VEGETABLES FOR THE TROPICAL REGION

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PREFACE TO THE SECOND EDITION

The wide acceptance of the first edition of this book and its increased demand particularly among the agricultural students encouraged us to revise it.

Manuscript for the first edition was completed during 1970 and since then great activities in the field of research on vegetable crops at various research institutes and agricultural universities have been observed. Another attempt was made to screen through all the available literature published during the last twelve years in the country. Two more crops, viz. winged bean and fenugreek, have been included in the current edition considering their importance on a large scale. As a result, additional 192 selected references have been incorporated to make this revised edition up to date as far as possible. However, it may not be considered as the final word because active work is still going on in different parts of the country.

To keep pace with the fast progress in developing better varieties, it necessitated to delete illustrations of certain obsolete or already popular varieties and include varieties recently developed. Considering the increasing cost of printing, however, this too has to be restricted.

We are thankful to Dr O. P. Dutta and Dr K. R. M. Swamy for valuable assistance in compiling some of the informations. We must confess that the inspiring soul behind this book has been late Smt. Dharmsheela Nath (Mrs Prem Nath) whose contribution in various ways has been most valuable.

We are grateful to Dr J. P. Singh, Assistant Director-General (Horticulture), ICAR, for his continuous encouragement and valuable help. Many thanks are due to Vegetable Specialists who have discussed various ideas which appear in this book or who have criticised the manuscript.

Thanks are due to the Indian Council of Agricultural Research, for giving opportunity to revise this book and to the Chief Editor and his colleagues for their best cooperation.

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August, 1984
PREFACE TO THE FIRST EDITION

Modern living has brought about little change in the food preferences of our people, but there has been a significant change in the availability of various foods including vegetables. This is evident from the availability of relatively more and better quality vegetables in the market. Today, people in every walk of life are consuming more fresh vegetables than ever before, thus making the growing of more vegetables vitally important. To properly feed the expanding population in a land where vegetable production is inadequate and where the people have become quality conscious, it is incumbent on us, the agricultural scientists, to improve the existing inferior varieties and to modernize the agro-techniques to get maximum harvest from them.

A comparison of the status of the horticulture in India today with that of a few decades ago will reveal advances in practically every sphere. The objective of writing this book has been to incorporate into it all new information available in India. Endeavour has been made to describe the field-oriented details on all common vegetable crops. Although written primarily for agricultural graduates, extension workers and vegetable growers, the book strives to offer a good background material that will be of value to amateur gardeners and junior students. Most of the information on nutritive values of various vegetable crops have been quoted from the special Report Series No. 42 of the ICMR. The book is not to be considered as the final word by any means. Active work is still going on and much remains to be done.

I express my sincere gratitude to my colleagues Mr O. P. Dutta and Miss S. Subramanyam for valuable assistance in compiling the information. I am sure this book could not have been completed in time without their continuous and unfailing help. Many thanks are due to Mr Dase Gowda for typing the manuscript and to Mr V. N. Ranganathan for taking the photographs included in this publication.

I am highly grateful to Dr G. S. Randhawa, Director, Indian Institute of Horticultural Research, Bangalore, for the encou-
agement and for providing all facilities for writing this book. Thanks are due to all staff members of the Division of Vegetable Crops and various specialists of this Institute for their co-operation and help. I am conscious of my debt to vegetable specialists who have either discussed with me various ideas that appear in this book or who have read and offered their critical comments on the manuscript. I would fail in my duty if I do not thank the Indian Council of Agricultural Research for assigning this task to me.

Prem Nath
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1. INTRODUCTION

Vegetables play an important role in human nutrition. During recent years, the interest in vegetable production has increased rapidly as a result of greater appreciation of the food value of vegetables and of the place of vegetables in the nation's food requirements. The findings of scientific study and their wide application in the field have enhanced this interest to a great extent among growers and consumers alike.

Vegetables belong to about thirteen plant families and have originated from widely differing parts of the earth. Some of them are said to be native of India.

Vegetables are so common in human diet that a meal without a vegetable is supposed to be incomplete in any part of the world. In India, vegetable crops occupy only about 1.2% of the total cultivated area and the total production is about 16 million tonnes per year which is extremely low. An improved diet is supposed to have about 400 g of vegetables per day per caput, but in India the average per caput consumption of vegetables per day is reported to be less than 45 g. The role of vegetables in the Applied Nutrition Programme has already been emphasized (Nath, 1971b).

Vegetables provide proteins, carbohydrates, minerals, vitamins and roughages which constitute the essentials of a balanced diet. Surveys carried out in different parts of the country have shown that the chief deficiencies in our diet are calories, vitamin A and riboflavin. It has been pointed out that the protein yield per acre of the leafy green vegetables far exceeds that from other sources and they can also supplement the amino acid consumption through cereals and pulses. Leafy and some other vegetables can supply calcium and iron at low cost. Vegetables like tomato, muskmelon, bittergourd and tinda contain vitamin C, which also facilitates the absorption of these minerals. The major sources of vitamin A are milk, egg, liver and fish, all of which are in short supply. It is encouraging that vegetables like carrot, spinach beet, spinach, amaranths, muskmelon, watermelon are rich sources of vitamin A. So far as the availability of riboflavin is concerned, next to animal sources, green
leafy vegetables are the best sources. It is needless to say that peas and beans are the best sources of proteins. It has not been realized yet that a liberal consumption of vegetables can reduce the need of other foodstuffs like cereals which contain more of carbohydrates.

The vegetables should be more widely recognized and used not only because (a) they supply both basic and accessory nutrients, and (b) taste good, but also because (c) they furnish maximum quantity of food for the area planted, and (d) they grow quickly.

From the climatic as well as vegetable production point of view the country can be broadly divided into (a) temperate, (b) subtropical, and (c) tropical regions. In this book the common vegetables which can be grown in the subtropical and tropical regions of the country have been described for their scientific cultivation. It covers the improved practices followed in the plains of northern, southern, central, eastern and western regions of the country where subtropical and tropical climates prevail. The information on vegetable cultivation in the temperate regions including hilly areas have not been included. With regard to seed production, the discussion relates to tropical vegetables only. No mention has been made of seed production in cabbage, late cauliflower, knol-khol, beet root, and exotic varieties of radish, carrot and turnip which do not produce seeds in the tropical region. In the manurial and fertilizer recommendations it is a question of principles which must be modified in particular cases in accordance with the prevailing conditions. An attempt has been made to make the readers aware of the plant-breeding work done on individual crops in our country. Some of the crops like beans, melons, gourds, solanaceous crops, leafy vegetables and root crops belonging to one family and having similar cultural requirements have been grouped to avoid duplication. Some crops have been treated briefly as guidance for their culture may be found in the chapter on similar crops.

During 1970, the launching of the All-India Co-ordinated Vegetable Improvement Project by the Indian Council of Agricultural Research had marked a new era in the history of research on vegetable crops in India. It is envisaged that the
results would provide base for nation-wide vegetable development work as well as basis for further research work on these crops.
2. CLASSIFICATION OF VEGETABLE CROPS

Vegetables may be classified on the basis of (i) season, (ii) cultural practices, (iii) plant part used as vegetable, (iv) morphological resemblance or botanical classification, and (v) major climatic regions.

Classification based on the season for cultivation

This is the most important classification for growers as well as students of agriculture. Based on the distinct growing seasons prevailing in most of the plain areas, vegetables have been classified for their best growth, development and production. In other words, they are season-bound. A group of vegetables are considered specific to a particular growing season, if their best production coincides with that period. The distinct growing seasons in the plains of India are: (a) summer or spring; (b) rainy season or kharif; and (c) winter or cool season or rabi. In some areas like Bangalore, these seasons are not very distinct and hence crops like tomato, brinjal, sweet pepper, chilli, okra and gourds can be grown throughout the year. However, the various vegetable crops suited to the three seasons are:

**Summer-season crops.** Muskmelon, watermelon, longmelon, snapmelon, roundmelon, bottlegourd, bittergourd, snakegourd, ashgourd, ridgegourd, spongogourd, pumpkin, summer squash, cucumber, bhindi, tomato, brinjal, sweet pepper, chilli, cowpea, cluster bean, amaranths and portulaca.

**Rainy-season crops.** Roundmelon, bottlegourd, bittergourd, snakegourd, ashgourd, ridgegourd, spongogourd, pointedgourd, pumpkin, bhindi, tomato, brinjal, sweet pepper, chilli, coccinia, chocho, cowpea, cluster bean and dolichos bean.

**Winter-season crops.** Cabbage, cauliflower, knol-khol, Brussels sprouts, sprouting broccoli, radish, turnip, carrot, beetroot, methi, spinach beet, lettuce, onion, garlic, French bean and pea.

The summer or spring season prevails from February to June in the northern plains and from January to May in the southern plains. The winter season (October to January) is more or less the same throughout the plains in India. However, the rainy season (June to September) has slight variation in different
regions depending upon the time of the rains and its duration. Some of the vegetables can be grown in both summer and rainy seasons, though in a specific sense they might have been grouped under a particular season for maximum performance.

Classification based on the cultural practices

This classification is useful to growers because vegetable crops requiring the same cultivation practices have been grouped together.

Cole crops and lettuce. Cauliflower, cabbage, knol-khol, Chinese cabbage, Brussels sprouts, sprouting broccoli and lettuce. All are winter crops and have more or less similar cultural requirements. In each case sowing is carried out in the nursery-bed for raising the seedlings for transplanting.

Leafy vegetables. Spinach, spinach beet, coriander, fenugreek, amaranths and mustard green. In each case the seeds are generally sown directly in the field.

Root vegetables. Radish, turnip, carrot, beetroot. In each case the seeds are sown directly in the field.

Cucurbitaceous crops. All melons, gourds, cucumber, pumpkin and summer squash. Seeds are sown directly in the field.

Solanaceous crops. Tomato, brinjal, sweet pepper, chilli. In each case seed is sown in the nursery-bed to raise the seedlings for transplanting.

Beans. French bean, dolichos bean, broad bean, lima bean, cluster bean and cowpea. Seeds are sown directly in the field.

Bulb vegetables. Onion, garlic. Onion seed is sown in the nursery, whereas garlic is usually planted in the field.

Others (each independent). Coccinia, pointedgourd, chayote (chocho), bhindi. Coccinia and pointedgourd are propagated by cuttings, chayote by fruit and bhindi is propagated by seed.

Classification based on the plant part used as vegetable

Based on the plant parts consumed as vegetables, the crops may be grouped as follows:

(a) Leaves : Cabbage, lettuce, spinach, spinach beet, amaranths, fenugreek, etc.

(b) Stem : Knol-khol, asparagus, amaranths, spinach, cauliflower, etc.
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(c) Fruits: melons, gourds, tomato, brinjal, capsicum, etc.

(d) Flowers: Broccoli, etc.

(e) Underground: Radish, turnip, carrot, beetroot, onion, portions garlic, potato, sweet potato, etc.

This classification is not of much use because of the differences in the cultural requirements of each crop in a particular group.

Botanical classification

This classification is based entirely on the relationship among various crops. It is of use to students for their easy understanding but is of no practical value to growers.

I. Monocotyledons

Family—Alliaceae: Onion, garlic, leek

Liliaceae: Asparagus

Araceae: Colocasia

Dioscoreaceae: Yam

II. Dicotyledons

Family—Chenopodiaceae: Spinach, spinach beet, beetroot

Cruciferae: Cabbage, cauliflower, knol-khol, Brussels sprouts, sprouting broccoli, turnip, radish, mustard green, Chinese cabbage

Papilionaceae: Pea, dolichos bean, French bean, lima bean, cluster bean, cowpea, methi

Amaranthaceae: Amaranths

Malvaceae: Bhindi

Umbelliferae: Carrot

Solanaceae: Tomato, brinjal, sweet pepper, chilli, potato

Convolvulaceae: Sweet potato

Cucurbitaceae: All melons, all gourds, pumpkin, squash, cucumber, chocho, cococinia

Compositae: Lettuce, artichoke
Classification based on major climatic regions

Depending on the ability of the plant to flower, fruit and produce seeds in different climatic regions of the world, the vegetable crops have been classified into two major groups: (a) temperate crops, and (ii) subtropical and tropical crops. In the former case, the plant needs temperate climate or extreme winter to be able to flower and produce seeds. Here the crops can be grown for vegetable both in the tropical and temperate regions but it would produce seeds wherever temperate climate prevails (Fig. 1). For example, the cabbage is able to produce excellent head for vegetable in the tropical plains but normally fails to produce seeds there. It produces seeds freely in the hills where temperate climate prevails. Similarly, cauliflowers have been grouped now into four maturity groups. Varieties of first three maturity groups, known as Indian cauliflowers, can produce seeds successfully in plains, while that of fourth maturity group (Snowball type) temperate climate is required for seed production though it is also cultivated successfully in tropical and subtropical regions during winter. In some crops like carrot, radish and turnip there is a great variation among the varieties regarding their adaptability. The exotic or temperate varieties require temperate climate to produce seeds, whereas the tropical or Asian varieties produce seeds freely in the plains.

There is another important criterion on which the crops have been classified. In regions where frost is a common feature during winter, some of the crops which would have grown otherwise fail to grow (Fig. 1). This is of utmost importance in the tropical plains. It is possible to grow tomato or brinjal or gourds during winter in the plains of eastern and southern states, but in north-western states this is not possible because of the frost which kills the crop. Tropical crops flower, fruit and produce seeds freely in the warm or tropical climate.
Fig. 1. Vegetable-growing regions in India.

Based upon Survey of India map with the permission of the Surveyor General of India.

The territorial waters of India extend into the sea to a distance of twelve nautical miles measured from the appropriate base line.
3. NURSERY MANAGEMENT

Almost all vegetable crops are propagated by seeds, except a few like cocinia, pointedgourd, kakrol, sweet potato, asparagus, garlic and potato, which do better if propagated by cuttings, roots, cloves and tubers. Among the vegetable crops which are propagated by seeds, most of them like cucurbits, beans, peas, radish, turnip, carrot, leafy vegetables and okra are required to be sown directly in the field, whereas crops like tomato, brinjal, capsicum, chilli, cabbage, cauliflower, khol-khol, lettuce, Brussels sprouts and onion are first sown in nursery-beds where seedlings are raised and then transplanted. Proper nursery management for raising seedlings and transplanting them are important operations in vegetable production. A nursery has the following advantages: (i) it is very convenient to look after the tender seedlings; (ii) timely and careful plant protection measures are possible; (iii) most favourable growth medium is provided; (iv) seedlings are in a protected place and usually timed for early crop; (v) it ensures uniform growth and establishment of plants in the field; and (vi) there is economy of land and seed, and more time is available for field preparation.

Soil preparation

The soil should be fine, moist and firm to provide better germination and excellent medium for seedling growth. Enough of well decomposed farmyard manure should be mixed thoroughly in the soil. Usually the soil mixture for the pots should have two parts of garden soil, one part of sand and one part of leaf mould. In case of nursery bed, the width should not be more than 120 cm and the length 150 cm or more. This width facilitates weeding and watering without trampling the bed. The bed is usually kept raised about 15 cm high so as to provide proper drainage of excess water and the level of the bed surface is also made slightly raised in the centre with a little slope on the two sides.

