stand. After the first year weeds give little trouble in close-
drilled fields. When sown in rows, an early spring cultivation to kill volunteer grass seedlings and to put the soil in a receptive condition for moisture, and one or two cultivations later to destroy weeds, are usually required.

SEED PRODUCTION OF WHEATGRASSES

Crested wheatgrass: Crested wheatgrass has good seed habits. It yields well, matures early, and can be harvested with machinery available on grain farms. As the seed ripens while the plants are still green, the straw is of some value for feeding. Because crested wheatgrass seed shatters readily, harvest should begin when the seed reaches the stiff dough stage. Much of the seed may be lost in windy weather if the grass is allowed to become too mature. A fair yield of seed when grown in rows is 200 to 300 pounds per acre, and under more favorable conditions 400 to 500 pounds may be obtained.

The crop may be cut with a grain binder and should be shocked immediately. Under normal weather conditions, ten days in the shock is sufficient for drying before threshing. The seed is easily threshed with an ordinary grain separator. To avoid loss of seed in threshing, the speed of the fan should be reduced or the air intake to the fan closed. With some separators, it is desirable to lower the rear of the machine so that the seed may pass back to the delivery and the straw be handled more satisfactorily. Under certain conditions, best results in threshing are obtained by reducing the speed of the cylinder somewhat, although this is not always necessary or desirable. All, or practically all of the concaves should be removed.

Crested wheatgrass seed can be cleaned with an ordinary farm fanning mill equipped with the proper sieves. A top sieve having oblong openings of one-fourth by one-eighteenth inch and a bottom wire screen with a mesh of 6 by 26 or 4 by 26 will, under most conditions, give the best cleaning results. Larger sieves may be required for a preliminary cleaning if the threshed material contains an undue amount of trash.

Recleaned crested wheatgrass seed should weigh at least 22 pounds per bushel, be 94 percent pure and have a germination of 85 percent. Choice seed will weigh 24 to 26 pounds per bushel. There are from 165,000 to 200,000 seeds per pound.

The acreage and seed production of crested wheatgrass, the only wheatgrass on which seed acreage and production statistics are available, during the 30 or more years it has been under culture in the United States, increased to an average in the three years (1942-1944) of 113,000 acres, and a production of 12,500,000 pounds of seed. During the five years (1945-1949) the averages dropped to 28,400 acres and 2,900,000 pounds, respectively. The statistics on United States acreage and production prior to 1942 are incomplete. The average imports from Canada for the 7-year period 1940-1946 were 1,015,000 pounds. For the last three years (1947-1949) they averaged only 105,300 pounds.

Western wheatgrass: Seed production of the native stands of western wheatgrass in the northern Great Plains is usually good, although somewhat uncertain. Apparently the production of viable seed is dependent on favorable moisture and temperature conditions during the early part of the season. As these conditions obtain throughout most of the northern range of the species, this area is the leading source of seed. But since the wide distribution of native stands practically insures the possibility of a good seed crop each season at some place within its range, it is not considered necessary to produce seed of unselected native strains under cultivation.

Flowering begins in middle and late July with seed maturing in late August and early September. The height, growth and size of seed of this species permit the use of ordinary harvesting machinery in the collection of the seed. The grass may be either cut with the binder and threshed, or harvested with the combine. Yields of 150 to 200 pounds of seed per
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acre, germinating 60 percent, are not uncommon. Since the seed does not carry any objectionable appendages, it will feed through the regular grain drill without any processing. Good seed well cleaned should have a purity of 95 percent and a germination of 92 percent, and weigh at least 18 pounds per bushel. A pound of seed contains 100,000 to 125,000 seeds.

Slender wheatgrass: Good crops of seed of slender wheatgrass with high germinative capacity are produced in normal years. Larger crops are produced from cultivated rows than from solid stands. The seed crop can be harvested with the combine or with the grain binder and then threshed. The seed shatters readily when mature, and for this reason there is considerable danger of loss of seed when the combine is used. Seed yields vary from year to year, depending on growing conditions, but can be expected to average about 250 pounds per acre. Good seed should have a purity of 95 percent and a germination of 92 percent, and weigh at least 18 pounds per bushel. There are 140,000 to 160,000 seeds to a pound.

Intermediate wheatgrass: Seed production of intermediate wheatgrass is dependable, particularly when plants are grown in rows to permit interrow cultivation. Seed yields of 300 to 400 pounds per acre have been had from row plantings. Seed may be harvested with standard farm equipment such as a binder, combine or swather. As with other wheatgrass species, the quality of seed is improved by processing with a hammer mill and cleaning with a fanning mill.

Bluebunch wheatgrass: Seed production from native stands is erratic. It depends upon moisture conditions during the spring months and upon cool temperatures during the critical period of blooming. The two species produce seed satisfactorily when grown under cultivation; yields of more than 250 pounds per acre have been reported.

Seed may be harvested with a binder, a combine, or a swather, equipment that is most effective when the seed crop is grown under cultivation in rows. Native stands frequently occur on sites that are too rough, stony, and uneven for use of machinery; under such circumstances seed heads may be collected by means of a hand stripper or sickle. Mowing mature seed hay and subsequently scattering this seed material on a prepared seedbed has been practiced satisfactorily on areas that are not too extensive.

As seed material comes from the thresher or combine, it often contains excessive amounts of dirt, chaff, straw, and other inert material. The divergent awns of bluebunch wheatgrass often are a great hindrance to the handling of this seed in drills of standard make. Processing the seed material with a hammer mill to remove the awns results in a clean seed product that can readily be drilled with standard seeding equipment. This process is not costly, and the improved quality of seed more than pays for the small additional cost of time as well as labor.

WHEATGRASS HIGHLIGHTS

1. The wheatgrasses are a most important group of forage grasses in the Northern Great Plains of the United States and Canada. Two native species and two introduced species have come into important agricultural use in that area. Another introduced species, quackgrass, has become a noxious weed, and another native, the bluebunch grass, forms a very important part of the native forage vegetation of the Pacific and Intermountain States.

2. Crested wheatgrass seed production reached a peak in 1944 with 165,000 acres and 17 million pounds of seed. The averages of the three following years (1945-49) were 28,400 acres and 2,900,000 pounds of seed. Imports from Canada also dropped during those three years to less than half of the previous three years.

3. There are two species of Agropyron known as crested wheatgrass, Standard crested wheatgrass (A. desertorum) which is more generally grown in the United States, and Fairway crested wheatgrass (A. cristatum) which is more generally grown in Canada.

4. Crested wheatgrass has a longer productive life than most other wheatgrasses. Stands over 25 years old are still productive.
5. The wheatgrasses are better adapted than most of the introduced grasses to be used as pure cultures. There are only a few native grasses compatible with them, and few legumes sufficiently drought or alkali-resistant to be productive under conditions suitable for wheatgrass.

6. All the wheatgrasses described here have good seed habits and can be harvested, threshed and cleaned with regular equipment.

7. The harvested forage of wheatgrasses if early-cut and well-cured is generally nutritious and palatable.

8. A number of the wheatgrasses are somewhat alkali-tolerant but western wheatgrass ranks among the first of all forage grasses in its adaptability to the extremely alkaline soils of the Northern Great Plains.

9. Western wheatgrass constitutes a considerable proportion of the native range in the Northern Great Plains.

10. Western wheatgrass, with the same habit of growth as quackgrass can be readily controlled and is one of the most useful native grasses of the Northern Great Plains for both forage and erosion control.

11. Western wheatgrass starts growth early and matures late, so with adequate moisture and not too close grazing furnishes a long season.

12. Slender wheatgrass was the first native grass to be artificially sown and harvested for forage to any extent in the United States.

13. Primar wheatgrass, a variety of slender wheatgrass, is particularly adapted for use in mixtures with sweetclover in the Pacific Northwest.

14. On the eastern border of the Great Plains, intermediate wheatgrass (Ree grass of South Dakota) has demonstrated its exceptional value in erosion control on banks and in gullies, at the same time, furnishing valuable forage.

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Forage literature of the West contains many references to the wheatgrasses (Agropyron spp.). The material used in this chapter was obtained largely from Westover and Rogler (US-285), Hoover, Smith, Ferber, and Cornelius (US-116), Hoover, Hein, Dayton and Erlanson (US-115), Swallen (Feb. 1943), and Whitman and Stevens (ND-15). The manuscript was reviewed by Franzke of South Dakota, Newell of Nebraska, Rogler of the Northern Great Plains Station, and Swallen of the Smithsonian Institution.

Chapter reference numbers: COL-13; MONT-1, 2, 7, 8, 13; ND-14, 15, 16; SD-3, 7; UTAH-14, 17; WASH-20, 24; US-50, 67, 77, 115, 116, 120, 219, 283, 287; MISC-16.

The reference numbers given here refer to references which are given in full by State, U.S.D.A., and Miscellaneous, on pages 682 to 724, and which are cross-referenced by author on pages 725 to 731. Citations in the text are indicated by abbreviation and number in parentheses.
Without buffalograss and several of the gramas, the Great Plains would not be what they are today in supplying grazing, both summer and winter, for range livestock. There are other grasses which furnish large quantities of grazing, but none that equal this group of short grasses the year round as a source of supply. These grasses are definitely adapted to the subhumid or semiarid conditions of the Great Plains but will respond to moderate additional water supplies in their native habitat when these are available, except under strong bluestem competition.

Buffalograss (Buchloe dactyloides) has no superior as a productive source of livestock feed on at least a part of the rolling, erosive, and unproductive areas in the Central Plains. It likewise is well adapted as a protective turf on newly-developed air-fields, cantonments, ordnance plants, and other units in the region where the control of dust and erosion is essential. For these purposes, particularly on the heavier soils in the drier section of the Central Plains where Bermuda-grass is not sufficiently hardy, buffalograss has no superior.

All of the gramas (Bouteloua spp.) are native to the Western Hemisphere. About 18 species occur in the United States. They are well represented throughout the Great Plains and Western States. They are reliable producers of good forage on range and pasture land and are prized, therefore, in various sections.

The gramas are summer growers, and the amount of forage they produce depends upon the moisture available during the growing season. In years of extreme drought they make little or no top growth. Most species cure naturally, however, and standing growth from various seasons makes very satisfactory and palatable forage for most classes of livestock.

BUFFALOGRASS  
(Buchloe dactyloides)

Buffalograss is one of the important crops of the Central Great Plains States. Its value in soil conservation and in the production of meat, milk, wool, and leather has long been recognized. Unfortunately, too many acres of the native prairie were plowed up for the production of other crops before its true value to the agriculture of the area was fully appreciated. The need for practical methods of reestablishing this grass has been growing.
with the years. In the absence of seed, methods of resodding were developed, but owing to excessive labor costs, the resodding practice was accepted only for establishing lawns and other small areas. Since 1944, however, seed has been available on the market and methods of inducing high germination have been developed. It is now practical to reestablish buffalograss with consistent success.

DESCRIPTION

Buffalograss is a low-growing, long-lived, drought-resistant perennial grass which spreads vegetatively by numerous surface runners. Profuse branching of the runners enables this grass to form a dense sod which is capable of withstanding considerable trampling. The short, dense, flat leaves of buffalograss are covered with fine hairs which give the leaf surface a gray-green color instead of a bright green such as some grasses possess.

The flowers are either staminate or pistillate and usually only one kind occurs on a plant, but occasionally both are found on the same plant. Staminate plants are distinguishable by the inflorescences which protrude an inch or two above the leaves. The pistillate plants bear their inflorescences, consisting of from two to five extremely short spikes, commonly referred to as burs, down among the leaves where they are revealed only by close examination. These burs are produced on culms varying in height from ground level to several inches high, depending somewhat upon height and density of the leaves.

ADAPTATION

Climate: Buffalograss normally thrives best in the Great Plains territory having a rainfall range of from 12 to 25 inches. Wet seasons such as 1941 and 1942 create conditions more favorable for the bluestem grasses than for buffalograss, and when they gain sufficient foothold they will crowd out the latter grass. Over a period of years the eastern boundary of the buffalograss region will be found to occupy a shifting position, retreating westward in wet periods and advancing eastward in dry periods.

The present boundary line between the short and tall grasses is approximately 75 miles east of where it would have been placed a generation ago. Because the bluestems were so extensively reduced during the severe drought years of the 30s, and because of the present methods of pasture management, it appears that this boundary will continue in approximately its present location.

Along with drought resistance, buffalograss is heat resistant and has a fairly high degree of cold tolerance. Except in the extreme north, it is able to survive successfully the coldest winters. It also withstands the rather frequent severe droughts and periods of high winds that are common to the entire Plains area. Buffalograss cannot, however, survive in dense shade, which limits its use for landscape-planting purposes.

Soil: Buffalograss will grow on a fairly wide range of soil types but prefers the heavier soils and does not thrive on soils containing an excessive amount of sand. Areas consisting of heavy to semi-heavy soils should be planted to mixtures containing a high percentage of buffalograss. As the soils become lighter, the proportion of buffalograss should be decreased and supplemented by better-adapted species, such as blue grama, side-oats grama, little bluestem, sand dropseed and hairy grama. On the more sandy soils, the use
BUFFALOGRASS

of buffalograss in the mixture should be extremely light or omitted entirely.

ESTABLISHING A STAND

Nearly every farm in the territory where buffalograss is adapted has at least a small acreage of cultivated or waste land that is desired back in grass and, of course, a number of farms have large areas that should never have been plowed. There are at this time three general methods of obtaining buffalograss on the areas that are suited to its production. These methods include (a) natural revegetation, (b) vegetative propagation, and (c) sowing seed.

Natural revegetation: Natural revegetation, as the name implies, simply means allowing the land to revegetate itself naturally any way it will. Although the method has been used quite extensively in the past because of the absence of more practical methods, it requires so long and is such a wasteful system of management that its use is not generally to be recommended. Investigators who have studied the practice report that such land seldom becomes fully revegetated with the more desirable grasses in less than 25 years, and often more than 40 years are required.

Transplanting vegetative material: Because of its spreading habit of growth, buffalograss lends itself to vegetative methods of propagation. When the need for regrassing the most unproductive cultivated areas became apparent, investigators, looking for a way to reestablish this valuable grass, turned to vegetative methods to determine their possibilities in the absence of seed supplies.

Methods of establishing stands through use of vegetative material have been developed and successful results have been obtained, but they are ordinarily not practical except for lawns or for other limited areas or for specialized seed production. Where vegetative propagation is used to establish fields that are to produce seed, attention should be given to using both pistillate and staminate plants, with a larger proportion of the former.

Sowing seed: Until within the last few years, establishing stands of buffalograss by the seed method was impossible because there was no seed available. It was unavailable largely because the seed is produced so near the ground its harvest was considered impossible and it was thought that all seed was of low quality and would not grow successfully, even if it could be collected. The normal low yield of seed likewise provided no incentive for the perfection of machinery to accommodate its harvest. Today, however, buffalograss seed is appearing on the market and successful methods of handling to insure good germination and successful establishment have been developed.

Although most of the buffalograss seed available at this time is harvested from native pastures where low yields and unstable production prevent an adequate supply, the future is brightened by the fact that new methods of handling improved types give promise of high, consistent yields that will do much toward supplying normal demands.

These facts are of considerable importance to the agriculture of the region because they mean that buffalograss may now be successfully and economically established on cultivated land within a short time, where heretofore, it required from three to five years by the best sodding method and from 25 to 40 years where the areas were allowed to revert naturally.

Treatment of buffalograss seed usually is necessary if the best results are to be expected. This is because dormancy is so pronounced that only a small percentage of the seed will grow the first year after planting. Before this fact was discovered the use of buffalograss seed was regarded as impractical because it was thought the quality of most seed was so low that satisfactory stands could never be obtained.

Treatment of seed: Treatment of buffalograss seed usually is necessary if the best results are to be expected. This is because dormancy is so pronounced that only a small percentage of the seed will grow the first year after planting. Before this fact was discovered the use of buffalo-
grass seed was regarded as impractical because it was thought the quality of most seed was so low that satisfactory stands could never be obtained.

Many natural and artificial treatments have been studied in the search for practical methods of inducing immediate germination in buffalo grass. In general, the results have been highly successful, but the most effective procedures have by necessity become rather involved. The structure of the buffalo grass seed-unit (bur) itself has complicated this process. Natural weathering will improve germination of the seed, but this process is necessarily slow and much seed is likely to be lost.

Untreated buffalo grass seed has a normal germination of less than 10 percent the first year after harvest. Chilling treatments developed at Hays, Kansas, and dehulling methods devised at Woodward, Oklahoma, greatly improve the germination. Soaking the seed in a 0.5 percent solution of KNO₃ (saltpeter) for 24 hours followed by chilling while wet at 40° F. for six weeks will increase the germination to 70 or 80 percent. New seed should always be treated before planting.

**Source of seed:** In general at Hays, Kansas, stands obtained from southern seed exhibited more vigor, heavier yields, better palatability, and tendency toward greater resistance to certain foliage diseases than those established with northern seed. Such stands, however, were more susceptible to winterkilling, were usually deficient in seed production, usually produced a thinner turf and the foliage was often frozen down in the fall while growth was yet vigorous.

Seed originating at points from south to north only 100 miles apart showed differences in growth responses of the grass from places having similar latitude. In general, the growth was less and the active growing season shorter for each successive northerly point of origin. Higher altitude in general had the same influence as a more northerly point of origin.

These observations indicate that for average revegetation purposes, native grass seed should be obtained from the better-adapted local sources or from points some-what to the south, rather than from the more northern locations. To avoid the risk of winterkilling, 150 miles should be considered the south to north limit from point of origin to location of planting.

**Preparation of seedbed:** It is important that buffalo grass be planted on a firm seedbed free from weeds. Field plantings made in a protective covering of stubble mulch have been highly successful, especially in sections of the country where blowing is serious, or on steep slopes where erosion is troublesome. Sudan or cane drilled in the summer previous to sowing the grass in the spring is desirable for this purpose if care is taken to prevent the crop from maturing seed which would volunteer and cause serious trouble.

**Time of sowing:** Spring is usually the best time to sow buffalo grass and mixtures containing it. The specific time will vary with preparatory seedbed treatments and with prevailing seasonal conditions. Inasmuch as buffalo grass and the species with which it is usually sown are all warm-season grasses, germination will not take place much before the average date of the last killing frost in the spring, regardless of when sown.

**Rate of sowing:** Rate of sowing will depend upon a multitude of factors such as whether sowing alone or in mixtures, the prevailing price of seed, its quality and germination, the value and productivity of the land on which it is to be sown, the method of sowing, and the time limit set for the establishment of a satisfactory pasture. From one to three pounds of buffalo grass seed per acre is suggested for various mixtures, and a maximum of 8 pounds is suggested where pure seed is sown. For lawns, landscape areas, and airport use, where more expense for seed is justified, heavier sowing rates are recommended.

Since there are over 35,000 seeds (burs) to a pound, assuming uniform distribution, 90 percent purity, 25 percent field germination, and a loss of one-third of the plants in the field, and 8-pound rate of sowing should give a minimum of one plant per square foot which has proved satisfactory.

**Depth of sowing:** Shallow sowing cannot
BUFFALOGRASS

be over-emphasized in sowing buffalograss and mixtures. The only complete failures with sowing buffalograss at Hays during the past six years are directly traceable to sowing too deeply. One-half inch is considered the optimum sowing depth on most soils but may increase slightly as the amount of sand in the soil increases.

Methods of sowing: Drilling is usually considered the best method of sowing buffalograss. Pure buffalograss seed is readily sown through all common grain drills. However, because of the light fuzzy nature of such seed as blue grama, mixtures containing these grasses cannot always be drilled with ordinary equipment. Mixtures containing side-oats grama and western wheatgrass may be drilled if all the seed is reasonably clean before mixing. Some drills cannot be closed down sufficiently to sow pure buffalograss at a rate of 8 pounds per acre. When this is the case every other hole on the drill should be plugged up. It is advisable to follow the drill with a packer to firm the soil around the seed and level the ridges to lessen danger from covering by torrential rains.

DISEASES AND INSECTS

Buffalograss is susceptible to several diseases. The true economic importance, however, of each disease has not been fully determined. None of the present known diseases appear to cause excessive loss where the grass is used strictly for grazing. Where it is grown for seed production under cultivation, as appears at present to be a practical procedure, disease troubles are generally aggravated and are of more serious concern. Among the diseases which affect buffalograss are smut, leaf blotch, leaf rust, witches broom, nematodes and yellows.

Buffalograss in early growth is palatable to grasshoppers and damaged easily by defoliation. In seasons when grasshoppers are numerous, serious damage often results. The greatest damage is done to the runners which are chewed off frequently before they are rooted, leaving them to wilt and die. Effective control may be obtained in new seedlings by keeping the weeds clipped short and by repeated spreading of poison bran mash. Other insect enemies of buffalograss include the leafhopper, June beetle, and mound-building prairie ant. Their damage to the grass is similar to that done to other crops on which they prey. Further information is given on diseases and insects in chapter IX.

UTILIZATION

In the Great Plains area, where buffalograss is at home, its greatest usefulness is as a pasture grass. However, it has characteristics which, along with its hardiness and drought resistance, make it a valuable plant for several other uses, all of which should be given consideration, not only because of its adaptability but also because of there being so few desirable species that will survive under such severe conditions.

Pasture: Buffalograss and most other native grasses grow and establish themselves so slowly, particularly under normal weed competition, that no grazing can be expected the first season without involving considerable risk to the stand. In a preliminary yield study with buffalograss under irrigation, yields the second season, and to some extent the third season, were depressed by clipping in the first year.

Under average rainfall, some grazing can usually be expected by the middle of the second season. Thereafter a system of moderate grazing will provide considerable pasturage and allow for complete establishment of the grasses. Severe overgrazing of new stands reduces the vigor and yield and encourages the encroachment of weeds.

In a clipping experiment at Hays on native buffalograss pasture, conducted from 1934 to 1940, inclusive, yields of air-dry grass were 456 pounds per acre when clipped an average of six times from May 1 to September 15, as compared to 823 pounds per acre when clipped only on July 1 and September 15. Similar results were obtained in Texas from a two-year clipping study in which it was found that clipping at intervals of eight weeks gave greater yields than more frequent clippings.
Buffalograss is famous for its palatability and nutritional qualities, especially in respect to winter utilization. Seasonal conditions, however, play an important part in determining both the quantity and the quality of forage, whether it is utilized in summer or in winter. Heavy rainfall increases forage and protein production and gains in livestock weights, and lowers the fiber content of the forage. Years with unseasonably wet periods in the fall may result in a late rank growth which, if frozen down, is lower in quality than usual. Similarly, wet periods occurring late in the fall after the forage has already cured, cause leaching and will rot the forage, resulting in a serious lowering of its nutritional qualities.

Mixtures with buffalograss: Pastures or ranges rarely consist of pure stands of buffalograss except where continuous close grazing or a period of cultivation has eliminated the other grasses. Likewise, in resowing it seems that, except for special uses, it is more advisable to sow a mixture for pasture than to use buffalograss alone. A mixture for pasture has the following advantages: (a) Longer grazing season; (b) greater variety of forage; (c) increased palatability in that the less palatable species are partially taken with those of first preference; (d) greater success in securing stands and in obtaining maximum production as reflected through better adaptation to varying soil and moisture situations; (e) insurance against adversities in climate and grazing which one grass may be able to withstand better than the rest; and (f) maximum erosion protection by assuring the greatest sod density on all parts of the field, regardless of variations in soil and moisture conditions.

In the words of Savage (US-226), "The inclusion of blue grama and other grasses with buffalograss in a mixture improves the immediate and ultimate value of the pasture. These grasses add desirable qualities not possessed by buffalograss alone and provide helpful indicators of over-grazing to assist in pasture management."

Soil type and soil moisture conditions will determine largely what grasses should make up the mixture. On the heavier soils where frequent flooding does not occur, buffalograss and blue grama should comprise the bulk of the mixture. Side-oats grama, western wheatgrass and sand dropseed are other native grasses to consider in mixtures with buffalograss and blue grama.

Erosion control: The value of buffalograss in controlling runoff and erosion is well demonstrated in the results of a 9-year study made by the Soil Conservation Service at Hays, Kansas, 1938. This study was conducted on fertile upland soil having a uniform slope of 5 percent. The water losses from cultivated crops as compared with buffalograss were two to three times as large, but soil losses were even more striking in that buffalograss sod showed an average annual loss of only about one-tenth that of continuous wheat land and less than one-thirtieth that of kafir land.

Other uses: Buffalograss in its native environment is also adapted for use in lawns, on airfields, in highway development, on athletic fields or golf courses, and in parks and cemeteries.

SEED PRODUCTION

Because native pastures cannot be depended on for consistent seed production and because yields are invariably low, the growing of improved strains of buffalograss under irrigation, where large, consistent yields of high-quality seed may be readily harvested with low-cutting combines, appears to be the most practical system of production. This makes the production of buffalograss seed for the market strictly a specialized business, made so by the need for heavy capital outlay and special machinery, the need for a special knowledge of the crop and all phases of its management.

The first scattered flowers appear about May 10 and with normal seasonal conditions the height of the flowering period is reached the last of May. Favorable rainfall during the month of May is essential to the setting of a heavy seed crop. Continued favorable rainfall during June is necessary for the growth and develop-
BUFFALOGRASS

ment of this crop which usually ripens between July 15 and July 20.

Production from native pastures: Native pastures are neither productive nor reliable as a source of seed. Many factors contribute toward this situation but the chief reason is the low annual rainfall. Being a perennial crop, the grass occupies the land during the entire year. This and the fact that growth is greatest during the season of highest rainfall permits no period for building up a reserve of moisture which can be carried over for the production of a seed crop. For the above reasons, seed is produced only in those seasons which have an abundance of rainfall from the fall of one year until July, or the normal ripening period, of the next year.

Yields of buffalograss seed from native pastures can be expected to vary from failures to 100 pounds per acre. In 1938, the most favorable season for native pasture production at Hays in recent years, a yield of 54 pounds of seed per acre was obtained from relatively pure buffalograss areas in the station's pastures. In 1941, a very favorable year for native pastures in western Kansas, reported yields of commercial harvests ranged between 50 and 100 pounds per acre. During 1942, native pastures in eastern Colorado were reported to yield from 10 to 100 pounds with 30 and 40 pounds being an average.

Production under dry-land cultivation: Growing buffalograss under dry-land conditions with cultivation where seed is expected as the main source of income, is attended with considerable risk. It should be more practical than relying upon native pastures, but not as reliable or as practical as where irrigation can be used.

Since it always requires a full season for the establishment of buffalograss after sowing, no return can be expected the first year. When weeds are serious and rainfall is light, it may even require a second year, but once the grass becomes established, yields from failures to 200 pounds per acre can be expected, depending upon the season. The use of improved seed types will increase the chances of higher yields. Fields established by seed and grown under dry-land conditions usually are the most productive from the second to the fifth years, after which a reduction in vigor and a lowering of yield takes place until yields approaching those from native pastures are all that can be expected.

Seed production under irrigation: Growing buffalograss under irrigation appears to be the most successful and reliable method of producing seed. By the use of improved types and the employment of good management methods, high yields of good quality seed can be consistently produced.

Planting unimproved seed under irrigation specifically for the purpose of growing seed, may provide a fair return but the practice does not give promise of being as profitable as where improved types are used. If complete coverage is obtained the year of sowing, average seed yields of from 100 to 400 pounds per acre may be expected for a period of four or five years. By the end of this time the planting becomes either so weedy or so reduced in vigor that the lower yields make continued irrigation impractical.

Results indicate that maximum seed production can be secured only by planting sod of improved types of buffalograss under suitable conditions of irrigation. Seed yields from the best strain tested at Hays, Kansas, up until 1942, not only averaged over 1,000 pounds per acre, but the production was consistently high from year to year and the seed quality was generally good. The value of the hay produced in addition to the seed also amounted to considerable. Such hay, properly cured and stored, has excellent feeding qualities as determined from both laboratory analysis and actual feeding trials at the station. Fortunately, even better seed production can be anticipated in the future as the manifestations of continued improvement efforts and better management practices become apparent.

Seed grown under irrigation is felt to possess all the qualities of seed produced under dry-land conditions. This is true because all improvement work is conducted under dry-land conditions. Thus, growing the crop for one generation un-
Irrigation is little different in effect than an extremely favorable season.

Establishing seed fields with improved material: Two general methods of establishing seed fields with improved material are possible: namely, by sowing improved seed, or by transplanting sod of a selected type. Each method has its advantages and its limitations, making a wise choice possible only after proper consideration of all factors. Sowing seed has the advantage of being the simpler and less expensive method. The sod method has one distinct advantage in its favor. Maximum seed yields are possible. This is true since stands from seed contain approximately 50 percent pollen-bearing plants, whereas, it appears that only from 10 to 20 percent are required for satisfactory pollination. Another reason for the higher yields of sod-planted fields is the slightly larger yield per unit area of seed-producing material, simply because improvement has not yet reached the point where these improved strains will "breed true" when planted from seed. For the same reason, seed from sod fields is generally considered of more value for sowing pastures or seed-producing areas than that from fields established with seed because it is one generation less removed from improvement.

Hays buffalograss, an improved selection of buffalograss developed at the Kansas Agricultural Experiment Station, is a good seed producer, and its seedstalks grow tall enough to permit easy machine harvesting of the seed. However, it does not produce much pollen. When cultivated for seed production, Hays plants are set together with pollen-producing plants of another buffalograss strain. Sod pieces 3 to 4 inches square are planted 2½ to 3 feet apart. Sods of the Hays strain are used in a ratio of about 8 to 1 sod of the other strain. This predominance of seed-producing plants results in a seed yield much greater than that of natural stands of buffalograss in which staminate plants are normally as numerous as pistillate plants.

Field management for seed production: Timely irrigation, early harvesting and avoidance of grazing are conducive to maximum seed production and quality. Where buffalograss is being grown for seed the crop should never be allowed to suffer because of lack of water. A shortage of water following harvest may result in a lowering of vigor and stand; a shortage during the winter months may result in a partial loss of stand due to winter-drying and winterkilling; a shortage at blooming time will result in a poor crop; and a shortage at filling time will result in low-quality seed. Seed production is also indirectly affected by any shortage of water that results in a thinning of stand or a lowering of vigor, which encourages the development of weeds.

Grazing at any time during the period of seed development is certain to reduce the yields of seed. The actual reduction in seed yield may not be so serious as is the lowering of its availability for harvest with combine machinery. Grazing or clipping the forage at this time reduces the height of the foliage, which automatically lowers the seed and its availability.

Harvesting equipment: Seed-harvesting machinery embodying various principles of operation has been developed and perfected by both the experiment station and private interests. The success of each machine is dependent upon the conditions under which the harvest is to be made. Both vacuum machines and windblast machines have been developed and successfully used to harvest buffalograss seed. A small, specially constructed combine was built at Hays, Kansas, in 1941 and 1942 for handling buffalograss seed from cultivated fields established primarily for seed production and usually irrigated. This last embodies all of the principles found necessary for successful performance.

BUFFALOGRASS HIGHLIGHTS

1. The value of buffalograss for pastures, erosion control, airports, roadside development, lawns, athletic fields, golf courses, and general landscaping purposes in the Central Great Plains area has long been recognized.

2. Buffalo grass occurs naturally throughout the Great Plains region but is best adapted to the heavier soils in the Central Plains.
3. In the past the scarcity of seed, the poor results from seed, and the high cost of sodding have prevented the widespread use of buffalograss.
4. Natural revegetation on abandoned farm land usually is impractical because of the long time required to get results.
5. Successful methods of growing, harvesting, treating, and sowing buffalograss seed have been developed so that the grass can now be used where adapted with general success.
6. Treatment of the seed is usually necessary to overcome the natural dormancy of the seed which for years was considered of poor quality and low viability.
7. Planting treated seed on a satisfactory seedbed in an approved manner will normally result in a productive, erosion-resistant pasture by the end of two years.
8. Seed should be secured from the better-adapted local sources or from slightly southern points rather than from more northern locations.
9. For pastures, mixtures with blue grama and other adapted native grasses are usually more desirable than buffalograss alone.
10. Sowing in undisturbed stubble in the vicinity of Hays, Kansas, should be done from April 10 to April 20, while deferred sowing in cultivated seedbeds or fallow should be done approximately a month later.
11. Three pounds of good quality treated buffalograss seed per acre in a mixture or 8 pounds sown alone should give satisfactory results where pure stands are desired.
12. The seed should be drilled not more than one-half inch deep or broadcast and covered to approximately this depth. The importance of shallow sowing cannot be over-emphasized.
13. Weed growth should be clipped at intervals during the first season to admit light and to reduce the competition for moisture.
14. Vegetative propagation of buffalograss is practical on a fairly large scale on either dry or irrigated land. Small pieces of sod are set at intervals of 2 to 4 feet in well-prepared soil.
15. Four-inch cubes of sod when spaced 1 foot apart covered the ground the first season, 2 feet apart the second season, 3 feet apart the third season, and 6 feet apart the fifth season.
16. When 4-inch cubes are set 3 feet apart, 2 square rods of sod are required to plant an acre.
17. Since buffalograss spreads largely by surface runners, it should not be disturbed by hoeing or cultivating.
18. Clipping at a height of 2 inches or moderate pasturing at intervals throughout the season to control other growth and admit sunlight is beneficial to the spread of buffalograss.
19. Grazing cannot be expected the first season after sowing without involving considerable risk to the stand. Usually by the middle of the second season judicious grazing can be practiced.
20. Grazing too early in the spring and overstocking are the most common abuses of short grass pastures.
21. Burning short grass pastures is always accompanied by a temporary reduction in yield and vigor of grass.
22. Buffalograss is unequaled for dryland lawns in sunny locations throughout the central Great Plains. Sow from 3/8 to 3/4 pound of treated seed per 1,000 square feet of lawn area in rows approximately a foot apart.
23. Buffalograss has several natural diseases and insect enemies that may cause varying degrees of concern. The true economic importance and successful methods of control of each have not been determined fully.
24. Varieties with greater forage and seed production, height of seedstalk, disease resistance, and better turf qualities seem to be probabilities in the near future.
25. Native pastures are unreliable, nonproductive sources of common seed which does not possess any of the desirable traits of improved types.
26. Growing improved types under irrigation has given consistently high yields of both seed and forage. Irrigation does not appear to affect the drought resistance of the grass any more than a favorable season.
27. Seed-harvesting machinery embodying various principles of operation has been developed and perfected both by the experiment station and by private interests.

BLUE GRAMA
(Bouteloua gracilis)

On 48 million acres in Arizona and New Mexico, or more than a third of the total usable range in those States, as well as on ranges in adjacent Texas, and north through the Central Great Plains into the
Dakotas, blue grama is the dominant forage plant. Throughout the Southwest, blue grama is of primary importance on 13 national forests, on other public lands, and on great areas of private range.

There are three outstanding reasons for this superiority. Blue grama provides excellent forage, is highly resistant to grazing and drought, and is an effective soil binder. To a considerable degree the welfare of the livestock industry in the Southwest is dependent upon maintaining the dominance of blue grama and the further protection and extension of present well-established stands. For these reasons a widespread understanding of the simple principles of utilization and management required to maintain this high-grade forage and to make the most of its soil-protective characteristics is highly desirable.

Blue grama grass is a low, sod-forming perennial with fine, curling, basal leaves of a grayish green color. The leaves are commonly 2 to 5 inches long and less than one-eighth inch wide. They have hairs at the junction of the leaf blade and stem, and in some cases they are distinctly hairy. Usually, however, the leaves are smooth and relatively free from hairs.

The flowering stems are 6 to 12 inches in height, slender and distinctly jointed. Each stem usually has two, (although the number may vary from one to four) one-sided, purplish spikes extending at a sharp angle from the main stem. The spikes vary in length from 1 to 2 inches and are made up of numerous spikelets. As maturity is reached, or when the plants are suffering from drought, the spikes become a golden-brown color and tend to curve backwards.

The root system is made up of dense masses of fine roots mainly concentrated in the upper 2 1/2 feet of soil, but often in some locations fully occupying the soil to a depth of 4 feet.

Blue grama is frequently confused with buffalograss (Buchloe dactyloides). The principal point on which the two species may be readily distinguished is the presence of above-ground runners on buffalograss. The presence or absence of these runners may be determined by running the fingers through the foliage close to the ground. If the species is buffalograss the runners are certain to be encountered. Also, blue grama leaves may be distinguished by being uniformly and prominently veined, while those of buffalograss have alternate groupings of prominent and inconspicuous veins.

ADAPTATIONS

Blue grama is found from Wisconsin to California and from Alberta to Mexico. In the Southwest it occurs on dry plains, foothills, and plateaus. Its greatest abundance is in the short-grass region of western Texas and eastern New Mexico and in the pinon-juniper woodlands of Arizona and New Mexico, but it also extends...
upward into the ponderosa-pine zone
and downward into the upper edge of
the semi-desert grasslands. It is found
at elevations of 5,500 feet on the south­
western plains, at 8,500 feet in the San
Francisco Mountains of northern Arizona,
and even at 10,000 feet on the Carson
National Forest in New Mexico and will
endure temperatures ranging from -40°
to +110° F. In its region of best growth
this grass is found mainly on loamy soils
or the so-called tight lands, but it also
grows elsewhere on coarse-textured soils.
At the higher elevations and northern
latitudes, where temperatures and evap­
oration are relatively low and precipita­
tion is relatively high, blue grama tends
to spread out into a dense, ground-hug­
ging turf with short leaves and flower
stalks. At lower elevations, however, where
temperatures and evaporation are relative­
ly high and precipitation is relatively low,
notably on the Coronado National Forest
along the Mexican border in southern
Arizona, the stand is usually more open,
and the plant has more the appearance
of a bunchgrass. It is here, at elevations
of about 5,000 feet, that blue grama ordi­
narily makes its best volume growth.
Blue grama sometimes occurs in almost
pure stands, but in the shortgrass region
is commonly associated with buffalograss,
galleta, side-oats, and black or hairy
gramas. As this type of range deterio­
rates, it is replaced by broom snakeweed,
the less palatable three-awns, and ring
muhly. In the pinon-juniper woodlands
the stand may be nearly pure, but more
commonly it includes grasses like west­
ern wheatgrass, galleta, and wolftail. An
indication of deterioration in wood­
land ranges is the intrusion of broom
snakeweed, rabbitbrush, three-awns, ring
muhly, and pingue actinea. Where blue
grama occurs within the semidesert grass­
lands, curly mesquite, and black, hairy,
and slender gramas are often found with
it. At the higher limits of its distribution,
blue grama is a secondary species in
stands of mountain muhly, Arizona fes­
cue, pine dropseed, bottlebrush squirrel­
tail, and prairie junegrass.