Sowing

The common practice is to broadcast seeds in the nursery-bed but line sowing is preferred so as to check proper germination
and to facilitate weeding, hoeing and plant protection operations. The rows are usually kept about 5 cm apart. The size of the nursery-bed to raise seedlings to plant a hectare of tomato, brinjal and capsicum would be 50 m × 1.2 m, 54 m × 1.2 m and 180 m × 1.2 m respectively. In case of cole crops like cauliflower, cabbage and knol-khol, a nursery-bed of 115 m × 1.2 m would be sufficient to raise seedlings for one hectare of plot. These could be made into smaller beds instead of making a single bed. Small seeds should be sown mixed with a little sand and covered with soil. This covering should be still lighter in heavy soils. Covering the seeds in furrows or rows may be done gently by fingers or with the aid of a wooden strip, followed by a light irrigation with a sprinkler.

**After-care**

Watering of the bed is done uniformly and gently so as to avoid a packing of the soil or washing away of the soil covering. It is always advisable to make the nursery-beds near the source of irrigation water.

In the beginning if the sun is too warm, the mid-day sun may be avoided by covering the seedlings with a thin layer of leaves, twigs or thatch. During summer, the seedlings may be protected against warm wind and sunshine. When the seedlings are more than 2.5 cm tall, too much of shade and water make them yellow, succulent, lanky and susceptible to insect pests and diseases, like damping-off, especially in humid and warm weather. The diseased plants should be removed immediately. A week before transplanting, the seedlings may be exposed to full sunshine and the number of watering reduced so that the seedlings become hardy to bear the shock of transplanting.

**Transplanting**

If seedlings are allowed to grow too tall, they become weak and may start flowering. Transplanting should be done as soon as seedlings are about 4 to 8 weeks old, 10- to 15-cm long and have formed about 3 to 4 true leaves. The bed must be watered 24 hours before uprooting the seedlings for transplanting so that they may not suffer from desiccation. Transplanting should always be done in the evening so that plants may establish themselves in the cool weather at night and may recover from
the shock of transplanting before the sunrise. Transplanting should be done as early as possible after carefully removing the plants without damaging the roots. The soil should be prepared thoroughly before transplanting. Each seedling is placed vertically in the centre of the hole made in the field and the soil near the roots is pressed down with the fingers to make the soil firm. This may be followed by immediate watering. During transplanting, care should be taken to protect the seedlings against wilting by frequently sprinkling water on them and by covering the root zone by moist soil or leaves. Regular watering is necessary after transplanting. Seedlings not doing well may be removed and replaced by new ones. Any attack of disease or insect pest must be controlled immediately. Sometimes, seedlings are transplanted twice. As soon as they begin to crowd after the first transplanting, they are taken out and transplanted again in the field, spacing them further apart for proper growth and development. For example, cauliflower seedlings are sometimes transplanted twice to get stockier seedlings. Studies have shown that the hardening of cauliflower plants by repeated transplanting markedly improved the growth of plants in all respects and the yield of curd also increased considerably. However, double transplanting may damage seedlings and result in delayed maturity. It is needless to say that it would naturally involve increased cost of production with whatever advantage it may have and that is why this system is not commonly practised.
4. SOLANACEOUS CROPS

TOMATO

Origin

TOMATO is said to be the native of tropical America (Thompson and Kelly, 1957). The word tomato, not used until 1695, is said to be derived from the Aztec ‘Xitomate’ or ‘Xitotomate’. From tropical America it spread to other parts of the world in the 16th century and it became popular in India within the last six decades.

Distribution and uses

Tomato is now the most widely grown vegetable crop in India. It is grown throughout the country in farm gardens, small home-gardens, and by market gardeners for fresh consumption as well as for processing purposes. Tomatoes are good, whether fresh or canned. They have an outstanding vitamin contents like ascorbic acid or vitamin C, vitamin A, thiamine or vitamin B₁, and riboflavin or vitamin B₂, in that order. Tomato is used in many ways. It is taken cooked, raw or is made into soups, salads, preserves, pickles, chutneys, ketchups, sauces and many other products.

Botany

The tomato, Lycopersicon lycopersicum (Lycos, wolf; persica, peach; esculentum, edible), belongs to the family Solanaceae and is related to brinjal. It is a herbaceous annual plant with bisexual flowers. The fruit is a true berry. It is a self-pollinated crop but in some cases as high as 30% cross-pollination has been reported. Depending upon the growth habit, the tomato plants have been categorized into two—indeterminate and determinate types. The plant of former type terminates in a vegetative bud, whereas that of the determinate type terminates in a flower-bud and is appropriately called ‘self topping’ or ‘self pruning’ type. Many varieties of determinate type tomato plants do not have adequate foliage to protect their fruit. Some of them fruit very early. The determinate varieties can be harvested in 2-3 harvests while the fruiting period of indeterminate type is prolonged.
**Plant breeding**

Earlier most of the outstanding varieties were introduced from the western countries and some of them became popular among the growers and consumers in different agro-climatic regions depending upon their adaptability. The former Division of Plant Introduction at the Indian Agricultural Research Institute, New Delhi, had introduced almost all the important tomato varieties from all over the world which were evaluated for various purposes (Mital *et al.*, 1965). Some of the introduced American varieties like ‘Sioux’, ‘Marglobe’, etc. were recommended for commercial production. An outstanding achievement was made at the IARI, New Delhi, where the new tomato variety ‘Pusa Ruby’ was evolved by crossing ‘Sioux’, a good-quality American variety with ‘Improved Meeruti’, an indigenous hardy variety. The new tomato varieties ‘Arka Saurabh’ and ‘Arka Vikas’ from IIHR, Bangalore (Tikoo and Anand, 1983), ‘Co-3’ from Coimbatore, ‘Sel-120’ and ‘Sel-152’ from IARI, New Delhi, ‘S-12’, ‘Punjab Chhuvara’ and ‘Punjab Kesari’ from PAU, Ludhiana (Nandpuri *et al.*, 1977), ‘HS-101’ from Hisar, ‘KS-1’ and ‘KS-2’ from Kalianpur, ‘AC-238’ and ‘Pant T-3’ from Pantnagar, and ‘Sweet-72’ from Gwalior are promising beside some old varieties like ‘Pusa Ruby’, ‘Pusa Early Dwarf’, ‘Sioux’, ‘Roma’ and ‘La Bonita’. The varieties ‘Roma’ (Singh *et al.*, 1977), ‘La Bonita’ (Thomas *et al.*, 1976) and ‘Dwarf Money Maker’ (Thomas *et al.*, 1979) hold promise for commercial cultivation in different regions of our country in view of their higher yield and better fruit quality.

Genetics of the tomato with regard to heterosis and gene effects have been studied by Gill *et al.* (1976), Misra and Khanna (1977), Peter and Rai (1978), Mittal and Singh (1979), Singh *et al.* (1979), Rama Rao and Choudhury (1975, 1979), and Rattan and Saini (1979). Presently, the emphasis has been to breed tomato varieties resistant to the serious diseases and pests which have become limiting factors in tomato cultivation in various regions. The Indian Institute of Horticultural Research, Hessaraghatta, Bangalore, has been engaged in breeding varieties resistant to bacterial wilt, leaf-curl virus, tobacco mosaic virus, root-knot nematode, phytophthora fruit-rot, septoria leaf-spot and fruit-borer, while the Division of Vegetable Crops at IARI
is engaged in breeding varieties resistant to tobacco mosaic virus. The best source of resistance has been recorded from the wild tomato (*L. peruvianum*), but it does not cross with cultivated varieties normally. However, this was made possible with special techniques by Majid *et al.* (1968), where few interspecific hybrids were obtained with high resistance to various diseases.

Besides, the efforts at IIHR, Bangalore, have been to understand the mechanism of resistance to different diseases, to breed varieties with multiple disease resistance, high total soluble solids, moisture stress and better fruit shelf-life. The progress is very fast. The performance of the selections and hybrids developed through problem-oriented programmes is outstanding and is expected to fill up a major gap in this field soon.


**Climatic and soil requirements**

The tomato is a warm-season crop. It is not only sensitive to frost but it does not thrive at low, non-freezing temperatures. High temperatures, accompanied by low humidity and dry winds, frequently damage floral parts and there is no fruit-set. Smith (1932) found that tomato pollen grains germinate best at 29.4°C, nearly as well at 21°C, poorly at 10°C and very poorly at 37.3°C. Thus both high and low temperatures interfere with the setting of fruit. The tomato withstands drought fairly well but fruits are subject to blossom end rot and to growth cracks if moisture supply follows drought. It cannot be grown successfully in regions of higher rainfall.

The tomato grows on practically all soils from light sandy to heavy clay. Light soils are good for an early crop, while clay loam and silt-loam soils are well suited for heavy yields. If the soil is acidic liming is advocated, as tomatoes do best in a soil that has a soil reaction from pH 6 to 7.
Planting requirements

In the northern plains where frost occurs during winter, usually two successful crops are taken, whereas in frost-free areas where winter is not severe three crops in a year are possible. In regions where frost occurs, the first transplanting is done in February after the frost is over and the second crop transplanting is done around July when the rain has set in. In the southern plains where there is no danger of frost, the first transplanting is done in December-January, second in June-July and third in September-October depending on the irrigation facilities available.

Good tomato seeds remain viable for about four years and the germination is about 85 to 90%. Seed quantity of 430 to 550 g is sufficient to plant one hectare of land. The seeds are sown in nursery-bed. When the plants are about 4- to 5-week old and 12 to 15 cm in height, they are transplanted in rows at 60-75 cm apart. The planting distance within a row is kept 30 cm for determinate varieties and 60 cm for indeterminate varieties. For F₁ hybrids the distance is increased as per the agro-techniques recommended for such hybrids. Initial trials indicated that planting in double-row system (30 cm x 30 cm x 1 m) on raised beds provide higher yield of healthy fruits besides facilitating in intercultural operations.

The transplanting is done in small flat beds in light soils where irrigation is available and on shoulders in shallow furrow where irrigation water is scanty. In heavy soil it is usually transplanted on ridges and during the rains also it is advantageous to plant the seedlings on ridges.

Manurial and fertilizer requirements

The tomato crop responds very well to manurial and fertilizer application. A crop of tomato producing about 37 tonnes/ha of ripe tomatoes removes 80 kg of nitrogen, 20 kg of phosphorus and 130 kg of potassium (Yawalkar et al., 1962). The exact requirement of manurial and fertilizers would depend on the fertility status of the soil in which the crop is being taken. However, the different recommendations made in various regions are 66 to 110 kg of nitrogen usually in the form of ammonium sulphate, 35 to 60 kg of phosphorus in the form of
superphosphate and 35 to 60 kg of potash (muriate of potash) per hectare. In addition, about 20 cartload of fully decomposed farmyard manure are also applied. Generally, the complete dose of farmyard manure, phosphatic and potassic fertilizers are applied at the time of field preparation for transplanting the seedlings. The fertilizers are placed in bands 7.5 to 10 cm deep on both sides of the row before making furrows. The nitrogenous fertilizer is applied in two equal split doses, the first to be given before transplanting along with phosphorus and potassic fertilizers and the second dose to be applied around each plant about 45 days after transplanting. Kamalanathan and Thamburaj (1970) recommended 100 kg of nitrogen, 80 kg phosphorus and 50 kg potash over 25 tonnes of FYM/ha for the tomato plants spaced at 75 cm × 45 cm apart. Kamruddin et al. (1978) reported that high doses of nitrogen produced significantly more number of flowers and fruits than the lower doses. Six sprays of 1% urea at weekly intervals, starting at the seedling stage, produced significant increase in the yield of tomato (Tiwari and Chhonkar, 1967). In rare cases, a deficiency of boron was reported which was corrected by the soil application of 8 to 12 kg/ha of borax (Datta, 1961). Single morphactin treatment significantly checked the abscission and shedding of flowers thereby increasing the number of fruits per plant. The quantity of fruits was maximum when treated with GA₃ followed by control and morphactin-treated plants. Also, comparatively higher values of pyruvic acid and glyoxylic acid were recorded with GA₃ treatments (Mukherjee, 1980).

F₁ hybrids of tomato respond to higher dosage of fertilizer.

**Intercultural operations**

The irrigation should be so arranged that the soil remains moderately moist. Excessive irrigation induces the plant to vine and dropping off the blossoms. During summer season, irrigation at every 3 to 4 days interval is necessary, whereas in winter 10 to 15 days interval is sufficient.

Inter-tillage and hoeing should be done at regular intervals so as to keep the field free of weeds and to facilitate soil aeration and proper root development. Treflan at the rate 0.25 kg/ha was effective in controlling the weeds of tomato around Bangalore for about two-and-a-half months (Dhuria and
Leela, 1970). As the plants grow the intercultural operation should be shallow so that the damage to the roots, present 5 cm below the soil, may be avoided.

Staking plants has proved to be beneficial in the cultivation of tomato. In case of indeterminate varieties the yield and quality have improved and more so in rainy and winter seasons where the incidence of some of the diseases of fruit and foliage is also reduced. Rajeswar and Patil (1979) observed that unpruned staked plants gave significantly more yield/plant than the unstaked, unpruned plants.

Pruning and training of tomato plants are practised in American and European countries, but it has not become popular in our country except in some F₁ hybrids, because of non-consistent results at various places and the cost involved therein.

Some of the growth-regulating chemicals have shown useful results on experimental basis but commercial utilization needs to be exploited. Spray of gibberellic acid (50 ppm) at the fruit-setting stage increased the ascorbic acid content (Oza and Ranganekar, 1969).

Harvesting

Depending on the mode of disposal, the tomato fruits may be harvested at various stages of maturity: (a) Green stage—The fruits are fully developed but are green and suitable for sending to distant markets; (b) Pink stage—Some of the portion is red or pink and the fruit is not fully ripe. It is most suited for local markets; (c) Ripe stage—The major portion of the fruit is red and the softening begins. It may be picked up for home or table use; (d) Full ripe stage—The fruit develops maximum colour and turns soft. It is suited for processing purposes. After picking the fruits are graded and sorted out into cracked, bruised, injured fruits and well-matured ripe fruits. For marketing purpose ISI standard is advocated.

On an average yield of 250 q/ha is expected from the improved tomato varieties but an excellent crop has produced as high as 400 q/ha.

Improved varieties

The following varieties were recommended by the IARI, New Delhi.
‘Sioux’. It is a high-yielding American variety with dwarf, spreading and determinate growth habit. The fruits are medium to large with whitish green colour when unripe, and uniform red colour on ripening. It yields about 250 q/ha.

‘Pusa Red Plum’. It has been evolved by Pal et al. (1956) at the IARI by a cross between a cultivated tomato and the wild *L. pimpinellifolium*. It is an early variety suitable for table use. The fruits are small, borne in clusters with red colour and high vitamin C and sugar content. The plants are tall, with determinate growth habit, vigorous and high yielding.

‘Pusa Early Dwarf’. It is an early ripening selection from the cross between ‘Improved Meeruti’ and ‘Red Cloud’—a typical dwarf type with medium-large fruits of uniform colour. It has been observed to do well in both the seasons, and yields up to 395 q/ha (Mital et al., 1965).

‘Pusa Ruby’. It is an early and hardy variety evolved at IARI (Pal et al., 1956). The plants are medium and determinate. The fruits are medium-sized, lobed, uniformly red when ripe and yield 330 q/ha around Bangalore.

Some other varieties like ‘Sel-120’ and ‘Sel-152’ have been recently recommended by IARI.

The promising varieties recommended from Kalianpur, Hisar, Pantnagar and NBPGR have already been indicated in this chapter under the Plant Breeding.

**Varieties recommended by Karnataka State**

The following varieties of tomato are recommended by the Karnataka State.

‘Arka Saurabh’. Developed by Indian Institute of Horticultural Research, Bangalore, it is a high-yielding (40 tonnes/ha) variety exhibiting 30-35% higher yield than ‘Pusa Ruby’. It is semi-determinate, bears very firm, deep red, medium-sized fruits with smooth skin and thick flesh. The fruits are round with nipple tip. It has very good transport and keeping quality, 8-10 days at room temperature amongst the round-fruited varieties. It has an excellent blend of sugars (TSS 3.9%) and acidity (0.39%) and is very suitable both for fresh and processing purposes particularly for ketchup and juice-making (Fig. 2).

‘Arka Vikas’. Another high-yielding variety (35-40 tonnes/ha)
with large-sized, oblate, medium firm fruits. It is suitable for fresh market.

Varieties recommended from other places

The varieties recommended from other states are given below.

'Co-I'. The new variety was recommended by the former Department of Agriculture, Tamil Nadu, for the state. The plant is dwarf having semi-spreading habit with dark-green foliage. The fruits are round and smooth, pale green when unripe and capsicum red when fully ripe. The fruits are borne in cluster of 6 to 8, each weighing about 125 g. It yields an average of 380 q/ha (Kamalanathan et al., 1969).

'S-12'. The new round-fruited variety was recommended as a high-yielding variety for the State of Punjab by the Punjab Agricultural University. It has been developed through irradiation.

'Punjab Chhuhara'. Medium-size, pear-shaped fruit and a high-yielding variety released by the Punjab Agricultural University.
‘Sweet-72’. Developed at the Regional Agricultural Research Institute, Gwalior. It is a cross between ‘Pusa Red Plum’ and ‘Sioux’. It bears round, scarlet red, sweet fruits. Yield is about 200 q/ha.

Hybrid tomatoes have been grown but commercial utilization is still awaited because of the absence of commercial method of seed production. Attempts are being made to make use of male sterile parents to facilitate commercial hybrid seed production (Mital et al., 1962). Recently IIHR, Bangalore, has taken the lead in developing hybrids using exerted stigma, potato-leaved plant and combining nematode resistance. These are under the final testing (Tikoo and Anand, 1983). Indo-American Hybrid Seed Company, Bangalore, is selling the seeds of 4 $F_1$ hybrids which are gaining popularity in certain areas especially in Maharashtra region. Several $F_1$ hybrids from private seed companies and research centres are now under the testing by the All-India Co-ordinated Project.

**Diseases and their control**

Important diseases of tomato and their control measures are given below.

*Damping off* (*Rhizoctonia* sp., *Phytophthora* sp., *Pythium* sp. or *Pellicularia* sp.). The stem of the seedling decays at the soil surface and finally it collapses due to shrinking of tissues of the stem near the ground. The disease may be controlled by the sterilization of the nursery soil by steam or formalin and by treating the seeds with the fungicide Ceresan or Agrosan GN in the proportion of 1,000 parts of seeds with 3 parts of the fungicide. Soil sterilization is done by commercial formaldehyde at the rate of 1 litre in 270 litres of water and 1.37 litres/m$^2$ of soil. Planting in such case should be done two weeks after the treatment.

*Fusarium wilt* (*Fusarium* sp.). The lower leaves become yellow, wilt and die. The diseased plant remain stunted. It may be controlled by (a) using seed from healthy plants only, (b) rotating crops to decrease the fungus population, and (c) growing resistant varieties like ‘Marglobe’ and ‘Rutgers’.

*Bacterial wilt* (*Pseudomonas solanacearum*). In this case there is a sudden wilting of the plants which do not recover at all. The disease is known to be soil borne. It is difficult to control
The only solution seems to be to use resistant varieties. Such varieties are at advanced stage of release from IIHR, Bangalore.

**Early blight (Alternaria solani).** Dark-brown to black spots with concentric rings are formed on leaves and stems and dark decayed spots on the ripe fruits. Sharma et al. (1966) reported that the defoliation caused by *Alternaria solani* (Ellis and Martin) and *Stemphylium solani* Weber may be checked effectively by the spray of Dithane Z-78 at 0.2% concentration at weekly intervals. The seeds from infected plants may not be used and the clean seeds may also be treated with Ceresan to avoid infection, if any. A proper crop rotation should be followed avoiding solanaceous crops. Spray of Zineb has also been helpful in controlling the disease.

**Fruit-rot (Phytophthora lycopersici).** Brownish spots appear on fruits at the point of contact between the fruit and the soil. The fruit decays and becomes unmarketable. The disease is effectively controlled by weekly sprays of Difolatan (0.3%) or Bordeaux mixture (4:4:50) in high rainfall areas. To reduce the infection the plant should be staked and the drainage system should be improved.

**Powdery mildew (Oidium sp.).** The vegetative parts are very much damaged by the appearance of white mealy growth which leads to defoliation ultimately. It may be reduced by the application of 0.2% sulphur in dust or wettable spray form at intervals of one to two weeks.

**Septoria leaf-spot.** Symptoms of the disease are small circular water-soaked spots that later get dark margins and a grey to yellow centre. In the latter stage the leaves dry up and drop off. Dithane Z-78, blue copper or Difolatan (0.3%) or Blitox (0.5%) if sprayed at 7-10 days intervals give effective control.

**Leaf-curl virus.** It is the most serious disease of tomato specially during summer in the northern plains. The symptoms are size reduction, puckering and curling of the leaves and stunted growth of the plant. The disease is spread by white fly. One of the ways to reduce the infection has been to uproot the infected plants but it would not help much if alternate hosts are present around the field. Efforts have also been made to reduce the white fly population by the spray of Ekatox at
0.02% at 10 days interval till the fruit formation. At fruiting stage this may be stopped by spray of 0.05% Malathion at 10 days interval. The fruits may be harvested after two days for use.

*Tobacco mosaic virus.* The virus is highly infectious and spreads even through the hands of the workers engaged in various cultural operations in the field. It is a very serious disease in the northern plains though present in other regions also. The disease is characterized by the appearance of chlorotic areas on the leaves and occasionally the chlorotic areas turn yellow and are seen interspersed with green patches. The infection may be reduced by the use of seeds which are collected from healthy plants and by acid treatment of seeds.

*Cat face.* The damaged fruits are distinguished by the distortion of the blossom end rot and have ridges, furrows, indentations and blotches. A good number of varieties are free from this physiological disease.

*Sun injury.* The fruit surface exposed to the sun may become yellow or develop brown burnt areas. This may be reduced by the use of varieties with abundant foliage so as to cover the fruits with leaves. While picking the fruits from the vine, care should be taken not to turn the plants. Foliage diseases may be controlled timely so as to avoid defoliation leading to exposure of fruits to sun.

**Insect pests and nematodes**

Some of the important insect pests of tomato are described below.

*Fruit worm* (*Heliothis* sp.). It becomes a serious pest in some of the states. The caterpillars feed on the vegetative part and cut holes on unripe as well as ripe fruits. The damaged fruits may be picked up and destroyed completely. It may be controlled by the spray of 0.1% DDT at fortnightly intervals in the early stage of development of fruit. Fenitrothion (0.1%) also gives a good control of the pest (Mathur and Rajgopal, 1970).

*Epilachna beetle* (*Epilachna* sp.). Sometimes it becomes a serious pest of the foliage. Both larvae and adult feed on the leaves which give the plant a lace-like appearance. The larvae and eggs in the field may be picked up by hand and killed. It may be controlled by the spray of 0.1% DDT. All matured fruits should be picked up before spraying.
Jassids (*Empoasca* sp.). The insect sucks sap of the leaves causing curly appearance. The spray of 0.02% monocrotophos at about two weeks interval gives a satisfactory control.

**Root-knot nematode** (*Meloidogyne* sp.). The minute worm-like pest causes stunting of plants. Yellowish to bluish colouration of leaves followed by knot-like irregular swellings on root. The plant shows wilting in hot weather and may result in premature death. A proper crop rotation with non-solanaceous crops reduces infection. The use of nematode resistant variety like 'S-120', 'Pelican' or 'NMR-1' is beneficial. Hameed (1970) reported that the organic additives from *neem* and *Chrysanthemum* followed by big marigold profoundly minimized the incidence of the nematodes in tomato fields. It was also effectively controlled by the soil application of Nemagon at 6 to 7 litres/ha.

**Seed production**

The method of tomato cultivation for seed production is more or less the same as that of the cultivation for fruit production. Individual plants with good fruiting should be marked and ripe fruits should be collected for extracting seed. To get true-to-type seeds no other tomato variety should be grown at least within 50 metres around so as to avoid any chance of contamination with other varieties (Anonymous, 1971a).

The extraction of seed from the ripe fruits is done as follows: (a) **Fermentation method**—The crushed fruits are allowed to ferment for 1-2 days and then put in water where pulp and skin float and the seeds settle down at the bottom, (b) **Acid method**—About 100 ml of commercial hydrochloric acid is thoroughly mixed to 14 kg of crushed tomato fruits. The seeds separate out from the pulp within half an hour which may be cleaned up and dried.

Singh *et al.* (1964) recorded an average of 143 kg/ha of tomato seed. The quantity of fruit required to produce 1 kg of tomato seed varied from 160 to 210 kg depending on the variety. The average cost of production of 1 kg of seed worked out to be Rs 11.35 during 1955-57.

**BRINJAL**

**Origin**

Brinjal is said to be the native of India (Thompson and Kelly,
1957) with the secondary centre as China. More than 16 species, many of which closely related to brinjal, are found to grow wild in various parts of the country.

**Distribution and uses**

Brinjal is grown commonly in almost all the parts of the country and liked by both poor and rich. It is a main vegetable of the plains and is available more or less throughout the year. Used primarily as cooked vegetable, brinjal is popular for the preparation of various dishes in different regions of the country. It is supposed to contain certain medicinal properties in ayurvedic medicines.

**Botany**

Brinjal or egg plant, *Solanum melongena* L. belonging to the family Solanaceae is a herbaceous annual with erect or semi-spreading habit. The fruit is a berry, borne singly or in clusters. It is a self-pollinated crop but the cross-pollination to the extent of 30 to 40% has been reported in Bulgaria (Daskalov, 1937). Similar extent of cross-pollination has been observed in India.

Krishnamurthi and Subramaniam (1954) reported four types of flowers in brinjal. They reported that long-styled and medium-styled flowers produced fruits whereas pseudoshort-styled and true short-styled flowers did not set any fruit. Fruit setting in the brinjal varieties with long-styled flowers varied from 70 to 86%, while short-styled flowers did not set fruit (Prasad and Prakash, 1968). Vashistha and Nath (1969) studied fruit-set and fruit development, whereas Narayanaswamy and Sulladmath (1980) reported on gradual growth and composition pattern in developing brinjal fruits.

**Plant breeding**

A great genetic variation with regard to colour, shape, vegetative growth and presence or absence of spines exists among the indigenous materials. Studies on floral biology in long and round cultivars of brinjal were reported (Vijay et al., 1977). Earlier more emphasis was laid on the selection among the existing strains, which resulted in the release of varieties like 'Pusa Purple Long', 'Pusa Purple Round' and 'Pusa Purple Cluster' at the Indian Agricultural Research Institute, New Delhi. The
oblong variety, 'Pusa Kranti', was developed at the same Institute for North Indian conditions (Choudhury et al., 1971). The high-yielding and good-quality new varieties, 'Arka Sheel' (dark purple long), 'Arka Shirish' (long green), 'Arka Kusumakar' (small green clusters) and hybrid 'Arka Navneet' (purple round), have been developed for the southern plains by the Indian Institute of Horticultural Research, Bangalore (Vijay et al., 1971, 1978).

Pal and Singh (1949) reported increase in yield up to 40 to 50% in hybrids over the better parent. The hybrids invariably gave large fruits of superior quality. Vijay and Nath (1978) reported hybrid vigour up to 156.9% over the better parent in the cross 'Arka Kusumakar' × 'Supreme'. The hybrid combination 'IIHR 22-1' × 'Supreme' named 'Arka Navneet' proved to be the best combination for fruit quality and yield (Vijay et al., 1978).

Test involving a large number of Solanum species and varieties of Solanum melongena indicated that S. auriculatum was immune to little leaf virus (Anjaneyulu and Ramakrishna, 1968), which may possibly be used for breeding resistant varieties. Correlation studies in egg plant indicated significant positive association between plant spread and number of branches and between fruit number and yield (Singh and Khanna, 1978). The nature and magnitude of genetic variance involved in the inheritance of some quantitative characters were investigated in a 6 × 6 diallel cross in brinjal (Singh and Khanna, 1979). Mode of inheritance of certain qualitative traits like spineness and purple leaf colour has been reported (Randhawa and Sukhija, 1975). Chadha and Sidhu (1983) studied variability and correlation of newly developed genotypes and observed total yield to be highly correlated with plant height, number of branches and fruit weight.

Climatic, and soil requirements

Like tomato, the brinjal is also susceptible to frost. It requires a long and warm growing season. The plants should not be transplanted in the field until the daily mean temperature reaches 18.3° to 21.1°C.

The soil requirements for brinjal are the same as that of the tomato.
Planting requirements

It can be grown just at the same time when tomatoes are grown.

The seeds are sown in well-prepared nursery-bed and the seedlings about 15 cm high are ready for transplanting in 5 to 6 weeks. About 200 to 300 g seeds are sufficient to raise seedlings needed for planting one hectare. The brinjal seed is light in weight with the germination of 75 to 80%.

The land should be deeply dug and well prepared before the seedlings are transplanted. Usually there is less mortality in the transplanted seedlings which are placed 75 to 90 cm in the rows and 90 cm apart rows either in the plain beds or on ridges.

Manurial and fertilizer requirements

Depending on the fertility status of the soil, the following recommendations have been made for different regions of the country. They are 45 to 110 kg nitrogen in the form of ammonium sulphate, 66 to 110 kg phosphorus in the form of superphosphate and 56 to 135 kg potash in the form of muriate of potash per hectare. In addition, 25 to 50 tonnes of farmyard manure per hectare is applied at the time of field preparation, whereas the complete dose of phosphatic and potassic fertilizers are top dressed just before transplanting of the seedlings. Yawalkar et al. (1962) suggested three split doses of nitrogen. The first dose is to be given one-and-a-half month after transplanting, the second dose one month after the first dose and the final dose three-and-a-half months after transplanting. Fertilizer dose for hybrids is generally higher than the pure varieties and should be followed as recommended for such hybrids.

Intercultural operations

The intercultural operations are more or less the same as in tomato.

Muthukrishnan and Srinivasan (1963) reported a significant increase in yield of 50% by whole plant sprays of 2,4-D at 2 ppm at intervals of one week over a period of 60 to 70 days from the commencement of flowering.

Harvesting

The brinjal fruits are harvested when they are immature. Al-
though the fruit is harvested before it fully ripens, it should be allowed to attain a good size and colour. Its surface should not lose its bright and glossy appearance. At harvesting, the calyx and stem-end are left attached to the fruit. Large, round varieties should be handled with care. Depending on the variety and the season it produces 250 to 400 quintals of fruits per hectare. Usually the fruits are packed in baskets for the markets.

The fruit can be stored for two to three days during winter and one to two days during summer under ordinary conditions but it can be kept for about a week in a fairly good condition at 7.2°C to 10°C and 85 to 95% relative humidity.

Diseases

Important diseases of brinjal and their control measures are given below:

**Damping off** (*Phytophthora* or *Pythium* spp). Due to the attack of this disease the seedlings rot at the ground level and then fall over the ground. It may be controlled if the nursery soil is sterilized before sowing and the seeds are treated with Ceresan before sowing. Hot-water treatment of seeds at 51.7°C for 30 minutes has also been effective in controlling this disease.