MAP SHOWING DISTRIBUTION OF BLUE GRAMA
(Bouteloua gracilis)

Establisning a stand
Sowing seed: Artificial resowing of blue
grama has been tested extensively on New
Mexico ranges. Three to four pounds
per acre of clean, viable seed sown in
rows, or five to eight pounds broadcast,
is sufficient to produce a good stand un­
der favorable conditions. For best results
the seed should be covered uniformly
with soil to a depth of not more than 1
inch nor less than one-half inch. Recent
tests indicate that where soils are light
and sandy and tend to blow readily, a
preparatory cover crop of close-drilled Su­
dangrass, sorgo, or other sorghum, mowed
so as to leave most of the hay on the land
and a protective stubble 8 to 12 inches
high, provides a safer and more desirable
seedbed for sowing blue grama the fol­
lowing year. In some localities in east­
ern New Mexico blue grama has been
successfully established on abandoned
plowed lands by mowing a nearby good
stand of blue grama and disking the mix­
ture of seed, chaff, and hay into the soil.
With all of these methods the minimum
requirements for successful resowing are:
(1) Stabilized soil, (2) viable seed, (3)
straw, stalk, hay, or soil mulch covering
the seed, and (4) sufficient soil moisture
for germination and growth.
Before a system of processing the seed
was developed, the most acceptable
method of sowing was to broadcast the
seed on the field and then to run over it
with a drill, preferably in two directions.
This method is still useful, where proce-
essed and cleaned seed is not available. Successful stands have also been obtained by spreading the hay on a well prepared seedbed and then running over it with a drill or packer or allowing livestock to trample the seed into the ground. In sowing the processed seed with a grain drill, special care should be taken that the seedbed is firm and the seed is not covered more than one-half inch deep.

**Tillering:** While blue grama spreads naturally from seed, its most effective method of increase is by tillering, or the lateral spread of established clumps through the development of new shoots at the outside edge. Rapid expansion by this process normally offsets the natural death losses from old age and other causes.

**UTILIZATION**

**Grazing:** Blue grama is greatly relished by livestock throughout the year. Although under favorable conditions it cures well on the stalk, about half of its nutritive value is lost in curing—and still more when growth is halted by frost rather than by drought. Blue grama compares favorably with timothy hay in amount of protein, is high in calcium, and has a moderate phosphorus content. Both of these minerals are important in the prevention of such diseases as creeps, bone chewing, and brittle bones. During the summer growing period when the herbage is green and succulent, blue grama is very rich in vitamin A but it becomes rapidly poorer in this respect with maturity and may be deficient after curing.

On ranges where it is the dominant plant, blue grama usually constitutes 75 to 90 percent of the feed, and where blue and black gramas occur together it is usually preferred by livestock.

Blue grama withstands trampling well, although it does not equal buffalograss in this respect. It is a 60- to 80-day grass, requiring relatively high temperatures and average moisture for best growth, and ordinarily maturing in late September and early October. It is relatively drought-resistant but fluctuates in density with climatic variations—losing during a single dry year as much as 40 percent. When little or no rain falls during the usual growing season, it remains practically dormant. Slight growth is made from winter moisture; consequently, blue grama furnishes little or no green feed during the spring, when succulent forage is especially needed.

Growth of this species in the North begins early in May, and it grows rapidly, often maturing by late July or early August. The mature forage cures standing and retains much of its nutritive value, thus providing excellent fall and winter grazing.

Blue grama in bloom.
Because of its short growth and low volume production of forage, blue grama is not an important constituent of prairie hay. Its utilization depends almost entirely on grazing animals. Studies on the native range vegetation in western North Dakota indicate that normal yields of forage for this species will usually be between 400 and 600 pounds of air-dry material per acre.

Erosion control: Blue grama, if utilized properly, has great soil-protective value and under the best conditions will completely cover the soil surface. The dense fibrous roots, formed mainly in the upper 18-inch soil layer and mostly near the surface, bind the surface soil very effectively. Only when the stand is markedly reduced by heavy grazing or drought, or a combination of both, does blue grama fail to give adequate soil protection. When that occurs, however, it is very difficult to check the topsoil movement on the compact clay loams on which blue grama often grows.

SEED PRODUCTION

Blue grama spreads by tillering and by seed. The native stands produce seed of varying quality and germinative capacity. In good seasons excellent seed crops may be produced, but generally the seed crop is rather light and of doubtful quality. Seed harvested from native stands may be expected to have a live, pure seed content of from 20 to 40 percent. Purity of this species is usually low because of blasting of the florets at the time of blooming, but germination based on 100 percent filled florets may be high, many lots germinating 90 percent or better.

Seed of excellent quality has been produced at the grass nurseries, where the sowing was done in double 6-inch rows spaced 30 inches apart to permit cultivation. Under these conditions seed has been observed to show practically complete emergence within 48 hours after planting. Since plants grown from seed stock obtained from different localities show distinct differences in habit of growth, observations are being made with a view to finding the best sources of seed for revegetation. Marked differences occur in plants grown at Lincoln, Nebr., from seed collected in Oklahoma, Colorado, New Mexico, and Nebraska. The southern strains tend to mature later and to be more vigorous in comparison with those obtained from northern sources.

Harvesting: Blue grama seed is usually harvested by means of bluegrass strippers. In the central and southern Great Plains small combines have been used extensively, as have the header and thresher. Either combine or header will give higher yields than stripping since the loss of seed by stripping is usually about 25 percent.

Processing: The blue grama spikelet consists of an awned fertile floret and an awned, densely bearded, rudimentary floret. These appendages make the seed light and fluffy and prevent it from feeding well through a grain drill. Removing these appendages by processing the seed raises the purity, increases the bushel weight, and puts it in such a condition that it will feed readily through a drill, particularly in mixtures with heavier seeded species.

BLACK GRAMA
(Bouteloua eriopoda)

Black grama, also known locally as woolly-foot or crowfoot grama, is by far the most important forage grass on the 89 million acres of semidesert grasslands in Arizona, New Mexico, southwestern Texas, and southern Utah. Although not as common now as in the early days, black grama can be maintained on the range and even brought back by management based on careful consideration of its forage and soil-protection values, its methods of spreading, and its ability to stand up under drought and grazing.

As a prime indicator of range utilization, black grama ranks second only to blue grama over the entire Southwest. The two sometimes occur together in mixed stands, but blue grama typically grows in pinon-juniper woodlands and on the heavier soils of the short-grass plains, whereas black grama is found on
the better-drained soils in the short-grass country and the warmer and lower semi-desert grasslands. Black grama may be easily distinguished from other grasses by its widely creeping runners or stolons, which root at the joints and send up new shoots that later become separate plants.

Black grama has three important characteristics that make its retention on southwestern ranges essential—its wide occurrence, its forage value, and its usefulness as a soil protector.

ADAPTATIONS

This grass thrives throughout the Southwest and is also found in southern Utah, usually inhabiting dry mesas and hills at elevations of 3,500 to 5,500 feet above sea level, and growing equally well on compact sandy or gravelly soils. Although most abundant in the southern portions of its range, it is important as far north as the Verde Valley on the Prescott and Coconino National Forests in Arizona and the Cibola National Forest in New Mexico. On the 13 southwestern national forests it is one of a dozen foremost forage plants and is a primary indicator of range utilization on 8 of them—the Cibola, Coconino, Coronado, Crook, Gila, Lincoln, Prescott, and Tonto.

ESTABLISHING AND RESTORING STANDS

The necessity for keeping the forage and soil-protection values of black grama on ranges that are in good condition, and restoring these values on run-down ranges, makes it important to understand how the grass spreads and reproduces.

Artificial resowing and transplanting of black grama have been tested at several locations in the Southwest, both on the national forests and elsewhere. Seedlings were actually grown on the range from broadcast sowing in southern New Mexico, but seed production of black grama is usually so poor that this method is costly and uncertain at best. Transplanting sod was more successful, the survival from summer plantings being about 60 percent, but this method also is far too costly for practical use under ordinary range conditions. After several years of experimentation, natural revegetation remains the simplest and most practical method of maintaining and restoring black grama on the range.

Black grama spreads or reproduces naturally in three ways: (1) by means of seed, (2) by runners from the old plants, and (3) by tillering or the lateral spread of new stems arising from the outside edge of the tuft. Seed production is negligible, for, although flower stalks and flowers are usually abundant, few seeds are matured in most years. Germination may be as high as 94 percent but is usually under 15 percent, and only under unusually favorable conditions do black grama seedlings grow and survive.

Successful spreading by runners requires two successive favorable growing seasons, the first for the new plants to get started, and the second for them to become rooted and firmly established as individuals. A black grama tuft may produce from one to nine runners, but excessive trampling by livestock breaks off many of them before they become rooted. The main advantage of runners is that new plants become established at some distance from the parent plant, thus under moderate use spreading the stand more rapidly to ungrassed areas. This method is of greatest importance at the lower elevations where seedlings are scarcest.

Tillering and the breaking up of black grama tufts into new plants is generally the most effective means of revegetation. Spread during a given growing season depends chiefly on the vigor resulting from climatic conditions during the preceding year. In other words, the stockman can have the benefit of almost a year's advance notice of changes in amount of black grama, since above-average rainfall of one year produces an increased stand the following year, and contrariwise.

UTILIZATION

Pasture: The black grama is highly relished and nutritious at all times of the year. Although fully 90 percent of the
growth is produced during the summer rainy season (usually July, August, and September), it ordinarily cures well on the stalk, and the stems remain green several inches up from the ground. In feed value it compares very favorably with other important range forage grasses, and, except under occasional conditions of extreme dryness, it retains its nutritive value through the dry spring period when most other range vegetation is parched and harsh. Black grama is a dependable forage relished all year long by livestock, especially cattle and horses. Under conservative grazing it is usually eaten somewhat more sparingly by sheep and goats. Where black and blue gramas occur together, the latter is usually preferred.

Because black grama is such good feed, it has been grazed to the point that today there are few pure stands left. It has often given way to poorer forage plants such as three-awns and certain dropseeds and on many ranges has nearly disappeared.

Proper grazing utilizes about 50 percent of the total growth of black grama on a weight basis by the end of the grazing season, which usually means that from 70 to 85 percent of the height growth is taken on most plants. On ranges in fair to good condition, the grazed stubble should be cropped not closer than 2 or 3 inches above the ground by the end of the grazing season in June, under both year-long and seasonal winter use. In addition, one-fifth of the flower stalks and most of the runners should be ungrazed.

Cattle actually graze in such fashion, cropping off certain plants and leaving others untouched, or partially grazed; thus, a few tufts are sometimes grazed to within 1 inch of the ground, and others are utilized to within only 4 or 5 inches. Consistent grazing to within 1 or 2 inches of the ground constitutes severe overutilization.

Erosion control: Although black grama grows under precipitation that supports hardly more than 0.3 to 0.4 of a complete plant cover, it will, if properly utilized, provide sufficient soil protection. Its dense tufts, and especially its runners rooting at the joints, hold soils well in place. Only when the tuft area is seriously reduced by severe grazing or drought, or both, does the plant fail to perform this soil-protective function. Once the topsoil movement is accelerated, it is very difficult to stop, because the soils continue either to be eroded away from the plant roots or to be deposited on top, thus weakening or killing the plants.

SIDE-OATS GRAMA
(Bouteloua curtipendula)

Side-oats grama is the most widely distributed of all the gramas and is found generally throughout the United States east of the Rocky Mountains.

Although a perennial with scaly rootstocks, side-oats grama generally assumes
a bunch habit of growth. It is found in association with other gramas and because of its leafiness is prized as a forage plant. The stems, however, are not palatable and often remain standing after the leafy foliage has been eaten by livestock.

DESCRIPTION

Side-oats grama is a perennial grass of medium height that has increased in abundance in some sections of the Great Plains since the recent drought years. It has short, scaly, rhizomes, but the plant usually assumes a bunch form and only occasionally forms a sod. The flowering stalks seldom exceed 3 feet in height, and in most situations they are usually somewhat shorter; the leaves vary from about 2 to 6 inches in length and are usually flat or only slightly rolled. Commonly, the leaves are slightly less than one-fourth inch wide and are usually quite hairy. The hairs are especially prominent along the margins of the leaves, and have small characteristic, bulb-like enlargements at the base which are readily noticeable.

Flowering usually occurs in July and August. The inflorescence consists of a large number (20-50) of pendulous-stalked, purplish spikes, each about one-half inch long set on a slender, zigzag axis about 4 to 8 inches long. The stalks of the spikes are twisted, so that the spikes are all on the same side of the central axis. When the species is in flower, the bright red stamens stand out conspicuously from the florets contained in the spikelets.

The root system of side-oats grama is moderately deep, usually extending to about 5 feet, but it is well-branched with many fine rootlets and has a wide lateral spread. The root system is especially well developed in the upper 2 feet of soil, in this characteristic being much like the root system of blue grama.

ADAPTATIONS

Side-oats grama has an unusually wide distribution occurring throughout the United States except in the southeastern and extreme western parts. Its major distribution, however, is in the Great Plains area, being most important in the central section. It does not occur to any appreciable extent in the drier areas, but is commonly associated with the bluestems on the lowland prairie areas. Side-oats grama is not so drought tolerant as blue grama and the needlegrasses, and makes its best growth in the more moist situations. In practically all situations it occurs rather sparingly, and does not form pure stands. It does fairly well on most soil types, if moisture is available, but it is usually found on sandy or gravelly soils that are largely free from alkali.

Side-oats grama propagates by rhizomes and by seed. The rhizomes are usually quite short—from 2 to 6 inches in length—and the spreading habit of this species by this means is lacking in aggressiveness.

During the years of drought, it increased considerably, especially in the central Great Plains; and this increase has been due in part to propagation by rhizomes and in part to its seeding habits.

SOWING THE SEED

Side-oats grama is ordinarily sown in mixtures with other grasses at the rate of 15 to 25 pounds per acre, the rate depending upon quality of seed, sowing conditions, and the other grasses, if any, used in the mixture.
GRAMAS

UTILIZATION

Hay: Side-oats grama may make up an appreciable portion of the hay cut on the bluestem meadows of the northeastern Great Plains but will hardly enter into the composition of prairie hay from the western part of the Great Plains. In a few limited areas, however, it may be abundant enough to be a fairly important constituent of the hay even in that section. In feeding value as hay it compares favorably with big bluestem, and chemical analyses indicate that it has approximately the same protein content. Protein is apparently considerably lower in this species, however, than in blue grama.

Pasture: Side-oats grama provides excellent summer pasture for livestock and a good quality of hay when cut in the proper stage. Like blue grama, this species begins its growth late in the spring, but it grows rapidly and remains green relatively late into the season. The forage produced is of high palatability and is fairly good for winter grazing. The grass is capable of withstanding moderately heavy grazing, but does not have the resistance of blue grama in this respect. The seed-stalks are relatively unpalatable and usually are not grazed by livestock.

SEED PRODUCTION

Because of its tall growth, leafiness, and good seed production, this species seems to offer considerable possibility for domestication. Seed can be harvested from native stands by means of grass seed strippers, small combines, or by the ordinary grain binder. Yields obtained have varied from 30 to 150 pounds per acre. Seed harvested in this manner will probably have less than 25 percent purity, but germination on the basis of good seed is usually high, from 80 percent up in most cases.

The cluster of spikelets making up the spike is usually not broken up in threshing. Processing in the hammer mill breaks up the spikes and spikelets, so that the seed will feed readily through the drill. Processing and cleaning have increased the purity of this seed from 20 up to 86 percent, and increased the bushel weight from 7.5 pounds to 24.5 pounds. Yields of good seed from native stands may be around 100 pounds per acre and from cultivated rows have been upwards of 400 pounds per acre.

Side-oats grama offers its best promise for use in mixtures with other grasses for pasture and hay purposes.

Hairy grama

(Bouteloua hirsuta)

Much that has been said here about blue grama applies equally well to hairy grama except that the latter is much less palatable than blue grama and altogether is not so valuable a forage grass as blue grama or as useful in reducing soil erosion. Hairy grama occurs sparingly on rocky, caliche, and sandy soils throughout the region. Unlike blue grama it seldom occurs thick enough in natural stands to justify harvesting for seed; consequently, seed supplies must be increased by artificial means. Its palatability is considered equal to blue grama, but the forage production is usually less. Its range of greatest usefulness is limited to sandy soils and to other sites less favorable for the maximum development of blue grama. Several vigorous strains of this species, isolated at Woodward, have produced growth comparable to the better strains of blue grama. Griffiths and his coworkers report that “The habits of the species render it of much less value than its close relative, the blue grama, but on account of its very wide distribution and abundance as a filler over large areas it is a very important species. It is not a well-rooted species, and consequently does not withstand trampling by stock very well.

Rothrock grama

(Bouteloua rothrockii)

Rothrock grama occurs in the southern half of Arizona and southwestern New Mexico, where it often forms extensive pure stands.
It is an erratic, short-lived perennial, resembling blue grama except for the more numerous flower spikes. Ranchers consider it better than the annual gram, but not as valuable as the blue and hairy gramas with which it is frequently associated.

This grass does not withstand overgrazing, but during favorable periods the number of plants increases rapidly because of good seedling habits. With adequate protection it produces excellent cover on relatively sterile soils where but few other species will grow and for that reason especially is desirable for revegetation.

Seed of this grass should be produced under cultivation as the collection of seed from native stands is difficult and expensive.

**GRAMA HIGHLIGHTS**

1. Blue grama is one of the most valuable and dominant range plants over most of the Great Plains. It is associated with black grama, hairy grama, and Rothrock grama in the Southwest, and with side-oats grama to a limited extent over most of its entire range, especially in the subhumid areas of the central Great Plains.
2. Blue grama provides excellent forage both summer and winter, is resistant to grazing and drought, and is an effective soil binder.
3. The livestock industry, of the Southwest in particular, is dependent upon maintaining the dominance of blue grama.
4. Blue grama is commonly associated on the range with buffalo grass and other gramas. It is often confused with buffalo grass, but the two can be readily distinguished by the leaves, stems, and flowers, and the presence of runners on buffalo grass.
5. Artificial resowing of blue grama on the range is practical. Under reasonably favorable conditions and good practices, 3 to 4 pounds of seed drilled, or 5 to 8 broadcast, will give a good stand. Its most effective increase, however, is by tilling, or by the natural spread of clumps from the outer edge.
6. Blue grama is greatly relished by livestock all the year round. It makes excellent summer and winter feed but loses much of its value for winter use from natural curing on the range.
7. Blue grama is primarily valuable for grazing. Because of its short growth, it is not an important constituent of prairie hay.
8. The fibrous roots of blue grama in the upper 18 inches of soil make it an effective soil binder, and a valuable plant for control of soil erosion.
9. The seed of blue grama from native stands is generally of light weight and doubtful quality, and may have a live pure seed content of only 20 to 40 percent. Seed of excellent quality has been produced in grass nurseries.
10. Blue grama seed is usually harvested with bluegrass strippers, but higher yields are obtained with combine or header.
11. Side-oats grama has the widest distribution of all gramas, extending throughout the United States east of the Rocky Mountains.
12. Side-oats grama is easily distinguished from other gramas by its habit of growth and characteristic inflorescence.
13. In the moister locations of the central Great Plains, often in association with big bluestem, side-oats grama may form an appreciable proportion of the prairie hay, the two species having about equal feed value.
14. Side-oats grama will withstand moderately heavy grazing but is not equal to blue grama in this respect.
15. Side-oats grama, especially the improved variety, Eleno, because of its tall growth, leafiness, and good seed production, offers greater possibilities for domestication than other gramas.

**SPECIAL CROPS—GRASSES**

7. Blue grama is primarily valuable for grazing. Because of its short growth, it is not an important constituent of prairie hay.
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**THIS CHAPTER**

The material used here on buffalo grass came largely from Wenger's (KAN-28) comprehensive work on this grass, supplemented by material from Savage (US-225), Mecmen of Kansas, and Whitman and Stevens (ND-15). That on the gramas came mostly from Crafts and Glendenning (US-41), Campbell and Crafts (US-26), Hoover, Smith, Ferber, and Cornelius (US-116), Savage (US-225), and Whitman and Stevens (ND-15). The manuscript was reviewed by Meemen of the Branch Experiment Station, Hays, Kan., and Savage of the Southern Great Plains Station, Woodward, Okla.
Chapter reference numbers: 

Buffalograss: KAN-1, 28; TEX-22; US-223; MISC-9, 11, 15, 17, 42.


The reference numbers given here refer to references which are given in full by State, U.S.D.A., and Miscellaneous, on pages 682 to 724, and which are cross-referenced by author on pages 725 to 731. Citations in the text are indicated by abbreviation and number in parentheses.
OTHER GREAT PLAINS GRASSES

**Bluestems, Switchgrass, Wild-rye, Needlegrasses, Indian ricegrass, and Dropseeds**

There are many native grasses of the Great Plains which have forage value, but relatively few of them have been domesticated or are being used to renovate the native range, or for sowing on cultivated land. Entirely new techniques have had to be developed to harvest and sow some of these dryland grasses, which has prevented very rapid progress being made in their use. Among the most important ones used so far are the wheatgrasses, buffalograss, and the graminoids which have been covered in foregoing chapters. Some of the others used are the bluestems, switchgrass, wild-rye, the needlegrasses, Indian ricegrass, and the dropseeds, all of which are described in this chapter.

**THE BLUESTEMS**

*(Andropogon species)*

The two major species of bluestems commonly known as big bluestem *(Andropogon gerardii)*, *(A. furcatus* of most forage literature), and little bluestem *(A. scoparius)*, sometimes referred to as beardgrasses, are among the most important forage grasses of the Great Plains. They constitute a large part of the prairie hay which comes into the Kansas City market. The genus *Andropogon* is represented in the United States by some 32 species of rather coarse perennial grasses occurring largely in the areas east of the Rocky Mountains. Big and little bluestems are found growing naturally throughout the region from the Atlantic coast to the Rocky Mountains, but are most common in the Great Plains and tall grass prairie where they form a large part of the native grass flora in the areas of higher rainfall.

**BIG BLUESTEM**

*(Andropogon gerardii)*

**Description:** Big bluestem is a large, perennial, sod-forming grass, spreading slowly by short rhizomes. Frequently, it assumes the bunch type of growth. In flower, it is usually about 3 to 4 feet tall, but may reach a height of 6 feet or more under favorable conditions. Usually, the foliage is tinged with red or purple, frequently having a mottled appearance.

The tall flowering stalks are stout and coarse, usually purple-tinged, and are solid in contrast to the stalks of most other grasses which are hollow. The racemes are purplish and present a claw-like appearance from whence comes one of the common names, "turkeyfoot."

This grass has a coarse, deeply penetrating root system which may reach a depth of 9 feet or more in favorable situations. While branching of the root system is extensive, the branches are somewhat coarse. This feature of the root system is no doubt related to the relatively low drought resistance shown by this species.

**Adaptation:** Big bluestem is generally distributed throughout the eastern part of Oklahoma, Kansas, Nebraska, South Dakota, and North Dakota, but in the west-
ern part of these States where climatic conditions are more severe, it is found only in scattered stands on the most favorable sites. The old saying that “big bluestem land is good cornland” is indeed true, for much of the fine agricultural land of the western part of the Corn Belt was at one time covered with dense stands of this and associated tall prairie grasses.

This grass does well on most soil types. It is usually associated with little bluestem, porcupinegrass, side-oats grama, Canada wild-rye, and others. Its relative drought resistance is quite low and it has been replaced by more resistant grasses in many situations as the result of the recurring droughts of recent years. It also is not tolerant of excessive moisture and can stand only small amounts of alkali.

Establishing a stand: Information at hand regarding the proper rate, date, and the method of sowing indicates that success in establishing stands of this grass depends largely upon the preparation of the seedbed and the depth of sowing. As a usual practice, the seedbed should be prepared as for ordinary grain crops and the seed sown not more than one-half inch deep. The fact that this is a native grass does not mean that it can be sown with any less care than the tame grasses. Rates of 6 to 8 pounds an acre, if it is sown in rows suitable for cultivation, and 15 pounds if sown broadcast, have been found to give satisfactory stands.

Utilization: Big bluestem, along with switchgrass and some other prairie forage grasses, make up the best grades of prairie hay and bring the highest market prices. The quantity of such hay produced and marketed has been greatly reduced in recent years. Big bluestem is a rather coarse grass so should be cut for hay shortly after blooming in order to insure a high protein content and a reasonably high yield of forage. Flowering usually begins in July and continues on into August. Chemical analyses indicate that protein content is quite high in this grass at full bloom and crude fiber is relatively low.

Big bluestem furnishes excellent summer pasture and provides a hay of high palatability and good nutritional qualities. The stock will hunt out patches of big bluestem in native pastures and keep them closely grazed down during the entire summer, indicating the high degree of relish with which the tender juicy grass is eaten. Growth of this species begins late in the spring, but carries on through the summer. Big bluestem often remains green after most of the other grasses have dried. After the seed has matured, the stalks become coarse and woody, and the grass is less desirable for grazing. It has but little value for winter grazing.

While big bluestem will stand moderately heavy grazing, it is not as resistant as blue grama grass and some other species, and if too heavily grazed, it will be replaced by less desirable grasses or by weeds.

Big bluestem, even if sown alone, gives the soil excellent protection against ero-
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SPECIAL CROPS—GRASSES

with a hammer mill and cleaned with a
fanning mill, should have a purity of at
least 40 percent, a germination of about
60 percent, and should weigh around 23
pounds per bushel. A pound of pure seed
contains 140,000 to 170,000 seeds.

LITTLE BLUESTEM
(Andropogon scoparius)

Description: Little bluestem is a tufted
perennial grass, which is appreciably
smaller than big bluestem, its close rela-
tive. It usually grows from about 10
inches to 2½ feet in height, although in
favorable situations it may be somewhat
taller. When growing in the drier situa-
tions, it usually has a distinct bunch form,
but in association with other grasses it
shows sod-forming tendencies and does
not become distinctly bunched.

An outstanding characteristic of this
glass is its distinctive reddish-brown color,
developed as the glass matures. The early
growth of the leaves is light green, but
they generally soon become tinged with
purple and as the plants mature the color
increases and changes to reddish brown.

A large number of flowering stalks are
produced by each clump, which makes
the grass very stemmy. The flowering
stalks also assume a reddish-brown color
in late summer, and the inflorescence,
which is in the form of a loose raceme
becomes distinctly fuzzy. This fuzziness
results from the hairy nature of the spike-
lets. Flowering stalks are usually formed
in July and August with seed maturing
in August and September.

Adaptation: Little bluestem grows natu-
rally in about the same area and under
the conditions required by big bluestem,
but is well adapted also to poor, droughty
sites. Hence it is found on gravelly soils,
on ridges, and in other exposed locations.
One of the main areas where it grows
naturally, is the flint hill section of east-
central Kansas and Oklahoma.

Utilization: Hay of fairly good quality is
provided by this species if it is cut early.
Little bluestem is usually a fairly impor-
tant constituent of hay from the native
meadows of eastern Great Plains. Chem-

sion. Usually it is sown in mixture with
species with which it grows naturally.
Perhaps its most important use is to re-
tire cropland to meadows and pastures.
It builds up the organic content of the
soil rapidly through decay of roots and
tops.

Seed production: Big bluestem will no
doubt be one of the first native grasses to
be grown generally by farmers for the
production of seed because the demand
for the seed is increasing and ordinary
farm machinery and methods can be used
in its production.

Few fields of big bluestem produce
seed every year. This is because the
combination of plentiful moisture and
moderate temperatures does not occur
regularly. When grown in rows and cul-
tivated, however, this grass regularly pro-
duces from 150 to 200 pounds of seed
per acre. The seed normally matures in
late September or October.

Stands of big bluestem should be ex-
amined with great care before seed har-
vest to determine the set of seed. Under
best conditions a seed fill seldom exceeds
50 percent. A fill of 20 percent usually
justifies harvesting the seed. The seed has
been harvested satisfactorily with power
stripers, ordinary binders, and with
small-grain combines. Yields of 75 to 100
pounds per acre, field run, averaging 25
percent pure seed by weight have been
obtained with small-grain combine har-
vesters. Combine- or thresher-run seed
material of this grass, when processed

Map showing distribution of big bluestem.
ical analysis of the grass in the full-bloom stage indicates that its protein content is not equal to big bluestem and may be only one-third to one-half that of blue grama at the same stage of maturity.

While little bluestem is quite widespread and abundant in the Eastern Great Plains it is not one of the first-rank forage grasses. This is because of its relatively low degree of palatability, which is generally considered to be less than one-third of that of blue grama. The spring growth is quite palatable, but once the woody flowering stems are developed the grass becomes unpalatable and the livestock will not graze it. Since the coarse growth is carried over from year to year, the grass usually receives very little spring grazing.

Little bluestem, however, does have considerable value on the winter range. Since it is grazed only to a small extent during the summer, the coarse forage accumulates over a period of years and is available as reserve feed. If other forage is short during the winter, little bluestem will be closely grazed, especially where cottonseed cake or some other concentrate is given to the livestock.

Little bluestem does not stand continual close summer grazing as does big bluestem, and the bunches die out and are replaced by shorter grasses, when subjected to this treatment for several seasons.

Because of its habit of growth and the wide range of soils on which it thrives, little bluestem has great merit for erosion control. It is suitable for use in crop rotations and also in mixtures for regrassing abandoned cultivated land.

**Seed production:** Timely summer rainfall, reserve moisture, and favorable temperatures at blooming time are needed for seed development. It is seldom that any area not under cultivation produces a seed crop 2 years in succession. The seed matures in late September or October in Nebraska and to the south, and just before frost farther north. A seed fill of 70 percent is considered excellent; one of 30 percent is satisfactory for harvesting. When grown in rows and cultivated, little bluestem has sometimes yielded 200 to 300 pounds of seed per acre.

Little bluestem seed is harvested successfully by direct combining and also with a binder or with a swather and a
pickup combine. Threshing, processing with a hammer mill, and cleaning with a fanning mill should result in seed purity of 40 percent or more and germination of 60 percent. A pound of pure seed contains around 250,000 seeds.

The seed of this grass can be harvested readily from native stands with power strippers or with small-grain combine harvesters. If collection is made with a stripper, the seed material should be threshed with an ordinary small-grain separator and cleaned with a clipper fanning mill. If harvested with combine harvester equipment, special care should be used in adjustments of air and screens to clean the seed without unnecessary waste.

Seed collected from native stands usually contains various amounts of associated species such as big bluestem, switchgrass, Indian grass, dropseed, and grama. Such seed mixtures are considered desirable for the reseeding done by the Soil Conservation Service because they represent the natural association of grasses that are adapted to the region where the work of revegetation is being done.

Excellent yields of high-quality seed have been obtained in the nurseries of the Soil Conservation Service from plantings in 6-inch paired rows spaced 30 inches apart to permit cultivation. If the seed is sown in this manner, a rate of 6 to 8 pounds per acre is sufficient, but if it is drilled or broadcast on a field scale, 20 pounds is necessary.

**SAND BLUESTEM**

*(Andropogon hallii)*

Sand bluestem is a vigorous, broad-leaved, perennial, sod-forming grass with a deep fibrous root system and aggressive underground stems. A single plant sometimes forms a dense colony as large as 30 feet in diameter. This species is native to the central and southern Great Plains. It can survive prolonged drought and is primarily adapted to the region's deep sandy soils. It is an excellent grass to include in mixtures with other grasses for pasture or hay production on sandy soils.

Growth begins rather early in the spring in the southern part of the region and from 2 to 3 weeks later than that of cool-season grasses in the northern part, and continues at a rapid rate throughout the summer. Plants generally reach a height of 5 to 7 feet. If cut early before seed heads form, sand bluestem produces fair to good quality hay high in palatability and nutritive qualities. It is excellent for summer grazing but is eaten much less readily than most other grasses during the winter.

Sand bluestem rarely sets a heavy crop of seed; under ordinary conditions a fill of 60 percent is considered excellent. The seed is usually very chaffy and low in purity but high in germination. It has not yet become extensively available in commercial quantities but can be harvested with fair success in native stands or increased plantings. The chaffy seed usually requires sowing rates of 15 to 30 pounds to the acre to give satisfactory stands if sown alone. Dehulled seed gives equally good results when sown at 3 to 5 pounds an acre.

The seed matures in late September or October. Harvest should not be undertaken if seed fill does not amount to 20 percent. The best method of seed harvest is to combine directly from the field. Seed yields from native stands seldom exceed 30 to 50 pounds per acre. When reseeded, the seed should have a
purity of 40 percent or more and a germination of about 60 percent. A pound of pure seed contains around 110,000 to 120,000 seeds.

**CAUCASIAN BLUESTEM**  
(*Andropogon intermedius caucasicus*)

Caucasian bluestem, a perennial bunchgrass, was introduced by the Department of Agriculture from the Union of Soviet Socialist Republics and has been grown at experiment stations in the central and southern Great Plains. It shows great promise as a pasture and hay grass in those areas. It is easily established from seed and makes good growth even if moisture supplies are low. The seeds are small, and when they mature the seed heads shatter; therefore, seed yields are relatively low. However, seeds scattered from established plants germinate readily, with the result that originally thin stands soon become more dense.

Tests of Caucasian bluestem indicate that its soil and climatic adaptation resembles that of native little bluestem, a grass to which it is decidedly superior in quality and quantity of forage. Methods of growing the grass and harvesting the seed, also, are similar to those recommended for little bluestem.

**TURKESTAN BLUESTEM**  
(*Andropogon ischaemum*)

Turkestam bluestem, a perennial semi-prostrate bunchgrass known in some localities as yellow bluestem, was introduced by the Department of Agriculture from India. It was sown in trials first at experiment stations in the central and southern Great Plains. Results have indicated that the grass is suitable for use in these areas for both pasture and hay. Turkestam bluestem has very leafy foliage. It appears to be similar to little bluestem in area of adaptation and use, and to excel it in quantity of forage produced. The forage is relished by all classes of livestock.

Seedlings of Turkestam bluestem are vigorous, and the grass volunteers readily. Methods of growing the grass and harvesting the seed are similar to those described for little bluestem.

**SWITCHGRASS**  
(*Panicum virgatum*)

Description: Switchgrass is a vigorous, native, perennial, sod-forming grass that occurs throughout most of the United States. It is most abundant and important as a forage and pasture grass in the central and southern parts of the Great Plains.

It usually grows 3 to 5 feet high, with short, vigorous rhizomes. The stand looks like a colony rather than a sod. The flowering head is a widely-branching open panicle. The leaves are usually from one-fourth to one-half inch wide, and 6 to 18 inches long. Leaves are green to bluish-green. Switchgrass occurs on nearly all
Switchgrass is sown usually with the species with which it occurs naturally. Best seedling stands have been obtained where the seed was sown on a clean, firm, well-prepared seedbed. Growth begins in late spring and continues through the summer if there is enough moisture. Forage is produced in abundance and—especially during the period of early rapid growth—is acceptable to livestock. Hay of good quality can be had by mowing the grass when seed heads begin to form.

Seed production: The seed matures in September. Seed production depends on moisture and cool temperatures during the period of blooming and seed formation. Binders and combines have been used for seed harvesting. Native stands commonly yield more than 100 pounds of seed per acre; this yield can be increased to 300 pounds by growing the plants in rows under cultivation.

Recleaning the seed with a fanning mill should give a purity of 95 percent and a germination of 30 percent. Germination improves during storage and may be twice as high if the seed is held in dry storage for a year after harvest. A pound of pure seed contains about 390,000 seeds.

WILD-RYE

(Elymus species)

The genus *Elymus* is well represented in the native grass species of the Western States. Most wild-rye species are perennial and many are bunchgrasses; a few, however, form sod.

These grasses have coarse and rough foliage and are relatively unpalatable, but they are most useful for revegetation because of their rather good seed habits, high forage production, wide adaptation to a variety of soils, and relative ease of establishment. The seed of all important species is inclined to shatter badly, and one species used on the Pacific Coast, *E. triticoides*, has low germination and delayed dormancy.

The wild-rye grasses are susceptible to ergot, a fungus disease that replaces the kernel of the seed head. If livestock eat large quantities of ergot, losses may be serious.

CANADA WILD-RYE

(*Elymus canadensis*)

Of the several species of wild-rye that grow on the Great Plains, Canada wild-rye has the greatest value, both for conservation and for forage production. It is winter hardy and grows well on many kinds of soil. The seedlings are very vigorous; therefore, new plantings can be established quickly. This makes Canada
wild-rye very useful in mixtures with other grasses, especially with those that do not produce ground cover rapidly.

**Description:** Canada wild-rye is a large, coarse perennial bunchgrass which grows from 2 to 5 feet high and has a thick spike which nods at maturity. It begins growth about a week later in the spring than smooth bromegrass or crested wheatgrass, and it usually continues to grow all summer if moisture conditions are favorable, and may make further growth in the fall if enough moisture is available then. It produces exceptionally high yields of forage which is palatable to all classes of livestock. Hay of fairly good quality may be obtained if the wild-rye is harvested just as the seed heads are emerging from the boot. Recovery after cutting is rather slow. When used for pasture, grazing should be delayed until there is about 5 inches of growth.

**Adaptation:** Canada wild-rye is found throughout the United States, with the exception of the extreme southeast, south, and southwest. It is apparently better suited to a relatively cool climate and finds its major distribution in the northern Great Plains and Intermountain regions, wherever moisture conditions are suitable. It makes its best growth in swales, moist ravines, among bushes, and along banks of watercourses. It is also quite abundant in roadside ditches, especially in the sandy districts.

Because of its relatively high moisture requirements, it seldom occurs in extensive stands, and is usually found associated with other grasses. It seems especially well adapted to growth on sandy soils, although it is not confined to soils of this texture. Apparently in the Great Plains region it does not have a high degree of tolerance to alkali, but in the Pacific Coast States and Intermountain Region, some of the best stands are found in wet alkali soils if the salt content is not too high.

**Sowing seed:** The most satisfactory time to sow Canada wild-rye is in the early fall, if soil moisture is satisfactory. Successful sowing can be done either in the late fall or spring. In most cases, nurse crops should not be used.

Good seed should be sown at about 5 pounds per acre in rows, and ten pounds per acre when seeded solid. When sowing the seed, it should be agitated continuously to give a uniform flow through the drill.

The depth of sowing may be greater than for most grasses because of seedling vigor. If the surface of the soil is dry, planting may be made up to one inch or slightly more in depth.

Seed of Canada wild-rye germinates more slowly than that of grasses such as crested wheatgrass. Seedling emergence, therefore, is often as much as a week after that of crested wheatgrass when both are planted at the same time. When grown strictly for seed production, it is advisable to sow in regular 42-inch rows which can be cultivated with standard corn cultivation equipment. On locations where there is danger of soil blowing, or where it is to be used for pasture, stands should be sown solid. Fair to good seed production
is often obtained from solid plantings. Establishment is relatively rapid, but it may take a year before weeds are crowded out.

**Mandan wild-rye**: Mandan wild-rye is an improved variety of Canada wild-rye developed at the Northern Great Plains Field Station at Mandan, North Dakota. In the northern Great Plains, it is superior to ordinary Canada wild-rye in several ways; the plants are finer, shorter, and more leafy, and their leaf texture is softer. Also, they are longer lived than those of many strains and can withstand grazing over a period of several years. This variety is somewhat susceptible to rust, but is more resistant than the others that have been tested. In the Intermountain Region, it has not proved superior to some other ecotypes selected.

The main virtues of Mandan wild-rye are ease of establishment, rapid growth, and high yields of forage and seed. It can be used to greater advantage in mixtures with grasses that are slower in establishment but may have high forage quality. It recovers fairly well after cutting or grazing. In palatability it is about equal to other commonly used forage grasses, ranking somewhat lower than smooth brome or crested wheatgrass. It appears to be well adapted for use in crop rotations.

In establishing a seed plot where seed of satisfactory purity is to be produced, care should be taken to establish it the required distance from other Canada wild-rye. This species is relatively self-fertile, but some crossing occasionally takes place. After seed plots of Mandan wild-rye are established, a few large, coarse, off-type plants may be found. These should be rogued out before flowering.

**Seed production**: The seed matures in late summer, about two weeks later than crested wheatgrass. The first good seed crop may be expected the second year after sowing. Seed heads should be examined very carefully before harvest to determine seed fill. This may vary from 40 to 90 percent, depending upon moisture conditions, soil fertility, and temperature during the period of blooming and seed development. Fields having less than 50 percent seed fill are not satisfactory for seed harvest.

Seed of Canada wild-rye is harvested most satisfactorily with a binder. A combine may be used if it has proper screens. This species produces abundant seed; yields of 300 to 400 pounds per acre from native stands are common. If the grass is grown in rows and cultivated, seed yields average considerably higher.

Combine- or thresher-run seed should have an average purity of 65 percent and a germination of 90 percent. Seed must be processed to remove the awns before it can be sown satisfactorily. Cleaning with an ordinary fanning mill after removal of the awns should result in a seed purity of at least 90 percent. A pound of processed pure seed contains from 85,000 to 110,000 seeds, and weighs around 26 pounds per bushel.

**RUSSIAN WILD-RYE**

*(Elymus junceus)*

The first recorded introduction of Russian wild-rye in the United States was in 1927. Some of the original introductions of crested wheatgrass came from the same general region as this lot of Russian wild-rye. This species appeared in this country prior to this introduction of record, probably having been brought here in mixtures of other grasses.

**Description**: Russian wild-rye is an erect perennial bunchgrass. The flower stalks or culms are naked above, arising from...
an abundance of long and dense basal leaves. The culms are normally 2 to 4 feet tall when grown in rows under cultivation. The leaves are lax, strongly nervèd, and light green in color. The flowering head is a dense erect spike, resembling rye, the spikelets containing usually two to four flowers. The roots are coarser than those of crested wheatgrass and may penetrate the soil to a depth of 8 to 10 feet, but at least 80 percent of them are in the first foot of soil.

**Adaptation:** This species is adapted to a fairly wide range of soil types, but produces best on fertile clay loams. Successful plantings have been made throughout the northern and central Great Plains and the Prairie Provinces of Canada. In the Pacific Coast States where it has been under trial for 20 years, Russian wild-rye grows on any good soil in subhumid areas and at elevations up to 6,000 feet above sea level.

**Sowing the seed:** Russian wild-rye should be sown without a nurse crop, especially in the drier parts of the northern Great Plains. The most desirable depth of sowing is about one-half inch. The grass may be sown in the fall or spring. Early fall sowing, about September 1, if moisture conditions are favorable, is the best time. The same general cultural treatments can be followed as those for crested wheatgrass.

**Use:** It is quite evident that Russian wild-rye will prove to be better adapted for use as a pasture grass than as a hay crop. In the Northern Great Plains, it is likely that its greatest use will be for pasture in mixtures with other grasses such as crested wheatgrass, bromegrass, and others that do not have too vigorous seedlings. Its palatability is below that of either bromegrass or crested wheatgrass early in the grazing season. Later in the season, however, it is readily eaten by cattle with apparent relish. In the Intermountain Region it is used alone for dryland pasture because of its unique “season-of-use.” No other grass there seems to be as well suited to late summer grazing.

**Seed production:** Russian wild-rye is not a consistent seed yielder, and the seed shatters badly. In order to avoid the loss of seed, harvesting must be done before the seed is completely mature or while still in the soft dough stage. The seed is ready for harvest approximately 2 weeks earlier than crested wheatgrass at Mandan, North Dakota. Harvesting can be done with the ordinary grain binder, and threshing with the usual machine. The seed usually requires processing before it will feed out of a grain drill because the seeds are covered with short stiff hairs and carry a short awn. If properly threshed, this may be unnecessary.

For the production of seed, Russian wild-rye should be sown in rows at the rate of 2 to 3 pounds per acre and cultivated. Unless sown in rows, the chances of its producing a seed crop are very poor. The rows should ordinarily be at least 42 inches apart.

**GIANT WILD-RYE**

*(Elymus condensatus)*

Giant wild-rye is a coarse, robust, perennial with thick, short rootstocks. It occurs in all the Western States. It is the largest of the native ryegrasses. Individual plants often grow 10 feet high and form clumps several feet thick. The erect flower spikes may grow 1 foot long. Leaves are flat and coarse, nearly 1/4 inch wide and 2 feet long. The extensive root system has short, thick, perennial rootstocks.

This bunchgrass is abundant on moist or wet saline soils; it occurs also on moderately dry fertile soils, but moderate grazing, especially during early spring, is essential to good stands.

During the early settlement of the Western States, it was a primary source of spring grazing and winter feed for livestock. Excessive use, particularly while the plants were young and succulent, has depleted the natural stands.

Giant wild-rye is grazed readily while young. Later the foliage becomes coarse and harsh, and livestock leave it if they can get more palatable forage. If it is left standing, the grass provides a considerable amount of winter feed for cattle and horses. Fairly good hay can be had from the young growth.
Good stands of giant wild-rye have been obtained by drilling the seed about an inch deep. It is valuable for range reseeding on flood plains. Seed of native stands can be harvested by combine.

Scarcity of seed has limited the use of giant wild-rye for revegetation of range lands in the West.

**BLUE WILD-RYE**  
*(Elymus glaucus)*

Blue wild-rye is a native perennial bunchgrass that grows throughout the Western States, particularly on old burns and cut-over areas in the Northwest. It commonly grows in small tufts and rarely forms dense, pure stands. It is the most widely distributed and common species of wild-rye in the Western States.

Seedstalks may grow to 5 feet high, with broad, flat, smooth leaves nearly 12 inches long. Roots are vigorous and penetrate deeply. The plant derives its name from the bluish bloom on leaves and stems.

Blue wild-rye is native to the forest and transitional areas. It is most abundant on moist soils and is not particularly drought-tolerant. The foliage, although rather coarse, is grazed by cattle and horses, especially during the early part of the season when they seem to relish it.

Blue wild-rye produces good growth during the cool season in parts of California; it also persists very well there under limited rainfall and shows promise for use as dry-land pasture, hay, or range.

Experimental plantings as a vegetative cover in wood lots in Washington have been successful; black locust trees made optimum growth in plantings with various grasses and legumes as ground cover. Blue wild-rye was shade-tolerant, provided excellent ground protection, and gave the highest forage yields of the several grasses under test. When planted with alfalfa under these conditions, the forage yield of alfalfa-grass was good, but the grass-legume mixture seeding depressed tree growth.

When grown under cultivation, seed yields of 300 to 400 pounds an acre have been obtained. The threshed seed had a purity of 80 percent as it came from the thresher; when it was cleaned, its purity was 97 percent and the germination was 81 percent. The test weight is about 23 pounds per bushel.

Blue wild-rye has not been used extensively in reseeding, primarily because of inadequate seed supplies.

**STIPAS OR NEEDLEGRASSES**  
*(Stipa species)*

The *Stipas* are distributed through the temperate zones. About 30 species grow in the Western States. Each spikelet has one flower and terminates in a prominent awn. The seed also is very sharp-pointed and needle-like on the callus end, which accounts for the common name "needlegrass" that often is used for the various species of this genus.

Stipa grasses rank fairly high as forage grasses on the western ranges because of their wide distribution, long growing period, and capacity to cure well on the ground.

The injuries that the long, sharp awns on seeds of some species cause on grazing animals are a serious objection to these grasses, regardless of their other virtues.

**FEATHER BUNCHGRASS**  
*(Stipa viridula)*

Feather bunchgrass, known also as green needlegrass, is a native perennial bunchgrass usually found on heavy soils throughout the greater part of the northern and central Great Plains. It grows naturally in mixture with western wheatgrass and native grasses.

New plantings are readily established. Apparently feather bunchgrass is best used
in mixtures with other grasses. Because the young seedlings make rapid growth and resist drought and grasshopper injury, the species has great merit for conservation use.

**Description:** Feather bunchgrass is a tall, perennial bunchgrass, usually growing from 1 1/2 feet to 3 feet in height. The leaf blades vary from 4 to 12 inches in length and are usually somewhat wider than the leaves of needle-and-thread, varying from less than one-eighth inch to about one-fourth inch in width. They are usually partly rolled.

The inflorescence is a rather compact panicle varying from 4 to 10 inches in length and is usually rather greenish, or occasionally tinged with purple at maturity. Flowering takes place in early June with seed maturing in late June and early July. The seed has an awn about 1 inch in length and is covered with short hairs. The awn is not injurious to livestock.

This species has rather deep, fibrous roots which in favorable situations may extend to a depth of 10 feet or more. The roots in the upper soil levels are coarse, tough, and wiry, but become finer below. The lateral extent of the root system is usually about 2 feet and the soil beneath the plant is thoroughly permeated by the profusely branching roots.

**Adaptation:** This grass has its major distribution in the northern Great Plains, but is found as far south as New Mexico. It occurs only sparingly in most of the associations of native vegetation. It is distinctly less well adapted to dry soil conditions than needle-and-thread, and occurs in greatest abundance on areas where the native vegetation has been disturbed, or in swales where moisture conditions are somewhat more favorable. It is particularly abundant in the early stages of natural revegetation of abandoned cultivated fields. It seems to be fairly well adapted to most soil types, but makes a better growth on the sandier soils, if moisture is sufficient, than it does on the heavier soil types.

**Use:** The palatability rating for feather bunchgrass is quite high, and chemical analyses indicate that it has fairly good nutritive qualities. Growth begins early in the spring, and continues into the fall when moisture conditions are favorable. It makes excellent recovery after grazing or clipping and provides good pasture forage throughout the season. It seems to stand up fairly well for winter grazing.

In some areas feather bunchgrass makes up an appreciable part of the yields of native hay from upland areas or from flats. The hay is apparently of good quality and is eaten readily by livestock. Since the seeds of this species are not troublesome to animals, it can be cut whenever it is in a favorable growth stage. Usually, however, it is not cut until August or September at the same time that associated species are cut. This is a little too late to provide the best quality of hay.

**Seed production:** Seed of feather bunchgrass matures in early July in North Da-
kota, and earlier to the South. The crop depends on favorable moisture conditions and moderate temperatures during the blooming and seed-development stages. Seed ripening progresses from top to bottom of each seed head; thus the upper part of a seed head may shatter while the lower part is not yet ready for harvest. In order to harvest the seed when the largest amount of mature seed may be obtained, the seed heads must be examined very carefully. It is seldom possible to get more than 50 percent of the seed.

Seed of feather bunchgrass cannot be harvested satisfactorily by any method other than binding, heading, or swathing followed by threshing. Binders and headers give best results. Combines can be used, but this results in harvesting rather large amounts of immature and underripe seed.

Seed yields of 150 pounds per acre have been obtained from natural stands. When grown in rows and cultivated, this grass has yielded 300 to 500 pounds of seed per acre.

Combine- or thresher-run seed should have a purity of about 70 percent and a germination of 5 to 10 percent. Storage for a year usually increases such a germination to one of 50 to 60 percent.

Feather bunchgrass seed has light awns that make sowing with standard drills impossible. These awns can be removed readily with a hammer mill, and the seed cleaned with a fanning mill. A pound of pure seed contains from 175,000 to 190,000 seeds.

Green-stipagrass: Green stipagrass is an improved variety of feather bunchgrass developed from a single plant at the Northern Great Plains Field Station, Mandan, North Dakota. This variety is superior to others of feather bunchgrass in general vigor and size. It recovers very rapidly after being mowed or grazed and is especially useful for sowing pastures. It grows well with other grasses, and for general farm use should be sown in mixtures.

**NEEDLE-AND-THREAD**

*(Stipa comata)*

Needle-and-thread is a deep-rooted, long-lived, native bunchgrass that occurs generally on the western ranges and most abundantly on the sandy soils of the northern Great Plains. It grows in almost pure stands as an invader on some of the abandoned croplands of the Plains. It derives its name from the appearance of the seed, which is sharp-pointed and has a long, bent, twisted, threadlike awn that looks like a threaded sewing needle.

Seedstalks grow 1 to 4 feet high, with leaves less than one-eighth inch wide and 8 to 12 inches long. Leaf auricles are absent, but the ligule is membranous, notched, and prominent. Seed awns, also prominent, usually average 6 inches or more in length.

Flowering of this species usually begins early in June, and the seed matures and is shed in July. Livestock graze the plants sparingly during this period. Palatability is reduced by the sharp points of the seeds, which injure livestock by working into the mouth parts and the hide. Except for the period when seeds are present, livestock eat the forage readily. They make good use of the standing cured forage for winter grazing.

Seed is produced in abundance most years, but the heavy awns and sharp points on the seed make it difficult to handle. Sowing is almost impossible with an ordinary grain drill, because the long awns cause the seed to mat into large clumps that clog the seeding spouts. Pro-
cessing the seed with a hammer mill to remove awns improves its quality. Although this grass has wide adaptation in the Plains, it has been used only sparingly for resowing, mostly because of objections to it for grazing and difficulties in handling the seed during sowing operations.

Indian ricegrass

(Orzyopsis hymenoides)

Description: Indian ricegrass is a densely tufted, perennial bunchgrass which usually ranges between 12 and 18 inches in height. It has long slender leaves, commonly involuted, and often about as long as the stems. The flower head is a widely spreading, branched panicle, the branches being in pairs and forking at nearly right angles. The florets are solitary on the ends of the branchlets. When the grains are mature they are nearly round, black in color, tipped with a short awn, and densely covered with conspicuous white hairs. These plump, millet-like grains were at one time an important food for the western Indians.

Distribution: This grass was formerly widely distributed over the western ranges, particularly in the semi-desert areas. It is highly palatable, and overgrazing has resulted in its virtual elimination from much of its former range. Indian ricegrass is highly drought-resistant and somewhat tolerant to alkali. Throughout its range it occurs mainly on the dry sandy soils and frequently is important even in dune sand areas.

Establishing a stand: Satisfactory stands of Indian ricegrass are usually obtained from sowing 8 to 10 pounds of seed per acre. The seed, however, is very erratic as to germination and periods of dormancy. Storing seed for over a year is often recommended. One selected strain is showing high germination immediately after harvest. Maintenance of stand is often accomplished by natural resowing.

Utilization: The palatability and nutritive value of this grass give it high rank for all classes of livestock and make it a desirable species to use in revegetation work. It will probably be most useful when sown in mixtures with other grasses, especially on sandy areas. It greens up early in the spring, and at this time it is of especially high palatability. It cures well standing and furnishes excellent winter grazing. Not only is the forage good winter forage, but the grains are a highly nutritious feed. In the desert areas of the West it is especially prized for winter grazing. Its desirable qualities make it a valuable pasture grass.

Seed production: Propagation in this species is by tillering and by seed. Usually an abundance of seed is produced which can be harvested satisfactorily with a combine. Small amounts of the seed can be gathered locally by hand stripping. Before this seed can be handled in a grain drill, it is necessary to process it with a hammer mill to remove the hair and other appendages. There are about 140,000 seeds to a pound.
The seed of this grass shows delayed germination, consequently it is advisable to store the seed for a year before planting. Treatment with sulphuric acid has also been used to break the dormancy. The seedlings of Indian ricegrass are vigorous and capable of making rapid growth, especially in loose, sandy soil, but they are subject to attack by root-rots and precautions should be taken before sowing this species. See chapter on plant diseases.

DROPSEEDS

(Sporobolus species)

The Sporobolus genus is large and widely distributed. The species native to the United States number 36 and are most abundant in the southern Great Plains and the Southwest. The scientific name is derived from the Greek spora, seed, and ballein, to cast forth; the common name, dropseed, refers to the prompt casting of seed as it nears maturity.

Spikelets of Sporobolus are single-flowered. In most species the stems are solid or pithy, rather than hollow. Most of the perennial species are palatable to animals.

Practically all the dropseeds produce an abundance of viable, long-lived seed that—because of a hard, impermeable seed coat—may lie dormant many years before germinating under natural conditions; that characteristic is sometimes an advantage and accounts for the appearance of seedlings after long periods of drought.

ALKALI SACATON

(Sporobolus airoides)

Description: Alkali sacaton is a densely tufted, long-lived, native bunchgrass that occurs generally throughout the western and southwestern sections.

The seed stalks are erect, smooth, solid, and about 3 feet tall. The seed heads are open panicles that terminate in single florets. The foliage is basal and abundant; the leaves are about one-fourth inch wide and 8 to 18 inches long. The roots are coarse and fibrous and penetrate the soil to good depths. The grass is commonly found on moist alkaline soils but it occurs also on other types of soil. Normally the stand has a distinctive tufted or bunchy appearance.

Use: Alkali sacaton produces much forage, which is eaten freely by cattle and horses during the growing season. As the plants mature, however, the foliage becomes coarse, tough, and unpalatable and does not cure into nutritious winter feed. Grass that is kept closely cropped affords good grazing. It produces hay of fair quality if cut at the proper stage of development.

Seed production: Seed is ordinarily obtained from native stands, no doubt because of the general abundance of the species over wide areas. Nearly always a satisfactory seed crop matures at some place each season. Seed can be harvested with a combine or by threshing mature seed hay. Seed of excellent quality has been produced under cultivation, but the procedure seems unnecessary as long as native stands are a dependable source.

SAND DROPSEED

(Sporobolus cryptandrus)

Sand dropseed is a tufted, widely distributed, native grass. It occurs most abundantly in the southern Great Plains and the Southwest. It is a pioneer or invader species on raw, denuded soil and is most prevalent on sandy soil.

Description: Sand dropseed plants grow about 2 to 3 feet tall, with solid stems and fairly numerous leaves about one-fourth inch wide and 4 to 12 inches long. Seed heads are open; the finely branched panicles average 8 to 12 inches in length, and terminate in single spikelets. Characteristically, many of the seed heads remain within the upper portion of the surrounding sheath, so that the plants tend to retain large portions of their
DROPSEEDS

Seeds. Roots are coarse, fibrous, and penetrating—a characteristic that accounts partly for the wide adaptation of the species.

Sand dropseed. Sand dropseed produces a fairly large amount of foliage, which is taken readily by livestock while green but only sparingly after the plants reach maturity.

Use: Its widespread occurrence has encouraged its use for revegetation. It is generally recommended for sowing in mixtures with adapted species at about 1 pound per acre. Because of the small size of the seed (usually more than 5 million in a pound), it should be sown shallow and the new seeding should be protected during the period of seedling establishment.

Many excellent characteristics make it valuable for revegetation use. It is widely adapted as to soils and climate; forage production is satisfactory (although not outstanding in its total quantity or quality).

Seed production: Sand dropseed is a prolific seeder and, when protected or properly grazed, tends to increase in density on the depleted range.

Seed matures in late summer and is readily harvested with a small grain combine. When the grass has been grown in rows and cultivated or grown under irrigation, exceptionally high yields have been obtained exceeding 1,000 pounds an acre.

Seed production is excellent under most conditions; and the delayed germination appears to be a useful characteristic for any species that must withstand wide extremes of climate.

Sand dropseed, like other species of the genus, has hard seed, which ordinarily do not germinate unless scarified or treated with acid to make the seed coat permeable, or held in dry storage for at least a year.

This chapter

The material for this chapter came largely from Hoover, Smith, Ferber, and Cornelius (US-116), Hoover, Hein, Dayton, and Erlanson (US-115), and Whitman and Stevens (ND-15). The manuscript was reviewed by Rogler of the Northern Great Plains Station, Mandan, by Newell of Nebraska, and in part by Hafenrichter of the S.C.S., Oregon.

Chapter reference numbers:


The reference numbers given here refer to references which are given in full by State, U.S.D.A., and Miscellaneous, on pages 682 to 724, and which are cross-referenced by author on pages 725 to 731. Citations in the text are indicated by abbreviation and number in parentheses.
CHAPTER XXVI

SOUTHERN FORAGE GRASSES

Bermuda-grass, Dallisgrass, Bahiagrass, Vaseygrass, Vine-mesquite, Paragrass, Blue panicgrass, the Lovegrasses, Carpetgrass, Rhodesgrass, Napiergrass, Pangolagrass, St. Augustinegrass, and the Zoysias

A number of the cool-weather grasses generally adapted to the northern half of the United States are grown to some extent in the South, especially at the higher altitudes. Among these are timothy, orchardgrass, Kentucky bluegrass, and tall fescue. The grasses grown most in the South, however, are those particularly adapted to that region, some of which are adapted only to the Deep South. Among these are Bermuda-grass, the three paspalums, (Dallisgrass, Bahiagrass, and Vaseygrass), the three panicgrasses, (Paragrass, blue panicgrass and vine mesquite), the lovegrasses, carpetgrass, Rhodesgrass, Napiergrass, Pangolagrass, centipedegrass, St. Augustinegrass, and the Zoysias, all of which are covered in this chapter.

BERMUDA-GRASS

(Cynodon dactylon)

Although Bermuda-grass is now distributed throughout the tropical and subtropical parts of the world, the best evidence points to Asia, and particularly to India, as the land of its origin. Other common names sometimes used are Bahama grass, wire grass (Virginia and Maryland), devil grass (Arizona and California), and dog’s tooth grass.

In the United States, particularly in the Southeast, it has been a serious pest in cultivated fields for years. It is easy to understand, therefore, why farmers dependent upon cotton and tobacco for a livelihood, developed a definite dislike for Bermuda-grass. Only recently, with the growing interest in livestock production and soil conservation, have they begun to recognize the merits of this grass for forage. Pasture specialists agree that Bermuda-grass is the best upland pasture grass for the Southeast. As a plant to prevent soil erosion it is unsurpassed and is now being planted on land no longer suited for cultivation. Also, as a turf grass for air fields and golf courses, it is coming into more general use. Many farmers who have fought Bermuda-grass for years are now planting it. That it will enjoy a greater use and a better reputation in the future seems certain.

Producing winter feed is the number one problem of cattlemen in the South- eastern States. The winter feeds which they desire must be palatable, nutritious, dependable, and also cheaper than present feeds.

Of the many crops now used for this purpose, few seem to meet these requirements as well as Coastal Bermuda-grass. This highly productive hybrid has been shown through repeated tests to be outstanding for both hay and pasture purposes. The high yield potential, the consistent production from year to year, and the ability to grow over a wide range of soil and climatic conditions are important characteristics of this grass. Perhaps the feature that makes it best suited for hay production in the humid Southeast is the ease with which it may be cured. No other adapted hay plant can be cured so quickly and handled so easily.

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DESCRIPTION

Bermuda-grass is very variable and many forms can be selected. Some of the improved varieties developed by plant breeders are vigorous in growth habit, resistant to leaf-spot diseases, and more cold-resistant than common Bermuda. Coastal and Suwannee No. 99 varieties appear to be promising grazing plants. These improved Bermuda varieties produce seed sparsely or not at all, so pastures are established by planting underground runners or sprigs. Freshly cut hay has also been used successfully in planting these strains.

Common Bermuda-grass: Common Bermuda-grass is a rapidly spreading perennial having both underground and aboveground creeping stems. The plants reach a height of 4 to 20 inches, depending upon soil fertility. The leaf blades are narrow and 1 to 4 or more inches long. The seed stalks commonly have 4 to 5 branches which are 1 to 2½ inches in length. The seeds are small (less than ½ inch long) and grayish to yellowish in color. At Tifton, Georgia, common Bermuda produces seed heads containing viable seed from April until October.

Tift Bermuda: In 1929 an unusual Bermuda-grass plant was found growing in an old cotton field near Tifton, Georgia. It was characterized by having rather long decumbent stems, few seedheads, and an abundance of large stolons and rhizomes (above- and below-ground runners). This plant was increased by planting the runners and was found to be superior to common Bermuda-grass for both hay and pasture purposes. Stolons of this selection were distributed under the name of Tift Bermuda.

St. Lucie Bermuda: St. Lucie is a Bermuda-grass established and spread by surface runners. This variety of Bermuda has been used on the muck and sandy muck soils underlaid with lime on the lower east coast of Florida. It has no underground stems.

Coastal Bermuda: When compared with common Bermuda the stems, stolons, and rhizomes of Coastal Bermuda are found to be larger and to have much longer internodes. Its leaves have a characteristic light green color, are much longer, and form a more acute angle with the stem than the leaves of common Bermuda. Coastal Bermuda produces very few seed heads, and those that are produced rarely contain viable seed. It is one of the most nearly seedless strains that has been produced at the Coastal Plain Experiment Station and ranks well above Tift Bermuda in this respect. It is more resistant than common Bermuda to the Helminthosporium leaf spot that causes the leaves of Bermuda-grass to turn dark and die.

Coastal Bermuda may be readily distinguished from Tift Bermuda by its larger and much more erect habit of growth and its lighter green and more flexible leaves which droop more than the leaves of the Tift strain.

Suwannee Bermuda (Selection No. 99): Suwannee Bermuda-grass was developed at the Coastal Plain Experiment Station.
Tifton, Georgia, at the same time as Coastal Bermuda was developed. It is somewhat better adapted to soils of low fertility than Coastal, and has been distributed in some parts of Florida for this reason. It is equal to Coastal Bermuda in production but will not tolerate close grazing so well, so is usually considered inferior to Coastal Bermuda as a pasture plant.

ADAPTATION
Climate: Bermuda-grass is the most important pasture grass in the South. It occurs northward as far as Maryland, Kansas, and the warmer valleys of Washington and Oregon. In Virginia and Maryland it is usually more troublesome as a weed than valuable as forage. Bermuda-grass became well established in the South as early as 1807, probably coming either from India or the Mediterranean region.

Coastal Bermuda has in several instances tolerated several degrees more frost than common Bermuda, indicating that it is more frost resistant. Although its maximum cold tolerance has not been determined, preliminary observations indicate that it will survive the winter wherever common Bermuda grows.

Soils: Bermuda-grass is best adapted to well drained and fertile soils, especially the heavier clay and silt soils not subject to flooding, which are well supplied with lime and complete fertilizer high in nitrogen. It often spreads into cultivated areas and is difficult to eradicate.

Coastal Bermuda will grow on any well drained soil in which common Bermuda will thrive. Although it will tolerate flooding for rather long periods, it makes little if any growth on water logged soil. Like common Bermuda, it may thrive on soils low in fertility but will produce little feed. Few grasses respond so readily to fertilizer, particularly nitrogen. It is affected little, if any, by soil reaction and at Tifton, Georgia, has made good growth on both acid and "over-limed" alkaline soils. On this "over-limed" soil having a pH well above 8, the common cultivated crops have not made satisfactory growth.

ESTABLISHING A STAND
Use of seed: Seed is obtained under irrigation in the southwestern part of the United States, and can be purchased from the larger seed houses in the South. The use of seed, however, has not given general satisfaction. The germination is slow and takes place only in warm weather. The young plants are lacking in vigor and are easily smothered by crabgrass and weeds. From 8 to 10 pounds of seed per acre is usually advised.

In connection with the problem of establishing meadows and pastures of Bermuda-grass, the factors involved in the establishment of this grass from seed were studied at the Arkansas Agricultural Experiment Station by E. L. Nielsen (Ark-11). For three successive years from 1938 to 1940, inclusive, it was sown on well-prepared and leveled soil at the rate of 5 pounds to the acre at weekly intervals over the 14-week period from the last week in March to July 1, at 0-, 1/4-, 1/2-, and "over-limed" depths. The aim was two-fold—to determine the most favorable depth of planting and the climatic conditions necessary for the development of the best stand of grass.

Hulled commercial Bermuda-grass seed harvested in Arizona with an average purity of 93.9 percent and 86.6 percent germination was used.

From the data presented, Nielsen concludes that "seeding should not be made before a mean daily temperature of 65°F. is attained. Lack of sufficient moisture or low temperatures retarded seedling emergence and stolon development. Heavy rains retarded seedling emergence regardless of prevailing temperatures. Relatively high mean temperatures and sufficient available moisture favored rapid stolon development." Results also indicated that seed should not be covered to a depth of more than one-half inch.

Data were also accumulated indicating the importance of such factors as weed competition and winter injury on the establishment of Bermuda-grass turf from
BERMUDA-GRASS

seed. Isolated plants were rather easily killed as a result of the heaving of the soil in the winter, following either sowing or sodding. In areas where a definite sod had been established, however, there was little winter injury.

Use of sod: The old plan of setting out bits of sod on prepared land is very dependable. Numerous methods are followed. Sod is cut into pieces which are pressed into the soil. A single piece of rootstock or stem with a joint can start growth. Care must always be exercised to keep the sod from becoming dried like the corn or cotton. In a favorable season the grass, it is said, will be well distributed by fall. Usually it is best to avoid heavy pasturing much the second year, in order that a vigorous and complete stand may be obtained. However, some grazing and mowing to reduce weed growth are preferred to no grazing.

In the sandy soils of the Southeast the stolons should be planted 4 to 6 inches deep in rows or uniformly spaced hills in well prepared land. Best results are obtained if the tips of the sprigs are left above the surface of the ground. Deep planting can hardly be overemphasized, especially if the stolons will not be watered when set. Under such circumstances deep-planted stolons have a much better chance to survive than those only covered an inch or two with loose soil. Various machines such as modified tobacco planters have been devised to reduce the labor required for this job, but many of them fail to plant the grass deep enough. In the spring, if the soil is moist, the stolons need not be watered when planted. The soil should be rolled after planting, however, to bring the stolons in intimate contact with the soil particles and thus help to keep them from drying out and dying. In the summer this procedure frequently results in

Bermuda-grass spreading from central root planting in very dry season in Oklahoma.
poor stands if dry weather follows the planting date.

Coastal Bermuda, once established in rows or hills, will spread and cover the ground faster than common or Tift Bermuda without cultivation. Observations at Tifton indicate, however, that it will cover over twice as fast if given one or two cultivations between the rows and will produce enough hay the first season to pay the cultivation cost.

In the latitude of Georgia, Coastal Bermuda could probably be planted in any month of the year if care was taken to keep the stolons from dying due to desiccation or cold injury. When no special care, such as watering, is given, early spring plantings are most likely to give the best stands.

Fertilizer: Side dressings of fertilizer, particularly nitrogen carriers, applied to the rows once they are established, will greatly hasten the spread of the grass. Some preliminary observations indicate, however, that fertilization without cultivation on land heavily infested with annual weeds is of no value. In these instances the annual weeds have drawn upon the fertilizer sufficiently to outgrow the Bermuda-grass and have furnished so much competition that it has covered no better with fertilizer than without.

Numerous experiments at Tifton, Georgia (Ga-14) have shown that Bermuda-grass must be fertilized if much growth is desired. Data taken from an experiment begun in 1942 and continuing through 1947 show that high production can be maintained over a period of years with adequate fertilization.

In the first year of the experiment, the yield on the unfertilized plot was 3,540 pounds per acre, and on the plot fertilized with about 100 pounds of nitrogen and 250 pounds of 0-16-8 per acre, was 12,250 pounds. The average of the five succeeding years was 1,630 pounds per acre for the unfertilized plot, and 10,100 pounds for the plot fertilized with an average of about 130 pounds of nitrogen per acre. In the sixth year the unfertilized plot produced only 1,047 pounds of hay per acre or only 30 percent of the first year's yield.

Increased rates of nitrate nitrogen increased the yields and protein content but had no appreciable effect upon any of the other chemical constituents measured. Heavy rates, however, were required for sizable increases in protein content. The efficiency in nitrogen utilization begins to decline with 200 pounds of nitrogen for hay production and 400 pounds of nitrogen for protein production.

Alexander of Georgia (Ga-5) says that "Contrary to some people's opinion, Bermuda-grass requires certain conditions to make its best growth. These conditions are good land, good drainage and plenty of plant food, especially nitrogen. Even though Bermuda-grass will grow on almost any kind of soil, it does best on well-drained soil varying in type from clayey loam to sandy loam."

"In establishing a Bermuda-grass pasture, the first thing to do is to apply lime, where needed, and then plow and harrow the soil into a good seedbed, about as would be done for corn. A good pasture fertilizer, suitable for Bermuda and the other plants to be used with it, should then be applied broadcast and harrowed in. A good fertilizer to meet these needs in Georgia is 600 to 1,000 pounds of 20 percent superphosphate and 100 to 150 pounds of muriate of potash, or their equivalents, per acre. After this is done, rows three to four feet wide should be laid off on the contour with a fertilizer distributor. In this operation 200 to 300 pounds of a complete fertilizer such as a 4-8-6 or 6-8-6 should be applied. It is best to plant in early spring, but planting can extend into the summer.

"Freshly dug Bermuda-grass rootstocks, which have been kept moist and have not been damaged by molding, should then be dropped into these furrows and covered three to four inches deep by listing on the furrow. If more rapid developing of a sod is desired, apply 100 pounds or more of nitrate of soda, or its equivalent, on the row when the Bermuda begins to send out shoots. By fall, if the season is favorable, the land should
be about covered. By the end of the following year a dense sod should be established.

"For the best grazing, Bermuda-grass should be reinforced by legumes such as lespedeza and white or hop clover, and possibly other grasses. Since soil treatments, as suggested above, have put the soil in condition for these plants, planting is all that is necessary. White or hop clover should be sown in the fall after the Bermuda is set, at the rate of four to six pounds per acre. The seed should be well inoculated. The lespedeza should be added the following spring at the rate of 15 to 20 pounds per acre. If Dallisgrass is added it should be sown in the spring along with the lespedeza. If bluegrass, herd's grass or orchardgrass are added, they should be sown in the fall with white or hop clover.

"Many pastures are established by sowing lespedeza at the time the Bermuda is set, but the lespedeza retards the spread of the Bermuda, especially if the stand is thick.

"White clover has also been sown in the early spring with good results, but if the season is favorable, fall sowing is best."

**UTILIZATION**

**Coastal Bermuda for hay:** Coastal Bermuda is an excellent hay plant. In numerous small plot comparisons at Tifton, it has consistently produced several times more hay per unit area than common Bermuda. Its erect growth habit and greater lodging resistance make it more suitable for hay production than Tift Bermuda. In four cuttings of duplicate tenth-acre plots in 1942, Coastal Bermuda produced approximately 75 percent more hay than the Tift strain. Plots of Coastal Bermuda receiving 500 pounds of 4-8-4 fertilizer and 480 pounds of nitrate of soda per acre as top dressings, produced nearly six tons of air-dry hay in four cuttings in 1942. The chemical composition of this hay compared favorably with the chemical composition of timothy hay.