**Phomopsis blight** (*Phomopsis* sp.). The foliage is attacked at any time during the season. The lesions usually appear first on the leaves and later on the fruits near the ground. The spots are clearly defined, circular, grey to brown and have a light-coloured centre. The affected leaves may turn yellow and die. It may be reduced by the use of seeds obtained from disease-free plants and hot-water treatment of the seeds at 50°C for 30 minutes. A suitable crop rotation may also help in reducing the incidence of the disease.

**Little leaf virus.** It is a very serious disease in some of the states. The leaves become smaller, the petioles get shorter considerably, many buds appear in the axil of leaves, internodes get shortened and give the plants a bushy appearance. Removal of the diseased plants in the initial stages and fortnightly spray of insecticide like Ekatox or Folidol till the fruit-sets may help to check the spread of the disease which is transmitted by insects, *Eutettix phycitis* and *Empoasca devastans.*

**Bacterial wilt** (*Pseudomonas solanacearum*). This disease has
gained importance in several parts of India. A satisfactory solution to this problem is that the cultivation of both brinjal and tomato may be avoided in wilt-sick plots and wilt-resistant varieties may be used. I IHR, Bangalore, has developed recently bacterial wilt-resistant promising lines which may be tried.

Insect pests and nematodes

Some of the important insect pests of brinjal are described below.

\textit{Brinjal fruit- and shoot-borer (Leucinodes orbonalis).} It is the most serious pest of this crop. The borer or caterpillar attacks the plant from nursery and continues till the crop remains in the field. It becomes inactive during winter. The caterpillars bore into the young shoots and fruits as a result of which the shoots wither and dry up while the fruits become unfit for consumption and in severe cases even rot. The infected shoots should be removed and destroyed. Ratoon crop should be avoided and suitable crop rotation should be followed. The infestation can be reduced with the spray of Sevin (0.4\%) at 10 days interval and the fruits may be harvested after three days.

Attempt has also been made to isolate resistant varieties (Gill and Chadha, 1979).

\textit{Stem-borer (Euzophera perticella).} The caterpillars bore into the stem and often kill the plant. The infested plants or plant parts should be removed and destroyed. The plants may be sprayed with 0.02\% monocrotophos after harvesting the fruits and the next harvest must not be made within three days.

\textit{Jassids (Empoasca sp.).} The leafhopper sucks sap from the leaves causing curling of leaves. It may be controlled by the spray of 0.1\% Ekatox at 3-week intervals before fruiting. At fruiting it may be sprayed with Malathion (0.15\%) at weekly intervals. The fruits may be harvested before spray and must not be harvested for a few days after the spray.

\textit{Root-knot nematodes (Meloidogyne sp.).} The plants become stunted and the leaves become chlorotic. Nodules are formed on the roots. It may be controlled by the soil fumigation of Nemagon or DD. Proper crop rotation will help in the reduction of nematode population.
Seed production

The practices normally followed for the crop raised for fruit production need to be adopted for seed production also. It is a self-pollinated crop but cross-pollination may also take place as discussed earlier. The two varieties meant for foundation seed production may be kept 200 m apart to avoid contamination (Anonymous, 1971a).

For the purpose of seed production the ripe fruits turned yellow are crushed and stored overnight so that the seed after washing with water is sieved and dried. The washing is usually done in the morning so that the seed is atleast half dried during the day otherwise it may germinate. It has recorded a seed yield of 590 to 880 kg/ha (Singh et al., 1964).

Improved varieties

The following varieties were recommended by the IARI, New Delhi.

‘Pusa Purple Long’. It is a selection from the mixed ‘Batia’ variety grown in the Punjab, Delhi and western Uttar Pradesh. It is an early-fruiting variety becoming ready for picking in 100 to 110 days. The slender, shining, purple fruits measure 20 to 25 cm in length and give an average yield of 275 q/ha.

‘Pusa Purple Cluster’. This is a variety with medium growth of plants. It bears small dark purple fruits in clusters which are useful for different cooking purposes. It has shown relatively higher yield in some regions (Gill et al., 1978).

‘Pusa Kranti’. The fruits are oblong and stocky than slender (as in ‘Pusa Purple Long’) with attractive dark purple colour. This variety is suitable for both spring and autumn plantings under North Indian conditions.

‘Pusa Anmol’. It is a new hybrid variety with attractive dark purple oblong fruits. It produces early and increased yield of about 80% over ‘Pusa Purple Long’.

The promising brinjal varieties developed at the Indian Institute of Horticultural Research, Bangalore, are as follows (Vijay et al., 1971, 1972).

‘Arka Kusumakar’. It is a dwarf, bushy variety which bears finger-shaped fruits in clusters. The fruits are light green in colour and used in various preparations in the southern region. It is a heavy yielder giving as much as 397 q/ha.
'Arka Shirish'. This variety has extra-long fruits with very few seeds. It is an early variety and yields about 384 q/ha.

'Arka Sheel'. This variety has medium-long, thick fruits with deep shining purple colour. It is a medium early and yields about 394 q/ha.

'Arka Navneet'. The hybrid developed as a cross between 'IIHR 22-1' and 'Supreme' (an Australian variety) has shiny dark purple round oval fruits. On an average it produces about 633 quintals per hectare. It has been recommended by the All-India Co-ordinated Project for an All-India release based on its consistently best performance at almost all the centres of its testing (Fig. 3).

![Image of brinjal fruits](image)

Fig. 3. A very high-yielding F\textsubscript{1} hybrid of brinjal, 'Arka Navneet'.

Indo-American Hybrid Seed Company, Bangalore, has released one F\textsubscript{1} hybrid named 'Sufal'. Several promising hybrids from IIHR, IARI, Pantnagar, Ludhiana are under the test.

**CHILLI AND GREEN PEPPER**

*Origin*

Green pepper is reported to be the native of Tropical America (Thompson and Kelly, 1957). Chilli and pepper are known
from pre-historic remains in Peru. These were widely cultivated in Central and South America in early times and were unknown in Europe prior to the discovery of America. In India its introduction is believed to be through the Portuguese in the 17th century.

**Distribution and uses**

The chilli is grown in almost all plains throughout the country whereas the green pepper is grown at a little high elevations also where the climate is relatively mild. Chilli and green pepper are consumed by every Indian. There is hardly a vegetable where chilli is not used as a condiment while cooking. The chillies are used green as well as dry in the powdered form. It is a rich source of vitamin A and C among the vegetables. The chillies are usually more pungent than the green pepper. The pungency is due to the presence of the chemical capsaicin and the bright red colour at the ripening stage is due to the pigment capsanthin. Awasthi and Singh (1979) reported ascorbic acid and capsaicin content of different chilli cultivars.

**Botany**

The common chilli is *Capsicum annuum* var. *longum* and *accuminatum* L., whereas the green pepper or the bell pepper is *Capsicum annuum* var. *glossum* L. The chilli includes a large number of horticultural varieties and is the most important economically. The fruit varies in size from 1 to 20 cm in length from thin long to conical and thick fleshy blocky shapes. It includes both pungent and non-pungent varieties but most of the varieties grown in our country are pungent varying from very pungent to non-pungent.

Green pepper are fleshy, blocky, of various shapes—more like a bell and hence named bell pepper. Almost all the varieties are very mild in pungency and some of them are non-pungent and as such could be used as stuffed vegetable. The fruits of pepper and chilli are 'berry' botanically.

Studies on flower development, fruit maturity and floral biology in sweet or green pepper have been reported (Vijay *et al.*, 1979).

**Plant breeding**

A great genetic variation exists in chillies and sweet pepper
with regard to shape, size, pungency and pigmentation of the fruits. Most important strains have been reported from various parts of the country where it is intensively grown for dry as well as green chillies. The important centres of growing chillies are Andhra Pradesh, Maharashtra, Karnataka, Tamil Nadu, Madhya Pradesh, Rajasthan, Bihar and Punjab. In these states efforts were made by the breeders to evolve suitable strains which are being widely cultivated. In some of these chilli-growing areas there has been a setback because of the serious incidence of the virus disease. However, the insect pests could be controlled by chemical measures. Attempts have been made to breed high-yielding varieties coupled with resistance to diseases, and high vitamin C content (Pal et al., 1941; Cheema et al., 1944; Deshpande, 1944; Parthasarthy and Kedarnath, 1950; Jeswani et al., 1956; Jagadish et al., 1964; Singh and Singh, 1970; Singh et al., 1977). The probable source of resistance to virus disease was reported by Jayarajan and Ramakrishnan (1969). Source of resistance to anthracnose, cercospora leaf-spot, bacterial leaf-spot and powdery mildew have been identified by Cheema (1982), Rawal et al. (1983), Ullasa et al. (1981) and Singh et al. (1982). Soh et al. (1977) suggested that the backcross breeding method would be appropriate for a rapid development of a pepper veinal mottle virus resistant and commercially acceptable chilli cultivar. Sontakke (1981), Raju (1979) and Cheema (1982) also suggested different breeding methods for the improvement of chillies and sweet pepper.

Deshpande (1933) demonstrated hybrid vigour in chillies with regard to total number of fruits and total weight of dry produce. Sontakke (1981) observed heterosis and heterobeltiosis for yield, branches, earliness, plant height, carotenoids, ascorbic acid, fruit size, etc. Similarly, Pal (1945) observed increased yield and early maturity in hybrid chillies. Singh and Singh (1978) said it may be worthwhile to subject the parents to diallel selective mating for fostering greater recombinations if simultaneous improvement of developmental characters related to productivity is sought in chilli.

Arya and Saini (1977) reported that the degree of genetic variability was highest in rind thickness per fruit (223.33%) and fruit size per plant (129.86%) in pepper. Usha Rani (1981)
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and Raju (1979) studied variability, heritability and gene action in chillies and sweet pepper for various traits including ascorbic acid, pigment and pungency.

Several variants and mutants have been observed which are mainly useful for genetic studies. However, use of closed flower mutant (cf) and male sterile (ms) mutants can be used for hybrid seed production (Deshpande et al., 1983a, b; Pathak et al., 1983a, b). Use of synthetic or composite varieties and need for reciprocal recurrent selection for simultaneous improvement for various characters have been advocated by Sontakke (1981), Usha Rani (1981) and Cheema (1982).

**Climatic and soil requirements**

Chillies can be grown in the same climate where tomato and brinjal are grown. It is also susceptible to frost. It germinates well at soil temperature of 18.3° to 26.7°C. Plants kept at 10° to 15.6°C at the time of anthesis indicated that 99.3% of the flowers set fruit, but all fruits develop parthenocarpically in green pepper (Cochran, 1936).

Chillies can be grown on many classes of soils like tomato and brinjal. However, the germination and early vigour were very much affected in saline soils (Kaliappan and Rajagopal, 1970).

**Planting requirements**

Like brinjal and tomatoes the chillies can also be grown as summer, rainy and winter crops in the frost-free areas of the plains and as only summer- and rainy-season crops in areas where frost and severe winter occur.

Seeds are sown in nursery-beds and seedlings become ready for transplanting in about 6 to 7 weeks when they are 15- to 20-cm high. About 500 to 990 g of seed is required for transplanting an hectare of area. Usually the seedlings are transplanted in rows about 45 to 60 cm apart either in plain beds or on the ridge depending on the type of soil and irrigation facilities available. The plants in the row are kept about 30 to 45 cm apart.

**Manurial and fertilizer requirements**

Depending on the fertility status of the soil, manurial and fertilizer applications may be as follows: 50 to 98 cartload of
FYM, nitrogen 30 to 54 kg in the form of ammonium sulphate, 50 to 110 kg of phosphorus in the form of superphosphate and 75 to 98 kg of potash per hectare (Roberts and Singh, 1951; Purewal, 1954; Relwani, 1963). The complete dose of FYM should be mixed with the soil at the time of preparation. Potassium and phosphatic fertilizers should be mixed in the plant rows just before transplanting. The ammonium sulphate may be given in two split doses, one at the time of transplanting and the other at the time of earthing-up or 1½ months after transplanting. Tripathi and Bisen (1969) observed increase in yield with the increase in the dose of nitrogen. Under semi-arid conditions, the closer spacing of 45 cm × 30 cm with the balanced fertilization of 150 : 120 : 60 of N : P : K per hectare was recommended for higher yields with better-quality fruits for irrigated green chilli crop of the variety ‘Jwala’ (Chaugule and Mahajan, 1979).

Intercultural operations

Intercultural operations are similar to that in brinjal and tomato.

Harvesting

The chillies are harvested at two stages—one for green vegetables and the other as dry chillies. The green chillies and green peppers are harvested when they are fully mature and before they change from green to red on approaching the ripe stage. They are picked up at frequent intervals possibly twice a week. Sweet peppers can be harvested only once in a week.

The average yield of green chillies ranges between 74 and 98 quintals per hectare, whereas the dry fruits are produced at the rate of 9.0 to 9.5 q/ha. From fresh ripe fruit 25 to 40% of dry fruit can be obtained depending upon the varieties which differ in quantity of seeds and the thickness of the inner wall. In the villages the fruits are dried by spreading on the floor or roofs of the houses in the sun. With the indigenous method it takes 10 to 15 days to dry, whereas commercially it is dried at about 54.4°C in 2 to 3 days. Improved sweet pepper varieties yield 200-300 q/ha of green fruits, while the hybrids can yield up to 400 q/ha.

Green chillies and peppers can be stored for about 40 days at
0°C and 95 to 98% relative humidity (Platenius and Thompson, 1934). Dried chillies can be kept for months together in dry places well protected from insect pests.

Improved varieties

A. CHILLIES

The important varieties of chillies are given below:

‘Jwala’. It is a prolific yielder evolved by a cross between ‘NP 46 A’ × ‘Puri Red’ at Division of Genetics, IARI, New Delhi. It is tolerant to thrips and leaf-curl. Fruits are long but curved.

‘NP 46 A’. It is a medium, early and prolific variety. The fruits are long, thin and green when unripe and bright red when ripe. It is a pungent chilli variety.

‘Pant C-1’. A good yielder and tolerant to leaf-curl. Evolved at Pantnagar by crossing C. annuum with C. frutescens.


‘Co-1’. Released from Coimbatore in 1979. Yields up to 20 q/ha of dry fruits per hectare.

‘K-2’. Released from Kovilpatti in 1975. Yields up to 18 q/ha dry fruits per hectare.

Besides, there are many local/improved varieties popular in different regions like ‘Byadgi’ and ‘Sankeshwar’ (Karnataka-Maharashtra), ‘Longia’ (Bihar), ‘G-3’, ‘G-5’ and ‘Cross 235’ (Andhra Pradesh), ‘Theni’ (Tamil Nadu), ‘Sanauri’ (Punjab, Himachal Pradesh), etc. Very ambitious breeding programmes are going on at Indian Institute of Horticultural Research, Bangalore, to develop varieties with higher yield, high and retentive pigments, resistant to multiple diseases and for irrigated and rainfed cultivation. Other centres of research work are Coimbatore, Kovilpatti, Ludhiana, Lam, Kalianpur, etc.

B. SWEET PEPPER

The important varieties of sweet pepper are:

‘California Wonder’. A medium-tall, popular variety with stocky and upright plants. Blocky, green drooping fruits medium-thin flesh and having 3-4 lobes. Yield 120-150 q/ha.

‘Chinese Giant’. It is also one of the popular varieties.
Plants are dark green and vigorous. Fruits are 3-4 lobed with medium flesh thickness. Yields 100-150 q/ha.

'Yolo Wonder'. It is a dwarf, prolific and late green, blocky, drooping fruited variety. Flesh thickness medium; 3-4 lobed fruits. Yields 100-125 q/ha.