If cut when 15 to 18 inches high, Coastal Bermuda gives good yields of nutritious, palatable hay that is easily cured. As the grass grows taller the percentage of stem increases and the quality and palatability of the hay decreases.

Preliminary observations indicate that crimson clover grows well with Coastal Bermuda. The first cutting of hay made May 7, 1942, contained two-thirds crimson clover and one-third Bermuda-grass, making an excellent quality hay. The crimson clover made no growth thereafter, but its decaying roots supplied the grass with considerable nitrogen, thereby increasing the growth and nutritive value of the grass.

Tift Bermuda has ordinarily yielded two or three times as much hay as common Bermuda. In trials on a Tifton sandy loam in 1941-42 of Tift and Coastal Bermuda, the latter yielded 75 percent more hay per acre than Tift. In chemical composition there were no significant differences between the two.

A comparison of the chemical composition of common and Coastal Bermuda showed higher percentages of leaves, fat, crude fiber, ash, calcium, and phosphorus in the Coastal Bermuda, but these differences were not in all cases very significant.

**Pasture:** Most of the Bermuda-grass planted in the Southeast is used for pasture. Bermuda-grass and lespedeza ranked high in the pasture experiments at the Middle Tennessee Station, especially where white clover was added. Bermuda by itself affords little more than a maintenance ration after early summer. Close grazing is necessary for the most nutritious pasturage, but overstocking, resulting in a lowering of production, is not uncommon.

Coastal Bermuda tolerates more frost, grows more in the fall, and remains green much later than common Bermuda. In the fall of 1941 a plot of Coastal Bermuda that had been cut for hay on September 8, made considerable growth, survived several light freezes in the upper twenties and was still quite green the second week in January. A fourteen-degree freeze at that time killed all of the above-ground growth. These character-
istics of Coastal Bermuda should enable it to furnish much more late fall and early winter grazing than the common types.

Actual grazing studies conducted at the Coastal Plain Experiment Station for several years indicate that Coastal Bermuda will produce about twice as much beef as common Bermuda. Animals gained on Coastal Bermuda in late summer and fall when they usually were able only to maintain their weight.

Alexander also says that Bermuda-grass is one of the best pasture grasses for Georgia. It is objectionable on cropland, but the aggressiveness that makes it undesirable on cropland makes it a good pasture plant. When fed properly it is high in nutrients and is eaten readily by all classes of livestock. The Coastal Bermuda-grass is a decided improvement over the common variety. It makes more rapid growth, produces few seed heads, and remains green longer than the common variety. At this station the beef gains per acre have been twice those from the common kind.

Kenney of Kentucky (Ky-21) recognizing one of the fears about the use of Bermuda-grass, says: "It is well known that on upland soil low in fertility and which will be consistently dry throughout the growing season, Bermuda-grass grows very slowly. On the other hand it spreads rapidly on fertile soil, preferably at the bottom of a slope from which the midsummer rains will drain and settle on it. An ideal location then is a piece of such bottom land with a ditch or creek on the lower side, with a thick growth of bushes or trees on the bank which by shade prevents the Bermuda from getting into the ditch and arousing fear of its spread to places where it is not wanted. A fence row grown up in bushes running from the ditch up the slope as far or further than the Bermuda will be planted, will serve as a complete barrier on the two ends of such a plot."

SEED PRODUCTION

Commercial Bermuda-grass seed, all of which is the common variety, is produced almost entirely in southern California and Arizona. No other section of the country seems to be adapted to successful Bermuda-grass seed production. In recent years almost the entire production has been within 50 or 60 miles of Yuma, Arizona. Some improved strains and varieties of Bermuda-grass have been developed in the southeastern States but these produce little or no seed, so have had to be increased by vegetative propagation.

The average production of Bermuda-grass seed in the United States for the 8 years, 1939-46, was 1,090,000 pounds, with a low of 700,000 pounds in 1939. The average for the past three years, 1947-49, was 1,920,000 pounds or 77 percent higher than the previous 8 years. Also 70 percent of it was produced in the first crop and 30 percent in the second.

Bermuda-grass seed is now produced regularly by farmers, whereas, in the early days it was primarily a by-product of alfalfa seed production. Today the largest producers of Bermuda-grass seed grow it only for seed and want no other crop intermingled with it.

The Bermuda-grass seed producing area is largely one of alfalfa seed production, but in certain saline areas it is difficult to maintain stands of alfalfa. These are often half Bermuda-grass. Many of the fields are straight Bermuda-grass where the salt in the water and in the land is excessive for alfalfa production. Such areas are taken over for the production of Bermuda-grass seed. No pasturing of Bermuda-grass or harvesting of it for hay is ever done in the seed producing area.

Fields of Bermuda-grass often become infested with other grasses in three or four years, so as to become unfit for seed harvest, while other fields may remain suitable for seed harvest for five or more years. The average yield of Bermuda-grass seed is from 250 to 300 pounds per acre.

Harvesting seed: The first crop of Bermuda-grass seed is harvested during the first half of July, and the second crop soon after the first killing frost which is usually in November or early in De-
December. It is the custom to let the second crop of Bermuda go as long as it will in the fall before harvesting in order to develop all the seed possible, as the light, frosted seed can be blown out in processing.

Seed is usually harvested with a mower having a windrow attachment. From the windrow it is either picked up by combines or is shocked and hauled to threshers. The seed is cleaned over regular sifting and gravity mills, depending on the purity and kinds of weed seeds present.

Germination and purity of seed: There are no standard grades or qualities of Bermuda-grass seed, so the seed is ordinarily marketed as Fancy and Extra Fancy Unhulled with a purity of approximately 95 to 98 percent, and germination of 82 to 88 percent, and Fancy and Extra Fancy Hulled with a purity of 92 to 95 percent and a germination of 85 to 88 percent. Unhulled seed ordinarily weighs 35 to 40 pounds and hulled seed from 60 to 65 pounds to the measured bushel.

BERMUDA-GRASS HIGHLIGHTS

1. Bermuda-grass is distributed throughout the tropical and subtropical parts of the world. It probably originated in India.
2. Bermuda-grass, like some other plants now recognized as having real forage value, was once considered a serious pest in the Southeast, and still is listed as a noxious weed in certain States.
3. Only recently have pasture specialists agreed that Bermuda-grass is the best upland pasture grass for the Southeast.
4. As a plant to prevent soil erosion, it is unsurpassed and is now being used on land unsuited for cultivation.
5. Bermuda-grass does best on heavy clay or silt, well drained, fertile soils, well supplied with lime and complete fertilizer high in nitrogen.
6. Coastal Bermuda, an improved variety, is distinctly superior to common and other varieties of Bermuda-grass for both hay and pasture.
7. Coastal Bermuda, like most improved varieties, is seedless, which necessitates it being vegetatively propagated for increase. The method of transplanting pieces of sod is satisfactory and practical under favorable conditions. When these pieces of sod are set out during March or April about two feet apart, the ground should be well covered by fall.
8. Bermuda-grass seed is sown in the spring from March to June when a mean temperature of not less than 65°F is attained, at the rate of 5 to 10 pounds per acre, at a depth not to exceed one-half inch. Germination is slow and the young plants are not vigorous, so the results from sowing seed are not always satisfactory.
9. Common Bermuda-grass seed is produced mostly in Arizona and southern California. The average production of Bermuda-grass seed for the 8 years, 1939-46, was 1,090,000 pounds and for the past 3 years, 1947-1949, was 1,920,000 pounds or 77 percent higher.

THE PASPALUM GRASSES

(Paspalum species)

Of the 400-odd species of Paspalum, few have economic importance in the United States. The most important are Bahia grass and Dallisgrass; Vaseygrass is of minor value.

The main center of variability of these grasses appears to be in Brazil, where some of the species form the dominant cover over large areas.

Paspalum grasses are primarily pasture grasses. Some are short-lived, but Dallis and Bahia maintain good stands and remain productive for a long time if properly fertilized and managed.

DALLISGRASS

(Paspalum dilatatum)

Dallisgrass is a native of South America, and was probably first introduced around New Orleans before 1880.

Description: Dallisgrass is a smooth perennial, with a deep strong root system and
Dallisgrass grows in clumps or bunches 2 to 4 feet high but forms a sod under grazing. The leaves are numerous near the ground but few on the stems. The stems are slender and usually drooping with the weight of the flower clusters.

Adaptation: Dallisgrass is adapted to a wide area in the Southeast from North Carolina to Florida, and west to Arkansas and Texas where it occurs abundantly. Farther north it is too tender. It prefers rich lowland soil but is highly heat and drought resistant, so is especially useful for late summer pasture when bluegrass is dormant.

Dallisgrass needs a higher fertility level than carpet and Bahia grasses, lime and complete fertilizer high in nitrogen being particularly important. It is especially suited to be planted with clovers. It may be used on the very best soils of the pine lands, provided lime and fertilizer are applied. The growth of this grass in Florida is practically limited to the muck soils of the Everglades, and to the heavier textured soils of western Florida. In the sandy soils of Florida it is susceptible to ergot and crown rot.

Establishment: In sowing Dallisgrass great care must be used to have the ground in the very best possible condition. The seed is very light, hence it is best to sow broadcast 8 to 10 pounds of high-germinating seed per acre. Sow on ground which has been thoroughly harrowed and then roll or plank the seeds in. In the extreme Southern States, it is usually best to sow in October or November.

Uses: In the Southern States where it spreads naturally, some farmers have permanent meadows or pastures consisting largely or partly of Dallisgrass. Owing to its tendency to lodge, this grass is better suited for pasture than for hay. It is one of the best winter pasture grasses for heavy, moist, black soils. It remains green all winter unless injured by severe frosts, and persistent grazing will not injure it. An immense number of leaves are produced which are renewed more quickly after grazing than those of Bermuda-grass, and under favorable conditions a Dallisgrass pasture will last indefinitely. Wherever Dallisgrass is adapted permanent pastures of carpet-grass or Bermuda-grass are made more valuable by including this grass.
Seed production: Dallisgrass seed is produced usually as a by-product of Dallisgrass pastures. The principal area of production is the Black Belt of Alabama, Louisiana, and Mississippi, where Dallisgrass is grown largely for pasture. Dry summers are favorable to seed production because one of the greatest obstacles to seed production in the Southeast is ergot which develops more extensively under humid conditions and destroys much of the seed. Because the seed is produced throughout the summer, it is possible to harvest two crops or more in a season. The first growth is usually best for seed because of its relative freedom from ergot, but this growth is usually pastured and later growth harvested for seed which is ordinarily badly infested with ergot.

Dallisgrass seed of the best quality is harvested by hand because it ripens unevenly from the tip down and shatters as soon as ripe. Commercial seed is usually combined directly but it is sometimes cut and windrowed and picked up with combine.

The farmer usually sells his seed on sample to the processor without cleaning, since the seeds are fluffy and the cleaning is a difficult operation. Seed yields of 100 to 200 pounds per acre are common. Occasionally a yield of 700 pounds is obtained. If a high percentage of filled seed can be obtained the germination may be fairly high (75%—85%), but frequently less than 20 percent are filled which brings the germination down very low, often as low as 5 to 10 percent. The weight per bushel varies considerably with the tightness of packing. The generally accepted weights are 15 pounds per bushel, and 340,000 seeds per pound.

Owen (La-11) has the following to say about Dallisgrass seed production in Louisiana in 1942 and 1943: “Variation in total yield of seed per acre between strains was sufficiently large to be considered beyond the limits of chance. The acre yield of different strains at Haumburg, Louisiana, the region in which most of Louisiana’s Dallisgrass seed is produced, ranged from 225 to 446 pounds per acre. * * * The quality of the seed was affected by the time of the season in which the seed was harvested. Seed harvested in July contained fewer viable seeds than that harvested in September. * * * Seed produced on the sandy soils was definitely inferior in quality to seed from the more fertile soils. * * * The results of the investigations for 1943 show that Dallisgrass seed production may be increased about three-fold on the present acreage by giving more attention to methods of culture, and by planting better strains. * * * Until adequate supplies of seed from improved strains are available, seed producers may resort to improved practices to increase the seed yield. It has been found in south Louisiana that seed harvested in September and October generally is of better quality than that harvested in July and August. * * * If seed fields are not grazed, it is considered best to control rank growing plants by mowing at intervals throughout the early part of the summer. Shading appears to weaken Dallisgrass plants more than heavy grazing or continuous mowing practices.”

BAHIAGRASS

*(Paspalum notatum)*

Description: There are four varieties of Bahiagrass—common, Paraguay, Pensacola, and Argentine. Common Bahiagrass is a low-growing perennial spreading by short, stout, woody runners, and by seed. The runners are rooted heavily with large fibrous roots which form dense, tough sods, even on droughty sandy soils. The leaf blades are generally hairy on the margins and less than 1/2 inch wide. This grass seeds prolifically during the summer; the seedstalks are 1 to 2 1/2 feet high, and usually have two (sometimes three) branches. The branches on the seedstalks are about 2 1/2 inches long. The seeds are oval in shape, yellowish-green in color, glossy in appearance, and about 1/8 inch in diameter.

Paraguay Bahiagrass, recently introduced from Paraguay, produces seedstalks similar to common Bahia, but the leaf blades are more hairy and narrower than
in common Bahia. It seeds very heavily and the seeds are of good quality.

Pensacola Bahiagrass is a narrow-leaved type similar to Paraguay, but less hairy. It is much more frost-resistant than common or Paraguay. The seeds are smaller than common or Paraguay Bahiagrass and more seeds are produced per head because of the longer branches which may number from 2 to 6 per head. This grass seeds heavily and the seed is of excellent quality, so pastures sown with this variety sod quickly.

Argentine Bahiagrass is a medium broad-leaf type which makes a rapid and abundant growth, and is more frost-resistant than either common or Paraguay. Adaptation and uses: Bahiagrass is widely adapted, growing on both high and low soils. It will grow on drier soils than most other pasture grasses because of its deep root system. Like carpetgrass, it furnishes little feed during the winter months. It is primarily a pasture grass, but mowings may be saved for hay.

Establishment: Bahiagrass is established with seed planted 1/2 to 1 inch in depth at the rate of 10 to 20 pounds per acre. The seed often germinates slowly because it is surrounded by a tough, waxy coat which does not allow water to enter for germination. Seed scarification with sulphuric acid has encouraged rapid germination when good quality seed is treated. Most of the seed is imported from Cuba and South America, but the grass seeds readily in Florida. Seed from established pastures should be harvested, since it is difficult to locate seed for planting new pastures.

VASEYGRASS

(Paspalum urvillei)

Vaseygrass is a native relative of Dallisgrass and, like it, is a native of the Argentina-Uruguay region. It was accidentally introduced around New Orleans before 1882, but was probably in the United States some years earlier. The grass has spread abundantly, especially on the more moist lands in Louisiana, eastern Texas, and southern Mississippi, but it occurs more or less in the Coastal Plain region from North Carolina to Texas and also in California. It does not survive the winter at Washington, D.C. It is of relatively minor importance as a forage crop.

Description: Vaseygrass is an erect perennial, growing in tufts or bunches about a foot in diameter, with many erect leaf blades. The flowering culms are from 2 to 6 feet tall, each flower cluster bearing from 6 to 25 spikes. The flowers are very rarely attacked by the ergot so common on Dallisgrass. The grass continues to produce flowering culms during a long season.

Uses: Where Vaseygrass has become abundant much of it is cut for hay, and the quality of the hay is considered good. In pastures, continuous heavy pasturing must be avoided as, like most of the bunchgrasses, Vaseygrass is killed out by such treatment. Vaseygrass continues to grow all winter, except in very cold weath-
cr, and therefore affords late pasturage. Vaseygrass, like Dallisgrass, is remarkable for its ability to grow in wet land and also to withstand very severe drought. It thrives best on heavy soils, but succeeds well on moist, sandy land.

Seed production: The seed of Vaseygrass is very hairy, light in weight, greyish brown in color, and smaller than Dallisgrass seed. It is produced in abundance, but on the same plant every stage from young flowers to ripe seed may be found at any time from June to November. In other words, the seed crop is never all ripe at one time. Apparently, the best practice is to cut the first crop for hay and the second or last crop for seed. By this procedure more of the seed is ripe at one time. If the seed is fully ripe when harvested it germinates well, but if cut earlier it must be well cured to secure satisfactory germination.

SOUTHERN PANICGRASSES

(Panicum species)

The Panicum genus includes approximately 500 species that grow chiefly in warm regions of the world. The species native to the United States occur primarily in the Southeast but are well represented also in the warmer parts of the West. *P. virgatum* grows over the larger part of the United States.

Panicagrasses belong to the millet tribe, *Panicum* being the Latin name for millet. Proso or broomcorn millet, (*Panicum miliaceum*) is believed to have been the first cereal cultivated by man.

VINE-MESQUITE

(*Panicum obtusum*)

Description: Vine-mesquite is a vigorous, long-lived, native perennial. The stiff, erect culms are 1 to 2 feet tall; leaves are 4 to 6 inches long and about ¼ inch wide. Stolons are numerous, often several feet long, with swollen hairy or woolly nodes. The seed panicle is 2 to 5 inches long with a few raceme-like branches.

Adaptation: This grass grows where rainfall is scant but is generally most abundant in the southwestern States where additional water is received in occasional floods.

Establishment: Seed is rather hard to get and is generally of low quality, an undesirable feature that is offset somewhat by the ability of the plants to spread rapidly by stolons which may grow 15 feet in a single season. The plants therefore can well be propagated by transplanting sod pieces. Vine-mesquite hay, cut after the seed heads mature, can be used as another means of establishing new seedings.

PARAGRASS

(*Panicum purpurascens*)

Paragrass is now commonly cultivated in most tropical countries. It is grown somewhat commonly in southern Florida, in some well-protected areas in central Florida, and to a rapidly increasing extent in southern Texas, and here and there throughout the Gulf region.

Description: Paragrass is a rank-growing leafy perennial with long, large surface runners which root at the joints, giving rise to independent plants. It grows 3 to 5 feet in height. The leaves are generally 4 to 12 inches long and ½ inch or less in width. This grass does not seed heavily in Florida and is established by spreading runners or mature stems and covering by subsequent disking.

Adaptation: Paragrass makes its best growth on damp soils, though it has been fairly successful on Texas ranches on heavy soils without irrigation where irrigation is needed for most other crops. It is not injured by prolonged overflows and makes a vigorous growth where the land has been under water for several weeks. It is especially valuable for planting on the margins of ponds and on soils too wet and seepy for the cultivation
of other crops. Paragrass will not withstand a lower temperature than about 18° F. It is, therefore, adapted only to the extreme southern portion of the country, and perhaps to southern California. At Gainesville, Florida, it does not survive the winters, except in well-protected places on the better soils.

Establishment: Paragrass is usually propagated by planting pieces of the running stems. Such pieces 6 to 12 inches long and having three or four joints grow rapidly when simply pushed into freshly plowed ground, so propagation is neither difficult nor expensive. The first growth from the cuttings is in long prostrate runners nearly as thick as a lead pencil, but as soon as the ground is fairly well covered the branches become more nearly erect, soon reaching a height of 3 or 4 feet; so the closer the cuttings are planted the sooner a crop for mowing will be produced. Cuttings may be planted at any time when there is sufficient moisture in the ground, from early spring until as late as September, though late plantings will make little growth until the following season.

Uses: If wanted for hay, Paragrass should be cut when it reaches a height of 3 to 4 feet. From three to five cuttings may be made in a season, and as 1 to 3 tons of hay per acre are obtained at each cutting, the total yield is heavy. The hay is rather coarse but is of excellent quality if cut as soon as it has made sufficient growth and before the stems become hard and woody. When the grass is allowed to stand too long before cutting the stems become woody and unpalatable.

Paragrass to be used for pasture should be protected until the grass is 1½ to 3 feet high and well sodded. It should be grazed rotationally rather than continuously, and an occasional disking stimulates growth.

BLUE PANICGRASS

(Panicum antidotale)

Blue panicgrass is indigenous to Australia, Afghanistan, and the plains of India. It was first introduced into the United States from India in 1912. In 1920 and again in 1935 seed was brought into this country by the United States Department of Agriculture from Australia. Numerous trials have been conducted since that time in various parts of the United States. Description: Blue panicgrass is a deep-rooted, erect, glabrous perennial grass forming tough crowns by means of short, thick, bulbous rhizomes. It grows in large, dense tufts to a height of 3 to 7 feet and is of a blue-green color. The top growth resembles that of switchgrass. The lower part of the culm has large nodes with lean internodes. The leaves are long-linear and the ligule is short and jagged. The loose panicles are terminal and rather narrow. Spikelets are sessile and arranged in clusters or short spikes.

Adaptation: Blue panic appears well adapted to heavy loams or dark clay soils and may be recommended for growing under irrigation or on areas of favorable moisture in the southwestern United States, particularly south Texas, New Mexico, Arizona, and California. It does not succeed well on sandy soils. It has failed to show promise in the southeastern humid States, although ample moisture exists for best growth. Its northern limit of usefulness, except as an animal, is approximately 35° latitude. As an annual it would not be equal in production to Sudangrass.

Sowing the seed: Since the seed is very small, some difficulty may be had in sowing with ordinary seed drills. Rates will vary depending on method of sowing. If sown in rows, 1 to 2 pounds per acre of clean seed are sufficient, but if broadcast, 5 to 6 pounds are needed.

Use: Blue panicgrass appears to be useful for hay or pasture and can be compared with Rhodesgrass in general growth habit. The herbage is palatable if not allowed to become too mature. In the immature stage an abundance of tender succulent leaves is produced. Numerous reports indicate that as the plant approaches maturity and the numerous seed heads appear, it becomes woody and harsh, has a bitter taste, and is not relished by livestock. While it is a perennial it will not withstand close, intensive grazing or cut-
ting, and declines in vigor after the first year. Observations indicate that rotation grazing should be practiced for best production and to maintain the stand. It would seem that this grass should not be considered a long-lived perennial grass for permanent pasture or hay crops. One to three tons per acre of air dry forage, depending upon moisture and fertility, may be anticipated.

**Seed production:** Blue panicgrass makes rapid spring growth and seed maturity occurs before hot weather. The flowering panicles mature so irregularly that seed harvest by mechanical methods represents only a part of the total seed produced. Seed may be harvested with a grain combine and afterwards separated by means of a fanning mill. A grain binder can be used for harvesting the seed if the grass is cut before shattering takes place. After harvesting, the seed should be thoroughly cured and dried before sacking to prevent heating and molding.

Under dryland conditions a yield of 100 to 150 pounds per acre may be expected, while under irrigation two to three seed crops may be harvested with a total annual yield varying from 200 to 600 pounds per acre. The seeds are quite small, approximately 650,000 in a pound. Germination and purity will vary, depending on the care in harvesting, cleaning, curing, and processing, but average seed should have a purity of at least 70 percent and germination of 65 percent.

**The Lovegrasses**

(Eragrostis species)

The genus lovegrass, *Eragrostis*, comprises 250-odd species and is represented in all temperate regions. Only a few species, some native and some recently introduced, have been recognized as of agricultural value in the United States. Several native species are considered weeds.

Several species are recognized for their capacity to produce an abundance of seed and forage on soils of low fertility; hence they are used to provide vegetative cover on eroding sites.

The best known species is *E. abyssinica*, called Tef in Ethiopia, where it is cultivated as a cereal. It is cultivated also in India and Australia but usually as a forage plant. Although introduced at various times, it has never found a place in American agriculture.

In the United States where about 40 species occur naturally, only three have been noted as of much value. *E. obtusi-flora*, ranging from New Mexico and Arizona southward into Mexico, is a hard and rigid perennial that spreads by rhizomes and thrives on alkaline soil. It furnishes a great deal of forage in areas where it grows naturally.

Plains lovegrass, *E. intermedia*, which grows on dry or sandy prairies, is a native to South Africa. It was introduced by plant explorers from the mountainous part of Tanganyika in 1927. Several importations of it have been made in the past 20 years; the most promising importation, from which the present seed stocks were obtained, was brought into the United States in 1934 and was first tested and grown in the Southwest.

**Description:** Weeping lovegrass is a native to South Africa. It was introduced by plant explorers from the mountainous part of Tanganyika in 1927. Several importations of it have been made in the past 20 years; the most promising importation, from which the present seed stocks were obtained, was brought into the United States in 1934 and was first tested and grown in the Southwest.

**Weeping Lovegrass**

(Eragrostis curvula)

Weeping lovegrass is a native to South Africa. It was introduced by plant explorers from the mountainous part of Tanganyika in 1927. Several importations of it have been made in the past 20 years; the most promising importation, from which the present seed stocks were obtained, was brought into the United States in 1934 and was first tested and grown in the Southwest.

**Description:** Weeping lovegrass is a perennial bunchgrass which makes a rapid and vigorous growth, has strong seedling vigor, is resistant to heat and drought, and is a heavy seed producer. Under favorable conditions it produces an abundance of very small seed on rather tall,
erect stems, and a luxuriant basal growth of extremely long, slender, pliant leaves, from which it gets its name, "weeping lovegrass." It is one of the earliest grasses to start growing in the spring, and the last to turn brown in the fall.

Adaptation: Weeping lovegrass is adapted to a large area of the southern Great Plains, including Oklahoma, Texas, New Mexico, and Arizona, and makes a satisfactory growth over most of this area. It is not as winterhardy as some of the native grasses of that region, and may freeze if moved much north of Oklahoma. It has survived temperatures as low as 11°C.

Seemingly it does well on any type of well drained soils but prefers the sandy loams. It does well on tight wheatland soils, blackjack sand, or red clay loams. It will not grow on wet seepy soils, and will not survive standing water.

Like any other crop, it responds to soil fertility, although it will grow on soils of low fertility much better than most grasses. For seed, pasture, or hay, it is advisable to plant it on soils of average fertility and apply commercial nitrogen and phosphate, or barnyard manure.

Establishment: Weeping lovegrass is easily established from seed. April is the best month for sowing, but it may be sown in May or June or in late summer. One pound of clean seed would be sufficient to sow an acre, if it could be distributed evenly over the area. One-fourth to one-half pound of seed per acre would be sufficient for sowing in rows 3 to 3½ feet apart, if a planter is available for this fine calibration. The seed should not be covered over ½ inch deep. Too heavy sowing rates result in too many plants and stunted growth, and too deep sowing is a waste of seed. The resulting stand may seem sparse, but the gaps will soon be filled in.

If planted in rows, weeping lovegrass should be cultivated the first year very much like other inter-tilled crops. If grass and weeds become too tall and thick, moving the field will encourage the lovegrass. No cultivation is necessary after the first year.

Uses: Weeping lovegrass makes good pasture during early spring and fall, and during the entire summer, if enough livestock are available to keep it grazed close to the ground. It may be used very effectively in grass and legume mixtures for permanent pastures. A combination of this grass and Korean lespedeza makes an excellent summer pasture.

For hay, it may be cut any time during the summer before it becomes tough and fibrous. Hay yields of from a ton or less per acre under very dry conditions, up to 4 tons or more under favorable conditions, have been obtained in Oklahoma. Larger hay yields were obtained from solid stands than from rows.

This grass also is excellent for terrace ridge protection, water outlet systems, and meadow strips used to handle terrace water. Some people have used it for winter pastures after the last seed crop.

Seed production: Weeping lovegrass is a very prolific seed producer. The first crop of seed usually matures early in June. If rains occur, one additional crop may be harvested during the summer or fall season. The seed may be harvested with a combine or binder, or, if in small plots, with a hand sickle. One person can cut one-half to one acre a day if the grass is planted in rows. The bundles should be tied and when dry bagged, so that further loss of seed will not occur. The grass should be cut when one-third of the head has turned brown, if harvesting is done by hand. The seed is easily threshed with combine, thresher, or by hand.

The seed of this grass is very small and oblong in shape, very much like a wheat kernel. It is hard and vitreous and has a high germination. There are approximately one and ¾ million seeds per pound. The seed when well cleaned will weigh slightly over 60 pounds per bushel. It usually has a good germination. A sowing rate of ½ pound per acre will place around 20 seeds to each square foot of surface. Because of the very small size of the seed, it is difficult to distribute it evenly.

Usually not much seed is produced the first year. If the grass makes a rapid growth, it should be clipped at least twice during the summer to cause the plants to
SOUTHERN FORAGE GRASSES

SOUTHERN GRASSES. Good seed crops can be expected by June the second year, and if rains occur in July or August, a second crop may be obtained. When a seed crop is taken, the grass should be pastured or cut close to the ground to allow new growth and new seed stems to develop. Do not graze or cut too close to the ground during the late fall because of danger of winter freezing.

Seed yields of under 30 pounds per acre under very dry conditions, up to more than 200 pounds under favorable conditions have been obtained in Oklahoma. Larger seed yields were obtained from rows than from solid stands.

SAND LOVEGRASS (Eragrostis trichodes)

Description: Sand lovegrass, a vigorous, long-lived, native bunchgrass, occurs on sandy soils of the central and southern parts of the Great Plains. Plants normally grow to 3 to 6 feet. The elongated panicles are sometimes half as tall as the plant and have a distinctive purple color. The slightly hairy leaf blades are ¼ inch wide and about 12 inches long. Leafy foliage, primarily basal, is abundant. It starts growth several weeks earlier in the spring and continues later in the fall than most other warm-weather species. It is superior in palatability to most other grasses during the growing season and is eaten readily by livestock during the winter. It is less drought-resistant and probably is shorter-lived than the short grasses, but it compares favorably with them in nutritive qualities.

Establishment: Sand lovegrass is easily established from seed. It makes excellent growth when sown either alone or in mixtures on sandy soils but does not thrive on heavy soils. It should not be sown in a mixture with the much less palatable weeping lovegrass and preferably not with other grasses. Recommended rates of sowing are ¼ to ½ pound in mixtures and 1 to 2 pounds in pure stands. It volunteers better in natural stands than most other species, with the possible exception of sand paspalum and sand dropseed. It is one of the best warm-weather grasses to use in sowing weed-infested abandoned land or depleted range land of a sandy nature.

Use: It is generally considered one of the most palatable and nutritious of the range grasses, and frequently it suffers from continuous overuse. By some it is considered satisfactory for use in mixtures with side-oats grama, blue grama, and other palatable grasses on sandy soils. It is so highly palatable, however, that it should represent a substantial part of the mixture. A light sprinkling of this grass in a mixture is likely to be sought out by cattle, heavily overgrazed, and eventually eliminated. A pure stand of the grass or a heavy proportion of it in a mixture can be stocked properly to obtain maximum gains without abusing the stand by excessive use. The extensive root growth of sand lovegrass makes it valuable in soil conservation.

Seed production: Sand lovegrass produces an abundance of very fine seeds when conditions are reasonably favorable. Considerable quantities are now commercially available. The seed ripens in the fall and is fairly easy to harvest with a combine or binder. Many of the seeds are semi-hard and delayed in emergence. Their germination increases with age and is promoted somewhat by freezing temperatures.

In some places native stands are not suitable for seed harvest because of the presence of brushy plants such as sand sagebrush, shinnery oak, or the skunkbush. Seed yields have exceeded 400 pounds an acre under irrigation and 150 pounds on dry land.

Binders and combines have been used for seed harvest. Cleaning the seed with a fanning mill should result in a purity of 98 percent and a germination of 75 percent.

CARPETGRASS (Axonopus affinis)

Carpetgrass, a native of Central America and the West Indies, was introduced into the United States before 1832. A
specimen collected near New Orleans that year is still preserved.

Carpetgrass has now spread over the Coastal Plain from Virginia to Texas, and inland to Arkansas. It now grows in the Tropics of both hemispheres.

SPECIAL CROPS—GRASSES

Description: Carpetgrass is a perennial creeping grass which makes a dense sod and is distinguished by its compressed, two-edged, creeping stems, which root at each joint, and by its blunt leaf tips. The slender flower stems grow a foot high—rarely 2 feet if the soil is fertile. Because it has no underground stems, it never has become a pest in cultivated fields.

Adaptation: Carpetgrass is especially adapted to sandy or sandy loam soils, particularly where the moisture is near the surface most of the year. It grows well in the low flat woods in the Coastal Plains region, and is spread over Florida. It is moisture loving, but it does poorly in swamps or where seepage is continuous.

Sowing the seed: The usual rate of sowing is 5 to 10 pounds to the acre. Seed can be sown on a well-prepared seedbed, or broadcast on burned-over open areas in timberland. It is spread quite easily by grazing animals and by natural resowing. Sowing may be done in spring, early summer, or even midsummer.

Uses: Over much of the area where it is grown, carpetgrass is probably most valuable for permanent pasture. It also has value for firebreaks in forests, for lawns and turf, for use along roads, and for open areas in the pine forests. The cheapness and abundance of seed and ease of establishment make it popular in the South.

Because its sod is dense and its habit of growth is aggressive, legumes are maintained with difficulty in a cultivated pasture when carpetgrass is used. On fertile soils it makes a good growth, but generally it is not high enough in feed nutrients to furnish a balanced diet. Consequently, it is not generally recommended for the improved, high-producing pastures.

It tends to become established naturally and is the most common permanent pasture grass in Florida because of its adaptation to low fertility and its prolific seeding.

Seed production: This grass seeds prolifically during the period from July through November. The long, slender seedstalks usually have 3 branches and bear many brownish-grey oblong seeds less than 1/10 inch long.

Seed is harvested mainly in Mississippi and Louisiana. Seed harvested with a combine (the general practice now), if properly handled, is usually superior in color, purity and germination to that cut
with a mower, shocked in field, and threshed later. A pound contains about 1,350,000 seeds; a bushel of seed weighs 18 to 36 pounds.

**RHODES GRASS**

*(Chloris gayana)*

Rhodes grass was first brought to the attention of the agricultural world by the late Cecil Rhodes, after whom it is named. It is a native of South Africa and was first introduced into this country in 1902.

**Description:** Rhodes grass is a fine-stemmed, very leafy perennial grass which grows approximately 3 feet high. The spreading, clustered spikes of the flowering head number from 10 to 15, and seed is produced in abundance. Some strains of Rhodes grass spread by running branches, or stolons, that are 2 to 6 feet long and root and produce a plant at every node. That factor suggests that such strains might become troublesome weeds, but such has not been the case. Tests show that it can be easily controlled. See illustration of inflorescence in Chapter I.

**Adaptation:** Rhodes grass is not winter-hardy and rarely withstands temperatures below 15° or 18° F. Its adaptation, therefore, is limited. However, it is winter-hardy and grows as a perennial in a narrow strip along the Gulf Coast from Florida to southern Texas, and in southern Arizona and California. Farther north it must be treated as an annual, but as yet its use in that way is not recommended.

It does best on fairly moist soil, although it will make growth during several months of drought. It grows well on sandy soils in south Texas, well-drained peaty soils in Florida, and on soils too alkaline for alfalfa, cotton, and other crops in southern California. So far, no strains produce satisfactory permanent pasture in Florida.

**Sowing the seed:** Rhodes grass can be sown any time during warm weather where there is sufficient moisture in the soil, but early spring usually is preferred. The seed is generally broadcast at the rate of 5 to 7 pounds per acre. In regions of abundant rainfall or in irrigation fields, rates of 10 to 12 pounds may be advisable. The quantity also varies with the quality of the seed and condition of the land. A well-prepared seedbed will help insure a good stand, although stands have been established on rather loose, rough ground.

Uses: Rhodes grass was first cultivated for pasture. It withstands trampling, recovers quickly, and is relished by livestock. Rotation grazing is the best method of management to insure greater production and maintenance of stand. It will also yield a leafy hay of high quality. The production for pasture or hay varies greatly, depending on soil fertility and the season. Yields of 5 to 7 tons of hay an acre have been reported.

**Seed production:** Rhodes grass will produce three or four crops of seed a year, but the seed development lacks uniformity. The first crop is generally the most productive. Annual yields of 400 to 500 pounds an acre are not uncommon. Seed
is harvested with combine, binder, or, sometimes, with seed strippers. Because of lack of uniformity in maturity, great care is necessary to obtain seed of good quality. The seeds vary greatly in size, but average approximately 2 million to the pound.

**NAPIERGRASS**

*(Pennisetum purpureum)*

Napiergrass, or Napier fodder (also called elephantgrass) is a native of that part of Africa lying between the latitude of 10° north and 20° south. It was first cultivated in Rhodesia in 1909, and from there it has been introduced into most warm countries. It was first obtained by the United States Department of Agriculture in 1913 and is proving to be very valuable, in Florida, California, Puerto Rico, and Hawaii.

**Description:** Napiergrass is a perennial, having much the same habit as sugar cane. It grows in clumps, which consist of 20 to 200 stalks about an inch in diameter, and 6 to 8 feet tall when in bloom. The leaves are one-half to 1 inch broad, and 2 to 3 feet long. The flowers are in a long, narrow, erect golden spike from 5 to 10 inches long.

**Adaptation:** Napiergrass is adapted to about the same area as Japanese sugar cane, namely, from Wilmington, North Carolina, west to Shreveport, Louisiana, and southward, and in southern California, but can be grown on the Atlantic Coast as far north as Goldsboro, North Carolina, if the crown is given slight protection during the winter months.

Napiergrass should be planted on well fertilized and limed soils. It is widely adapted from the standpoint of moisture requirements, but does not survive in flooded soils. It makes good growth on dry soils when properly managed.

**Establishment:** Two methods of propagating Napiergrass are used, both of which are easy. By the first method, the clumps are dug and separated into root cuttings, each bearing a live, healthy bud. After the field has been prepared for planting by breaking the soil and fertilizing, furrows 5 or 6 feet apart are opened and the root cuttings are dropped about 3 feet apart in the furrows.

By the second method of planting, the stems are cut into pieces 3 joints long, and as soon as the field is prepared the live stems are planted in much the same manner as is given for the first method.
Two joints should be placed in the soil deep enough to barely cover the second joint. The third joint is left above ground.

The time that Napiergrass is planted is important. When root cuttings are used, the planting should be done as early in the spring as possible in order to obtain the benefit of feed in the late summer and fall. If stems are used they may be cut in the autumn and laid in a trench deep enough to keep the stems from drying or freezing. The stems are laid horizontally in the trench and covered until after danger of frost is over, then they are cut into lengths of about 3 joints and planted as described above. Stems which have been trench the preceding winter should be planted as early in the spring as possible. By waiting until early in July, the live stems may be cut and planted at the same time.

Uses: This grass may be used for temporary and rotational grazing and also for hay and silage. Hay is difficult to cure because of coarseness. Napiergrass should not be grazed until it reaches a height of 3 to 4 feet, but must be grazed then to obtain maximum feed value. Rotational grazing is necessary, 4 to 5 fields being required to furnish continuous grazing. If only one field is available, it may be grazed until the leaves are removed, after which the cattle should be withdrawn. It is palatable and steers have made excellent gains when ample leafy herbage is available. It might be used for fattening animals before marketing.

PANGOLAGRASS

(Digitaria decumbens)

Pangolagrass received its common name from the Pangola River in South Africa. It was collected by an English agricultural worker in 1935 and sent to America with more than 30 samples of grasses belonging to the same genus. These were tested at the Florida Agricultural Experiment Station, and Pangolagrass was chosen as the best strain to use for forage. There has been no improvement attempted with the Pangolagrass, therefore, there is only one strain known at present. There are, however, several grasses belonging to the same genus which might easily be confused with it.

The grass is not widely distributed in the United States, except in Florida where several thousand acres have been planted within the last few years. Pangolagrass is used primarily for pasture although some farmers have used it for hay. It cures rapidly in dry weather and therefore makes excellent hay when cut and cured before it becomes too stemmy.

Description: Pangolagrass resembles wild crabgrass but is a perennial, while wild crabgrass is an annual. It produces no underground stems but spreads rapidly by surface runners. Seed heads are produced in abundance but produce very few viable seed. It is therefore not necessary to propagate it vegetatively. The plant makes a succulent growth of palatable, nutritious foliage early in the spring and is killed to the ground by light frosts.

Establishment: The grass may be planted any season of the year by using rooted plants, after the danger of freezing has passed and when sufficient soil moisture is assured. Or, the runners may be mowed, spread over the prepared soil, and either disked in or pushed into the soil with sticks similar to the method used with sweet potatoes.

It is often advisable for a grower to establish a small nursery sufficiently large to furnish planting material for any pastures he may wish to establish. After the pasture has been planted to Pangolagrass, it should be kept mowed and grazed sufficiently to keep down weeds and surplus grass. An overgrowth of grass and weeds will slow up the formation of sod and will smother out the Pangola. After the sod has been established, it should be grazed carefully, as too heavy grazing is injurious.

To obtain maximum grazing, the pasture should be divided into two or three sections so that cattle may be removed from one section until the plants recover from the grazing. They may be placed on a second section during the time it takes for the first section to recover.
Proper management will avoid too close grazing.

**CENTIPEDEGRASS**
*(Eremochloa ophiuroides)*

Centipede grass is a native of southwestern Asia. It was first introduced into the United States in 1919 from China and has been distributed in the Southern States and as far west as the Pacific Coast. **Description**: A low-growing perennial, centipede grass spreads by stolons. In appearance it is intermediate between carpet grass and Bermuda grass; it has shorter nodes than the latter and makes a dense mat of creeping stems and leaves. **Adaptation**: Centipede grass is adapted to a wide range of soils, especially on the Coastal Plains of North Carolina to eastern Texas. It will grow on clay soils and the poorest Norfolk sand if enough moisture and plant food are available for it to get started. A complete fertilizer will encourage a more rapid spread and dense turf. Nitrogen fertilizer gives a most noticeable effect; there is no specific need for limestone. It has withstood temperatures of 12° F. or slightly lower, but it is not adapted to conditions in the North. **Propagation**: The grass does not produce sufficient seed to make its collection economical. The most common method of propagation is by stolons and plant cuttings. The cuttings are planted in furrows allowing the tip end to project out of the ground. A new lawn should be kept mowed and well watered. **Uses**: Because of its relatively low nutritive value, its best use is for lawns and erosion control. It is not suitable for heavy or intensive use, such as on airport runways. It is one of the best lawn grasses in the South, and is used on more lawns than any other grass in the extreme South. In pastures, it generally has given relatively poor livestock gains, but has produced fair gains on good soil when properly fertilized. Because of its dense and aggressive growth, it crowds out desirable legumes. It is occasionally affected with brown patch, but is not troubled with chinch bugs. Chemical analysis of grass samples, even in young vegetative growth, resembles (with some variations) the analysis of cereal straws. The crude fiber is higher in centipede grass than in straw, but the fat and nitrogen-free extract are lower.

**ST. AUGUSTINEGRASS**
*(Stenotaphrum secundatum)*

St. Augustine grass is native to the West Indies. It is also found in Upper and Lower Guinea, Africa, and in South Africa from Cape Town to Natal. In the Pacific area, from southern Mexico to Australia, it is also native. It has been introduced into southern France and Italy. In the Hawaiian Islands it was formerly called Manicmeric, a native name that is now applied to Bermuda grass there. In British Guiana it is sometimes called sheep grass. **Description**: St. Augustine grass is an extensively creeping, rather coarse, and glabrous perennial that produces stolons with long internodes and branches that are short, rather leafy, and flat. The sheaths are flat and folded; the blades short, 4 or 6 inches long and obtuse; the flowering culms are 4 to 12 inches tall. The flower spikes are 2 to 4 inches long, both terminal and axillary. **Adaptation**: St. Augustine grass is now found along the southern Atlantic coastal regions. In the region where it is adapted, it thrives in shaded areas so it is especially useful for lawns. On many golf courses in the South, it is used on fairways. It is naturally a seashore plant and will withstand salt spray. **Propagation**: Because practically no seed is produced, vegetative material must be used in making new plantings. Rooted runners used for this purpose, are planted in rows or disked into the soil during moist periods, and subsequently packed. Establishment is not difficult, and good stands are usually had. **Uses**: St. Augustine grass should be well fertilized. Nitrogen is especially essential; for lawns in Florida, two applications of 6 pounds per 1,000 square feet are recommended. Ample moisture is also neces-
SOUTHERN FORAGE GRASSES

Sary for best growth and development. Uses: St. Augustinegrass affords good pasture but it has not been used extensively for that purpose. It is used for grazing on muck soils in the Everglades in Florida where it furnishes more grazing than Paragrass which is commonly used there. The creeping, flat stems of St. Augustinegrass root to form dense sods which stand trampling. It is subject to brown patch and some damage is done by chinch bugs.

THE ZOYSIA GRASSES

(Zoysia species)

There are three species of Zoysia grown in the United States, Manilagrass (Z. matrella), Japanese lawngrass (Z. japonica), and Mascarenegrass (Z. tenuifolia). All are native of tropical or eastern Asia. Mascarenegrass: Mascarenegrass, the smallest, finest, and least hardy of the Zoysia species, is of least importance. It seldom grows more than 2 inches high and the plants have a shallow root system. It has been grown somewhat in the South and as far west as California. Japanese lawngrass: Japanese lawngrass has a broad, coarse leaf similar to that of redtop. It does not grow so tall as redtop but makes a dense cover. It is the most winter-hardy of the three species and has been grown successfully as far north as Boston. Because seed is not available, it has to be established vegetatively. Therefore, it is not now being recommended generally; it is of value for lawn or turf purposes only. It is tough, harsh, and unpalatable, and, once established, extremely hardy and persistent. Manilagrass: Manilagrass is the most important and widely used of the Zoysias. It turns brown with the first heavy frost in the fall and does not renew growth until after the last heavy frost in the spring. Near the District of Columbia, it remains green from mid-April to late October. It has survived the winter as far north as Rhode Island, but its general limit of northern adaptation is approximately 40° latitude. It will tolerate some shade, especially in the South.

Manilagrass is not very exacting in its soil requirements, but it appears better adapted to the heavier-textured soils. Complete fertilizers in regular applications are necessary to establish and maintain good turf. The same methods of seedbed preparation are recommended as for other lawn grasses.

Seed is not available in commercial quantities, and vegetative planting is necessary. One square yard of thick sod is sufficient to sprig-plant 750 to 1,000 square feet, with rows 8 to 10 inches apart and sprigs 3 inches apart in the rows. Because the plants are sensitive to cold, it is best to establish Manilagrass in the spring as soon as the soil is warm.

One of its principal weaknesses is its slow growth. It usually requires at least 2 years to obtain a good cover at the rate of planting recommended. Kentucky bluegrass, redtop, or similar grasses may be sown between the rows of Manilagrass sprigs to control weeds (unless hand weeding or cultivation is practiced) until the Manilagrass is established.

Considerable selection and improvement work is being conducted with Manila and Japanese lawngrass to develop superior turf strains, and it is likely that good seed-producing strains can be obtained. With seed available, the establishment of stands will be much less of a problem.

THIS CHAPTER

The material used in this chapter on southern forage grasses has been obtained from several sources, that on Bermuda-grass being from Burton of Georgia (GA-7), Mooers of Tennessee (TENN-11), and Blaser et al of Florida (FLA-7), and the final manuscript was reviewed by Burton; that on Dallisgrass, Bahiagrass, Vaseygrass, Paragmss, carpetgrass, Rhodesgrass, Napiergrass, Pangolagrass, centipedegrass, and St. Augustinegrass is mostly from Blaser et al (FLA-7), Hoover et al (US-115), and Piper (US-204 and 205), and was reviewed by Ritchey and Hein. The material on the southern panicgrasses and lovegrasses was mostly from Hoover et al (US-115), Savage (US-226), and Staten and Elwell (OKLA-20 and 22), and was re-
viewed by Staten and Savage of Oklahoma, and Potts of Texas.

Chapter reference numbers:¹

Bermuda-grass: ARK-11; FLA-7; GA-5, 7, 14; KY-21; NC-6; OKLA-14; SC-13; US-115.

Dallisgrass: FLA-7; GA-12; LA-11; MISS-22; NC-67; SC-13; US-115.

Bahiagrass: GA-13; MISC-54.

Paragrass: US-204.

Blue panicgrass: TEX-44; MISC-33, 46.


¹The reference numbers given here refer to references which are given in full by State, U.S.D.A., and Miscellaneous, on pages 682 to 724, and which are cross-referenced by author on pages 725 to 731. Citations in the text are indicated by abbreviation and number in parentheses.
CHAPTER XXVIII

SORGHUMS, SUDANGRASS, AND JOHNSONGRASS

(Sorghum species)

The forage sorghums, Sudangrass, and Johnsongrass are among our most important forage resources. The sorghums and Sudangrass are summer annuals that tolerate long, hot, dry periods of weather; thus they are particularly adapted to the Great Plains and valuable as emergency forage in the more humid areas. Johnsongrass, a rapidly spreading perennial where winter temperatures are not severe, is considered a serious weed in cultivated fields, but is valuable for hay and pasture in many parts of the Southern States.

All are of foreign origin. The sorghums were cultivated during ancient times throughout Africa and southern Asia. Johnsongrass is a native of the Mediterranean. Sudangrass was introduced from Africa.

SORGHUMS FOR FORAGE

(Sorghum vulgare)

The sorghums are for the most part natives of tropical Africa and Asia. The general culture of sorghum in the United States began with the introduction of a Chinese variety, Chinese Amber, from France about 1855. The most important single shipment of sorghums was that of 16 varieties from Natal, South Africa, in 1857. Hundreds of lots of sorghum seed have been received from foreign countries since that time. At first, most attention was devoted to the growing of sorghums as a source of sugar and sirup. The settlement of the prairie lands in the semiarid West, however, created a demand for drought-resistant forage crops, and now a large percentage of the acreage of sweet sorghums is harvested for forage.

Prior to 1944 the acreage of sorghums harvested for forage and silage exceeded that harvested for grain. The 10-year (1936-45) average for grain was 5,823,000 acres, and for forage and silage was 9,373,000 acres. For the next 4 years (1946-49) the average for grain was 7,080,000 acres and for forage and silage 5,650,000 acres.

The drought years included in the 10-year (1936-45) average account for both the large acreage of sorghums for grain and forage and also for the higher percentage harvested for forage.

Sorghums are especially valuable for winter feeding in the Great Plains where other forage crops are not well adapted. In severe winters in this area large numbers of cattle have been lost by starvation and exposure. Many of these losses could have been prevented by growing sorghums and storing the surplus produced in good years either as fodder or silage for emergency use. If storage for more than 1 year is contemplated the crop should be put in a silo, because the loss in stacks is considerable. Trench or pit silos are inexpensive, are practically indestructible, and will preserve properly-made silage almost indefinitely.

Sorghum is also often drilled or sown broadcast as a supplementary hay crop. As such it may often be sown as a catch crop on land originally intended for other crops but which, because of wet weather, floods, or for other reasons, cannot be sown at the proper time. In the Southern States, especially, it is used exten-
sively to feed mules and to a lesser extent for other farm animals. Though somewhat laxative, it is nutritious, and they do well on it. In this area no other crop except Sudangrass and Johnsongrass is equal to it for general farm feeding. Because it is often rather coarse and difficult to cure, it is not generally considered a good hay crop for market, although small quantities may be marketed locally.

ADAPTATION

Climate: The principal areas where sorghum is harvested for forage are in the Great Plains States of Texas, Oklahoma, Kansas, Missouri, Nebraska, and South Dakota. In the Southern Great Plains sorghum is the most dependable forage crop. In most of western Texas, Oklahoma, and Kansas, and in eastern New Mexico and southeastern Colorado, it is the basic feed crop for livestock. East of the ninety-eighth meridian in the Corn Belt and up to the northern boundary, alfalfa, timothy, clover, and soybeans are more highly prized than the sorghums for hay, and corn usually can be depended upon for grain, fodder, and silage. North and west of the regions where it is commonly grown, sorghum is not well adapted and is of little importance. Where sorghum is grown in the Pacific Northwest the Black Amber variety is most popular. In the southern two-thirds of the Great Plains sorghum varieties properly chosen can be depended on for both grain and forage. Except at high elevations, sorghums can, however, be grown as a secondary forage crop in all parts of the United States almost up to the northern boundary.

Sorghums do best in the southern half of the United States, where the temperatures are uniformly high during the growing season. The most favorable mean temperature for their growth is perhaps about 80° F., and they grow very little at temperatures below 60° F. Cool temperatures prevent sorghums from being grown at very high altitudes. The limits of successful production are reached at altitudes of 5,000 to 6,000 feet in Wyoming and Colorado, and at 7,000 feet in Arizona and New Mexico.

Sorghums are not so exacting in their moisture requirements as in their temperature relations. Despite the fact that the largest sorghum area in the United States is in a region of low and uncertain rainfall, the crop thrives under irrigation and where the rainfall is abundant. Sorghums are grown extensively in the semiarid plains, not only because they require little rain, but also because they are more productive than other crops under such conditions.

The sorghums are of most value in regions of uncertain rainfall, because they resist wilting and remain practically dormant during periods of drought and then resume growth as soon as there is sufficient rain to wet the soil.

Soils: Sorghum thrives on a variety of soils. Deep fertile sandy loams are best, but fair crops can be produced on heavy clays if they are well drained. Land too poor and thin to grow corn or wheat seldom produces a satisfactory crop of sorghum, although sorghum frequently is planted on such land. In humid areas or on irrigated land a legume, like cowpeas or clover, should be substituted in the cropping system and the productive power of the soil restored by applications of commercial fertilizers or barnyard manure. Sorghum is more tolerant of alkali in the soil than most crops.

Sorghum has the reputation of being “hard on the land.” Cotton, corn, oats, wheat and other crops usually yield less on fields that have produced a crop of sorghum the previous year than on fields preceded by most other crops. The differences in yield are more pronounced on wheat and oats which start growth under the temporary handicap of tied-up nitrogen, in which case these differences may approximate 15 percent. They are not so great with corn and cotton which start growth later in the spring.

Several factors contribute to the lower yield of crops following sorghum. The most important one in dry regions es-
especially with winter wheat is probably the rather complete exhaustion of soil moisture by the sorghum. Another is the poor physical condition of the soil resulting from the large clumps held together by the numerous fibrous roots of sorghum. The continued growth of sorghum plants until killed by frost in the fall tends to exhaust both available moisture and plant nutrients. On irrigated lands the chief deleterious effect on the soil after sorghum appears to be a temporary deficiency of available nitrates. Large quantities of sugar remaining in sorghum roots are believed to stimulate the growth of micro-organisms in the soil which take up the nitrates in their bodies. After the sugars are used up the organisms die, and the nitrates are again released for crop growth. The temporary deficiency in nitrates can be largely overcome on irrigated land by the application of ample barnyard manure or other nitrogenous fertilizers.

Because of these various effects on the soil, fall-planted grain does not usually succeed well on sorghum stubble. It is best to follow sorghum with a spring-sown crop or summer fallow.

The deleterious effects of sorghum on the land are temporary and usually disappear after the first crop following the sorghum. The sorghum-producing area of the Southwest (Kansas, Oklahoma, Texas) is closely associated with the winter-wheat area, although the two areas cannot be said to be identical. In this area where light-textured and heavy-textured soils often occur in an intimate association, the lighter soils of the farm are frequently used for sorghums and the heavier for wheat. Included in these soils are the Amarillo, Miles, St. Paul, Pratt, Abilene, and Grant. Sorghums are also important in southeastern Kansas, where they are produced on the claypan soils (Parsons, Cherokee) and on the Bates. Sorghums for grain are also grown to some extent in the Salt River and Yuma Valleys in Arizona, and the Imperial, San Joaquin, and Sacramento Valleys in California.

DESCRIPTION OF SORGO VARIETIES

The sorghums often are divided into four groups: (1) Sorgos, or sweet sorghums ("cane"), used for forage and sirup; (2) grain sorghums (kafir, hegari, milo, etc.), used for grain and forage; (3) grass sorghums (Sudangrass and Tunisgrass), used for pasture and forage; and (4) broomcorn, grown for its brush. This chapter deals largely with the sorgos, but also discusses grain sorghums commonly used for forage. The sorgos have sweet juicy stems and usually are 6 to 14 feet tall. The seeds usually are smaller than those of grain sorghums and are not especially desirable for feed because of their bitter taste and because a relatively larger proportion passes through the animal undigested. Only white-seeded varieties, such as Atlas, Axtell, Norkan, White African, and Tricker, are free from bitterness. Most of the sorgo varieties usually produce lower seed yields than the grain sorghums because of smaller seeds and heads, and because on farms they usually are planted thicker. The smaller seed yield is offset by the taller and heavier growth of stalks as compared with that of grain sorghums. Sorgos usually yield 25 to 50 percent more forage than grain sorghums except under very dry conditions.

At least 30 distinct varieties of sorgo are grown in the United States. Among the most important are Sumac, strains of Black Amber, Red Amber, Atlas, several strains of Orange, Sourless, Honey (African millet), and Gooseneck. Sumac: Sumac, usually called Reel Top, is the leading variety of Sorgo. It is grown extensively in Texas, Oklahoma, Kansas, and other States. Sumac has short, compact heads and very small dark reddish-brown seeds that thresh free from the hulls, and is of midseason maturity. It is less subject to lodging, and the stalks are more easily handled and harvested than those of several of the taller varieties. This, together with its usual leafiness and satisfactory yields, accounts for its great popularity. It is seldom used
for sirup and is generally considered unsatisfactory for that purpose. A special strain, Sumac 1712, popular in Oklahoma, makes satisfactory sirup. In western Kansas and a few other localities where the season is short, the Early Sumac variety is preferred. This variety is slightly shorter and earlier than the regular Sumac, but otherwise they are nearly identical. A strain called Medium Dwarf Sumac, is grown in south Texas. A new strain, Yellow Sumac No. 108, is grown in the Texas Panhandle.

Black Amber (Early Amber): Black Amber, including various strains such as Minnesota Amber and Waconia Amber, is the leading sorgo grown north of the latitude of northern Kansas. It is grown extensively in Nebraska, Colorado, South Dakota, Minnesota, and northwestern Kansas, and to a limited extent in many other States. This variety is early in maturity and of medium height (usually 6 to 9 feet) and has slender stalks with rather few leaves. The heads are loose, open, and usually nodding. The seeds are light brown and after threshing are nearly all enclosed in the black shiny glumes. Black Amber sorgo is grown chiefly for forage, but it also is the leading type for sirup in the northern half of the United States, where other heavier-yielding types do not usually mature. It yields much less than later varieties where they mature, and the forage often is of poorer quality because of the few leaves and because the stalks become dry earlier in the season.

Dakota Amber is shorter and earlier than Black Amber and is grown under the cool, dry, short-season conditions commonly prevailing in the Dakotas, Wyoming, and Montana. Rancher and 39-30-S, low in HCN, are widely grown in South Dakota.

Red Amber: Red Amber is similar to Black Amber except that it has dark-red instead of black glumes covering the seeds and is slightly later and heavier and with panicles slightly more compact. It is adapted to sections just south of where Black Amber is a leading variety. It is grown most commonly in southern Nebraska and eastern Colorado. It usually yields more and better forage than Black Amber where both varieties reach maturity, but south of northern Kansas it is inferior to many other varieties here mentioned that require a longer season.

Atlas: Atlas sorghum was originated in Kansas as a selection from a cross between Sourless sorgo and Blackhull kafer. It was distributed in Kansas in 1928 and now is very popular in the eastern half of Kansas and Nebraska and in western Missouri. It is gradually increasing in acreage in Oklahoma, Texas, Iowa, Kentucky, and other States. The Atlas variety is rather tall and late. It usually does not reach maturity where the frost-free period is less than about 170 days but matures and produces high yields of...
Sorghums for Forage

forage in most sections south and east of east-central Nebraska. It has strong stalks that lodge less easily than those of many of the tall varieties of sorgo commonly grown. The seeds are white, almost indistinguishable from those of kafir, a grain sorghum, and, unlike most other sorgos, it can be used readily as a grain feed.

Atlas combines the desired characteristics of a sweet forage sorghum with the white seeds and strong stalks of kafir to a large degree. It is taller and later and a heavier forage yielder than either parent from which it was produced.

The plant exhibits a remarkable tenacity, which enables it to remain green but dormant through long periods of drought and then resume growing when rains occur.

Axtell, a selection from Atlas, is grown in Kansas and Nebraska. It is about a week earlier and thus somewhat shorter, but otherwise is identical with Atlas.

Orange: Several strains of Orange sorgo are grown, and in addition the name Orange often is applied erroneously to several varieties.

Most strains are of medium height and maturity. The best-known definite strains of Orange are the Kansas Orange and Rox or Waconia Orange described later. Other strains are called Silver Top, Georgia Blue Ribbon, and Iceberg. The Colman variety usually is called Red Orange, and the Sourless variety is sometimes called White Orange.

Kansas Orange: The Kansas Orange variety is taller than Atlas and usually produces a slightly larger yield of forage. It is slightly earlier than Atlas, especially in a dry season. It is grown extensively in eastern Kansas and somewhat in other States, but is being replaced rapidly by Atlas. It is regarded highly as a sirup variety.

Kansas Orange sorgo has rather small oblong heads, with dark reddish-brown glumes and rather small brown seeds. This variety has been well known for more than 50 years. The strain now grown was selected for yield and sugar content at the Kansas station more than 40 years ago.

Rox (Waconia) Orange: Rox Orange is shorter and earlier than Kansas Orange and has bright-red glumes and medium-sized yellowish-brown seeds. The seeds extend well out of the glumes and give the ripe heads a yellowish-red appearance. Under favorable conditions Rox Orange grows to a height of 8 or 9 feet, but usually it is shorter. It is an important variety in Iowa, where it is popular for both sirup and forage. It is grown in other States as well. The name Waconia Orange is applied to the strain of the variety distributed by a commercial concern.

Sourless (African Millet): The Sourless variety, called also African millet and White Orange, is grown extensively in southern Kansas and western Oklahoma, mostly badly mixed as to type. It is a popular variety for forage under conditions of limited rainfall. The seeds are mostly a pale buff with some mixture of white seeds. The yellowish-brown glume fades out to a straw color at maturity. It is earlier and shorter than Kansas Orange.

Honey: Honey sorgo is among the most popular varieties south of Kansas. It is late in maturity, with very tall, thick stalks, large, open, brushy heads, and bright-red glumes that remain on the seeds after threshing. It is grown both for forage and sirup, and is one of the most productive varieties where the season is long enough and ample moisture is available to bring the crop to maturity. The Honey variety is known by many names. Throughout the South it is now commonly known as Texas-seeded Ribbon. Other names used are Honey Drip, Japanese Ribbon cane, and Spangle Top.

Gooseneck: The Gooseneck variety is the latest and largest sorgo grown in the United States, and, because of this, it is adapted only to the Southern States, where long growing seasons and ample moisture prevail; there the variety produces high yields of forage or sirup. The variety is distinguished by thick, compact heads that bend over and hang down, black glumes, and rather large brown seeds. The Gooseneck variety 25-30 years ago was most commonly called Texas
Seeded Ribbon cane which name is now applied to Honey sorgho.

**Norkan:** Norkan has the same general adaptation as Early Sumac and will mature farther north and in regions of shorter season than will Atlas. The forage of Norkan is not quite equal to that of early Sumac in sweetness and palatability, but the seed is similar to that of Atlas. The tonnage of Norkan and Early Sumac are about the same but less than that of Atlas.

**Leoti:** Leoti is adapted to about the same conditions as Early Sumac and may have some advantage in southwestern Kansas. It is resistant to the bacterial leaf diseases, but shatters easily. Leoti is one of the sweetest forage sorghums but sometimes the outside hull of the stalks tends to be somewhat hard. For this reason Leoti is not always consistently as high in palatability as is Early Sumac. It is also called Leoth red.

**Other varieties:** Among the other varieties grown for forage may be mentioned Tricker and Fremont, which are relatively early and drought resistant. Tricker is grown in western Kansas, is short, and low in forage yields. Seed of Tricker is very similar to that of Atlas, but the forage yield is not likely to be more than two-thirds that of Atlas. Fremont is an early variety adapted to northeastern Colorado and western Nebraska.

A number of other varieties grown on a limited acreage are valued for syrup production as well as for forage by many farmers in the Southern States. Of these, White African (White Mammoth) is about as tall and late as the Honey variety and has a similar adaptation. Colman (Red Orange), Planter (Planters’ Friend), Sapling, Sugar Drip, Rex (Red X), Folger (Folger’s Early), Collier, McCleau, Denton, Dwarf Ashburn (Dutch Boy), Straightneck, and Clubhead are medium late in maturity and, with the exception of Dwarf Ashburn, are rather tall. These varieties produce a satisfactory yield and quality of forage, although they are not particularly superior to the more popular varieties previously mentioned. They are planted for forage purposes chiefly because seed is available locally.

**GRAIN SORGHUM VARIETIES FOR FORAGE**

Grain sorghums are of most importance in the southern Great Plains and the irrigated portions of New Mexico, Arizona, and California. Some of them, such as hegari and the kafirs (Blackhull, Red, and Pink), and some others, such as Schrock, Grohoma, darso, and Freed, may properly be considered as dual-purpose sorghums, since they produce good yields of grain and also are satisfactory for fodder or bundle feed. Others, such as the milos, the durras, shallu, and usually feterita, have stalks so dry and unpalatable that they are seldom used for forage. There is always considerable waste in feeding them unless they are chopped, and at least they are fairly inferior to the sorgos. More than 20 percent of the total acreage of grain sorghum is harvested for fodder or bundle feed.

The grain sorghums listed above usually yield about two-thirds as much forage as do well-adapted varieties of sorghum. There are certain advantages in growing them for forage, however, because the shorter stalks are easier to handle. Also the bundles can be topped after harvest and the heads threshed or ground if grain is desired and the yield of grain is satisfactory. When most of the stalks fail to produce heads they are harvested for forage without subsequent topping of the stalks to remove the heads.

**VARIETIES RECOMMENDED FOR DIFFERENT AREAS**

There are many varieties of sorghum and they differ greatly in various characteristics, such as time required to mature, ability to endure drought, response to abundant rains, etc. It is fully as important to minimize the effect of adverse climatic conditions by a wise choice of varieties as it is to create more favorable conditions by means of irrigation or improved methods of culture. In no part
SORGHUMS FOR FORAGE

of the United States is the truth of this statement more often confirmed than in the semiarid portion of the Great Plains where the rainfall is undependable and where sorghums are generally recognized as the basis of a permanent diversified agriculture. An intelligent selection of varieties is the best insurance against failure. The time of maturity of a sorghum variety is the chief factor determining its adaptation to a particular locality. Early varieties are grown in the North and late varieties in the South, where a longer growing season and warmer weather permit the late varieties to mature. The earlier the variety the less forage it will yield under ordinary conditions. When sown broadcast or in cool climates, or in a dry season, when the development of all plants is retarded, large late varieties lose this advantage. In general, a variety should be grown that will reach maturity shortly before frost or when the soil moisture becomes exhausted.

The most reliable varieties for each part of the sorghum area are indicated in the following paragraphs, which refer to the accompanying map:

Region 1. Honey, Gooseneck, Medium Dwarf Sumac, and Atlas sorghums. Japanese sugarcane and Napier grass are more productive than sorghums for forage. Shalzu is the leading grain sorghum.

Region 2. Sumac, Orange, Honey, Gooseneck, White African, Sugar Drip, Rox, Colman, and Sapling sorghums. The grain sorghums Hegari, Schrock (Sagrain), Ajax, Darso, Blackhull kafir, and Gro-homa are suitable dual-purpose types.

Region 3. Sumac, Atlas, Kansas Orange and Sourless (African millet) sorghums. Hegari, Early Hegari, Blackhull kafir, Darso, several strains of Dwarf Blackhull kafir, Hydro kafir, Red kafir, Pink kafir, and occasionally Spur feterita are grown for forage and grain.


The varieties named for the various regions shown are recommended on the basis of the normal-planting date. When it becomes necessary for any reason to plant after the most favorable date, it is then often desirable to use an earlier-maturing variety.

SORGHUM CULTURE

Date of planting: Generally the highest quality of forage will be obtained if the crop is planted so as to mature shortly before frost. An early planted crop is likely to encounter periods of drought after the plants have reached an advanced stage, and the lower leaves will die and break off. The forage is easier to cure without souring when cut during cool fall weather. In the southern part of the sorghum region, where there is danger of injury to the grain by the sorghum midge, the crop should be planted...
as early as climatic and soil conditions permit—usually early in March. If forage only is desired, however, planting may be done at any favorable time up to July 15. Farther north the planting should be delayed until May. In the latitude of Oklahoma and Kansas, May 15 to June 15, on the average, is the best period for planting. A safe rule in all localities, except where the sorghum midge is troublesome, is to plant not earlier than about 2 weeks after corn-planting time. All sorghums are sensitive to cold soils and grow slowly until the soil becomes thoroughly warm. No advantage is gained, therefore, by planting too early.

Methods of planting: Perhaps 85 percent of the sorghum acreage is planted in rows sufficiently far apart to permit cultivation with an ordinary corn cultivator. When the sorgos are grown for hay they usually are sown broadcast or drilled with a grain drill. This is not done in regions subject to severe drought or where grain drills and mowers are not already available. There is very little difference in forage yield between drilled sorghums and those planted in rows to be cultivated.

The advantages in sown (drilled or broadcast) plantings over cultivated row plantings for hay lie in the fact that no cultivation is needed after sowing and that the hay produced is finer stemmed. The greatest drawback to such sowings is the failure of the sorghum to attain satisfactory growth in seasons of low rainfall. The crop is much more likely to head in cultivated rows than in drilled or broadcast seedings.

For planting in rows, two general methods are followed—surface planting and listing or planting in furrows. The first method is best suited to regions of moderate rainfall and the latter to dry regions.

Usually in surface planting the ground is prepared by plowing and harrowing, as in preparing ground for corn. If, however, the soil is left clean and mellow by the preceding crop, it may be possible to prepare it by disking or one-waying. The ordinary corn planter, if provided with sorghum plates, will plant the seed satisfactorily.

When a lister is used, sorghum may be planted successfully on grain stubble without much previous preparation, although this is not a recommended practice. Ordinarily, it pays to blank-list, disk, or both in the spring before planting with a lister.

Sorghum planted with a lister usually starts growth more slowly in the spring, because the soil does not warm so quickly at the bottom of the furrow. The roots are deeper in the soil, however, and after the rows and middles are leveled by cultivation there is less danger of lodging during a hard blowing rain. Listed sorghum, though making a poor appearance in the early part of the season, is often more productive in the end than surface-planted sorghum if the season is dry.

In the Southeastern States, where moisture is often excessive, a common practice in growing sorghum and other crops in rows is to plow the land and throw up beds with a lister. The crop is then planted on top of the bed or ridge instead of in the lister furrow, as is the practice in dry regions. The preparation of land for broadcasting sorghum or planting with a grain drill is practically the same as for surface planting in rows.

Rate of planting: The rate of planting sorghums in rows is of more importance when the crop is grown for grain than when it is grown for forage. The sorghum varieties stool or tiller freely. When soil moisture is abundant and the stand is thin each plant produces a large number of tillers, whereas, if moisture is deficient the plant tillers less. This habit tends to equalize in a measure differences in the initial stand. The largest forage yields are obtained when the plants are spaced about 2 to 4 inches apart in the rows.

If yield of grain is an important consideration, as when dual-purpose grain sorghums are grown for feed, a spacing of 6 to 8 inches is usually most satisfactory. The development of the plants is more nearly normal and the proportion of grain is greater than with thicker stands. In general, a 2- to 4-inch spacing
for sorghums and a 6- to 8-inch spacing for grain sorghums when grown for forage is recommended.

If every seed placed in the soil grew, 1 pound of seed of the Sunnle variety or 1 1/2 pounds of Amber sorgo to the acre would be sufficient to provide one plant for every 4 inches in rows 40 inches apart, but it has been found necessary under farm conditions to plant at least 3 to 4 pounds of seed to insure such a stand. In the drier parts of the sorghum region it is rarely, if ever, desirable to plant more than 4 pounds to the acre, and 2 to 3 pounds usually is sufficient. Farther east, where the rainfall is between 35 and 40 inches, it has been found preferable, when growing the crop for fodder or silage, to plant as much as 8 to 12 pounds per acre.

It has been the general practice among farmers to sow from 45 to 60 pounds of sorghum seed to the acre when close-drilled or broadcast. Very little difference in yield is obtained whether one uses 15 pounds or higher rates up to 75 pounds of seed to the acre. The 15-pound rate, however, gives a coarser growth, which is more likely to be infested with weeds, especially if the seedbed conditions are not the best or the weather is not favorable for good germination of the seed and a vigorous early growth of the plants.

It is recommended, therefore, on this basis to sow 30 pounds per acre west of the one hundredth meridian in the Great Plains, 45 pounds between the ninety-eighth and one-hundredth meridians, and 60 to 75 pounds east of the ninety-eighth meridian.

Sorghum-legume mixtures: The practice of sowing or planting mixtures of sorghum and some legume, such as cowpeas, soybeans, or velvetbeans when forage alone is desired, is commendable in theory, but in actual practice has not been a complete success. On the Great Plains, where the rainfall is deficient, the sorghums make a more vigorous growth than cowpeas or soybeans and usually crowd out the legumes. In the humid regions such mixtures are more successfully grown, but the difficulty of harvesting the mixed crop prevents its extensive use. The growing of any mixture of this kind should be attempted only in localities where both the sorghum and legume are well adapted to climatic and soil conditions.

Cultivation: The early growth of sorghum is slow, and the young plants therefore require care to prevent their being crowded out by weeds. Where the field has been plowed late in the spring and then surface-planted, a common practice is to cultivate once with a spiketooth harrow soon after the sorghum has emerged and later with an ordinary shovel cultivator, as may be necessary to control weeds. In other words, the crop is handled much the same as corn is in the same area. Late cultivations should be shallow in order to avoid breaking the feeding roots.

Fertilizers: In the Great Plains, where the larger part of the sorghum acreage is located, but little fertilizer is used on sorghum or any other crop. The limiting factor in all this region is moisture and not soil fertility; consequently, the use of fertilizers does not pay. Barnyard manure has been of some benefit to forage sorghums on most soils in the Great Plains.

In the Southeastern States any fertilizer known to be beneficial to corn under local conditions may be expected to be equally beneficial to sorghum. Where forage is the chief consideration it is desirable to have the nitrogen content of the fertilizer rather high. In the Cotton Belt it has been a common practice to apply 200 to 300 pounds of cottonseed meal per acre or its equivalent as a nitrogen-supplying fertilizer to land that is to be planted to sorghum. Phosphorus was most effective in increasing yields followed by nitrogen, potassium, and lime.

UTILIZATION FOR FORAGE

Sorghums grown for forage may be utilized as fodder, stover (fodder from which heads have been removed), silage or hay, or they may be grown as a soilings crop (cut and fed green) or for pasture. Also the heads may be fed as such, or they may be threshed and the grain used
as feed in much the same way as sorghums grown primarily for grain.