'Hybrid Bharat'. An F₁ hybrid released by Indo-American Hybrid Seed Company, Bangalore, in 1973. Fruits are 4-lobed with thick flesh. Yields 400-500 q/ha.

Recently, IIHR, Bangalore, has released three very high yielding varieties after thorough multilocation testing in Karnataka under the names of selections '13', '16' and '3'. These varieties have performed well in western and eastern India also. The yield, 35-40% higher than 'California Wonder', has been record ed on an average. These are:

'Arka Mohini'. A determinate variety with medium to large blocky, drooping fruits (80-100 g), dark green surface, thick flesh and 3-4 lobes. Suitable for both the seasons of cultivation. Foliage covers the fruits and avoids sunscald. Tipping of initial flowers advocated to get higher yield. Yield is 200-250 q/ha (Fig. 4).

Fig. 4. ‘Arka Mohini’ capsicum with thick flesh and high yield.
‘Arka Gaurav’. An indeterminate variety with dark green, blocky erect, 3-4 lobes, medium-sized fruits (70-80 g). Yield 180-250 q/ha. Good for both kharif and rabi seasons. Foliage covers the fruits and avoids sunscald. Tolerant to bacterial wilt disease (Fig. 5).

Fig. 5. High-yielding ‘Arka Gaurav’ capsicum with thick flesh and tolerant to bacterial wilt.

‘Arka Basant’. It is creamish white, conical, erect-fruited variety with thick flesh and prolific continuous bearing. It has an excellent keeping and cooking qualities. Good for stuffing. It has good aroma and crisp texture. Yields on an average 150-200 q/ha (Fig. 6). Suitable for both the seasons. It has very good export value of the fruits.

Seed production

The cultivation would be exactly the same as for growing dry chillies. It is considered as a self-pollinated crop but cross-pollination takes place to a great extent. To obtain pure seeds the two varieties may be kept 400 m apart to avoid any contamination (Anonymous, 1971a). For seed, good, healthy
Fig. 6. An indeterminate prolific bearer of creamish-white fruits with thick, succulent, sweet flesh capsicum, ‘Arka Basant’.

and well-developed fruits should be preserved. The seeds should be extracted after breaking the dry shells.

At Katrain, Kulu Valley, the average calculated yield of ‘California Wonder’ variety was 105 kg/ha with a maximum of 225 kg. The average cost of production for 1 kg of seed was Rs 12.63 (Singh et al., 1964).

Diseases

The common diseases are described below:

Damping off (Pythium, Phytophthora and Pellicularia spp.). The seedlings are attacked at or just below the soil level and they gradually die. It may be controlled by sterilizing the nursery soil one week before sowing. It may also be controlled by treating the seeds with Ceresan or drenching with Captan.

Anthracnose (Colletotrichum capsici). The foliage, stem and
fruits are attacked by this species causing 10-75% loss of fruits. In severe cases it causes the dieback of the plant especially by *C. gloeosporioides*. High humidity is conducive for this disease. Ceresan-treated seeds should be sown. Crop rotation with other solanaceous crops is advisable. It can be controlled by Benlate (0.1%) or Difolatan (0.2%) sprays at 7-10 days interval. Resistant varieties should be planted.

*Powdery mildew* (*Leveillula* sp.). It is serious especially during summer, and can be controlled by weekly sprays of Sulfex, Karathane or Calixin (0.2%). Resistant varieties are being developed at IIHR, Bangalore.

*Fruit-rot* (*Phytophthora capsici*). It is more serious during rainy season. Fruits become watery and fall. Weekly sprays of Bordeaux mixture or Dithane M-45 (0.2%) may control it to some extent.

*Bacterial wilt* (*Pseudomonas solanacearum*). Though chillies are not affected by it as much as tomato or brinjal, but sweet pepper varieties are susceptible to this wilt. ‘Arka Gaurav’ is claimed to be tolerant to some extent. There is no effective chemical control except to develop resistant varieties for commercial cultivation.

There are some other diseases like early blight (*Alternaria* sp.), and bacterial leaf spot (*Xanthomonas vesicatoria*) which can be controlled by sprays.

*Virus diseases*. The most important virus is leaf-curl causing curling of the leaf margins inwards and upwards and crumpling of interveining areas. In severe cases leaves fall off, checking the growth of the plant. The disease is transmitted by thrips and aphids. In the beginning the few plants showing infection should be uprooted and burnt to avoid further infection. However, the incidence of the disease may be reduced if the insects transmitting disease are controlled by the spray of either nicotine sulphate or other insecticides like methyl parathion (5 ml/litre of water). It is also suggested to use granular insecticides like Carbofuran (1.5-3 kg a i/ha) at the time of transplanting. ‘Pant C-1’ and ‘Jwala’ varieties of chillies are reported to be tolerant to leaf-curl virus.

Other virus diseases like cucumber mosaic virus (CMV), tobacco mosaic virus (TMV) and potato virus Y (PVY) are also important diseases of chillies and sweet pepper. The control
lies with the development of resistant varieties. The efforts in this direction are being made mainly at IIHR, Bangalore, and PAU, Ludhiana.

**Insect pests**

Some of the important insect pests of chillies and green pepper are given below.

*Chilli Thrips (Thrips sp.)*. The tiny sucking insects feed on leaves and lacerate the tissues. Damage is at all the stages of plant growth and they are more severe when plants begin to flower. It causes curling of the leaves and the yield is reduced considerably. It may be controlled by the spray of 0.25% nicotin sulphate or Zolone.
5. MELONS

Origin

MELONS include a group of fruits such as watermelon, muskmelon, longmelon, snapmelon and roundmelon. The place of origin of this group of vegetables (longmelon, snapmelon and roundmelon) is said to be India, and tropics and subtropics of both Africa as well as India in case of watermelon and muskmelon.

Distribution and uses

Most melons are grown in almost all states of India except roundmelon which is cultivated mostly in Punjab, Rajasthan, Delhi, western Uttar Pradesh, Madhya Pradesh, Bihar and Andhra Pradesh (Nath, 1971d). Melons are good sources of carbohydrates, vitamin A and C and minerals. They are mostly used as dessert (watermelon, muskmelon and snapmelon), as ingredients of salad (longmelon) and as vegetables (roundmelon and longmelon).

Botany

All melons belong to the family Cucurbitaceae. They are either vines or creepers. Flowers are monoecious or andromonoecious and are highly cross-pollinated in nature. The fruit is 'pepo' botanically and it varies in shape, size, colour and taste. The leaves are simple, alternate and palmately lobed in longmelon, snapmelon and muskmelon. In watermelon and roundmelon these are cordate at the base and deeply pinnated into three or four pairs of lobes. Tendrils are either simple as in muskmelon, longmelon and snapmelon, or branched as in watermelon and roundmelon.

Detailed studies on vegetative growth, flowering pattern, fruit set and fruit development in watermelon (Nath and Vashistha, 1969), muskmelon (Vashistha and Nath, 1969; Kaloo et al., 1983), longmelon (Vashistha and Nath, 1970) and snapmelon (Nath and Vashistha, 1970) have been reported.

Plant breeding

All melons belong to genera Citrullus and Cucumis. Though these two genera comprise a few cultivated species, yet there
is difference of opinion regarding their cytogenetics and sys-
tematic behaviour. Somatic chromosome numbers of watermelon
(Citrullus lanatus (Thunb.) Mansf.) and roundmelon (Citrullus
vulgaris var. fistulosus Watt.) are 22 (Khoshoo, 1955; Shimotsuma,
1965), whereas that of muskmelon (Cucumis melo L.), snapmelon
(Cucumis melo var. momordica Duth. & Full.) and longmelon
(Cucumis melo var. utilisimus Duth. & Full.) are 24 (Kozukhov,
1930; Whitaker, 1930). Most of the Indian authors considered
roundmelon (tinda) as a variety of watermelon, viz. Citrullus
vulgaris Schrad. var. fistulosus (Hooker, 1872; Chakravarty,
1946, 1959). However, on the basis of morphological characters,
geographical distribution and cross-compatibility, it was suggest-
ed that Citrullus vulgaris var. fistulosus should be placed in
the genus Cucumis (Shimotsuma, 1963). Whitaker and Davis
(1962), on the other hand, reported that Citrullus vulgaris var.
fistulosus was an aberrant form of Cucumis. Dutta and Nath
(1970), on the basis of poor crossability of roundmelon with
either watermelon or muskmelon, as well as its complete incom-
patibility with longmelon and snapmelon, suggested that it
should be placed in a separate genus Prae-citrurus. Similar
suggestion was also made by Pangalo (1930) and Guljaev
(1963). Based on the cytological studies, Trivedi and Roy
(1970) suggested that Citrullus vulgaris var. fistulosus should
be given a distinct specific rank.

A comparative study on sex expression and sex ratio in
common melons was made by Sharma and Nath (1970). Earlier,
pronounced effect of growth regulators on sex expression and
sex ratio in muskmelon was recorded (Soni et al., 1968). Studies
have also been made on pollen morphology and physiology in
common melons (Nath and Sharma, 1969, 1972), different
filial generations in watermelon (Katrodia et al., 1974) and round-
melon (Subramanyam et al., 1974).

At the Indian Institute of Horticultural Research, Bangalore,
a large number of indigenous and exotic collections of various
cucurbits have been evaluated for fruit quality and other
aspects and utilized in the breeding programme. Two improved
muskmelon varieties developed are ‘Arka Rajhans’, which
is resistant to powdery mildew and ‘Arka Jeet’ with high
sugar content (Nath and Dutta, 1969, 1971). In roundmelon, the
variety ‘Arka Tinda’ was developed as a cross between the local strains of Rajasthan and Punjab and selected as a uniform line in the F₅ generation (Nath and Dutta, 1971a, b; Nath et al., 1977). In longmelon the two superior true breeding lines have been developed which possess good fruit quality and high yield (Nath et al., 1977). As a result of a breeding programme in watermelon, a new variety ‘Arka Manik’ (Dutta et al., 1977) and a hybrid ‘Arka Jyoti’ (Nath et al., 1975) were developed.

**Heterosis**

Recently efforts were made to exploit hybrid vigour in commercial production. Nath and Dutta (1970a) obtained a maximum of 58 and 75% increased yield over the better parent in hybrid watermelon ‘IHR 20’ × ‘Crimson Sweet’ and ‘IHR 6’ × ‘Charleston Gray’ respectively. Dhesi et al. (1964) reported 72% increased yield in hybrid roundmelon. The hybrid between snapmelon, longmelon and muskmelon showed heterosis in fruit yield, which appeared to be the result of increased fruit number, fruit weight and increased flesh thickness (Nath and Dutta, 1970b, 1971; Dutta and Nath, 1971a).

**Genetics**

Information on the genetics of economic characters and hybrid seed production is also available in these melons (Mohr et al., 1955; Bains and Kang, 1963; Foster, 1968; Lozenov, 1969; Nath and Dutta, 1970a; Sachan and Nath, 1971; Brar and Sukhija, 1977; Chadha and Nandpuri, 1977, 1978). Recently, investigations have been reported on inheritance of seed characters in watermelon (Nath and Dutta, 1975; Nath and Khandelwal, 1978), and resistance to fruit-fly in watermelon (Khandelwal and Nath, 1978); and on combining ability and diallel crosses in watermelon (Sachan and Nath, 1975, 1976) and muskmelon (Chadha and Nandpuri, 1980). Source of resistance to fruit-fly in watermelon was isolated by Khandelwal and Nath (1979).

**Climatic and soil requirements**

All melons are grown in summer, but roundmelon and snapmelon are grown in rainy season also. However, in Rajasthan, where rainy season is as good as summer, watermelon is also grown in the rainy season (Nath, 1965a). In the case of
roundmelon, varieties suitable for summer season do not grow well in rainy season and vice-versa. Melons normally require a warm and dry weather, good sunshine, low humidity and frost-free period. Duration of crop varies from 85 to 110 days. **Optimum temperature for plant growth varies from 23.90° to 26.7°C with the minimum and maximum being 18.3°C and 32.3°C respectively.**

Melons grow best and give heavy early yield in a well drained sandy-loam soil. Heavy soil, if drained well, also gives good yield. They do not grow well in highly acidic or alkaline soil. However, some of the strains of watermelon, 'Jobner 21' and '18-1' (Nath and Sachan, 1967) and muskmelon 'Jobner 96-2' and '60-3' (Nath and Khangarot, 1968) performed well even under high soil pH conditions.

**Planting requirements**

All melons are sown directly in the field as they cannot withstand transplanting well. In the plains, sowing is done from November to middle of March for the summer crop. However, middle of February is the best time for most of the northern states while December-January is the best time for most of the southern states. In river-beds sowing is done from November to February. Rainy-season crop of roundmelon, snapmelon and watermelon (Mattera) is sown from middle of June to end of July (Nath, 1965a). In light soil sowing is done in furrows, whereas in heavy soils it is done on ridges. In both the cases sowing is done in hills 60 to 120 cm apart, whereas the spacing between rows is kept 2 to 3.5 m. Two to three seedlings are kept per hill.

**Manures and fertilizers**

Depending upon the climate and soil conditions, different doses of manures and fertilizers have been recommended for melons. As it is highly impractical to give any specific recommendation for different areas of melon production, a general recommendation based on experimental results will prove beneficial. The recommendation and practices followed at various places (Choudhury, 1957; Dhesi et al., 1966; Murthy, 1963; Padda et al., 1969; Nath, 1965a; Sharma and Shukla, 1971a; Singh and Choudhury, 1977) are given in Table 1.
TABLE 1. MANURIAL AND FERTILIZER REQUIREMENTS FOR DIFFERENT MELONS

<table>
<thead>
<tr>
<th>Crop</th>
<th>FYM (q/ha)</th>
<th>Nitrogen (kg/ha)</th>
<th>Phosphorus (kg/ha)</th>
<th>Potash (kg/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Watermelon</td>
<td>55 to 165.5</td>
<td>55 to 111</td>
<td>55.5 to 80</td>
<td>55.5 to 111</td>
</tr>
<tr>
<td>Muskmelon</td>
<td>447 to 494</td>
<td>56 to 106</td>
<td>36 to 84</td>
<td>28 to 40</td>
</tr>
<tr>
<td>Roundmelon</td>
<td>90</td>
<td>37 to 55.5</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Longmelon</td>
<td>336</td>
<td>35.5</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Snapmelon</td>
<td>336</td>
<td>35.5</td>
<td>—</td>
<td>—</td>
</tr>
</tbody>
</table>

Well-rotten FYM is applied to the field at the time of preparation of land. This is supplemented by full dose of superphosphate and potash and one-half dose of nitrogen at the time of sowing and the rest of the nitrogen is applied at the time of fruit-set.

Intercultural operations

It is necessary to control the weeds completely till the plant starts vining. Two weedings should be done at an interval of about 20 to 25 days from sowing. When the plant attains full growth, hoeing becomes difficult, but big weed plants should be pulled out by hand. Irrigation should be done at frequent intervals during the vigorous growth period of the plants. In heavy soils, irrigation should not be done immediately after sowing as it would form a hard crust which will not allow the tender seedlings to come out of the soil (Nath, 1965a). Under such conditions it is advisable to first irrigate the soil and then sowing should be done when the soil is loose and friable. Choudhury (1966) reported a significant increase in watermelon yield from the spray of TIBA (25 to 50 ppm) and GA (5 to 10 ppm) at the two-leaf stage and again after about a week.