**Fodder:** A large percentage of forage sorghums are cut and fed in bundles as fodder or bundle feed. That is, the whole plant, including the grain, is fed without removing the heads, or threshing. Such fodder, if fully matured and properly cured, with a little protein supplement will maintain livestock in good condition throughout the winter with little or no grain supplement. If, however, for any reason the bundles contain but little grain, some grain may well be added to the ration. Sorghum fodder, as chemical analyses show, is nearly equal to corn fodder in food value. It is much more palatable and hence can be fed with less waste.

Sorghum should be fairly mature before being cut for forage. There are several reasons for this: (1) The largest tonnage of dry matter is obtained from mature sorghums, (2) the feed is more palatable, (3) the plants contain less prussic acid, (4) the fodder does not sour in the shock so easily, and (5) the silage made from mature sorghum contains less acid and does not spoil when properly ensiled.

By the time sorghum has reached the beginning of the heading stage the plants practically have ceased taking up nitrogen and minerals, and very little more fiber is formed. Starch, sugars, and fats continue to be manufactured until maturity, and the total dry weight of the plants may increase about 40 percent between first heading and maturity. This increased weight is largely in the seeds and heads and in sugar stored in the stems. Experiments in which cuttings were made at different stages of maturity show that not only the largest quantity of cured forage is obtained when the crop is harvested after the seeds are well formed, but also the highest acre yield of protein, carbohydrates, and fat. In general, the best time to cut sorghum for fodder is when the seeds have reached the hard-dough stage.

The most efficient machine for harvesting sorghum in rows is a corn or row binder. A farmer, assisted by two men to shock the bundles, can harvest 6 to 7 acres per day. When once carefully shocked, sorghum keeps in good condition until late in the winter and can be hauled to the barnyard to be fed or stacked whenever other work is not pressing.

A long period for curing in the shock is necessary in the production of good sorghum fodder. Some difficulty is experienced in certain sections with souring in the shock. This usually is the result of cutting the sorghum while it is immature.

Sorgo fodder contains somewhat less protein than either corn fodder or kafr fodder, but in other respects the composition of the three is about the same. There is, however, a difference in digestibility, as shown by the same authority. Thus, for the dry matter of the fodder the percentage of digestibility is for corn 66, for kafr 59, and for sorgo 58. Corresponding figures for the dry matter of silage are for corn 66, for kafr 55, and for sorgo 57.

Sorgo plants consist of about 80 to 85 percent of water before maturity and of about 70 percent of water when ready to harvest. An average bundle of field-cured sorgo after 2 months in the shock, if from a good crop, will weigh from 12 to 16 pounds and will contain from 30 to 40 percent of water and from 10 to 20 percent of seed. A bundle will therefore contain approximately 9 pounds of dry matter, about 1½ pounds of which will be seed. The dry matter will consist approximately of 25 percent of heads (18 percent of seed), 15 percent of leaves, and 60 percent of stalks.

A bundle of grain sorghum fully matured and field-cured, harvested as fodder, will weigh 10 to 12 pounds and will contain from 20 to 40 percent of heads and from 15 to 30 percent of grain. A bundle will therefore contain about 8 pounds of dry matter, about 2 pounds of which will be grain. In other words, the proportion of grain and the total amount of grain per bundle is somewhat larger than in sorgo bundles.

**Hay:** Broadcast or drilled sorgo ("sowed cane") is usually harvested as a hay crop
SORGHUMS FOR FORAGE

with a mower. In dry climates farmers often harvest with a binder, but unless very dry weather prevails there is danger of spoilage in the bundle. Care must be observed in curing the sorgo when it has been cut with a mower, as the stems are very juicy, and it takes a long time to cure them sufficiently to be ready for the stack. It is best to allow the crop to lie in the swath for a day or two, then rake into windrows, and leave at least 4 days, or longer, if the weather is not favorable for curing. As soon as the leaves are fairly dry the hay may be placed in cocks to complete the curing process. The usual method is to bunch the hay into large cocks with a buck rake or dump rake. If cut in warm weather the stalks may sour. For this reason, planting so that the crop may be cut during cool weather just before frost is advisable. So far as practical, drilled or broadcast sorgo should be allowed to form seed before it is harvested, except when it has been severely injured by drought and the plants dry up in the field.

Sorghum hay may be utilized on the farm in the same way as any other hay crop. In general, the sorgos make better hay than the grain sorgums, though the latter are used for that purpose. Sorghum sown thickly for hay is more leafy than that grown in cultivated rows for fodder. Sorghum hay is often rather coarse, especially if planted too thin, and the stalks are likely to dry slowly and consequently contain too much moisture to permit baling. For these reasons sorghum hay is not generally suitable for marketing except locally.

Silage: Sorghum is rapidly replacing corn for silage in Kansas, Nebraska, Texas, Oklahoma, and western Missouri, and in other States where drought frequently injures the corn crop. In good seasons in these States the better varieties of forage sorghum frequently yield one-third to two-thirds more silage than corn, whereas, under conditions of severe drought or grasshopper injury when corn is nearly a failure, sorghums may still produce 3 to 8 tons of silage per acre. Sorghum is more certain than corn in dry seasons, and a smaller acreage can be planted with reasonable assurance that sufficient feed to fill the silo will be produced. Experiments in several States indicate that sorghum silage is slightly inferior in feeding value to corn silage made from a crop in which the ears are well filled. This difference, probably due to a higher proportion of and a better utilization of the grain in corn, is much more than offset by the higher yields of sorghum.

The relative advantages of corn, sorgo, and kafir silage expressed as pounds of beef or gallons of milk per acre are illustrated in a 5-year comparison at Manhattan, Kansas. The comparison shows in a striking manner the high value of sorgo when utilized as silage. Sorgo produced over 18 tons of silage, 3750 gallons of milk or 1850 pounds of beef per acre, as compared with corn at 11.8 tons, 2750 gallons and 1351 pounds of beef, and kafir at 11.9 tons, 2719 gallons and 1253 pounds of beef. There is little doubt that some, though not all, of this superiority over corn is lost in the succeeding crop, for most investigators admit that corn leaves the field in better condition for wheat or other small grains than does sorghum.

The feeding value of an acre of sorghum is about 50 percent higher when fed in the form of silage than when fed as fodder, as is shown by gains made in feeding experiments. Despite this difference only a small proportion of the sorghum crop is put into the silo at the present time, but such use is expanding rapidly. The necessity for allowing the crop to become ripe before it is cut for silage often has not been realized. Silage made from green immature sorghum is likely to be sour and will not keep well, but if the sorghum is not cut until the seeds are hard the silage is even less acid than corn silage and keeps fully as well. Acre for acre, sorghum silage is superior to corn silage in many sections. Sorghum that fails to produce seed because of drought also makes satisfactory silage.

Soiling: If sorghum is grown for soiling (cutting and feeding green) several successive seedings should be made or several varieties of different degrees of maturity
should be used, in order to extend the soiling season over a considerable period. A second growth starts promptly from the stubble, especially when the plants have been cut before maturity. The yield of soilage from sorghums is larger than that from almost any other crop. Yields of 12 to 15 tons per acre may be expected on fairly fertile soils. The crop can be grown for soiling either in cultivated rows or in close drills. Harvesting is a comparatively simple matter, the drilled sorghum being handled with a mower and rake and that in rows with a row binder or corn knife.

In using sorghums for soiling, special care must be observed to avoid bloating and prussic-acid poisoning. The sorghum can be cut from the time it is 2 to 3 feet high until it ripens, but earlier cuttings or small second-growth stalks are likely to contain dangerous quantities of prussic acid. Unless feed is badly needed, therefore, it is best to delay cutting until the plants have headed.

Pasture: Sorghum has been recommended as a summer pasture for livestock of all kinds, but there is more or less conflict of opinion regarding its value for this purpose. The general result of well-planned experiments is to discourage its use as pasture both for hogs and cattle. Most of the successes with sorghum as pasture have resulted from letting milk cows graze on a nearly mature crop. The principal objection is the danger of prussic-acid poisoning. There seems little danger to hogs and horses, but cattle, sheep, and goats are particularly susceptible.

Prussic-acid poisoning: A serious disadvantage in the use of sorghum as a pasture or soiling crop is the danger of cyanide or prussic-acid poisoning. Almost every farmer who has grown sorghum as a farm crop knows that it is dangerous to allow cattle to eat even a small quantity of sorghum before it has matured. The wild animals of Africa are said to avoid sorghum instinctively while it is young, refusing to eat it until it has ripened. However that may be, domestic animals in the United States show no such intuition, and a considerable loss of cattle occurs each year from sorghum poisoning.

The following points have been fairly well established:

1. The prussic-acid content of sorghum decreases as the plant approaches maturity. Small plants (including those retarded by drought), early second growth, and young branches and suckers are high in prussic acid. Mature plants with ripe seeds are seldom dangerous, especially if the growth has been normal and few young suckers or branches are present. Most of the prussic acid is found in the leaves, and particularly in the younger leaves.

2. Well-cured sorghum fodder has lost much of the prussic acid and ordinarily is safe to feed to animals. Partly cured sorghum may be dangerous.

3. Sorghum silage can be fed with safety.

4. Loss usually comes when hungry cattle stray into a field of sorghum. Pasturing of sorghum should never be attempted without first testing the field with an animal of little value. Even if the sorghum appears safe to pasture after such a test, the herd should not be turned into the field with empty stomachs. A light feed of grain given prior to turning the animals on the sorghum will do much to prevent injury.

5. Less trouble is experienced in the Southern States than in those farther north.

DISEASES AND INSECTS

The sorghums are attacked by a number of diseases and insects, among which are those mentioned below, which are more fully discussed in chapter IX.

Diseases: The red spot, formerly known as sorghum blight, is perhaps the most troublesome of all sorghum diseases from a forage standpoint. It affects both the stem and the leaves of the plant. There are two smuts that seriously affect the sorghums. In the kernel smut, the individual grains are attacked and changed into a mass of spores. In the head smut, which is less common, the whole head
when it emerges from the upper leaf is a mass of spores.

Insects: Grasshoppers are somewhat troublesome to sorghums, but much less so than to corn. The chief damage is to the ripening seeds. Grasshoppers eat sorghum leaves very reluctantly. They seem to prefer leaves of milo and hegari to those of most other sorghums.

Most of the better varieties of forage sorghums are not injured very extensively by chinch bugs unless the infestation occurs when the plants are small. Among the sorghos, Honey, Leoti Red, Black Amber, and Red Amber are most susceptible. Hegari is more susceptible than the kafirs and other grain sorghums commonly grown for forage. Milos are more susceptible to chinch-bug injury than any other of the sorghums.

The sorghum midge is abundant in the Southern States from central Texas eastward. In that region it often has prevented the production of sorghum seed to such an extent that the growing of grain sorghum is unprofitable.

SEED PRODUCTION

Much of the sorghum now grown, with the exception of the Sumac variety, is badly mixed. Pure seed is difficult to obtain except from specialized seed growers and dealers. When sorghum is grown strictly for forage, a high degree of purity of variety is not important, especially if the crop is drilled or broadcast for hay. The varieties in the mixture should be enough alike, however, to reach the desired stage of maturity at approximately the same time. Otherwise, there will be a loss in quality as well as in yield. In the growing of Atlas and other sorghum varieties having special qualities or purposes, or in growing sorghum for sirup, it is highly important to secure pure seed of the correctly named desired variety. This is best assured by purchasing seed from a grower or dealer who has had the fields inspected by someone competent to identify the variety.

All sorghums cross-pollinate freely in the field. The sweet sorghums are more often mixed as to variety than are the grain sorghums, because the seed crop is of less importance than the fodder. A special effort is therefore necessary to produce pure seed. Where a field is intended for seed production it should be rogued carefully, as the presence of stray plants of other varieties will permit hybridization. The crossing of varieties results in a lack of uniformity in ripening as well as in the size of the plants, thus causing difficulty in harvesting and loss in marketing the crop. Extra care in saving sorghum seed is justified, as there is a considerable demand for good pure seed of standard sorgo varieties, such as Black Amber, Sumac, Atlas, Honey, and Gooseneck.

In growing pure seed, certified, registered, or foundation seed of known record or origin should be planted, and the field should be separated by 40 rods or more from any other kind of sorghum, including broomcorn and Sudan grass. The purity of sorghums can be maintained only by complete isolation or by "selfing" individual heads. The latter is accomplished by fastening a paper bag over each head before it blooms, in order to exclude all pollen except that produced on the bagged head. Such a procedure is not practiced on a large scale, but may be resorted to for the production of pure seed for a seed plot.

Large quantities of the harvested heads thrown together in a crib or bin are likely to heat and lose their germinating power. In dry climates they may be piled in narrow ricks in the open, but it is better to place these ricks under cover. Damp or immature seed may be rendered worthless for planting if subjected to freezing temperatures.

An ordinary grain separator or a standing combine, if properly adjusted, can be used effectively for threshing. To avoid cracking the seed it is best to remove all but two or three rows of concave teeth and reduce the speed of the cylinder to about half that used in threshing wheat, but with the other moving parts operating at the speed used in wheat threshing. The distance between the cylinder and the concaves should be increased when threshing soft-grained sorghums like he-
gari, and reduced for sweet sorghums, which are harder to thresh.

SORGHUM HIGHLIGHTS

1. Sorghums are mostly natives of Africa, and a few of the varieties now grown in the United States originated there.

2. Of the more than 10,000,000 acres of sorghum now grown in the United States annually, approximately half is harvested for forage. In dry years both the total acreage of all sorghums, and also the percentage harvested for forage, increase.

3. The sorghums are especially adapted to the warm dry climate of most areas of the southern and central Great Plains States where they have proved a boon to dryland farming.

4. In the areas of the Corn Belt where droughts are frequent, sorghums have proved a valuable safeguard against total crop loss because of their greater certainty of producing a crop and supplying the necessary feed for livestock under dry conditions.

5. Sorghums are often not the best crops in rotations where they are to precede an important cash crop because they deplete the soil of both water and fertility, and reduce the yield of the succeeding crop.

6. The principal varieties of sorgo (sweet sorghum) grown for forage are Sumac, Black Amber, Atlas, and Honey. The grain sorghums most valuable for forage are Hegari, Early Hegari, and the Blackhull, Red, Pink, and Dwarf Kafirs.

7. There is little difference in the forage yield of sorghum planted in rows 40 inches apart and that sown in close drills, but the cultivated rows are most dependable in seasons and areas of low rainfall. However, the thinner the stand the coarser the forage will be.

8. Sorghum varieties hybridize freely, and lack of uniformity can be prevented only by planting pure seed.

9. Sorgo and some of the grain sorghums are excellent silage crops. Silage can be stored in trench silos at small expense. There is no danger from prussic acid poisoning in feeding sorghum silage.

SUDANGRASS

(Sorghum vulgare sudanense)

Sudangrass was discovered and introduced into the United States from Africa in 1909 during a systematic search for sorghums lacking the aggressive rootstocks which sometimes convert Johnsongrass into an obnoxious weed and without which it would be a much more valuable hay plant for the Southern States. Its widespread adaptation to many regions here has made it one of the most valuable of summer annual forage grasses. Like the other sorghums, it tolerates droughty conditions and its rapid growth from late sowing makes it an ideal emergency forage for pasture, hay, or silage.

DESCRIPTION

Under cultivation in the United States, Sudangrass has shown itself to be distinctly an annual. Only under practically frost-free conditions, such as obtain along the Gulf Coast and in southern California, have plants lived over winter. This grass is very closely related to the other cultivated sorghums and hybridizes with them readily.

Sudangrass when sown broadcast or in drills grows about 3 to 5 feet high and has stems about 3/16 of an inch in diameter (a little smaller than a lead pencil). If grown in rows and cultivated, it reaches a height of 6 to 8 feet, and the stems are about 3/4 of an inch in diameter. The panicle is loose and open, very much like that of Johnsongrass, but a little larger and a trifle less open. The hulls, or glumes, are awned and when in flower are often purplish in color. The grain usually fades to a pale yellow when ripe. The awns are broken off in threshing so that the commercial seeds rarely have awns. The leaves are broader and more numerous than those of Johnsongrass, giving the grass a much more favorable appearance as a hay plant. The most important difference, however, is that the aggressive underground stems, or rootstocks, with which Johnsongrass is equipped, are entirely absent in Sudangrass.

Sudangrass, like the cultivated sorghums, never develops anything but fibrous roots, therefore it cannot become a noxious weed as the perennial Johnsongrass does. Furthermore, it has shown little tendency to persist in fields as an annual weed.
SUDANGRASS

through volunteer seedlings. When it has plenty of room the grass tillers very freely. It is not uncommon to find over 100 stems arising from one crown. This decided tendency to tiller is most apparent after the first cutting, and usually makes the hay from the second cutting of finer texture than that from the first.

ADAPTATION

Climate: Sudangrass, like the sorghums, does best in a warm climate. In favorable seasons, where the growing period is long, as many as four cuttings can be obtained in one year. As in the case of all other crops, in determining the regions of greatest importance, climatic and soil conditions are linked with the acuteness of the need for such a crop. The principal regions of production in the United States are shown on the accompanying map as follows:

Region 1. Two or three good cuttings of hay are secured without irrigation in this region, the yields varying from 2 to 4 tons to the acre. This is the region of its greatest importance because of the need for a better hay grass in these States. Profitable seed yields are secured mostly west of the ninety-eighth meridian. The sorghum midge and certain foliage diseases usually prevent seed formation in the more humid district east of this meridian.

Region 2. Sudangrass thrives here almost as well as in Region 1, making good yields both of hay and of seed. Timothy, clover, and alfalfa, however, meet the hay requirements of this region so fully that Sudangrass is valued chiefly as a pasture and catch crop or for limited culture on soils not suited to these forage crops.

Region 3. This comprises the region west of Region 2, where the rainfall is too low for the successful cultivation of timothy and clover. Sudangrass commonly makes one cutting under such conditions, and in favorable seasons two, yielding 1 to 3 tons of hay to the acre. Its chief competitors in this region are alfalfa, sorghum and millet. Alfalfa is preferred to Sudangrass only in the more favored locations, such as river and creek valleys or where irrigation is possible. The better varieties of sorghum, will outyield Sudangrass, but the latter is better suited for pasture purposes, produces a better quality of hay, and is easier to handle with haying machinery. Seed production, though possible in most of this region, is profitable only in the southern part.
Region 4. Sudangrass yields abundantly both in hay and in seed in all irrigated localities in this region; yields of 4 tons of hay to the acre are not uncommon on good soils. It is used chiefly to supplement alfalfa in the rations of horses and dairy cattle.

Region 5. In this part of the United States Sudangrass is successful only in limited areas. Its failure except in these localities is due either to low temperatures caused by high altitudes or to insufficient rainfall.

Region 6. In this region, including Florida and the Coastal Plain along both the Atlantic and Gulf coasts, Sudangrass is usually a failure, largely on account of the injury to the foliage caused by diseases.

Region 7. This is a region 100 to 200 miles wide along the northern border of the United States. Sudangrass is not grown extensively in this section because of the cool summers and short growing season.

Since its introduction in 1909 Sudangrass has become known in nearly every part of the United States and is now being grown where it was at first thought to be wholly unadapted. Its short growing period permits it to thrive and make good crops of hay as far north as southern Michigan and New York. Throughout the timothy and clover region, though it may never become the leading hay grass, it will be used more and more as a catch crop in place of the millets and for summer pasture. Except in the extreme north, it has to a large extent replaced millet in this region. In the Rocky Mountain region (region 5), the results are for the most part unfavorable except in the irrigated valleys. At the higher altitudes untimely frosts and continued low temperatures during the summer months preclude a successful growth. The upper limits of profitable hay production seem to be 6,000 to 8,000 feet in New Mexico, Arizona, and southern California; 5,000 to 6,000 feet in Colorado, Utah, Nevada, and northern California; and 4,000 to 5,000 feet north of those States.

The altitudinal limits for seed production are at least 1,000 feet lower, respectively, than those named for hay, because under cool conditions it takes a month or more to mature seed after the crop is ready to be cut for hay.

That Sudangrass will grow and produce fair crops in regions of low rainfall has been demonstrated by numerous tests in the Great Plains. Its ability to endure periods of drought is equal, though not superior, to that of the best varieties of sorghum. In the South, where drought is usually combined with extreme heat, Sudangrass yields much better than millet, but in Montana and the Dakotas, millet makes a slightly larger yield.

Experiments have shown that Sudangrass requires more water to produce a pound of dry matter than does corn, sorghum, or millet. Notwithstanding this indicated high water requirement, Sudangrass has been successfully grown as a dry-land crop since 1912, when the first wide distribution of seed took place. As an emergency hay crop and summer pasture no other crop is better suited to conditions in the southern half of the Great Plains.

Soil requirements: Sudangrass is not at all exacting in its soil requirements. It does best on a rich loam, but it has been grown successfully on almost every class of soil from a heavy clay to a light sand. Where the soil is quite sandy, however, the yield may be expected to be light. Cold, wet, muggy soils are particularly unsuited to Sudangrass. Before it can be grown on such soils, thorough drainage must be provided. Small amounts of alkali
in the soil reduce the yields markedly and stronger concentrations prevent profitable culture.

CULTURE

Preparation of seedbed: In sowing Sudangrass a rather firm seedbed is best. Usually, when it is desired to drill the seed, the ground is plowed in the spring and harrowed well, as for corn. A cool soil delays the germination of the seed; therefore, spring plowing is preferable for the seedbed, because it assists in warming the soil. No fertilizers are necessary in the West, where the soil is reasonably good, but in the East it is probably advisable to use some nitrogen or complete fertilizer such as is applied for corn, or some combination of phosphorus and nitrogen, if the available potash in the field is ample. Few experiments have been conducted to determine the best practice to follow, but in Kentucky applications of superphosphate at the rate of 200 pounds per acre resulted in increases of yield in 8 out of 10 cases. The average increase attributed to the fertilizer was 68 percent.

Date of sowing: It has been found best to sow Sudangrass after the soil has become warm, or about two weeks after corn-planting time. When sown in cold soil the result usually is a poor stand or a slow growth for several months, so that in the end no advantage has accrued from the early sowing.

Widely scattered experiments have shown that in very few cases does early-sown seed give the highest hay yields. The experience so far indicates that for the extreme South the best time for sowing lies between April 1 and May 1; in the latitude of Oklahoma and Kansas, any time between May 1 and June 15; and in the latitude of Nebraska and South Dakota, between May 15 and June 15. From Kansas south, good crops of hay can be secured from seed sown July 1, or even later.

Method of sowing: For hay production in regions of abundant rainfall the best machine for sowing Sudangrass is no doubt the common grain drill. Well-cleaned seed feeds freely from this drill, and it can be distributed evenly and a good stand thus secured. If a press drill is used the ground is left level and in good condition for the mower. The depth of sowing has but little effect on the root system of Sudangrass. It seems to be a characteristic of the grass that the root system begins near the surface of the soil, regardless of the depth at which the seed is placed. The best depth, everything considered, is about 1 inch, but where the soil does not become packed the plant will force itself to the surface even from a depth of 3 1/2 to 4 inches.

In the semiarid regions for hay, and in any locality for seed production, better results are obtained by planting in rows far enough apart to allow cultivation. This can be accomplished with a grain drill by stopping up a sufficient number of the holes so that the rows will be the desired distance apart. If only the ordinary corn cultivators are available for the work, it is best to place the rows 36 to 42 inches apart. If a beet cultivator or some other similar tool is available, larger yields can be obtained from rows 18 to 24 inches apart. Twenty-four inches is perhaps as close as practicable for horse cultivation. Against any difference in favor of the cultivated-row planting over the broadcast field will have to be charged the cost of cultivation. A better quality of hay is produced from the broadcast stand, owing to the finer stems. The grass grown in cultivated rows is likely to be coarse and therefore not so desirable for market hay. For home feeding the coarseness will be of little disadvantage, as the stems do not become so woody that they are refused by stock.

Rate of sowing: Rates of 10 to 40 pounds of Sudangrass seed to the acre have been tested at the different agricultural experiment stations. There was, however, no definite superiority indicated for any one of these rates in drilled seedings. Sudangrass tillers so profusely in thin stands that the final number of stems per square foot of ground is usually very nearly the same, whether the rate is 15 or 40 pounds. Taking all the factors into consideration, 20 to 25 pounds per acre are recommended for drilled or broadcast
seedings in the humid regions, and 12 to 15 pounds in the dry sections.

Under irrigation, 15 to 20 pounds of seed are sufficient, owing to the more favorable conditions for germination. These quantities should be proportionately increased if the seed is of low germination or the soil in poor physical condition. A grain drill set to sow 2 pecks of wheat to the acre will ordinarily sow about 20 to 25 pounds of Sudan grass seed. If it is desired to sow a lesser quantity, this can be accomplished by stopping alternate holes in the drill or by mixing the Sudan grass seed with bran or some other mill feed in any proportion necessary.

For sowing in cultivated rows 36 to 44 inches apart, 2 to 4 pounds of seed per acre will be found sufficient, while in rows 18 to 24 inches apart, 4 to 6 pounds per acre will be required, the smaller quantity being used, as in sowing broadcast, for regions of light rainfall. If the crop is intended for hay, enough seed should be used in any case to insure a thick stand of plants in the row. When a seed crop is desired, the rate of sowing should ordinarily be somewhat less than for a hay crop.

**UTILIZATION**

**Feeding value of hay:** The slender leafy stems of Sudan grass make it easy to handle with the ordinary haying machinery. It yields well in most parts of the United States, and the hay is relished by cattle, horses and sheep.

The feeding value of Sudan grass hay is practically equal to that of millet, timothy, Johnson grass, and other non-legume roughages. This fact has been established both by chemical analyses and by practical feeding tests. Work stock can be wintered in good condition on Sudan grass hay without any supplementary grain ration. Farmers report that horses and mules stand plowing and other hard work in the hot summer months better when fed Sudan grass hay than when their roughage is alfalfa.

Stock cattle were maintained economically by the Kansas Agricultural Experiment Station on a ration of Sudan grass hay, sorghum silage, and a small supplementary ration of linseed or cottonseed meal. In another feeding experiment, milk cows produced 97.8 percent as much milk on Sudan grass hay as on alfalfa hay. Hundreds of farmers testify that cattle, horses and sheep all eat Sudan grass hay with no derangement of the digestive processes and with good results when measured in gains of flesh, ability to work, or to produce milk. Experts in feeding livestock claim, however, that Sudan grass hay gives the best results only when fed in connection with other forage. It should not be used as the sole roughage in rationing any kind of farm animals.

**Harvesting:** The most common way of harvesting Sudan grass for hay is with a mower. It cures readily and can be cut in the morning and, if the sun is bright, raked up that afternoon or the next day. After bunching, it is placed in cocks, just as with millet, and removed from these cocks to the barn or stacks after it has thoroughly cured. Because of the large amount of juice in the stems of Sudan grass, the leaves cure first and the hay often appears ready to stack when it is not; therefore, the only sure way to avoid injury by heating is to allow Sudan grass to remain in cocks long enough for the stems to become dry. The leaves are retained well, and if cut at the right stage of maturity and handled properly it will make a bright, leafy, sweet hay of the very best quality.

Where the crop is desired for seed, it is harvested like the small grains with an ordinary grain binder and allowed to cure in shocks. This method can also be used in making hay in the semiarid regions where such good drying weather prevails that the grass will cure in the shock. Where the planting is made in cultivated rows, a corn or row binder can be used, but in most cases a grain binder is preferable. Sometimes, where the growth is rank, trouble is experienced in getting the reel over the tops of the plants and at the same time cutting a short stubble.

**Time of cutting:** The time for cutting
Sudangrass is governed to some extent by the fact that several cuttings are expected in most cases, and this often makes it seem more profitable to cut the first time as early as possible, so that the grass will have more time for the second growth. Experiments have shown, however, that early cutting is not justifiable either from the standpoint of total yield or from that of food value. At the Fort Hays Experiment Station, Hays, Kansas, the average seasonal yield of air-dry hay for five years was as follows:

- Cut just before heading: 1.86 tons
- Cut as first heads appeared: 2.23 tons
- Cut when in full head: 2.15 tons
- Cut when seed was in milk: 2.28 tons

In the first stage two cuttings were obtained each year; in the second stage in three out of four years; and in the third stage in only two of the years. In the fourth stage, only one cutting a year was obtained, but the average yield was the largest of the four methods.

The above experiment clearly shows that it is not profitable to cut Sudangrass before it has begun to head. The preferable stage of maturity for cutting is from the time it begins heading until it is fully headed. There is little loss, however, when the grass is allowed to grow until the seed has reached the soft-dough stage, and only one cutting is then required to harvest the crop and obtain a maximum yield of forage.

Effects of late cutting on hay: There are very few hay grasses which are injured so little by standing beyond the proper stage of maturity as Sudangrass. This is due largely to the numerous tillers, which, arising from the base, mature successfully later than the primary stem and provide immature stalks throughout the entire growing season. There is in addition the fact that, like the sorghums, it holds its leaves well and makes the best quality of fodder when the seed has reached the dough stage. This characteristic makes it possible, where necessary, to extend the haying process over a long period without any material loss either in the quantity or quality of the hay.

An emergency crop: Although Sudangrass is an annual and can be introduced easily into any rotation, it probably never will be widely used as a staple crop in permanent rotations. To fill such a position acceptably a crop must serve either as a "money crop" or as a soil improver. Under certain conditions in the Southern States Sudangrass utilized as a hay crop or for seed production may be considered as a cash crop, but in most cases it will be grown as an emergency hay crop or for summer pasture. The other two crops most widely grown as catch crops or emergency hay crops are millet and sorgo, or "cane."

Compared with other crops: In the northern Great Plains Sudangrass is less productive than millet. In the central Great Plains and Corn Belt, Sudangrass shows an average hay yield of about one-fourth ton per acre greater than the yield of millet, while in the southern Great Plains its yield is nearly twice that of millet. The yield of sorgo when drilled or broadcast averages in each region, except the timothy and clover area, about 1 ton more hay per acre than Sudangrass. This is partly because of the larger amount of moisture in the sorgo hay, due in a measure to the greater difficulty of curing its coarse stems. Any difference in the actual yield of dry matter is offset in some degree by the better quality of the Sudangrass hay.

Sudangrass and alfalfa: In many of the irrigated parts of the West where alfalfa is the principal crop and dairying the chief industry of the people, alfalfa has been made the constant and the almost complete diet of the cows. The continuous use of this high-protein hay has caused digestive troubles, but this derangement of the digestive functions seems to disappear promptly when the feed is changed. Under irrigation south of Oregon and Wyoming Sudangrass makes an excellent crop to grow for mixing with alfalfa. Yields of cured hay obtained under irrigation in California and Arizona have been equal and in some cases larger than those of alfalfa. At Chico, California, Sudangrass when irrigated gave a yield of 9.8 tons of cured
hay per acre, as compared with a yield of 8.3 tons of alfalfa hay; and at Bard, California, in the extreme southern end of the State, Sudangrass on favorable soil gave a yield of 8 tons of hay per acre, as compared with 7.9 tons of alfalfa. The yield of 8 tons at this place was obtained from grass planted almost a month later than it should have been. At Phoenix, Arizona, the yield of Sudangrass was 7.8 tons per acre, as compared with a yield of 9.8 tons of alfalfa, and at Owens, Arizona, Sudangrass made a yield of 4.5 tons per acre with only one irrigation during the season.

The percentage of moisture is apt to be somewhat greater in Sudangrass than in alfalfa when the weights are taken directly from the field, but less labor is necessary to handle the Sudangrass because the maximum yield from it is secured in three cuttings, while with the alfalfa five or more cuttings are required to produce the yields mentioned.

Sudangrass is the only grass which yields under irrigation in the Southwest even approximately as much as alfalfa. It can be used, therefore, in providing a change of feed without reducing the tonnage obtained from the land.

Value as soiliaing crop: Sudangrass is admirably suited for use as a soiliaing crop, since it makes a large yield and is very palatable in the green state. By this method of feeding, a small area in the South where the rainfall is adequate or where irrigation is possible, can be made to support a goodly number of animals. Large yields are secured under irrigation because the growth is so rapid and the recovery from cutting so prompt.

Use for silage: The use of Sudangrass for silage will no doubt be limited, owing to the case with which it can be made into hay, to the fact that there is but little waste in feeding it as hay, and to the larger silage yields of the sorghums and corn. The Oklahoma Experiment Station has conducted some experiments with Sudangrass silage. A considerable number of analyses were made which showed that Sudangrass silage was about the same in chemical composition as corn silage. Sheep did not relish the silage as well as they did corn silage, but they liked it equally as well as they did the silage made from grain sorghums.

Mixtures of Sudangrass with cowpeas or soybeans can be grown for silage in humid regions. Such mixtures make a bright-colored, palatable silage of high feeding value.

Sudangrass and legume mixtures: The suitability of Sudangrass for growing in mixtures with cowpeas, soybeans and other legumes in regions to which Sudangrass and these legumes are well adapted is at once apparent. (1) Sudangrass grows strictly erect, with a stem stiff enough to support the vines characteristic of most legumes, and it thus makes the harvesting easier by keeping the legumes off the ground. It also allows them to cure more quickly by preventing the leaves from matting. (2) It is low in protein which is abundant in the legumes, and thus a well-balanced mixture is produced. (3) The yields in the humid regions are equal to those of Sudangrass when sown alone, but the difficulty of getting a good stand and of harvesting the mixture is greater.

Tests of Sudangrass and legume mixtures in the States of Maryland, Virginia, Kentucky, Tennessee, Mississippi, and Louisiana during a 4-year period gave the following average yields: For Sudangrass and soybeans 2.96 tons, Sudangrass and cowpeas 2.93 tons, and Sudangrass alone 2.67 tons per acre. In dry regions such mixtures are not profitable except when irrigated. If there is insufficient soil moisture to support both the Sudangrass and the legume, the grass almost invariably crowds out the legume. The growing of such mixtures should therefore be attempted only in humid regions or where irrigation is possible.

Pasture: Sudangrass has attained popularity as a summer pasture crop. In regions of low rainfall and high temperatures, its carrying capacity during the hot months is superior to that of any other grass or legume. On the experimental farm at Dodge City, Kansas, a herd of milk cows was pastured alternately on Sudangrass and on native grasses. The Sudangrass furnished abundant pastureage at the rate of one cow per acre for 125 days, and the
cows made a daily average of 3.8 pounds more milk per cow on the Sudangrass than on the native grasses.

At Chillicothe, Texas, mules, horses and cows allowed the run of a field containing equal areas of Amber sorgo, Golden millet, and Sudangrass all showed a decided preference for the Sudangrass. At the Arizona Experiment farm near Prescott, Arizona, Sudangrass without irrigation maintained 20 sheep per acre continuously for 100 days. The sheep pastured on Sudangrass fattened, while those grazing Amber sorgo made only ordinary growth. The California Experiment Station pastured a nonirrigated field of Sudangrass with sheep at the rate of 22 head per acre. The sheep made gains of one-third of a pound a day while on the pasture, and no injurious effects were noted.

Sudangrass is also one of the best pasture grasses for irrigated lands in the Southwest. On the Yuma Experiment Farm at Bard, California, a small area of about 8 acres was pastured for six months with milk cows and work horses. The field was divided in halves and each half pastured alternately in periods of two to three weeks. The grass was irrigated in each case as soon as the animals were removed. The field maintained an average of three head per acre in good condition throughout the entire period.

In Australia Sudangrass was compared with Dallisgrass as a pasture for dairy cows. Although the cows were turned on the Sudangrass later in their lactation period than when pasturing the Dallisgrass, the yield of milk was greater from Sudangrass than from Dallisgrass.

Besides tests by experiment stations, numerous farmers have reported excellent results with Sudangrass pasture. This is particularly true in Indiana, Illinois, Iowa, and eastern Kansas, where it is being utilized as a summer pasture by scores of farmers.

Hogs relish the grass, and when they have access to Sudangrass pasture, good gains can be produced with 60 to 70 percent of the customary grain ration.

Little danger from prussic acid poisoning: Sudangrass, like Johnsongrass, is less likely to contain dangerous amounts of prussic acid than the larger sorghums. Where the growth is normal and not checked by drought or frost there is little or no danger of poisoning when the grass is pastured, and none at all from feeding properly-cured Sudangrass hay. However, during years like 1934, when severe droughts occur over almost the entire area in which Sudangrass is grown extensively, the danger of prussic-acid poisoning is greater, and some losses due to grazing Sudangrass occur. In such years extreme caution in grazing Sudangrass should be observed, especially in the northern Great Plains, where the danger of loss appears greater than it is in the South and East.

Several facts in regard to prussic-acid poisoning should be kept in mind by the grower of Sudangrass.

(1) The formation of prussic acid is most frequent in Sudangrass that has been injured by drought or other unfavorable soil and climatic conditions.

(2) Hogs can be pastured on Sudangrass in safety, and horses and sheep are less susceptible to the poison than cattle.

(3) Sudangrass poisoning is almost unknown in the Southern States and east of the ninety-eighth meridian. North of Oklahoma and west of the ninety-eighth meridian care must be exercised in pasturing Sudangrass with cattle.

(4) A remedy for prussic-acid poisoning has recently been discovered by workers in the Bureau of Animal Industry, United States Department of Agriculture. A mixture of sodium thiosulphate with sodium nitrite, if administered in time, will be found effective. The treatment, which is described in U.S.D.A. Leaflet 88 (revised edition), should if possible be given by a skilled veterinarian.

**VARIETIES OF SUDAN GRASS**

Because of the value and importance of Sudangrass as a supplementary pasture crop, considerable effort is now being made to improve its forage value by selection and breeding for disease resistance and lower prussic acid content. As a result of the intensive breeding pro-
grams carried on by the United States Department of Agriculture, and a number of State agricultural experiment stations, several promising strains have been developed which are now becoming available for general distribution.

**Sweet Sudangrass:** Sweet Sudangrass is a new variety of Sudangrass developed by the Texas station through hybridizing Leoti sorghum and common Sudangrass. Small lots of seed of the new variety were distributed to growers for increase in 1943, from which around half a million pounds of seed were produced in 1944. Approximately five million pounds of seed were produced in 1945 when the crop was grown in nearly every State, and in 1946 it is estimated that approximately one-half of the Sudangrass seed grown in the United States was of this new variety. In 1949 even though both Texas and California produced more Sweet Sudangrass seed than other varieties, the production of Sweet for the United States was estimated at less than 40 percent of the total.

The characteristics, sweet and juicy stem, non-shattering seed, disease resistance, and the distinctive sienna glume color have been incorporated into the new variety from the Leoti parent, while at the same time retaining the grassy characteristics of Sudangrass. Incorporation of sweetness and juiciness into the new variety has made it more palatable to livestock. The distinctive sienna seed color of sweet Sudangrass permits ready detection of Johnsongrass seed contamination and distinguishes it from other Sudangrass seed. Sweet Sudangrass is somewhat resistant to certain of the foliage diseases found on common Sudangrass, although it is not as resistant as Tift Sudangrass. It is resistant to chinch bugs and also more resistant to charcoal rot than common Sudangrass. Sweet Sudangrass is slightly later than common Sudangrass which, together with its sweet and juicy stalks and resistance to plant diseases enables it to remain green and growing over a longer season and to furnish more grazing of a better quality. The palatability of the grazing does not deteriorate with maturity so much as it does with common Sudangrass, and the mature stalks or cut bundles still remain palatable.

**Tift Sudangrass:** Tift Sudangrass was developed at the Tifton, Georgia, Experiment Station, as a selection from a cross made between Sudangrass and Leoti sorghum in 1936. It has a pithy, non-sweet stem, and tends to tiller and develop side branches more than common Sudangrass, thus continuing vegetative growth and suppressing fruiting and seed development. Seed heads appear a week to ten days later than in common Sudangrass, are smaller, and produce lower yields of seed. The leaves are a lighter green and glossy, in contrast with the non-glossy leaf of common Sudangrass. The seeds are slightly larger than common Sudangrass seeds and have chocolate glumes which often fade to straw color. The vegetative character of growth typical of Tift Sudangrass makes for good yields of forage under favorable conditions, although the stalks and leaves are not so palatable as sweet Sudangrass or common Sudangrass for either pasture or hay. The tendency to remain vegetative and the glossy leaf characteristic undoubtedly contribute to the very high degree of disease resistance found in this variety. It is more resistant than other varieties of Sudangrass to leaf blight (*Helminthosporium turceum*), which so commonly attacks Sudangrass and sorghums in humid regions, thus making it a valuable variety for growing where this foliage disease is destructive.

**Sudangrass No. 23:** California No. 23 Sudangrass was developed as a plant selection at the Imperial Valley Experiment Station, in the early 1930's. It was named Sudangrass No. 23 and was reselected to eliminate the black seed and other off-types at the University Farm at Davis, and was distributed to farmers in 1938. Since then it has rather consistently produced around 15 percent more than Common Sudangrass which it has largely replaced in California. Sudangrass No. 23 grows taller and more vigorous, has a courser stem than Common Sudangrass, and has a good recovery after mowing and grazing. Of the 8,400,000
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pounds of Sudangrass seed produced in California in 1949, over 40 percent was No. 23 and 60 percent was Sweet.

SEED PRODUCTION

Sudangrass produces seed freely in a loose, open panicle which is held nearly erect by the stem and can be harvested easily. The seed is retained fairly well, and thus the loss from shattering is much less than in other wild forms of sorghum. However, on the Great Plains, high winds sometimes shatter out a large percentage of the seed.

Acreage and production: The total United States acreage of Sudangrass harvested for seed for the 10 years (1938-47) has averaged 126,000 acres with an average production for the same period of over 46,000,000 pounds of seed. The largest year's production for the period was 5,000,000 pounds of seed in 1941, and the smallest was 21,540,000 pounds in 1947. The averages for 1946 and 1949 were 63,000 acres and 27,000,000 pounds of seed.

At the present time (1948-49), California, Colorado, Texas and New Mexico are the largest seed-producing States, producing, respectively, for the 2-year period an average of 6,800,000 pounds, 5,200,000 pounds, 4,800,000 pounds, and 4,300,000 pounds. Nebraska, Kansas, Oregon, and Oklahoma also produce Sudangrass seed in commercial quantities, and sometimes one or another of them is far behind one of the three leading States. Seed yields are the largest in the irrigated regions of California where they range mostly from 600 to 900 pounds per acre, and are smallest in the dry, unirrigated sections of Oklahoma, Kansas, Nebraska, Colorado, and Texas, where they average from 250 to 290 pounds per acre.

Harvesting seed crop: Harvesting the seed is accomplished most economically with an ordinary grain binder or a row binder. When the seed is practically mature, Sudangrass can be cut and bound like grain and left to cure in shocks. It may then be hauled directly to the threshing machine or stacked in the same manner as bundle grain. There is danger in stacking Sudangrass, however, because the sap in the stems dries out slowly, and if stacked before it is cured thoroughly the grass will heat in the stack and injure the viability of the seed. Growers usually find it best, therefore, to allow the Sudangrass to remain in the shock until they are ready to thresh. The use of shock covers results in a much brighter, better quality of seed.

The ordinary grain separator threshes and cleans Sudangrass seed very satisfactorily. Care must be observed to so regulate the air blast as to prevent seed from being blown into the straw pile. A clover huller also has been used with success in threshing Sudangrass, but seed threshed in a clover huller is likely to be rather completely freed from the hulls and therefore weighs much heavier than ordinary seed.

There are about 55,000 seeds of Sudangrass per pound, and the seed varies in weight from 25 to 40 pounds per bushel. Good clean seed should weigh 36 to 40 pounds per bushel, and such seed will pass through the feed of an ordinary grain drill without clogging.

Sudangrass vs. Johnsongrass: The seed of Sudangrass resembles Johnsongrass seed very closely, except that it is larger and more plump. No machinery for separating the two kinds of seed has been devised; hence, the only way of obtaining pure Sudangrass seed is to guard against its mixture with Johnsongrass during the growing period and in the threshing process. South of 38° north latitude which runs through the center of Missouri and Kansas, Johnsongrass behaves as a perennial and is troublesome because it is difficult to eradicate. North of the thirty-eighth parallel of latitude, roughly speaking, Johnsongrass is not troublesome, because it usually is killed by the winter freezes. A slight admixture of Johnsongrass in the Sudangrass seed sown for hay production north of the thirty-eighth parallel is no great disadvantage. South of this line, where Johnsongrass is likely to become a pest, care must be used to see that the Sudangrass seed is free from Johnsongrass seed.
The following suggestions may be remembered with advantage by the farmer in the Southern States: When he buys Sudangrass seed and his land is free from Johnsongrass, he should try to purchase that grown outside the Johnsongrass region or from responsible growers in the South who can guarantee the purity of the seed. If the Sudangrass is to be sown on land already containing Johnsongrass, the presence of seed of the latter is a matter of small importance.

The presence of even a small number of Johnsongrass seeds can be detected by a properly trained seed analyst.

Hybridization with other sorghums: A point to be remembered in the production of Sudangrass seed is that the plant hybridizes very freely with other sorghums, especially with the sorgos. In dry regions where the pollen is carried for considerable distances by the wind, a Sudangrass field intended for a seed crop should be 60 to 80 rods from any other sorghum. Another source of cross-pollination exists in the volunteer plants of sorghum sometimes found in fields that were planted to sorghum the previous year. To avoid such sources of trouble, fields that have been growing other crops than sorghum should be chosen for the Sudangrass seed crop.

To make sure of pure seed, roguing the field at least once a year must be resorted to, and the rogues should be removed before a chance has been afforded for cross-pollination. The great need of special efforts to keep Sudangrass pure is illustrated by the present condition of the sorgos, very few fields of which are to be found anywhere that are pure as to variety. They are very commonly mixed not only with other varieties of sorgo, but also with the grain sorghums. Unless seedsmen and growers unite in an effort to keep their seed fields free from sorghum hybrids, Sudangrass will lose much of its distinctiveness within a short time.

**DISEASES AND INSECTS**

Several of the more common diseases and insects that attack Sudangrass are the following, which are more fully discussed in chapter IX:

**Diseases:** Sudangrass is subject to serious attack by at least three bacterial diseases, the bacterial spot disease, the bacterial streak disease, and the bacterial stripe disease, all three of which affect the leaves of the plant. The fungus that causes leaf blight of corn also attacks Sudangrass. It also affects the leaves of the plant thus lessening its ability to manufacture and store plant food.

Anthracnose of Sudangrass has also been reported from a number of States, mostly southeastern, where it has been especially severe some years. The leaf spot caused by *Ascochyta sorghini* has been reported on Sudangrass from Georgia only. There it is a well-established parasite capable of causing considerable damage. Sudangrass is also subject to the same covered kernel smut that affects sorghums.

**Insects:** Practically the same insects are injurious to Sudangrass that are troublesome to the sorghums, i.e., grasshoppers, chinch bugs, and the sorghum midge. The midge is destructive only in the South and largely prevents the production of Sudangrass seed from Texas east to the Atlantic Coast.

**SUDANGRASS HIGHLIGHTS**

1. Sudangrass was obtained in 1901 from the Sudan Government as the result of a systematic search for a form of Johnsongrass without rootstocks.
2. No other plant importation ever gained such immediate and widespread popularity in the United States as Sudangrass for hay or pasture.
3. Sudangrass is strictly an annual, without underground rootstocks. It grows to a height of 3 to 5 feet when sown in drills, and 5 to 8 feet in cultivated rows.
4. Sudangrass requires a warm climate for its best development and is of most value as an emergency hay and pasture crop.
5. Sudangrass is superior to millet in all except the northern third of the United States.
6. Sudangrass is generally drilled for hay
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and pasture production, and grown in cultivated rows for seed production.

7. The best time to cut Sudangrass for hay is when it is in full head, but the grass can be harvested somewhat earlier or later than this with no material loss in feeding value.

8. In irrigated sections of the Southwest, Sudangrass yields practically as much hay as alfalfa and is very useful in providing a variety of roughage for dairy cows.

9. Sudangrass hay is equal in feeding value to that of timothy, millet, or Johnsongras.

10. Sudangrass is a good soiling crop, but is of minor value for silage.

11. Sudangrass is being utilized chiefly as a summer pasture in the Central and Southern States, and is valuable as pasture in the irrigated districts of the Southwest.

12. There is less danger of prussic-acid poisoning in pasturing or feeding Sudangrass than with the larger sorghums, but care must be observed in pasturing the grass, especially in the Northwestern States.

13. Feeding experiments have shown Sudangrass hay to be an excellent roughage for work animals and stock cattle and only slightly less valuable than alfalfa hay for milk cows.

14. Seed production of Sudangrass is profitable only in certain favored localities. Johnsongrass seed is dangerous as an adulterant in Sudangrass seed south of the thirty-eighth degree of latitude.

15. Sudangrass hybridizes freely with the other sorghums, and care is necessary to keep it from becoming a mongrel crop, as have many of the sorghos.

16. Several varieties of Sudangrass have been developed, each having one or more improvements over ordinary Sudangrass.

17. Sweet Sudangrass, a new variety developed in Texas, is characterized by its sweet, juicy stem, non-shattering seed, disease resistance, and distinctive stem seed color. A large part of the Sudangrass acreage in Texas and other central Southern States and in California is now sweet Sudangrass.

18. Tilt Sudangrass is a variety selected for the Southeast, which is more disease-resistant than the common Sudangrass but is coarser and a poorer seed producer.

19. Sudangrass No. 23 is a heavy producer selected from common Sudangrass especially for California conditions.

JOHNSONGRASS

(Sorghum halepense)

Johnsongrass is a native of the Mediterranean coast countries of Europe and Africa and of Asia eastward from the Mediterranean through Arabia to India. It was introduced into the United States about 1830. Ten years later Col. William Johnson of Alabama sowed some seed on the rich bottom lands of the Alabama River. It thrived wonderfully in this new locality, and because Col. Johnson was the first planter to grow the new grass in any great quantity, it was named johnsongrass.

On account of its aggressive underground stems, johnsongrass has become a nuisance in the alluvial river bottoms and rich black prairie lands of the Gulf States and as far north as the Ohio Valley and southwestern Kansas. It is also classed as a dangerous weed on the irrigated lands of New Mexico, Arizona, and California, where it grows luxuriantly along the irrigation canals. Unless kept from maturing, the seeds are scattered each year over the fields in the irrigation water. The same thing happens also on the river-bottom lands farther east where they are subject to occasional overflows.

In spite of all the objections to johnsongrass, it must be said in its defense that it has supplied a substantial part of the hay for livestock feed in the South, that when it gives good yields of hay when properly managed, and that such hay, when cut at the right time and well cured, is equal or superior to timothy and most other grass hays. There is no intention here to encourage the extension of johnsongrass production, but to encourage the better and more efficient hay production on the present areas of occupation and the better use of the hay.

DESCRIPTION

johnsongrass is a stout, erect, perennial grass with rather broad leaves in
which the middle vein is thickened and white. The panicle, or seed head, is large and open when in bloom, and the spikelets, or seeds, are deciduous, shattering easily when ripe. Besides the fibrous roots customarily associated with grasses, Johnsongrass produces numerous underground stems, or rootstocks, which send up shoots from the nodes, or joints, thus producing new plants. It resembles and is closely related botanically to Sudangrass, the chief difference between the two grasses being the presence of rootstocks on the former. These rootstocks on Johnsongrass are most abundant at a depth of 6 to 8 inches, but in cultivated fields they often penetrate 18 to 24 inches beneath the surface of the soil. The stems vary in height from 3 to 6 feet, according to the richness of the soil and the abundance of soil moisture. Ordinarily, in thick stands, the stem is not more than one-eighth to three-sixteenths inch in diameter, but on exceptionally vigorous plants it often exceeds that thickness.

ADAPTATION

Climate: Johnsongrass is now rather abundant from the Atlantic coast west to central Texas south of the southern boundary of Tennessee. It is commonly perennial north to the northern part of Kentucky, central Missouri, and into southern Indiana and Illinois, and has persisted in cultivated fields even farther north than this. In western Texas and in Arizona, New Mexico, and southern California, Johnsongrass is found chiefly in the irrigated districts; but it extends along the Pacific coast in the river valleys as far north as Oregon and Washington. Soils: Johnsongrass is primarily a richland crop. It is always found on the better soils and makes only an indifferent growth on the uplands and poorer soils. On such land other crops may be grown even where Johnsongrass has obtained a foothold. On the river bottoms and the rich black soils of the Cotton Belt where Johnsongrass thrives, it is expensive to grow cotton or other crops on account of the labor required to keep these crops free from this grass.

HAY PRODUCTION

The largest centers of Johnson hay production, or at least the largest primary markets of this hay in the United States, are Augusta, Ga., Montgomery and Selma, Ala., Columbus and West Point, Miss., and San Antonio, Waco, and Fort Worth, Tex. Birmingham and Mobile, Ala., New Orleans, La., and Savannah and Atlanta, Ga., are also large marketing centers, but most of the Johnson hay on these markets is brought from a distance. The black prairie soils in the vicinity of Montgomery, Ala., are devoted to Johnsongrass almost to the exclusion of cotton and corn, the two major crops of the Gulf States. This is true also of the narrow belt of dark limestone soil as it extends westward to the western boundary of Alabama and northwestward in Mississippi past West Point. Meadows and pastures of Johnsongrass occupy much of this land, and the production of livestock is important.

Establishing a meadow: Very few of the Johnsongrass meadows in localities and on soils where the grass thrives have been established by sowing the seed intentionally, at least by the present owners and operators of the farms. The grass has become established in many fields unintentionally, by floods, or by the farmer sowing oats which were produced in a Johnsongrass region. Therefore, in localities suited to the production of Johnsongrass, it is rarely necessary for the grower to sow the grass, because it is already on his land. If sowing is necessary, a stand can be obtained easily by sowing the seed at the rate of 20 to 30 pounds per acre with an ordinary grain drill on land prepared by plowing and harrowing in the same way that is usual for the seeding of oats or other small grains. Johnsongrass should always be sown in the late spring or early summer, as it is a summer-growing plant.

Cultivation: The productiveness of a Johnsongrass meadow depends primarily
JOHNSON GRASS
upon the character of the soil. On the richest and most suitable soils, however, the meadows will not maintain their original yields unless they are cultivated at intervals. This cultivation consists in most cases of plowing in the fall or early spring and working the soil down with a disk or a spike-tooth harrow. This kind of cultivation which would be ruinous to most grasses, merely serves to stimulate the growth of Johnson grass. The thickness of the stand and the quality of the hay are both improved by frequent cultivation of the meadow in this way.

Most hay growers believe that plowing every third year is sufficient, and many plow only when their meadows become unproductive or so overrun with other grasses and weeds that the hay is of poor quality. 

Renovation: On some meadows where a heavy tonnage of hay has been removed annually for a period of years, the yields have gradually declined to such an extent that the production of hay is no longer profitable.

One remedy for such a situation is to break or cultivate the meadow early in the spring and plant it to soybeans. This practice serves to thicken the stand of Johnson grass; a valuable crop of legume hay is obtained, and the tonnage of later cuttings of Johnson grass is increased. Some producers are keeping their annual production up to 3 tons or more to the acre by following this practice. Another practice is to sow the meadow to sweetclover. Mixtures of Johnson grass and sweetclover should be cut when the sweetclover is just beginning to bud, in order to make a palatable hay of good quality.

On thin upland the soil is often too poor to produce profitable yields, even though a good stand of Johnson grass is maintained. In the Black Prairie Belt a good method of improving such meadows is to sow them to sweetclover and allow both Johnson grass and sweetclover to remain uncut for two years, then turn the whole mass of vegetation under. This usually results in a tremendous increase in the yield of Johnson hay.

Irrigation: The irrigation of Johnson grass is practiced extensively in the vicinity of San Antonio, Texas. The first cutting on these irrigated meadows is taken off late in April or early in May. If this cutting is weedy, it is raked up and pushed into the irrigation ditches, where it is burned. The field is then irrigated unless rain has been abundant and new growth starts immediately, so that the second cutting is usually ready early in July. The field is irrigated again as soon as the hay is off, and the growth is rapid, the third cutting being ready by August 15 to 20. This cutting is usually equal to the second in quantity; and ordinarily, as there is very little rain at this time of year to interfere with curing, the quality of the hay is excellent. Another irrigation is then given the land, and a fourth cutting is ready by the last of September or early in October. This usually ends the haying season, as frost normally occurs at San Antonio in October.

The growth of the grass on the irrigated fields is much more nearly uniform, the stand is usually better, and the yields are nearly double those obtained on unirrigated fields. This uniformity in growth and stand results in a higher grade of hay, because the time for cutting can be regulated to better advantage. The unirrigated meadows often present a ragged appearance, some spots in the fields showing a good stand and luxuriant growth, while the remainder is occupied by weeds and other grasses or by Johnson grass which has made only an indifferent growth.

When to cut hay: Other things being equal, the quality of Johnson hay depends largely on the stage of maturity at which it is cut. Most of the extensive producers begin cutting when the grass is in the "boot" or even before this stage is reached, and if possible complete the mowing before any of the heads have formed seed. On account of its high moisture content, Johnson grass cut in the "boot" is usually more difficult to cure than when cut at a more advanced stage of maturity, but when properly handled it makes the most desirable hay as regards both feeding value and market grade.
Johnsongrass should be cut at the time of day that will permit of its being cured and put into cocks, or stacks, or baled with the least possible exposure to dew, hot sunshine, or showers.

**Curing the hay:** Johnsongrass must be well cured before it is baled; otherwise, it is sure to heat and spoil in storage. The danger of injury in this way is greater in the case of this grass than with other hay grasses, because of its coarse stems.

Rapid, even, and thorough curing is essential to the making of a hay of high quality. Johnson hay that is left in the swath exposed to two or three heavy dews or an occasional shower loses quality through bleaching or weather staining, consequently the more quickly the hay can be cured sufficiently for baling, cocking, or stacking, the better the quality will be.

**Stacking:** Most hay dealers and some growers believe that a better average grade would be obtained if the hay were stacked and allowed to go through the sweat before it is baled. It is possible that the increased premium obtainable for the better grades under United States standards will induce a larger percentage of the producers to stack their hay.

Some let the hay cure thoroughly in the swath and windrow and stack direct from the windrow. Others put the hay in cocks before it is thoroughly cured and let it stand for several days before putting it in the stack. The latter method usually results in hay of a better color and is a safer practice to follow in unsettled weather, but it requires considerably more labor than stacking from the windrow. In good weather when hay may be safely stacked direct from the windrow the saving in labor will usually more than offset any gain in quality of hay that might result from cocking before stacking.

One objection offered to stacking in general, and particularly where the hay is put up in large stacks, is that frequently a considerable quantity of hay in the bottom of the stack will be damaged by absorbing moisture from the ground or by water from a heavy rainfall running under the stack. This trouble may be obviated to some extent by care in choosing the highest and driest ground for the stack site, and by placing a layer of poles or other damage under the stack to keep the hay from coming in close contact with the ground.

**Baling:** When conditions for curing are favorable, many growers rake the hay which was cut in the forenoon on the afternoon of the day following and place it in bales directly from the windrow on the third day in the afternoon. Baling is done directly from the windrow by the use of a pick-up baler, or a buck or sweep rake is used to push the hay to a stationary baler for baling. Other growers prefer to allow Johnsongrass to go through the sweat in cocks or stacks. When baled from the windrow, it has no opportunity to go through a sweat before baling; sweating then usually takes place in the bale after storage in barn, or a warehouse at the city market, or in a freight car if it is loaded directly for shipment. Sweating in the tightly compressed bales demands well-cured hay if spoilage is to be avoided.

Windrow baling is more generally practiced by producers with whom hay production is the principal enterprise and those farms are organized and equipped to handle the crop in an efficient and expeditious manner. Where conditions are favorable and the work is properly done, it is by far the most economical method of handling Johnson hay.

**Yields and quality of hay:** It is possible to cut Johnsongrass for hay three or four times each year. Frequently, however, the first cutting is too weak to be marketed and must be used for feed work on the farm or burned to get it off the land. In some places east of the Mississippi River, particularly near Augusta, Georgia, the narrow-leaf vetch volunteers in the meadows and is present in considerable quantity at the first cutting. The presence of this legume improves the feeding value of the hay.

Yields per acre vary considerably under different conditions in different areas from a top of around 6 or 7 tons on the irrigated lands in the vicinity of San...
JOHNSON GRASS

Antonio, Texas, 3 or 4 tons on the bottom lands near Augusta, Georgia, and 1 to 4 tons in the Black Prairie Belt of Alabama and Mississippi, down to 1 ton on the less productive unirrigated soils of any of the Johnson grass producing areas.

The average quality of the Johnson hay produced in Mississippi, Alabama, and Georgia is rather low. Much of this hay is discolored or bleached by the sun, and often there is a high percentage of other grasses or foreign material which lowers its market value. In order to produce hay that will grade high, it will be necessary to renovate the meadows oftener and use more care in curing to retain the bright-green color so desirable in market hay.

The hay produced at San Antonio, Texas, especially on irrigated meadows, is excellent in both color and purity. Hay from the unirrigated meadows in this locality lacks somewhat in purity, but has a good color, because the weather conditions during the summer are almost ideal for curing.

Feeding value: Stockmen in the Cotton Belt are practically agreed that Johnson hay has a higher feeding value than timothy. If a uniformly high grade of this hay could be obtained, there would be very little dissatisfaction with its feeding value. Most of the complaints arise from the fact that there is so much poor Johnson hay on the markets. Where Johnson grass is allowed to stand until the seed ripens, it becomes unpalatable, because it is coarse and stemmy. Other causes, such as weeds and leaching by frequent rains during the curing period, affect adversely the feeding value. Timothy is better cared for on the average, and this results in the impression among many feeders that it is a better hay.

The composition and digestibility of Johnson hay compare favorably with those of other grass hays. It is, however, much less valuable than the legume hays.

Weeds and crop mixtures: Various grasses, legumes, and weeds become abundant in Johnson grass meadows, especially in the humid portion of the Cotton Belt, if the meadow is not plowed or otherwise cultivated at intervals of two to five years. Some of the grasses and legumes are of considerable value as hay plants, whereas others are entirely worthless.

Even though some of these grasses and legumes are by themselves or in other mixtures of value for forage, they are generally considered undesirable in Johnson grass meadows for one reason or another. Johnson grass is rarely, if ever, included in a regular rotation system with other crops.

Mixtures with cowpeas and soybeans may be considered the exception to this general rule. If a Johnson grass meadow is plowed in the spring and sown to cowpeas or soybeans, the grass will come back and grow intermixed with the legumes. This produces at the first cutting a mixed hay which has a very high feeding value.

JOHNSON GRASS PASTURE

Johnson grass would appear to be eminently fitted for use as pasture. Its rhizomes or underground rootstocks provide for a continual supply of new plants; thus, even if the old plant did not possess the ability to renew its growth when it was cut off or grazed off, there would be new foliage on which the animals could feed. There is no trouble, either, regarding its palatability, all classes of livestock relishing it, particularly before it has headed and become stemmy.

Notwithstanding these advantages, Johnson grass is not a good pasture plant. When heavily grazed it weakens and gives way to other grasses and weeds, and even if the stand is maintained, the growth is less and less until it becomes unprofitable. Sturkie of Alabama, a number of years ago, found that Johnson grass rhizomes were formed each year and died during the following year. These rhizomes were formed largely as Johnson grass approached maturity. When kept closely cut new rhizomes did not form to any appreciable extent, and therefore the following years the stand was thinned considerably. This explains why Johnson grass is not well adapted for grazing.
Pasturing the meadows during the winter is resorted to regularly in the irrigated districts near San Antonio, Texas. The unirrigated meadows of Texas, Alabama, and Mississippi are sometimes pastured lightly, but all agree that pasturing at any time injures the grass and lowers the yield of hay. The injury is much less on the irrigated meadows. Pasturing in the States east of Texas usually results in the presence of other grasses such as Bermuda-grass and Dallisgrass, which are better than Johnsongrass for pasturage but much less desirable for hay.

Johnson hay growers who are not provided with facilities for irrigating their meadows are almost convinced that pasturing, even in a very limited way, injures the meadow. Most of them prefer to do without the pasture in order to preserve the yielding capacity of their meadows.

Pasturing Johnsongrass apparently causes the rootstocks to be smaller and to form near the surface. Therefore they do not provide as much food reserve as usual and are more subject to injury from low temperatures, drought, etc. Weeds and grasses invade the pastured meadows in greater numbers than those not pastured. Dallisgrass, Bermuda-grass, and crabgrass are all injured less by pasturing than Johnsongrass and therefore tend to become more abundant each year in the meadows which are pastured. Dallisgrass and Bermuda-grass make better permanent pastures than Johnsongrass but are less productive as hay.

SEED PRODUCTION

Johnsongrass produces seed in abundance, and it can be harvested easily either with a grain binder or a mower and rake. The greatest difficulty in saving a Johnsongrass seed crop is due to the ease with which the seeds shatter when even approximately mature.

The seed threshes out easily, and this operation can be performed with an ordinary grain separator by using special sieves or screens. Very little seed of Johnsongrass is required by the trade, because the grass is so nearly spontaneous in its habits of renewing old meadows and invading new areas, and because of the unpopularity of the crop.

Germination is nearly always retarded in a certain percentage of the Johnsongrass seeds, as it is in the hard seeds of clover and alfalfa. This dormancy of a part of the seeds adds to the difficulty of eradicating the grass, because these dormant seeds will germinate and produce new plants for several years after their production by the seed plant. Much of the discouragement attending the eradication of this grass from a cultivated field arises from this seed character.

JOHNSONGRASS HIGHLIGHTS

1. Johnsongrass is adapted to that part of the United States south of latitude 36°. In this region it has occupied the better soils, particularly those of limestone origin, and has made the production of other crops on these soils very difficult and expensive.

2. Where it already occupies the land, Johnsongrass may be utilized profitably as a hay crop with good field care, but it does not make a good permanent pasture.

3. Meadows are more productive if they are plowed up every third or fourth year. Unless the land is cultivated occasionally, other grasses invade the meadows and reduce the yield to a point where hay production is unprofitable.

4. Johnson hay, if cut early and properly cured, is equal in feed value to timothy and most other grass hays.

5. The demand and the price paid for Johnson hay are greater than they should be, because of the poor quality of much of the hay offered for sale. Better methods of curing and storing the hay would result in increased profits.

6. Pasturing Johnsongrass weakens it considerably and causes the rootstocks to be produced near the surface, thus making it easier to destroy the grass.

7. It is not profitable to grow Johnsongrass in the Northern States, where it behaves as an annual; and it is not adapted to poor, thin soils anywhere.

8. Johnsongrass is a bad weed in cultivated fields in the Cotton Belt, and it is rarely advisable to sow it on land where it is not already present.
The material on forage sorghums in this chapter was obtained mostly from Martin and Stephens (US-146), that on Sudangrass from Vinall and Hein (US-271), and that on Johnsongrass from Vinall and Crosby (US-273). This has been supplemented by material from bulletins of the stations in the Southern Great Plains and Central States. The manuscript on the sorghums and Sudangrass was reviewed by Karper of Texas, Lande of Kansas, and Martin of the U.S.D.A. That on Johnsongrass was reviewed by Karper and Martin, and also by T. H. Rogers of Alabama, and Hein and Hosterman of the U.S.D.A.

Chapter reference numbers: ¹

Sorghums: ARIZ-3, 7; COL-1; IDAHO-5; IOWA-25; KAN-22, 26; NEB-4; OKLA-13, 24; OREG-25; SD-2, 6, 10; TEX-25, 26, 28, 47, 48; US-140, 146.

Sudangrass: GA-9; IND-10; MICH-17; OHIO-33; OREG-25; SD-15; TENN-14; TEX-27, 29, 46; WIS-16; US-70, 87, 271; MISC-51.


¹The reference numbers given here refer to references which are given in full by State, U.S.D.A., and Miscellaneous, on pages 682 to 724, and which are cross-referenced by author on pages 725 to 731. Citations in the text are indicated by abbreviation and number in parentheses.
CHAPTER XXIX

MILLETS

(Setaria, Panicum, Echinochloa and Pennisetum spp.)

The name millet is applied to a number of cultivated annual grasses representing genera not closely related. Some of the millets are used largely as forage crops and others as cereals. In the United States all except the broomcorn millet are used almost exclusively for forage purposes, but in Africa, India, China, Korea, Japan, and Russia the millets are grown extensively for human food. In China the broomcorn and foxtail millets are most common. In India, pearl millet, which is grown there under the native name of bajra, is the most important millet. Korea and Japan produce considerable proso and foxtail millet, and the latter country also devotes a considerable acreage to barnyard millet, which is grown there almost entirely for its seed; but the millet crop is of minor importance in these countries, as it is in Europe, where it is not cultivated extensively except in the Mediterranean region and in Russia. Much proso or broomcorn millet is produced in Russia, especially in the southeastern provinces. Of all these millets, the foxtail millet is most important in the United States, especially for forage, and in the following pages, unless otherwise specified, any reference to millet will mean foxtail millet.

The use of all millets in the United States has declined during the past 15 or 20 years until now there is only a small percentage of the former quantity sown, but this varies considerably with the different kinds of millet. Because of there being no Government statistics as to acreage and production of millet seed available for recent years, a survey was made of a number of seedsmen who were known to have been important handlers of millet seed, to ascertain quantities handled by them now as compared with 10 or 20 years ago, when reports of acreage and production of millet seed were available.

The southern-grown German millet seed which was in such great demand some years ago was produced largely in Tennessee, Texas, and parts of Kansas, and Missouri. This production was reported by some dealers to have declined in some sections to from 10 to 30 percent of former production. It is probable that the total production and utilization of German millet today is less than one-fourth of what it was 15 or 20 years ago. The production and use of common millet has declined still more, so that some dealers who formerly handled considerable quantities do not even list it today. Hungarian millet that was formerly produced in Indiana, and to a small extent in some other Corn Belt States, has almost passed out of the picture. Some localities where it was formerly produced, do not produce any seed at the present time.

There is still some production of Siberian millet seed in the Dakotas, and perhaps elsewhere in the Northwest, but this also has declined materially, probably down to 25 percent of former production. The proso or broomcorn millets that have been produced in the Northern Great Plains States and Colorado principally for feed purposes instead of for forage, are still being produced in considerable quantities but much less than formerly.

Japanese or barnyard millet which
was produced principally in New York, Pennsylvania, and Iowa, is still produced in considerable quantities in the first two States, but has practically disappeared from production in Iowa. The reduction in New York and Pennsylvania is probably around 25 or 30 percent, or perhaps more than this, though it is estimated that 2 or 3 million pounds may have been produced in southern New York and northern Pennsylvania in 1948 where it is now mostly grown for both forage and seed.

Millet in the past has always been considered more as an emergency or catch crop to be sown on land which, for various reasons, could not be gotten into crop early enough in the year, or on newly plowed sod ground, than as a regular farm crop. Since the tractor and other mechanical tools have made it possible to prepare land and plant a crop in much less time than formerly, and because of the great range of season and availability of seed of hybrid varieties of corn, it has been possible to get in crops in the Corn Belt in much less time than heretofore, and to plant a crop better adapted to the time of sowing, so that there has not been the demand for catch crops like millet. Also, there have been other crops like Sudangrass, soybeans, sweetclover, and other legumes which are superior for this purpose to millet.

For these and other reasons, it is not probable that millet will ever again become as important a crop as it was some years ago. However, the millets cannot be ignored entirely and it is well to hold them in mind for certain uses for which other crops might not be so well adapted, or cannot be so economically used. The fact that millet seed can be produced so cheaply as compared with some other seeds puts it in a class with catch crops somewhat comparable to timothy with other perennial grasses.

**FOXTAIL MILLET**

*Setaria italica*

Foxtail millet was cultivated in China as early as 2700 B.C., and later introduced into Europe. In 1849 seed was distributed by the United States Patent Office, and by 1899 it had become a rather important crop in the Central States.

Foxtail millet has been one of the leading annual hay crops of the northern and central Great Plains States, and is of considerable importance in the Northern States, but its use in the Cen-
tral and Southern States in recent years has been curtailed by Sudan grass and certain legumes which have largely taken its place as emergency crops.

DESCRIPTION

The foxtail millets are annual grasses with slender, erect, or ascending stems. Under dryland conditions in the Great Plains, the plants vary in height from 12 to 40 inches, depending upon variety and season. In the Southcentral States, with greater rainfall, they grow to a height of 4 or 5 feet. The leaves are broad and flat and usually extend well toward the top of the culm. The flowers are borne in a rather dense cylindrical panicle or spike. In the foxtail millet, and in the green foxtail from which it is supposed to have been derived, there are from 1 to 3 awns or bristles at the base of each spikelet which give the whole spike a bristly appearance. The seeds are small, convex in shape, and are enclosed in thin papery outer glumes or hulls which are removed in threshing, and hard inner glumes or hulls which remain attached to the threshed seed. The inner hulls are of various colors, including a creamy white, pale yellow, orange, green, purple, or mixtures of various colors.

VARIETIES

The foxtail group of millets includes many varieties which are quite distinct in habit of growth and adaptation to different climatic conditions, although all are very closely related botanically. The five most commonly grown, and which are described here, are Common, German, Hungarian, Siberian, and Kursk. Common millet: Common millet was one of the first millets to be grown in this country. It is sown rather extensively over the entire area where millets are grown and makes up a large percentage of millets in the Dakotas, Iowa, Nebraska, Kansas, and Oklahoma. This is a distinct variety and not a dwarf early form of German millet developed by growing in the North or under dry conditions, as has been believed by some.

Common millet is fine stemmed and leafy, with a close, compact head, tapering slightly toward the upper end, the lower part of the head usually being looser than the middle and upper part. The individual seed is yellow to straw color, oval to elliptical in outline, and decidedly flattened on one side. Common millet is characterized by a short season of growth, being one of the earliest of the foxtail millets. Tests in the Central States show that under average conditions it can be cut for hay in 69 days after the date of sowing, and in many cases only 50 days are required for it to mature sufficiently for hay. Under favorable conditions it produces 1 to 2 tons of hay to the acre, and this hay is of first-class quality on account of the slender stems and abundant leaves.

German millet: This variety became important in the United States first in the central valley of Tennessee, and this locality has continued to be the center of its distribution, many farmers in the vicinity of Franklin, Tennessee, making a specialty of the production of German millet seed. In the Southern States it has almost entirely supplanted other foxtail millets and besides is perhaps the principal millet in the Central States, since it is handled by more seedsmen than any other variety. In many places where it is grown, the season is not long enough to mature a seed crop, but it becomes sufficiently mature for hay and makes larger yields than the earlier kinds.

German millet has heavy stems, with broad leaves and a distinctly lobed head, nearly twice the diameter of that of Common millet, but only slightly longer and not so compact. The individual seeds are smaller and more nearly round in outline than those of Common millet. The surface of the seed coat of German millet is quite rough, with numerous minute elevations, which give it a dull appearance, while Common millet seed has only indistinct transverse ridges, which give it a polished or somewhat shiny appearance.