Harvesting

Harvesting in melons is done when they are mature except in case of longmelon and roundmelon which are harvested when they are immature and tender. The maturity of muskmelon and snapmelon is judged as follows: (a) In most cases when the fruit is mature it slips out easily from the vine, leaving a circular
depression. This is known as the full-slip stage, and (b) in case of netted muskmelons, the green colour between the nets changes to yellow and nets become dirty white. In case of snap-melon the green rind turns yellow or orange at full maturity.

In watermelon, maturity is judged as follows: (a) On thumping the fruit with a finger, a ripe melon gives a flat dead sound, whereas unripe fruit gives a ringing sound, (b) colour of the rind which touches the ground changes from white to light yellow on ripening, (c) the tendril nearest to fruit becomes dry when the fruit is ripe, and (d) on putting pressure on the fruit a ripe melon cracks within. Usually watermelon takes 30 to 40 days from the date of pollination to maturity (Nath, 1965a). No single indication is sufficient for judging the maturity of this melon.

In roundmelon and longmelon, the fruits are tender as long as they retain their lustre of the rind. As soon as it fades, the rind starts becoming hard and the fruit quality is reduced. Harvesting should be done at an interval of 4 to 5 days. On an average the yield of watermelon, muskmelon, snapmelon, roundmelon and longmelon is about 270 to 300 q/ha, 100 to 135 q/ha, 170 to 185 q/ha, 85 to 100 q/ha and 75 q/ha respectively.

Improved varieties

**WATERMELON**

The varieties recommended by the IARI, New Delhi, are as follows:

- *New Hampshire Midget*. It is an early variety introduced from the USA. Fruit is small, weighing 1.5 to 2 kg. Shape is oval, skin colour bright green with dark green lacerations and red flesh inside. It takes 28 to 30 days from the date of pollination to ripening. It is an early home-garden variety.

- *Asahi Yamato*. It is a mid-season variety introduced from Japan. Fruit is medium large, weighing 7 to 8 kg. Rind colour is light green with laceration and deep pink flesh. It is quite adaptive to various regions.

- *Sugar Baby*. It is a mid-season variety introduced from the USA. Fruit is medium, weighing 4 to 5 kg, round in shape, blue black rind colour, and red flesh. It takes 30 to 35 days after pollination to attain maturity.
'Pusa Bedana'. It is a seedless variety of watermelon obtained as a hybrid between 'Tetra-2' of the USA and 'Pusa Rassal', a local purified type. Flesh is deep pink and sweet.

The watermelon varieties developed and recommended by the Indian Institute of Horticultural Research, Bangalore, are as follows:

'Arka Jyoti'. An F₁ hybrid between 'IHR 20' (a Rajasthan selection) × 'Crimson Sweet'. Recommended by All-India Co-ordinated Project for commercial cultivation. It is an early season crop having round fruits of 5-6 kg each, and each vine bearing 2-3 fruits (Fig. 7). Rind colour light green with dark green stripes. Flesh colour deep pink and very sweet (12 to 14% TSS). Average yield 800 q/ha. It has excellent keeping and transport quality.

Fig. 7. High-yielding, good-quality hybrid watermelon 'Arka Jyoti'.

'Arka Manik'. Developed by selection in advanced generations of a cross between 'IHR 21' × 'Crimson Sweet'. It can be grown as rabi-season or summer-season crop in Karnataka. It has triple resistance to anthracnose, powdery mildew and
downy mildew. Fruits are oval with light green to green stripes. Average fruit weighs 6 kg with excellent granular texture, high TSS (12-15%), deep crimson flesh with pleasant aroma (Fig. 8). Average yield is 600 q/ha. It has good keeping and transport quality (Dutta et al., 1977, 1982).

![Fig. 8. A new watermelon variety 'Arka Manik' with triple disease resistance.](image)

Besides, ‘Madhu’ F₁ from Indo-American Hybrid Seed Co., Bangalore, and ‘Durgapur Meetha’ (Durgapura) are also promising varieties and under the test.

**MUSKMELON**

The varieties recommended are given below.

‘Arka Rajhans’. An early-medium variety, with medium-large oval fruit, weighing 1 to 1.5 kg. Dirty-white rind with fine nets. It has excellent keeping and transport quality. Flesh thick, white with more sweetness (12 to 14% TSS). It is highly resistant to the powdery mildew. It yields about 320 q/ha (Fig. 9).
Arka Rajhans. A muskmelon with delicious flesh, resistant to powdery mildew.

Arka Jeet. A very early short duration (90 days) variety. It has small attractive orange yellow, round fruit weighing 400 to 800 g. It is very sweet (15 to 17% TSS) with high vitamin C (41.6/100 g fresh weight). It is an improvement over the local 'Lucknow Bati' strain of Uttar Pradesh. It yields about 156 q/ha.

Pusa Sharbati. It has round to oval fruit with netted rind and green stripes. It has a thick orange flesh with small seed cavity. It has been obtained by crossing a line of 'Kutana' with an American variety 'Cantaloupe Resistant'.

Hara Madhu. It is a late variety recommended by the Punjab Agricultural University. Fruit round, with white rind colour and green furrows. Flesh light green and sweet (11% TSS). The fruit does not slip from vine at maturity.

Durgapura Madhu. It is a mid-season variety recommended by the Department of Agriculture, Jaipur, weighing about 500 to 700 g. Shape oblong, rind colour light green with green
stripes. Light green flesh is very sweet (12% TSS).

Recently some varieties/F1 hybrids have been developed which are quite promising and are under the All-India Co-ordinated Project Testing. These include ‘Punjab Sunehri’, ‘Punjab Hybrid’ (Ludhiana), ‘Sel-1’ (Durgapura), ‘HM-1’ (Hisar), ‘Pusa Madhuras’ (IARI) and a hybrid from IIHR, Bangalore.

**ROUNDMELOM**

The important varieties are as follows:

‘*Arka Tinda*’. It is the first improved variety of roundmelon available in the country and developed at the IIHR, Bangalore. It is an early summer-season variety with large tender fruit, having very good cooking quality. Fruit round with slightly pressed poles with light green skin. It has soft hair at the harvesting time. It attains marketable size in five days from the date of pollination. It gives about 8 to 12 pickings and the crop is over in 90 to 95 days. It is tolerant to the common fruit-fly in the field and yields about 102 q/ha.

A variety named ‘Punjab Tinda’ has been released by Punjab Agricultural University, Ludhiana, and is grown in Punjab.

**LONGMELOM**

The commonly cultivated variety is:

‘*Arka Sheetal*’. It is a selection from the local strains of Lucknow made at the IIHR, Bangalore. Fruit medium long with light green skin and shallow furrows, each fruit weighing around 80-90 g (Fig. 10). Flesh crisp with excellent flavour. It has yield potential of 350 q/ha (Dutta and Swamy, 1982).

**Seed production**

All melons are highly cross-pollinated. Except for watermelon and roundmelon, others (snapmelon, muskmelon and longmelon) are highly cross-compatible with each other. Watermelon and roundmelon, however, do not cross with any other melon (Dutta and Nath, 1970). The different varieties of any one of the melons mentioned above should not be put together, otherwise these varieties would be contaminated by cross-pollination. The recommended isolation distance is about 800 m (Anonymous, 1971a). Proper roguing is very necessary. Ripe melons are good for the seed extraction. Seeds may be dried in the sun or mechanical driers may be used.
Fig. 10. A new longmelon variety, 'Arka Sheetal' with tender fruits.
6. PUMPKIN, GOURDS AND CUCUMBER

Origin

PUMPKIN [Cucurbita moschata (Duch.) Poir and C. maxima Duch.] is said to be the native of Northern and Southern America, while cucumber (Cucumis sativus L.) and gourds, viz. spongegourd (Luffa cylindrica Roem.), ridgegourd [Luffa acutangula (L.) Roxb.], ashgourd [Benincasa hispida (Thunb.) Cogn.] and snakegourd (Trichosanthes anguina L.) are said to be the native of India. The origin of bottlegourd [Lagenaria siceraria (Mol.) Standl.] is still undecided. It is found throughout the tropics and subtropics of both the hemispheres. Bittergourd (Momordica charantia L.) is said to have originated in the tropical regions of the old world.

Distribution and uses

All gourds and pumpkins have a wide adaptability and are grown in almost all the states of India. However, cucumber is grown more extensively in southern as well as northern states. Gourd and pumpkin fruits are cooked as vegetables. These cucurbits are good sources of carbohydrates, vitamin A, vitamin C and minerals. They are used as ingredients of salad (cucumber, longmelon), as pickles and conserves (cucumber), as sweets (ashgourd, bottlegourd, pumpkin) and in musical instruments and indoor decoration places (pumpkins and bottlegourd). Fibre from spongegourd and ridgegourd has domestic and industrial uses.

Importance of some of the minor gourds like chocho (Nath, 1971) and snakegourd (Nath and Seenappa, 1975) has been reported.

Botany

Pumpkin, cucumber and all gourds belong to the family Cucurbitaceae. Leaves are simple, palmately five lobed, sharply angled when young but subcordate at maturity in case of cucumber. In pumpkin leaves are five-lobed, simple, non-hirsute and soft textured. In Luffa spp. they are smooth and five-lobed. In bottlegourd, leaves are suborbicular, cordate, non-lobed or slightly lobed, softly pubescent. In bittermgourd, leaves are
deeply lobed, whereas in ashgourd and snakegourd these are five angled. Tendril is branched in pumpkin, spongegourd, ridgegourd, bottlegourd and snakegourd, while it is simple in cucumber, ashgourd and bittergourd. Flowers are mostly monoecious in pumpkin, cucumber and annual gourds. Fruit is a 'pepo' and varies in shape, colour, flavour and taste. Seenappa and Nath (1976) reported tendril flowers in snakegourd.

**Plant breeding**

Attempts have been made to study the flowering and pollen behaviour in cucumber (Vijay et al., 1976), bittergourd (Dutta et al., 1976), kakrol (Vijay et al., 1976), *Luffa* sp. and *Cucumis* sp. (Mathur and Nath, 1978). In bottlegourd interesting results on interrelations among anthesis, dehiscence, stigma receptivity, pollination and pollen germination were obtained which improved the hand-pollination work (Subramanyam et al., 1976).

Because of their high cross-pollinating nature, much genetic variation exists in these cucurbits. Breeding techniques in cucurbitaceous crops have been discussed (Nath, 1975) and the breeding work done for quality, yield and resistance to disease and insect pests reviewed (Nath, 1976, 1978). Some of the genetic materials have been profitably used within few decades and some excellent varieties have been developed in pumpkin ('Arka Suryamukhi'), bittergourd ('Coimbatore Long', 'Pusa Do Mausami'), bottlegourd ('Pusa Summer Prolific Long', 'P. S. P. Round', hybrid 'Pusa Meghdoot' and 'Pusa Manjari'), spongegourd ('Pusa Chikni'), ridgegourd ('Pusa Nasdar'), ashgourd ('Co-1') and summer squash ('Patty Pan' and 'E. S. P. Straight-neck') as per Pal et al. (1956), Nath et al. (1971) and Choudhury and Singh (1971). The new pumpkin variety 'Arka Suryamukhi' (Fig. 11) is reported to be the first variety resistant to common fruit-fly, *Dacus cucurbitae* (Nath and Dutta, 1971; Nath et al., 1976). New varieties through careful selection were obtained in pumpkin ('Arka Chandan') with high carotene content and yield (Nath et al., 1971), and in bittergourd ('Arka Harit') with good quality and high yield (Dutta et al., 1974).

Efforts have also been made to utilize hybrid vigour in commercial production of these cucurbits. Pal and Singh (1946) reported significant heterosis in bittergourd, whereas
Srivastava (1970) reported an increased yield of 64% over the better parent in hybrids. In bottlegourd, ‘Pusa Meghdoot’ gave an increased total yield of 75%, while in ‘Pusa Manjari’ it was 106% (Choudhury and Singh, 1971). A good deal of work has been done regarding the inheritance of various morphological characters in cucumber, gourds and pumpkin (Singh et al., 1946; Richharia, 1948; Pathak and Singh, 1950; Choudhury and Thakur, 1965; Thakur and Choudhury, 1966, 1967; Srivastava, 1970). Information regarding the breeding of disease and insect resistant varieties is also available (Nath, 1963a, b, 1964, 1969b, 1971; Nath and Thakur, 1965; Nath and Dutta, 1971; Vashistha and Choudhury, 1975).

Recent investigations have resulted in reports on inheritance of qualitative traits in bittergourd (Srivastava and Nath, 1972), leaf characters in pumpkin (Nath et al., 1979), economic traits in summer squash (Dutta and Nath, 1976), diallel analysis (Srivastava and Nath, 1976) and gene effect (Sirohi and Choud-
hury, 1979) in bittergourd, combining ability in summer squash (Bhagchandani et al., 1980), variability and correlation studies in pumpkin (Gopalakrishnan et al., 1980), ridgegourd (Thamburaj, 1973) and spongegourd (Panwar et al., 1977).

Climatic and soil requirements

The cucumber requires a relatively shorter growing season, whereas pumpkin and other gourds require a long growing season. Cucumber takes 45 to 80 days from seeding to maturity, whereas pumpkin and other gourds require 80 to 120 days. Pumpkin, cucumber and other gourds do not require as warm a climate as melons (Appendix B). These are more sensitive to fluctuations in light and temperature than other important cucurbits. An abundance of light gives rise to male flowers though within limits. Similarly higher temperature and long days help the increase in number of male flowers and reduce the number of female flowers. Crop of rainy season is more successful than the summer season crop in cucumber, pumpkin and most of the gourds.

Like other cucurbits they thrive well in a wide variety of soils ranging from sandy to moderately heavy, provided the drainage system is quite efficient. Generally they do not grow well in highly acidic or alkaline soil. Sandy-loam soil gives a heavy early yield.

Planting requirements

Pumpkin, cucumber and gourds are grown both in summer and rainy seasons. In the plains, summer-season crop is grown from January to March, whereas rainy-season crop is sown in June—July. In hot areas of Rajasthan, the summer crop of cucumber, pumpkin and gourds is not encouraged. In frost-free areas sowing is done in October, which gives the earliest crop in March. In order to escape the frost, sowing is done either at different depths or at different dates, thereby getting good stand of seedlings from the second or third sowing in case the previous seedlings get damaged by frost (Nath, 1965a). Generally, the vines are allowed to trail on the ground, except in case of snakegourd where staking is required for getting quality fruits. The seed rate and planting distances are mentioned in Table 2.
Table 2. **Seed rate, planting distance and depth of sowing in different cucurbits**

<table>
<thead>
<tr>
<th>Crop</th>
<th>Seed rate (kg/ha)</th>
<th>Planting distance</th>
<th>Depth of seed sown (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Row to row (cm)</td>
<td>Hill to hill (cm)</td>
</tr>
<tr>
<td>Watermelon</td>
<td>3.7–5</td>
<td>250–350</td>
<td>90–120</td>
</tr>
<tr>
<td>Roundmelon</td>
<td>3.7–5</td>
<td>180–240</td>
<td>60–120</td>
</tr>
<tr>
<td>Muskmelon</td>
<td>3–7</td>
<td>180–240</td>
<td>60–120</td>
</tr>
<tr>
<td>Snapmelon</td>
<td>2.4–3.7</td>
<td>180–240</td>
<td>60–120</td>
</tr>
<tr>
<td>Longmelon</td>
<td>2.4–3.7</td>
<td>180–240</td>
<td>60–120</td>
</tr>
<tr>
<td>Cucumber</td>
<td>2.5–3.7</td>
<td>150</td>
<td>60–90</td>
</tr>
<tr>
<td>Bottlegourd</td>
<td>3–6</td>
<td>200–300</td>
<td>100–150</td>
</tr>
<tr>
<td>Bittergourd</td>
<td>4.5–6</td>
<td>150–250</td>
<td>60–120</td>
</tr>
<tr>
<td>Ridgegourd</td>
<td>3.7–5</td>
<td>180–250</td>
<td>60–120</td>
</tr>
<tr>
<td>Spongegourd</td>
<td>2.5–3.7</td>
<td>180–250</td>
<td>60–120</td>
</tr>
<tr>
<td>Snakegourd</td>
<td>5–6</td>
<td>180–250</td>
<td>60–120</td>
</tr>
<tr>
<td>Ashgourd</td>
<td>5–7</td>
<td>180–250</td>
<td>60–120</td>
</tr>
<tr>
<td>Pumpkin</td>
<td>6.7–9</td>
<td>250–300</td>
<td>100–180</td>
</tr>
<tr>
<td>Bush squash</td>
<td>8–10</td>
<td>60–75</td>
<td>45–60</td>
</tr>
</tbody>
</table>

**Intercultural operations**

It is advantageous to keep the field free from weeds especially in the early stages. Frequent hoeing and weeding promote healthy growth and heavy fruiting. This is possible only till the vines are not fully grown, and at later stage only large weeds may be pulled out.