German millet is a long-season variety requiring on the average about 87 days, although under favorable conditions 65 days are sufficient for a hay crop. The
hay yield is larger than that of Common millet, but the quality of the hay is not so good.

**Hungarian millet**: This variety is characterized by a small, compact head, which in size and shape resembles that of Common millet very closely. The bristles, however, are usually purple in color, which, with the intermixture of dark-colored seeds, gives the head a darker appearance than that of Common millet. The individual seeds have the same oval or elliptical outline as those of the Common millet, but the color varies from pale yellow to brown, and sometimes very dark purple. Seeds of both colors are found in one head, but the colors are not mixed in a single seed. The season of maturity is about the same as that of Common millet, averaging 69 days in the Central States, but this variety will mature for hay in 54 days when soil and climatic conditions are right. Hungarian millet is not so well adapted to dry climates as Common millet, and the yield in such localities is apt to be small, but in the Eastern States, where the rainfall is greater, Hungarian millet does well and is widely grown.

The quality of the hay is first-class. The main objection to Hungarian millet in the humid regions has been its tendency to volunteer and persist on the land whenever it was allowed to produce seed.

**Siberian millet**: This variety was obtained from Russia about 1895. It is hardy and drought resistant, and is suited to Minnesota, the Dakotas, Montana, Wyoming, Colorado, western Nebraska, and western Kansas. In habit of growth and vegetative characters generally it is quite similar to Common millet, but it is a trifle more vigorous, and the head is somewhat larger.

The seeds, although similar in shape to those of Common millet in some cases and in others round like those of German millet, are always orange or yellow in color, and this character provides an easy method of identifying the variety when seed is purchased. The season of growth is slightly longer than that of Common millet and the yield is somewhat larger. The hay is about the same as that of Common millet in quality and feeding value.

**Kursk millet**: This variety is really a selection from Siberian millet. It was obtained by the United States Department of Agriculture in 1899, from the Province of Kursk, Russia, whence its name. Kursk millet has become popular in the western parts of North Dakota and South Dakota, and in eastern Montana and Wyoming, where no other variety can be so well depended upon to produce a hay crop in seasons of drought.

It differs from Siberian millet in being somewhat less vigorous in growth, and having a smaller, more compact head. The head resembles that of Hungarian millet very closely in size and shape and also in having purple-tipped or entirely purple bristles. Kursk millet is much more uniform than the commercial Siberian millet, because it has been the subject of selection during nearly the entire period since its introduction into the United States. This variety is the earliest of all foxtail millets requiring an average of only 64 days to produce a hay crop, and in many cases it has been ready to cut for hay in 45 days from the date of seeding. It produces large yields of seed, often exceeding those of the proso, or broomcorn millet which is considered distinctively a grain millet.

**Other varieties**: There are many other varieties of foxtail millet besides those described here, but no others have exhibited sufficient promise to warrant their discussion in this bulletin. It is quite possible that better varieties of millet may be developed than the German, Common, Hungarian, Siberian, or Kursk, but these varieties seem to supply the needs of the farmers at the present time.

### ADAPTATION

**Climate**: To succeed well, millet must have warm weather during the growing season. It does not grow well at high altitudes or in other localities where cool weather prevails during the summer months. Notwithstanding this preference for warm weather, millet is grown successfully in our most northern States,
especially those in the Great Plains region, because in those States the summers, though short, are hot. Millet, as it matures quickly, can be planted and harvested during these summer months. The long days prevailing in this latitude provide plenty of sunshine, and thus a less period of time is required for maturing the crop.

Millet does best in localities which have a fairly abundant rainfall. They do have a low water requirement, but they lack the ability to recover after being injured by a period of drought. The millets succeed in localities subject to drought almost entirely through their ability to escape periods of acute drought on account of their short growing season.

**Soils:** A rich, loose, loamy soil is best for millet. Plenty of humus is advantageous, and for this reason, millet is often planted on newly turned grass soil. It is a good crop for such situations also, because it seems to aid in disintegrating the sod. Good drainage is essential.

**CULTURE**

**Preparation of seedbed:** The millets are usually sown on spring plowing because of their use as a catch crop, and also on account of their being sown late in the spring. Spring-plowed is preferable to fall-plowed land, because the operation of plowing usually destroys one crop of weeds. If the plowing is done about two weeks before the time for sowing, another crop of weed seeds will germinate, and this second crop can be killed by cultivating the ground thoroughly with a spike-tooth harrow or a disk before sowing the millet. When fall plowing is used for the seedbed, it should always be disked before sowing the millet. A rather fine and firm seedbed is necessary on account of the small size of the seeds. As with other annual crops to be cut for hay, the ground should be thoroughly leveled and all of the clods crushed, so that there will be no unevenness in the surface to interfere with the mowing machine.

Fertilizers are not used with foxtail millet in the Great Plains. Farther east nitrogen and phosphate particularly have given increased yields in some cases, but as a general rule fertilizer should be applied to other crops in the rotation rather than to the millet.

**Date of sowing:** The time of sowing millets permits considerable latitude because of their short season of growth. Millet should not be sown, however, until the ground is warm. This means ordinarily about two or three weeks after complanting time. In the Central States the preferable time for sowing is between the last of May and the middle of June. From this date it can be sown with reasonable hope of success at any time up to August 1, and in the Southern States even later. The last sowing should allow for 60 to 70 days of growing season before the normal date of the first killing frost.

If weather conditions are favorable, a cutting of an early variety of millet can often be obtained 45 days from the date of sowing. Unfavorable conditions, however, including either a period of drought or unseasonably cool weather, result in an average period of about 70 days for Common, Kursk, and Hungarian millet and 85 days for German millet.

Where the season is long it is often possible to obtain a crop of millet after harvesting small grain, such as oats, barley, or fall wheat. In such cases the ground may be prepared for sowing by diskin the stubble. Double cropping of this nature, where both crops are nonlegumes, is not a good practice, since the following crop is usually very much reduced. It should be resorted to, therefore, only in cases of evident need of hay.

**Rate of sowing:** In the more humid areas it is a good practice to sow 25 to 30 pounds of millet per acre. In semiarid districts the rate can be reduced to 10 to 15 pounds per acre, especially if the seedbed is in good condition and a grain drill is used so that the seed will be applied uniformly over the entire surface. It is always well to use sufficient seed, so that weeds will not have an opportunity to obtain a foothold in the millet field.
It is much better to have millet plants occupying the soil than to have spaces filled with weeds.

**Method of sowing:** Where the seedbed has been put in good condition and sufficient seed is used, it is easy to obtain a good stand of millet either by using a grain drill or by broadcasting the seed. Care should be taken not to cover the seed too deeply unless the soil is loose and rather dry on the surface. If the surface is slightly rough, as it will be left after using a spike-tooth harrow, a light harrowing, with the teeth of the harrow sloped backward at an angle of 45°, will be sufficient to cover broadcasted seed. Where there is no danger of the surface of the soil baking, a plank or other drag will cover the seed and often insure a better germination than the spike-tooth harrow, because such tools pack the soil around the seed.

**Diseases and insects:** The foxtail millets are less subject to destructive plant diseases than most other crops. There is in some cases a slight tendency to smut, but this trouble does not affect the hay crop seriously, and in the semiarid regions the extent of the damage to the crop of grain is very slight.

The most destructive insect enemies of millet are the chinch bug and armyworm. These insects are very fond of the foxtail millets, and when abundant in any locality their injuries to the millet crop are frequently very great.

**Utilization**

**Place in the cropping system:** Millet is grown chiefly as a catch crop and is not important as a constituent in a regular cropping system. Most farmers use it to overcome an expected shortage in their hay supply or to occupy a field which would otherwise be idle on account of the failure of a regular crop or because climatic conditions have prevented the sowing of such a crop. Millet is admirably suited to such use because of its short season of growth and the case and certainty of obtaining a stand. The plant is also adapted to a wide range both of soils and of climates. Large yields are not obtained either on poor soils or in dry climates, but millet has been found to make a heavier yield under such conditions than most other hay crops. The strongest competitor of millet which has yet been found is Sudangrass, which has replaced millet in many localities as a catch crop. The quality of Sudangrass hay is superior to that of millet, and its yields under comparable conditions are nearly always larger but the growing season is a trifle longer than that required by either Common or Hungarian millet.

Foxtail millet is used to some extent as a soilng crop, but it is not as well suited for this purpose as the sorghums and some of the small grains. Pearl millet is better for use as a green feed than the foxtail millets, because of its larger yields and its ability to make a second growth after being cut down; and both pearl millet and barnyard millet are better silage crops than foxtail millet, because of their larger yields and greater succulence. Pearl millet is best adapted to the extreme Southeast for both pasture and harvested forage and barnyard millet is adapted to the Northeast, particularly the New England States, New York and Pennsylvania.

**Hay:** Millet can be cut for hay with a mower in the same manner as timothy or any other hay crop. It usually stands erect and does not interfere with the perfect operation of the mower. That which is cut early in the morning, if there is abundant sunshine, can usually be raked into windrows late in the afternoon. It is well, however, to allow it to cure in the swath about one day, after which it can be raked into windrows and allowed to cure sufficiently to be placed in cocks like timothy. After standing a week or more in the cock it can then be stacked and baled.

The principal use of millet is as hay. If the hay is designed for general use, that is, for feeding both cattle and horses, it should be cut just before blooming. The feeding value of the hay is perhaps greatest from this time until the seed reaches the milk stage.

The yields of foxtail millet hay usually range from 1 1/2 to 3 1/2 tons per acre.
Averages over 4 to 7-year periods run about as follows: Common millet from 1.7 tons in the northern and central Great Plains, to 2.5 in the northeastern Corn Belt; German from 1.5 in the northern and 2.7 in the central Great Plains to 3.7 in the northeastern Corn Belt; Hungarian from 1.5 in the northern and southern Great Plains to 2.8 in the northeastern Corn Belt; and Kursk from 1.8 in the northern Great Plains to 2.1 in the central Great Plains and northern Mississippi.

Feeding value of millet hay: Millet hay is usually considered inferior to that of timothy and some of the other tame grasses, probably because of its lower palatability. Chemical analyses, however, show that millet compares favorably with timothy and Johnsongrass in the actual amount of the different food elements which it contains. The digestibility of these different elements is about the same in millet as in timothy, and somewhat lower in Johnsongrass than in either of the others. The general opinion among feeders is that millet hay is somewhat more effective than prairie hay as a roughage for growing stock, especially cattle and sheep. Very few, however, consider it equal to alfalfa, clover, or other legume hays.

Morrison (NY-30) quotes from Hincebauch and from Bell and Williams in saying that "millet hay from Hungarian grass, Japanese millet, etc., is satisfactory for horses if cut before it is mature and if fed as only half the roughage. When fed as the only roughage to horses for long periods, millet hay has produced serious lameness and swelling of the joints and has increased the action of the kidneys. The latter was perhaps due to a considerable amount of millet seed in the hay, as it is claimed that these have a harmful effect on the kidneys."

Pasture: Most of the millets are not suitable for pasture purposes, and this is especially true of the foxtail varieties. The main difficulty lies in the shallow root system, which allows the plants to be pulled up very easily. Another weakness of millet as a pasture plant is that it does not renew its growth very quickly after being cropped off. The Common and Hungarian varieties are best in this respect.

SEED PRODUCTION

Harvesting seed: Where a seed crop is the object, millet is best harvested with a grain binder and placed in shocks like bundle grain. It can be allowed to stand in the field until the grain in the head can be rubbed out in the hand. When it has reached this stage of maturity there will be little trouble about the millet spoiling in the bundle unless a period of wet weather is encountered. In climates where cloudy, wet weather is apt to prevail during the harvesting season it is better to cut the millet with a mower and handle it as one would a hay crop. This method, however, wastes considerable of the seed, which shatters out when the crop is being placed in the cock and later when hauled to the stack. Cutting with a grain binder prevents a great deal of this loss and also leaves the millet in better shape to be threshed, so that the task of threshing can be accomplished more satisfactorily.

Threshing: Millet can be threshed with an ordinary grain separator, the only change necessary being a substitution of screens capable of handling the small seed. Clover screens are often used for millet. Where the crop has been harvested with a binder the concaves do not need to be set very close to the cylinder, as the seed shells out very easily. Under such conditions the straw will not be broken up badly, and little trash or inert matter will be present in the seed. The air blast should be regulated so that only the immature, nongerminable seeds will be blown out with the chaff. Yields of seed up to 20 bushels an acre are obtained under favorable conditions.

PROSO OR BROOMCORN MILLET

(Panicum miliaceum)

Proso, also called hog millet and broomcorn millet, is a plant cultivated since prehistoric times for human food. It is the “common millet” of Europe. It is probably native to central Asia and in all
MILLETS

likelihood was first cultivated there.
Proso is readily distinguished from the foxtail millets, as the flowers are in branching panicles and there are no awns to the florets. There are numerous varieties, varying in the looseness or density of the panicle and in the color of the chaff and seeds. The last may be white, yellow, red, brown, or black.

In America it is grown mostly in the Dakotas, Montana, and adjacent Canada, partly as a grain crop, partly for hay. It is considered more especially a dryland crop than foxtail millet.
Proso millet is not often grown for forage since the hay is not as desirable as that of foxtail millet, being more fibrous and less leafy. The yields, too, are smaller, ranging from 1 to 1½ tons per acre.

Proso is mainly grown as a catch crop on land where other crops fail. It will mature about 2 weeks earlier than foxtail millet when sown at the same time. It yields fairly large seed crops, commonly

10 to 30 bushels per acre. The seed is mostly used as feed, but should preferably be ground. It is good feed for hogs and poultry.

JAPANESE OR BARNYARD MILLET
(Echinochloa crusgalli frumentacea)

Japanese millet was originally described from India. In early times it was grown extensively in Japan, hence the name Japanese millet. It is also called barnyard
millet, being now regarded as a cultivated variety of barnyard grass. It is easily distinguished from foxtail millet by the different shape of the head and the absence of bristles.

Japanese millet will grow better in cool regions than will foxtail millet and so in the United States is grown mostly in New England and the northern tier of States, but it will thrive in practically every part of the country. It is a taller and coarser plant than any of the foxtail millets and can be utilized as green feed, silage, or hay.

This millet is a heavy producer of coarse hay which has a rather low feed value. It has never attained any great importance as a forage crop and its use is declining since the introduction of other high-producing crops of greater value as forage.

**PEARLMILLET**

*(Pennisetum glaucum)*

Pearl millet, a member of the same genus as Napiergrass, and sometimes called cattail millet, was introduced into the United States many years ago; we do not know the exact date. It came by way of the West Indies from India, where it is considered an important forage plant. It is now considered of importance in sections of the South, where it is used for grazing and silage.

**Culture:** Pearl millet requires a rich soil for best growth. Under favorable conditions it produces enormous amounts of green fodder and can be cut several times a season. It is a warm-climate crop and grows only in the warmer part of the year. It will mature seed as far north as Maryland, but can be used economically only farther south.

The seed is planted directly in the field where the crop is to be grown. It is commonly planted in 4-foot rows; 4 pounds of seed to the acre give good results.

**MILLET HIGHLIGHTS**

1. The millets include several kinds of annual grasses, which are used largely as catch crops. Except for proso millet, they are mostly used in the United States for forage.
2. The different millets cover a wide range of soils and climates in their adaptation and use.
3. The short growing season of proso and some of the foxtail millets enables them to escape periods of drought that might be disastrous to other crops.
4. Of the foxtail millets, German and Hungarian are the best varieties for humid regions, and Kursk, Siberian, and Common for the northern Great Plains.

5. Sowing, harvesting, and threshing any of the millets are easy and simple operations which can be performed with ordinary farm equipment.

6. Millet hay has about the same feeding value as timothy and Johnson hay.

7. Injury to horses may result when millet hay is fed to them. It can be fed safely to cattle and sheep.

8. None of the millets are valuable as constituents in crop rotations.

9. The millets are all remarkably free from injurious insects and diseases. Chinch bugs and army worms are occasionally disastrous.

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THESE CHAPTER

The material in this chapter on millets is largely from Vinall (US-272), Curtis, et al (COL-3), and Hoover, et al (US-115). The manuscript was reviewed by McKee, Hein, and Martin of the U.S.D.A.

Chapter reference numbers: COL-3; GA-11; MISS-8; OREG-25; SC-1; US-272.

The reference numbers given here refer to references which are given in full by State, U.S.D.A., and Miscellaneous, on pages 682 to 724, and which are cross-referenced by author on pages 725 to 731. Citations in the text are indicated by abbreviation and number in parentheses.
Part IV

Seed Tables and References
Any information given about seeds as to size, purity, germination, longevity, and other characteristics, is subject to so many conditions surrounding production, handling, processing, storage, and distribution that it must be taken only as a guide. However, even though there is a rather wide range in each of these factors, general information is useful.

The legal or generally accepted weight of practically all legume seed is 60 pounds per bushel, but those which are enclosed in a hull or bur weigh less than this. Most grass seeds are lighter than legumes because of their usually being enclosed in the glumes and often having light appendages, which with most species makes it difficult to give even a rough approximation of their weight per bushel.

The optimum sowing rate per acre varies with the condition of the seedbed, annual precipitation, character of the soil, method of sowing, and other factors. The rates given here are for seed sown broadcast or closely drilled. When sown in mixtures, lower rates are used. When sown in rows for cultivation which is common for seed production, seldom more than one to four pounds of any small-seeded grass or legume is used.

The region or area of adaptation given is based on general climatic conditions. Certain climate and soil conditions existing in a locality within a designated region may make a crop unadapted for such localities, even though generally adapted to the region. The accompanying map giving regions where the climatic conditions are somewhat similar will prove a useful guide. The region of adaptation for each crop is indicated by such designations as 2a, 3b, etc. which correspond to similarly designated areas on the map.

These data can be made really useful only when they are taken as a guide along with intelligent consideration of all modifying conditions. Only the crops covered as domesticated forage crops in this publication are included in these tables.
<table>
<thead>
<tr>
<th>Common Name</th>
<th>Scientific Name</th>
<th>Page</th>
<th>Seeds per Pound</th>
<th>Seed Purity</th>
<th>Viable Seed</th>
<th>Seed Longevity¹ Class</th>
<th>Sowing Rate Per Acre</th>
<th>Where Variety or Species Adapted</th>
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<tbody>
<tr>
<td>Alfalfa</td>
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<tr>
<td>Common or purple</td>
<td>Medicago sativa L.</td>
<td>247</td>
<td>220</td>
<td>98</td>
<td>90</td>
<td>3</td>
<td>8-20</td>
<td>All regions except 2b</td>
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<td>Variegated</td>
<td>Medicago medica Pers.</td>
<td>247</td>
<td>220</td>
<td>98</td>
<td>90</td>
<td>3</td>
<td>8-20</td>
<td>1a, 1b, 3a, 4a, 5a</td>
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<td>3</td>
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<td>Alyceclover</td>
<td>Alyseccarpus glauces L. D C.</td>
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<td>15-20</td>
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<td>Little</td>
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<td>98</td>
<td>90</td>
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<td>3</td>
<td>1b</td>
<td>2a, 2b, 4b, 5b</td>
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<td>Medicago arabica [L.] Huds.</td>
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<td>434</td>
<td>270</td>
<td>90</td>
<td>90</td>
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<td>20</td>
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<td>Clover [Trifolium]</td>
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<td>Alsike</td>
<td>Trifolium hybridum L.</td>
<td>301</td>
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<td>3</td>
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<td>Crotalaria spectabilis Houb.</td>
<td>451</td>
<td>55</td>
<td>98</td>
<td>90</td>
<td>3</td>
<td>70-120</td>
<td>All regions</td>
</tr>
<tr>
<td>Field pea</td>
<td>Pismum arvense L.</td>
<td>398</td>
<td>2-4</td>
<td>98</td>
<td>90</td>
<td>3</td>
<td>7-10</td>
<td>1b, 2a, 2b, 5b</td>
</tr>
<tr>
<td>Bairy Indigo</td>
<td>Indigofera hirsuta L.</td>
<td>460</td>
<td>260</td>
<td>98</td>
<td>90</td>
<td>3</td>
<td>70-10</td>
<td>1b, 2a, 2b, 5b</td>
</tr>
<tr>
<td>Endru</td>
<td>Pueraria thunbergiana [Steil and Zucc.]</td>
<td>468</td>
<td>40</td>
<td>98</td>
<td>70</td>
<td>2</td>
<td>20</td>
<td>1b, 2a, 2b, 5b</td>
</tr>
</tbody>
</table>

¹ Seed longevity is the time period during which the seeds are viable for germination.
<table>
<thead>
<tr>
<th>Crop</th>
<th>Common (Kobe)</th>
<th>Common [Tamm. 76]</th>
<th>Korean</th>
<th>Serbian</th>
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</thead>
<tbody>
<tr>
<td>Seed weight</td>
<td>361</td>
<td>361</td>
<td>361</td>
<td>362</td>
</tr>
<tr>
<td>Weight/seed</td>
<td>180</td>
<td>210</td>
<td>225</td>
<td>250</td>
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<tr>
<td>Seed weight</td>
<td>97</td>
<td>96</td>
<td>97</td>
<td>95</td>
</tr>
<tr>
<td>Weight/seed</td>
<td>90</td>
<td>90</td>
<td>90</td>
<td>90</td>
</tr>
<tr>
<td>Rate</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Rate/seed</td>
<td>20-30</td>
<td>20-30</td>
<td>20-30</td>
<td>20-30</td>
</tr>
<tr>
<td>Rate</td>
<td>1b, 2a, 5b</td>
<td>1b, 2a, 2b</td>
<td>1b, 2a, 5b</td>
<td>1b, 2a, 5b</td>
</tr>
</tbody>
</table>

**Lotus trefoil**

<table>
<thead>
<tr>
<th>Crop</th>
<th>Species</th>
<th>Seed weight</th>
<th>Weight/seed</th>
<th>Rate</th>
<th>Rate/seed</th>
<th>Adaption</th>
</tr>
</thead>
<tbody>
<tr>
<td>Big</td>
<td>L. uliginosus Schkhr.</td>
<td>428</td>
<td>1,000</td>
<td>95</td>
<td>95</td>
<td>2</td>
</tr>
<tr>
<td>Birdsfoot [Broadleaf]</td>
<td>L. corniculatus L.</td>
<td>417</td>
<td>375</td>
<td>95</td>
<td>95</td>
<td>2</td>
</tr>
<tr>
<td>Birdsfoot [Narrowleaf]</td>
<td>L. temul Wald.</td>
<td>417</td>
<td>400</td>
<td>95</td>
<td>95</td>
<td>2</td>
</tr>
</tbody>
</table>

**Lupines**

<table>
<thead>
<tr>
<th>Crop</th>
<th>Species</th>
<th>Seed weight</th>
<th>Weight/seed</th>
<th>Rate</th>
<th>Rate/seed</th>
<th>Adaption</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blue</td>
<td>L. angustifolius L.</td>
<td>441</td>
<td>3</td>
<td>99</td>
<td>99</td>
<td>1</td>
</tr>
<tr>
<td>White</td>
<td>L. albus L.</td>
<td>441</td>
<td>3</td>
<td>99</td>
<td>99</td>
<td>1</td>
</tr>
<tr>
<td>Yellow</td>
<td>L. luteus L.</td>
<td>441</td>
<td>4</td>
<td>99</td>
<td>99</td>
<td>1</td>
</tr>
</tbody>
</table>

**Rockspea**

<table>
<thead>
<tr>
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<th>Species</th>
<th>Seed weight</th>
<th>Weight/seed</th>
<th>Rate</th>
<th>Rate/seed</th>
<th>Adaption</th>
</tr>
</thead>
<tbody>
<tr>
<td>L. hirsutus L.</td>
<td>459</td>
<td>15</td>
<td>98</td>
<td>90</td>
<td>2</td>
<td>20-30</td>
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</tbody>
</table>

**Sesleria**

<table>
<thead>
<tr>
<th>Crop</th>
<th>Species</th>
<th>Seed weight</th>
<th>Weight/seed</th>
<th>Rate</th>
<th>Rate/seed</th>
<th>Adaption</th>
</tr>
</thead>
<tbody>
<tr>
<td>M. indica [L.] All.</td>
<td>457</td>
<td>275</td>
<td>95</td>
<td>90</td>
<td>3</td>
<td>9-10</td>
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</tbody>
</table>

**Soybean**

<table>
<thead>
<tr>
<th>Crop</th>
<th>Species</th>
<th>Seed weight</th>
<th>Weight/seed</th>
<th>Rate</th>
<th>Rate/seed</th>
<th>Adaption</th>
</tr>
</thead>
<tbody>
<tr>
<td>Glycine max [L.] Piper</td>
<td>493</td>
<td>5</td>
<td>98</td>
<td>90</td>
<td>1</td>
<td>5-10</td>
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</table>

**Sweetclover**

<table>
<thead>
<tr>
<th>Crop</th>
<th>Species</th>
<th>Seed weight</th>
<th>Weight/seed</th>
<th>Rate</th>
<th>Rate/seed</th>
<th>Adaption</th>
</tr>
</thead>
<tbody>
<tr>
<td>White</td>
<td>M. alba Desr.</td>
<td>340</td>
<td>260</td>
<td>98</td>
<td>90</td>
<td>3</td>
</tr>
<tr>
<td>Yellow</td>
<td>M. officialis [L.] Lam.</td>
<td>340</td>
<td>260</td>
<td>98</td>
<td>90</td>
<td>3</td>
</tr>
</tbody>
</table>

**Velvetbean Deering**

<table>
<thead>
<tr>
<th>Crop</th>
<th>Species</th>
<th>Seed weight</th>
<th>Weight/seed</th>
<th>Rate</th>
<th>Rate/seed</th>
<th>Adaption</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stizolobum deeringianum Bect.</td>
<td>412</td>
<td>1</td>
<td>98</td>
<td>90</td>
<td>2</td>
<td>10-20</td>
</tr>
</tbody>
</table>

**Vetch**

<table>
<thead>
<tr>
<th>Crop</th>
<th>Species</th>
<th>Seed weight</th>
<th>Weight/seed</th>
<th>Rate</th>
<th>Rate/seed</th>
<th>Adaption</th>
</tr>
</thead>
<tbody>
<tr>
<td>Common</td>
<td>V. sativa L.</td>
<td>380</td>
<td>7</td>
<td>97</td>
<td>90</td>
<td>2</td>
</tr>
<tr>
<td>Hairy</td>
<td>V. villosa Roth</td>
<td>379</td>
<td>10</td>
<td>97</td>
<td>90</td>
<td>3</td>
</tr>
<tr>
<td>Hungarian</td>
<td>V. panonica Crantz</td>
<td>381</td>
<td>10</td>
<td>97</td>
<td>90</td>
<td>3</td>
</tr>
<tr>
<td>Narrowleaf</td>
<td>V. angustifolia Reich</td>
<td>382</td>
<td>10</td>
<td>97</td>
<td>90</td>
<td>3</td>
</tr>
<tr>
<td>One-flower</td>
<td>V. arctuata Hornem.</td>
<td>381</td>
<td>12</td>
<td>97</td>
<td>90</td>
<td>2</td>
</tr>
<tr>
<td>Purple</td>
<td>V. atropurpurea Desf.</td>
<td>381</td>
<td>10</td>
<td>97</td>
<td>90</td>
<td>2</td>
</tr>
<tr>
<td>Smooth</td>
<td>V. villosa glabrescens Koch</td>
<td>379</td>
<td>20</td>
<td>97</td>
<td>90</td>
<td>3</td>
</tr>
<tr>
<td>Willamette</td>
<td>V. villosa L.</td>
<td>380</td>
<td>7</td>
<td>97</td>
<td>90</td>
<td>2</td>
</tr>
<tr>
<td>Woollypod</td>
<td>V. dasycarpa Ten.</td>
<td>380</td>
<td>10</td>
<td>90</td>
<td>90</td>
<td>3</td>
</tr>
</tbody>
</table>

1 - In this column 1 represents relatively short-lived seed, 2 intermediate, and 3 long-lived seed.
2 - Medium percent hard seed
3 - Unshelled or in pods or bare
4 - High percent hard seed
5 - Rate when planted in rows 3 to 4 feet apart
678

SEED TABLES AND REFERENCES

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<table>
<thead>
<tr>
<th>Seed Data and Adaptations</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Fescue</strong></td>
</tr>
<tr>
<td><strong>Chewings</strong></td>
</tr>
<tr>
<td>Festuca rubra commutata Gaud.</td>
</tr>
<tr>
<td>Festuca elatior L.</td>
</tr>
<tr>
<td>Festuca rubra L.</td>
</tr>
<tr>
<td>Festuca ovina L.</td>
</tr>
<tr>
<td>Festuca arundinacea Schreb.</td>
</tr>
<tr>
<td><strong>Grama</strong></td>
</tr>
<tr>
<td>Black</td>
</tr>
<tr>
<td>Bouteloua eriopoda [Torr.] Torr.</td>
</tr>
<tr>
<td>Blue</td>
</tr>
<tr>
<td>Bouteloua gracilis [H.B.K.] Lag.</td>
</tr>
<tr>
<td>Hairly</td>
</tr>
<tr>
<td>Bouteloua hirsuta Lag.</td>
</tr>
<tr>
<td>Red</td>
</tr>
<tr>
<td>Bouteloua rothrockii Vasey</td>
</tr>
<tr>
<td>Side-oats</td>
</tr>
<tr>
<td>Bouteloua curtipendula [Michx.]</td>
</tr>
<tr>
<td><strong>Hardinggrass</strong></td>
</tr>
<tr>
<td>Phalaris tuberosa atropurpurea [Buck] Hitchc.</td>
</tr>
<tr>
<td><strong>Indiangrass</strong></td>
</tr>
<tr>
<td>Sorghastrum nutans [L.] Nash</td>
</tr>
<tr>
<td><strong>Indian ricegrass</strong></td>
</tr>
<tr>
<td>Oryzopsis hymenoides [Ran. &amp; Schult.] Ricker</td>
</tr>
<tr>
<td><strong>Johnsongrass</strong></td>
</tr>
<tr>
<td>Sorghum halepense [L.] Pers.</td>
</tr>
<tr>
<td><strong>Lovegrass</strong></td>
</tr>
<tr>
<td>Lehmann</td>
</tr>
<tr>
<td>Eragrostis lehmanniana Nees</td>
</tr>
<tr>
<td>Trichodes</td>
</tr>
<tr>
<td>Eragrostis trichodes [Nutt.] Wood</td>
</tr>
<tr>
<td>Weeping</td>
</tr>
<tr>
<td>Eragrostis curvula [Schroed.] Nees</td>
</tr>
<tr>
<td><strong>Meadow fescue</strong></td>
</tr>
<tr>
<td>Alopecurus pratensis L.</td>
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<tr>
<td><strong>Millet</strong></td>
</tr>
<tr>
<td>Common</td>
</tr>
<tr>
<td>Setaria italica [L.] Beauv.</td>
</tr>
<tr>
<td>German</td>
</tr>
<tr>
<td>Setaria italica [L.] Beauv.</td>
</tr>
<tr>
<td>Hungarian</td>
</tr>
<tr>
<td>Setaria italica [L.] Beauv.</td>
</tr>
<tr>
<td>Japanese [Barnyard]</td>
</tr>
<tr>
<td>Echinochloa crusgalli frumentacea Wight</td>
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<tr>
<td><strong>Rye</strong></td>
</tr>
<tr>
<td>Setaria italica [L.] Beauv.</td>
</tr>
<tr>
<td>Pennisetum glaucum [L.] R. Br.</td>
</tr>
<tr>
<td>Panicum miliaceum [L.]</td>
</tr>
<tr>
<td>Setaria italica [L.] Beauv.</td>
</tr>
<tr>
<td><strong>Spleengrass</strong></td>
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<tr>
<td>Pennisetum purpureum Schumacher</td>
</tr>
<tr>
<td><strong>Needlegrass</strong></td>
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<tr>
<td>Feather beachgrass</td>
</tr>
<tr>
<td>Stipa viridula Trin.</td>
</tr>
<tr>
<td>Green trips</td>
</tr>
<tr>
<td>Stipa viridula Trin. var.</td>
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<tr>
<td>Needle-and-thread</td>
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<tr>
<td>Stipa comata Trin. and Rupr.</td>
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<tr>
<td><strong>Orchardgrass</strong></td>
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<tr>
<td>Dactylis glomerata L.</td>
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<tr>
<td><strong>Pangolagrass</strong></td>
</tr>
<tr>
<td>Digitaria decumbens Steud.</td>
</tr>
<tr>
<td>Common Name</td>
</tr>
<tr>
<td>---------------------</td>
</tr>
<tr>
<td>Panagrass</td>
</tr>
<tr>
<td>Paraggrass</td>
</tr>
<tr>
<td>Redtop</td>
</tr>
<tr>
<td>Reed canarygrass</td>
</tr>
<tr>
<td>Rescuegrass</td>
</tr>
<tr>
<td>Rhodesgrass</td>
</tr>
<tr>
<td>Ryegrass Common</td>
</tr>
<tr>
<td>Italian Perennial</td>
</tr>
<tr>
<td>Sorghum</td>
</tr>
<tr>
<td>St. Augustine grass</td>
</tr>
<tr>
<td>Sudangrass</td>
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<tr>
<td>Switchgrass</td>
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<tr>
<td>Tall oatgrass</td>
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<tr>
<td>Timothy</td>
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<tr>
<td>Vaseygrass</td>
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<tr>
<td>Vine mesquite</td>
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<tr>
<td>Wheatgrass</td>
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<tr>
<td>Bluestotch</td>
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<tr>
<td>Crested [Fairway]</td>
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<tr>
<td>Crested [Standard]</td>
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<td>Intermediate</td>
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<tr>
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<td>Western</td>
</tr>
<tr>
<td>Wild-rye Blue</td>
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<tr>
<td>Canada</td>
</tr>
<tr>
<td>Creeping</td>
</tr>
<tr>
<td>Giant Russian</td>
</tr>
<tr>
<td>Zoysias</td>
</tr>
<tr>
<td>Japanese lawn</td>
</tr>
<tr>
<td>Mauiflora</td>
</tr>
<tr>
<td>Mascarenegrass</td>
</tr>
</tbody>
</table>

1 In this column 1 represents relatively short-lived seed, 2 intermediate, and 3 long-lived seed.
SELECTED FORAGE CROP REFERENCES

CLASSIFIED BY
STATE, UNITED STATES DEPARTMENT OF
AGRICULTURE AND MISCELLANEOUS

ALABAMA

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ARIZ—No.


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15. WING, R. A. and WING, R. A. The

18. BROWN, B. A. and HOLLOWELL, E. A.

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16. ROYLMAN, D. W., and TUCKER, R. H. Pasture and forage

19. BROWN, B. A. and MUNSELL, R. I. The

2. HOLOW, H. A. Methods of fertilizers on

3. BROWN, B. A. Some factors affecting the

4. BROWN, B. A. Some factors affecting the

5. BROWN, B. A. The chemical composition of

6. BROWN, B. A. and HOLLOWELL, E. A. 

7. KUONCE, D. W. Six alfalfa varieties

8. KUONCE, D. W. High altitude forage

9. LUTE, A. W. Laboratory growth of

10. ROYLMAN, D. W., and MUNSELL, R. L.

12. ROYLMAN, D. W., and MUNSELL, R. L. Pasture and forage

13. BROWN, B. A. and MUNSELL, R. L. Test

15. WING, R. A. and WING, R. A. The

17. OWENS, T. S. and BROWN, B. A. Legumes and

18. BROWN, B. A. and HOLLOWELL, E. A.

19. BROWN, B. A. and HOLLOWELL, E. A. 

CONNECTICUT

1. BROWN, B. A. Effects of fertilizers on

2. HOLOW, H. A. Methods of fertilizers on

3. BROWN, B. A. Some factors affecting the

4. BROWN, B. A. Some factors affecting the

5. BROWN, B. A. The chemical composition of

6. BROWN, B. A. and HOLLOWELL, E. A. 

7. KUONCE, D. W. Six alfalfa varieties

8. KUONCE, D. W. High altitude forage

9. LUTE, A. W. Laboratory growth of

10. ROYLMAN, D. W., and MUNSELL, R. L.

11. ROYLMAN, D. W., and WING, R. A.

12. ROYLMAN, D. W., and WING, R. A. The

13. BROWN, B. A. and MUNSELL, R. L. An

14. BROWN, B. A. and MUNSELL, R. I. Grasses

15. BROWN, B. A. and MUNSELL, R. I. Grasses

16. BROWN, B. A. and MUNSELL, R. I. Grasses

17. OWENS, T. S. and BROWN, B. A. Legumes

18. BROWN, B. A. and HOLLOWELL, E. A.

19. BROWN, B. A. and HOLLOWELL, E. A. 

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4. BROWN, B. A. Some factors affecting the

5. BROWN, B. A. The chemical composition of

6. BROWN, B. A. and HOLLOWELL, E. A. 

7. KUONCE, D. W. Six alfalfa varieties

8. KUONCE, D. W. High altitude forage

9. LUTE, A. W. Laboratory growth of

10. ROYLMAN, D. W., and MUNSELL, R. L.

11. ROYLMAN, D. W., and WING, R. A.

12. ROYLMAN, D. W., and WING, R. A. The

13. BROWN, B. A. and MUNSELL, R. L. An

14. BROWN, B. A. and MUNSELL, R. I. Grasses

15. BROWN, B. A. and MUNSELL, R. I. Grasses
DEL—No.


FLORIDA

FLA—No.


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GA—No.

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IOWA—No.

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KY-No.


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