Spray of plant-growth regulators helps a lot in modifying sex and increased fruit set in cucumber and bottlegourd. The most effective plant-growth regulators are maleic hydrazide (MH) at 50 to 100 ppm, gibberellic acid (GA) at 5 to 10 ppm and alpha-naphthalene acetic acid (NAA) at 100 ppm. Spraying of aqueous solution of these chemicals is done at the two-leaf stage and then again after about a week. The increase in yield varied from 60 to 100%. In bottlegourd, two sprays with MH or TIBA at 50 ppm have recorded more than 100% increase in yield over the control (Choudhury, 1966).

In areas with relatively high rainfall the crop may require one irrigation at the interval of 2 weeks, whereas in areas with low
rainfall one irrigation per week is needed. During summer it becomes necessary to irrigate the field at intervals of 2-3 days.

**Manurial and fertilizer requirements**

All gourds, cucumber and pumpkin respond well to manuring and fertilizer application. The doses of fertilizers and manures depend upon the soil type, climate and variety. Based upon the common practices and experimental results, following doses of manure and fertilizer in different cucurbits would prove beneficial (Mehta, 1959; Kulkarni, 1962; Nath, 1965a; Dhesi et al., 1966; Yawalkar, 1969; Choudhury, 1967; Sharma and Shukla, 1971, 1972).

Full dose of FYM, superphosphate and potash is applied at the time of land preparation. Half dose of nitrogen is applied at the time of vining and rest at the time of initial fruit-set (Table 3).

In pumpkin, Gupta and Srinivas (1979) suggested the optimum fertilizer dosage under existing price situation to be 81.20 kg N and 64.27 kg P₂O₅ per hectare in 1976, and 80.64 kg N and 93.37 kg P₂O₅ per hectare in 1977. The maximum limit of fertilization was 87.84 kg N and 70.04 kg P₂O₅ in 1976, and 86.18 kg N and 98.92 kg P₂O₅ per hectare in 1977.

**Table 3. Manurial and fertilizer requirements of cucurbits**

<table>
<thead>
<tr>
<th>Crop</th>
<th>Nitrogen (kg/ha)</th>
<th>Phosphorus (kg/ha)</th>
<th>Potash (kg/ha)</th>
<th>FYM (q/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bottlegourd</td>
<td>22—55</td>
<td>20—60</td>
<td>17.5—44</td>
<td>450—600</td>
</tr>
<tr>
<td>Bittergourd</td>
<td>50—56</td>
<td>56—60</td>
<td>—</td>
<td>450—550</td>
</tr>
<tr>
<td>Sponge and Ridgegourd</td>
<td>17</td>
<td>—</td>
<td>—</td>
<td>220</td>
</tr>
<tr>
<td>Ashgourd</td>
<td>18—27</td>
<td>—</td>
<td>—</td>
<td>220—230</td>
</tr>
<tr>
<td>Snakegourd</td>
<td>20—44</td>
<td>22</td>
<td>—</td>
<td>336—345</td>
</tr>
<tr>
<td>Pointedgourd</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>220—230</td>
</tr>
<tr>
<td>Pumpkin and squash</td>
<td>103</td>
<td>106</td>
<td>40</td>
<td>—</td>
</tr>
<tr>
<td>Cucumber</td>
<td>24—35</td>
<td>—</td>
<td>—</td>
<td>370—490</td>
</tr>
</tbody>
</table>
Harvesting

Unlike other cucurbits, the proper stage of fruit maturity in cucumber is judged by the size and not by the age of the fruit. Cucumber for slicing should be picked up when they are 15-35 cm long, whereas for pickling they should be harvested when 6-15 cm long. In case of slices, at the marketable stage, spines on the fruit become soft and fall down. Cucumber can be stored for 10-14 days at 4.4° to 7.2°C and 85 to 95% relative humidity. Harvesting in gourds is done at short intervals when the fruits are tender. Proper stage of maturity in bottlegourd, sponge and ridgegourd is judged by (a) its fruit size, (b) the gentle press of finger nail which easily penetrates the epidermis, and (c) plugging the fruit which show fine tender flesh and quite immature seed. This test makes the fruit unfit for market. In bittergourd, harvesting is done at 4 to 5 days intervals. In most cases, it takes 12-15 days after pollination to attain marketable stage. Pumpkin and ashgourd are harvested at full stage of maturity. In most cases the fruit stalk becomes dry, and in pumpkin the fruit colour changes to yellow or orange yellow at full maturity. The yield in cucumber is 61 to 135 q, bottlegourd 74 to 185 q, sponge and ridgegourd 74 to 148 q, bittergourd 61 to 135 q, pumpkin 185 to 432 q, ashgourd 98 to 321 q, and snakegourd 98 q/ha depending upon the variety and season. However, the summer bush squash yields about 450 q/ha.

Seed production

Pumpkin, cucumber and gourds are highly cross-pollinated. Different varieties should not be put together, otherwise they would be contaminated by cross-pollination. Spongegourd and ridgegourd should not be put together in the same field for seed production, as they cross with each other. Similarly, most of the pumpkin varieties belong to the genus Cucurbita, viz. C. moschata and C. maxima. Crosses may occur between these two species. The producer therefore must know the species to which his varieties belong and should keep the standard isolation distance of 800 m between the two varieties (Anonymous, 1971a). Care should be taken to rogue out the off-type plants from the seed multiplication block.

Seeds should be extracted from dried fruits in bottlegourd,
spongegourd, ridgegourd, and from ripe fruits in bittergourd, ashgourd, pumpkin and cucumber. The growers in one particular village should grow only one variety of these cucurbits, quite adapted to that place and select fruits for seeds from the plants which were tagged in the beginning. This avoids any cross-pollination because no other variety is growing in that area and best fruits are selected from a large population of the same strain thus maintaining the purity of the best variety adopted in the area (Nath, 1965a).

**Improved varieties**

**Cucumber**

Some of the introduced varieties have been recommended for commercial cultivation in our country.

'Japanese Long Green'. An early variety, matures in 45 days only. The fruits are long (30 to 40 cm), green skinned, fleshy, light green and crisp.

'Straight Eight'. An early variety, fruit medium long, thick, straight and cylindrical with round ends, skin is medium green.

'China'. Medium late, straight variety, very hardy and prolific. Fruit very long (50 cm), slender, with deep green skin, white spined, flesh is white, firm and crisp.

'Poinsett'. Seeds are being multiplied by National Seeds Corporation Ltd, on a large scale. It has medium long, slender, dark green fruits. It is believed to be resistant/tolerant to certain diseases including downy mildew.

**Pumpkin**

The following varieties were developed at IIHR, Bangalore.

'Arka Suryamukhi' (C. maxima). Fruit small, economy sized (1 kg), round with flat ends, rind colour deep orange yellow, with discontinuous thin cream lining along with shallow furrows. Linings originate from the blossom end, whereas the furrows originate from the stem end. It has excellent flavour, firm texture, bright orange flesh colour and is rich in vitamin C (Fig. 11). It is highly resistant to fruit-fly, bears 8-10 fruits per plant. Yield is about 335 q/ha and the crop lasts for about 115 days.

'Arka Chandan' (C. moschata Duch.). Fruit medium sized
(2.5 to 3.5 kg), round with slightly pressed poles, rind colour light brown with creamy patches at maturity. It has excellent flavour, firm texture, bright orange flesh, rich in carotene content. It bears 2-3 fruits per plant and yields about 325 q/ha in 115-130 days.

'Co-1' (*C. moschata* Duch.). A late variety, matures in 175 days; fruits are attractive, globular, medium large (7 to 8 kg); each vine produces 7 to 9 fruits; yield 288 q/ha. The variety was released by the Agricultural Research Institute, Coimbatore.

'Co-2' (*C. moschata* Duch.). Fruit small sized weighing 2 kg with orange-coloured flesh. Yield 226 q/ha. Also developed at Coimbatore.

**BOTTLEGOURD**

The following varieties are recommended for cultivation:

'Arka Bahar'. Recently IIHR, Bangalore, released the variety. It has economy-sized, medium-long fruits (43 cm) with 26 cm girth, each weighing about 1 kg. Skin is light green with white tender flesh (Fig. 12). It yields 400-450 q/ha in 115-120 days in both the seasons.

The following varieties have been developed by IARI.

'Pusa Summer Prolific Long'. Fruits long (40-50 cm) with medium girth (20-25 cm) when young. Skin colour is yellowish green. It is suitable for spring and summer planting. It yields 119 q/ha.

'Pusa Summer Prolific Round'. Fruits green, round and 15-18 cm in girth when young. It is suitable for spring and summer planting and is a high yielder.

**Hybrid varieties**

The hybrid varieties of bottlegourd are:

'Pusa Meghdoot'. It is a cross between 'Pusa S. P. Long' and 'SI-2.' Fruit is long, light green and yields about 258 q/ha.

'Pusa Manjari'. It is a cross between 'Pusa S. P. Round' and 'SI-11.' The fruit is round, light green and yields 253 q/ha.

**SPONGEGOURD AND RIDGEGOURD**

The varieties recommended are as follows:

'Pusa Chikni'. It is an early variety of spongegourd and flowers in about 45 days both in spring and summer. It produces about 15 fruits per plant. They are smooth and green.
‘Pusa Nasdar’. It is a medium-early variety of ridgegourd which flowers in about 60 days in summer. Fruits are ridged and light green. Flesh yellow with firm texture, good flavour and high yield.

‘Co-1’. Fruits long, prominently ridged with light greenish yellow coloured flesh. Yield 141.3 q/ha. Duration of crop is 125 days.

ASHGOURD

The variety recommended is:

‘Co-1’. Medium early variety, fruit is attractive, globular, bigger in size (5 to 6 kg) with less seeds and more flesh. Yield 204 q/ha. Duration is 140 days.

SNAKEGOURD

The following variety has been recommended:

‘Co-1’. It has long (180 cm) fruits, dark green skin with white stripes, each fruit weighing 500-750 g, flesh is smooth, light green with good cooking quality. Each vine gives 10-12 fruits (4-5 kg) and yield about 180 q/ha in 135 days.
Bittergourd

The varieties recommended are:

‘Pusa Do Mousmi’. Fruit long and green. It grows well both in summer and rainy seasons. It is a prolific yielder and was recommended by the IARI, New Delhi.


‘Arka Harit’. Recommended by the IIHR, Bangalore. It has medium-sized, spindle-shaped fruits with green skin, thick flesh, moderate bitterness and less seeds (Fig. 13). It grows well both in summer and rainy seasons but maximum yield is obtained during rainy season. Fruits are ready for harvesting in 12 to 14 days after pollination. It yields about 120 q/ha in 100-110 days (Dutta and Nath, 1971b; Dutta et al., 1974).
7. POINTEDGOURD AND COCCINIA

Origin

POINTEDGOURD (Trichosanthes dioica Roxb.) and kundru [Coccinia grandis (L.) Voigt Syn. C. indica W. & A.] are believed to have originated in India.

Distribution and uses

Pointedgourd is widely cultivated in eastern part of India particularly in Bengal, Assam, Bihar and Uttar Pradesh (Nath and Subramanyam, 1972). Kundru, on the other hand, is common both in the eastern and southern states of India. They are good source of carbohydrates, vitamin A and C. They are cooked as vegetable. Pointedgourd is also used as sweet dish, whereas kundru is an ingredient of salad. Kundru has been regarded as a commercial crop in western areas (Nath, 1975; Nath and Subramanyam, 1971).

Botany

Plants are semi-perennial creeper, dioecious, leaf lamina cordate, ovate, oblong with basal lobes narrow round at base in pointedgourd, and angular or lobed in kundru. Tendril simple, rarely bifid. Fruit is ‘pepo’ botanically. They are small, round or thick long, green with white stripes or green with no stripes. There is no definite test to identify male and female plants at the young age on morphological traits except the flowers.

Plant breeding

No significant plant breeding work has been done in these crops. Studies have been made on pollen morphology and physiology in pointedgourd (Subramanyam and Nath, 1975) and in Coccinia (Subramanyam et al., 1973).

Climatic and soil requirements

Both pointedgourd and kundru prefer warm and humid climate. They remain dormant during winter season. They grow best in sandy loam and are not adapted to heavy soils. Both require perfect drainage and are very susceptible to waterlogging.
Planting requirements

Both *kundru* and pointedgourd are propagated by stem cuttings. In case of pointedgourd stem cuttings are made about 60 cm long from one-year-old fruiting vines of both male and female plants. Cuttings are prepared in October and put in sand medium in nursery for root development. The cuttings are ready for transplanting in the field in two to three months. They are planted in two ways.

*Straight vine method.* Long furrows about 30 cm deep are prepared and the soil is mixed up with farmyard manure. The cuttings are planted 15 cm deep in furrow at a distance of 2 m by end-to-end method.

*Ring method.* In this case the cuttings are made into a ring and planted in hills at a spacing of 2 m × 2 m.

In *kundru* 12-15 cm stem cuttings of pencil thickness, having 5-6 leaves, are taken and planted in basins of 60 cm diameter dug 175 cm apart. About 2-3 stem cuttings are transplanted 3-cm deep in each basin. Planting is done between July-February. Vines are trailed on bowers. About 10% male cuttings are sufficient to pollinate female plants in one hectare of land. About 8,000 cuttings are sufficient per hectare of planting.

Manurial and fertilizer requirements

No fertilizer is applied to the pointedgourd grown in river beds. If the soil is not fertile, farmyard manure should be applied at the rate of 225 q/ha. In case of *kundru*, 10 kg of well-rotted FYM is mixed with the soil up to a depth of 45 cm. A fertilizer dose of 20 kg N, 40 kg P₂O₅ and 20 kg K₂O has been recommended (Anonymous, 1974).

Intercultural operations and irrigation

Hoeing and weeding should be done during the initial stage carefully. Once the vines start trailing on the ground, intercultural operations become difficult unless the plants are trained on bowers. Under such conditions only pulling out of big weeds is possible. Irrigation becomes more important during summer when new shoots come up. Regular watering is necessary till the rain starts.
Harvesting and storage

Fruiting starts in pointedgourd and kundru during March to June. Second flush starts with the rains and fruiting continues till October. In pointedgourd, in the first year, relatively low yield of 13 to 18 q/ha is observed. However, during next year the same vine gives 110 to 135 q/ha. In kundru, maximum yield of 10 kg per creeper is recorded. On an average, it gives 110-150 q/ha fruit yield. The economic life of kundru is 3-4 years.

Pointedgourd and kundru, like other gourds, are harvested at the immature stage while still tender with immature seeds. The fruits should be harvested twice a week.

Improved varieties

No improved varieties have been recommended so far either in pointedgourd or kundru. Only local strains are planted in different regions. However, considerable efforts are being made to develop improved varieties of pointedgourd (parwal) at Faizabad, Sabour and Ranchi.

Seed production

Since both pointedgourd and kundru are propagated by cuttings, seed production is not important.

Diseases of cucurbits

Some of the important diseases and their control measures are given below.

Powdery mildew (Erysiphe cichoracearum D. C.). This is a severe disease of muskmelon, watermelon, longmelon and snap-melon, pumpkin, gourds and cucumber. Symptoms of powdery mildew first appear on the undersurface of the older leaves, as white fluffy circular spots, which increase in size and number, coalesce and eventually cover both surfaces. Severely attacked leaves become brown and shrivelled. The fungus attacks the leaves, stem and fruits. The disease may be controlled effectively by spraying 0.03% Karathane at weekly intervals. Avoid spray or dust of sulphur on cucurbits because most of them are sulphur susceptible. Growing powdery mildew resistant varieties of muskmelon, viz. ‘Arka Rajhans’ and ‘Pusa Sharbati’ is advisable.

Downy mildew (Peronoplasmosopara cubensis Berk and Curt.). The disease attacks muskmelon, watermelon, longmelon,
snapmelon, cucumber, bittergourd and ashgourd severely. The fungus attacks only the leaves. Symptoms appear as yellow to brown angular spots on the leaves with downy growth on the lower surface. In severe cases it attacks the stems, petioles and tendrils. It causes heavy defoliation and insipid taste in matur­
ing fruits. Humid climate is more favourable than the dry climate for the growth of the fungus. The disease may be con­
trolled effectively by spraying 0.2\% solution of Dithane Z-78 or Blitox.

*Anthracnose (Colletotrichum sp.)*. The disease is very serious in watermelon, muskmelon, bottlegourd, snakegourd and cucumber. In case of cucumber and muskmelon redish brown, dry leaf spots are formed resulting in the shrivelling and death of the leaf. In watermelon, the leaf spots are black and the foliage presents a scorched appearance. The fungus also attacks the stem and fruits. It over-winters in decaying vines and on seeds from diseased fruits. The seeds should be treated with Agrosan GN before sowing. Spraying Difolatan or Bavistin (0.1 \%) or Dithane Z-78 (0.2\%) at 7-10 days interval gives an effective control of the disease. Use of resistant varieties like ‘Arka Manik’ (water­

**Mosaic (Cucumis virus-I).** This virus infection causes heavy losses in cucumber. Infected plants show stunting growth and mottling of leaves. Dissemination of the virus takes place by aphids and over-wintering in wild cucumber and several other host plants. Clean cultivation should be followed and wild cucumber and other host plants should be eradicated. Diseased vines should be removed and destroyed. Resistant varieties should be selected for cultivation. Spray of Rogor (0.2\%) can be tried to control the vectors.

**Insect pests**

Common insect pests and their control measures are as follows.

*Red pumpkin beetle (Aulacophora sp.).* The insect attacks most of the cucurbits at the seedling stage. They are elongated, orange beetles and feed upon the cotyledonary leaves of cucurbit seedlings. Damage is caused both by the grub and adult. Soil application of 1\% Lindane at the rate of 19 to 24 kg/ha or spray with Lindane (0.1 \%) or Sevin (0.2\%) are effective in controlling
this insect.

_Fruit-fly (Dacus sp._). Maggots of this fly cause severe damage to the young cucurbit fruits. The adult fly lays eggs below the skin of young fruits. The eggs hatch into maggots which feed inside the fruits. The infested fruits carry sunken spots and under severe cases fruit shrivels or rot. The infestation can be minimized by baiting with Malathion and protein hydrolysate (½ kg of protein hydrolysate + 1.25 litre of 50% Malathion) during fruit-setting period. Growing fruit-fly resistant or tolerant varieties, viz. ‘Arka Suryamukhi’ of pumpkin, and ‘Arka Tinda’ of roundmelon, is recommended.

_Epilachna beetle (Epilachna sp.)._ The grub and adult cause severe damage to leaves of various cucurbits. They feed on the green matter between the veins giving a lace-like appearance to the attacked leaf. They can be controlled in the same way as the red pumpkin beetle.

_Jassids (Empoasca sp._). These are small sucking insects (0.32 cm long), green to greenish-yellow in colour. They suck the sap of the leaves which gives a shrivelled appearance. It can be controlled effectively by spraying 0.1% Malathion.

_Aphids (Aphis sp._). These are small green insects which suck the sap of the plant. They multiply very quickly and cause considerable damage when in large number, particularly in early stage. In full-grown plants the leaves turn yellow and plant looses its vigour. Spraying of 0.1% solution of Malathion is recommended to control aphids.
8. BEANS

Beans and pea belong to the same family Papilionaceae yet their cultural requirements have few points in common. The pea is relatively hardy and can be grown under cooler conditions, whereas the beans can tolerate relatively warmer weather. Beans and pea are capable of utilizing atmospheric nitrogen with the aid of bacteria found in the nodules on the roots of the plants. There are a number of cultivated species of beans in the plains. But the most commonly grown are French beans, cowpea, cluster bean and dolichos bean. These beans are commonly used as cooked vegetables either along with the green shell or without shell or as dry beans. They are rich in protein, carbohydrates, vitamin A and minerals. The biochemical constituents of French bean pods at different stages of maturity have been studied (Rawat et al., 1979). Beans are also used commonly as processed products for various vegetable preparations.

The bean is a self-pollinated crop and the fruit is a ‘pod’ botanically. Most of the cultivated varieties of the beans are vine types except the French bean where most of them are bush type. All the above mentioned beans are annual, whereas the plants of dolichos bean can be retained for about 2 to 3 years.

In Karnataka and in other similar areas beans can be grown all the year round (Pal and Nath, 1973).

FRENCH BEAN

Origin

The common bean or French bean, *Phaseolus vulgaris* L. is probably a native of South America and is undoubtedly of ancient origin (Thompson and Kelly, 1957).

Plant breeding

Local strains and some of the introduced varieties of French bean are available. Most of the genetic variations exist among the introduced varieties in the grower’s fields where no effort was made to maintain the genetic purity of a particular variety. Recently, 600 entries have been made in this crop (Bhagat et al. 1979). Some of the introduced varieties which performed well
under large scale production were recommended (Pal et al., 1956; Singh and Prasad, 1967). A breakthrough has been made by evolving a new variety 'Pusa Parvati' with the aid of mutation breeding (Swarup and Gill, 1968; Anonymous, 1971b). Some genetic studies with regard to economic characters have also been made (Patel and Chavan, 1961).

**Climatic and soil requirements**

French bean is a cool-weather crop but can thrive in higher temperatures than pea. The beans can be classified into long-day, short-day and day-neutral plants. Most of the French bean varieties are day-neutrals and hence the day-length does not affect the seeding habit except some semi-vine varieties which are short-day type. This bean is sensitive both to frost and to very high temperatures. The plants drop their blossoms or pods in very hot weather. The best pod is obtained at 15.6° to 21.1°C temperature.

It can be grown on practically all types of soils except clay. Sandy and sandy-loam soils are preferred for an early crop but heavier soils are desired for mid-season crop. It does not grow well on extremely acidic soils and is sensitive to high concentrations of aluminium and manganese. The most desirable pH is from 5.3 to 6.0.

**Planting requirements**

Since it is relatively a cool-weather crop it is grown in winter. In the plains, the seed is sown from the middle of August to October but where the winter and summer are not very severe it can be sown up to February.

Most of the recommended varieties are bush type, where the rows are spaced 60 to 70 cm apart and the plants are spaced about 10 cm apart within the rows. The seeds may be dibbled with hand or drilled mechanically at a depth of 2 to 3 cm. At some places the seeds are broadcasted which interferes with cultural operations. For planting a hectare of bush variety about 85 kg of seeds are required. There are some pole or vine varieties which are spaced about 1 m apart from row to row and hill to hill. About half-a-dozen seeds are sown in each hill and later on thinned to 3 or 4 plants. It requires about 30 kg of seeds to plant an hectare of area. For a continuous harvesting
of beans, 2 or 3 plantings should be done at regular intervals. The ridges on which sowing is done should be uniformly moist at the time of sowing to obtain good and uniform germination of seeds.

**Manurial and fertilizer requirements**

The manurial and fertilizer requirements of French bean depend on the condition of the soil. It has been estimated that an yield of 720 kg of grain and 630 kg of straw removes 66 kg of nitrogen, 27 kg of phosphorus and 55 kg of potash from the soil. The summary of fertilizer recommendations made are as follows: 24 to 77 tonnes FYM, 50 to 54 kg of nitrogen, 54 to 110 kg of phosphorus and the same amount of potash per hectare. The complete dose of FYM is incorporated in the soil at the time of field preparation, whereas N (50%), P and K should be placed in bands about 7 to 8 cm to the side of the seed and slightly deeper than the seed at the time of sowing. Remaining nitrogen is applied about 20-25 days after sowing. Under acidic soil conditions the application of N, P, K along with the basic application of lime 4.8 q/ha increased the crop yield by 8 folds over no manuring, whereas the application of fertilizers alone increased the yield by 3 folds only (Verma and Mandal, 1966).

**Intercultural operations**

As the vine grows it requires staking in the pole type of beans which may be done with the help of poles. In fact in some areas pole beans are intercropped with other crops like maize to get self-staking. In bush varieties no support is required. Weeds should be controlled either by hand hoeing or by the use of chemical herbicides like dinitro materials at the rate of 5 to 8 kg/ha.

Beans are shallow-rooted and sensitive to excessive moisture. A good yield is produced even in soils with low moisture content. However, optimum soil moisture should be made available at the time of fruit-set and pod-development. One trace spray at the onset of flowering may be effective.

**Harvesting**

The pods if required green are ready for harvest two to three weeks after the first blossom. Picking is usually done by hand. Dry beans are harvested when a large percentage of the pods
BEANS

are fully ripe but before they become very dry and begin to shatter. They are cured for two to three weeks and then threshed by bullocks or by machines.

The yield of green pods in the bush varieties varies from 60 to 120 q/ha. The yield of dry bean seeds varies from 11.8 to 17.7 q/ha. Yield in pole beans is almost double than the bush varieties.

Improved varieties

The improved varieties of French beans are given below:

‘Giant Stringless’. It is an introduced early variety with bush habit. The pod is green, medium-large, long, slightly curved, tender, meaty and stringless. Seeds are glossy and yellowish brown. It is highly productive.

‘Contender’. It is another introduced variety which is a high yielder. It is a bushy type with light-green, fleshy and thick pods without fibres. It matures about 4 to 5 days earlier than ‘Giant Stringless’ and produces higher yields than the latter in the plains.

‘Pusa Parvati’. It is a new variety developed through X-ray irradiation of an American variety, ‘Wax Pod’ at the IARI. It is an early bush type with attractive round, meaty, light-green pods which matures in 40 to 45 days. It has given about 12.5 to 25 q/ha of edible pods, more than the variety ‘Contender’ in the hills.

‘Arka Komal’. It has been developed at IIHR, Bangalore, through selection. It has got green, fleshy, tender, long and straight pods. It produces 200-250 q/ha of green pods in 70-75 days (Fig. 14).

‘Kentucky Wonder’. It is a late-introduced variety with vine growth habit. The pod is green, fleshy and large curved, round, thick and meaty which becomes stringy at the later stage. The seed is light brown.

‘Jampa’. It is a Mexican variety reported to be outstanding in performance in Maharashtra. The plant has a slight tillering habit. It flowers in about 47 days and the first picking is obtained after two months of sowing. In all, eight pickings within 40 days are obtained. The pod is flat, smooth, non-stringy and pale green. The seeds are black, smooth, small and flat (Kolhe, 1971).
Presently very active research work is going on at IIHR, Bangalore, and at Almora, Katrain and Solan to develop improved bush varieties with high yield and better pod qualities. However, there is a need to take up the work on pole beans also.

**DOLICHOS BEAN**

**Origin**

Dolichos bean, *Lablab purpureus* (L.) Sweet (Syn. *Dolichos lablab* L.) is supposed to have originated in this part of the world. Wild forms of beans are found in India and is probably the centre of origin (Choudhury, 1967).

**Distribution and uses**

It is grown all over the country but compact large acreage for commercial production is uncommon. It is primarily grown for green pods which are cooked as vegetables like other beans. The dry-bean seeds are also collected for various vegetable prepara-
tions. The pods, seeds and leaves differ greatly in size, shape, colour and texture. The mature seeds, especially dark coloured ones, contain a trypsin inhibitor and must be boiled before eating. The trypsin inhibitor is broken down by heat and a toxic cyanogenetic glucoside, soluble in cooking water, is removed (Anonymous, 1979).

Botany

It is a herbaceous perennial plant but cultivated as an annual. The cultivated strains with good vegetable pod qualities are vine type. The vine needs to be trained on trellis or on any other support. Like pole bean varieties these may be planted 1 to 1½ m apart between the rows and 1 m apart between the hills. It is an annual but the plant can be retained for two to three years in the kitchen gardens.

Climatic and soil requirements

The dolichos bean is relatively a cool-season crop. Sowing is done in July-August. It can be kept alive in summer to provide pods in the next season but bearing is poor. New plantings should be done every year. Some of the strains are highly drought resistant and are often grown along with castor or sorghum. It can thrive in a wide range of soils of average fertility as other beans. It fruits from the beginning of the season and continues to give green pods throughout winter and spring. Heavy flower shedding has been reported to be a problem and some of the varieties have a relatively high pod-set than others (Sheriff et al., 1969). This crop appears to be photosensitive. It requires short days to initiate flowering.

Plant breeding

Though it is grown all over the plains of India, not much research work has been carried out either to maintain the local useful strains or to improve upon the local strains for pod quality and yield. The genetics of some of the economic characters have been studied (Cruz and Ponnaiya, 1969; Joshi, 1971; Rajendran and Satyanarayana, 1981). A vine variety, ‘Pusa Early Prolific’, was recommended by the IARI. It bears early long thin pods in bunches and is suitable for sowing both as early spring and autumn crop. Some of the promising strains have also been reported from Coimbatore (Kunjamma and...

At IIHR, Bangalore, two lines, viz. ‘IHR 93’ and ‘IHR 140’, have been claimed to be rust resistant and high yielder with good pod quality. Some promising selections of dwarf, bushy, less photosensitive vegetable podded dolichos beans with 70 days duration are under final testing.

The cultural operations, diseases and pests are common to those of other beans.

**Yield**

It produces an average of 50 to 74 q/ha of green pods.

**VEGETABLE COWPEA**

**Origin**

Cowpea is probably a native of Central Africa (Thompson and Kelly, 1957).

**Distribution and uses**

It is a most common crop grown in the northern than in the southern plains where French bean is more common. It is primarily grown for green vegetables like other beans.

**Botany**

Cowpea, *Vigna unguiculata* (L.) Walp (Syn. *V. sinensis*) is a herbaceous annual both for the seed and for vegetable purposes. Most of the commercial varieties are of bush type but vine type of strains are also available. The pods are borne usually in clusters.

**Plant breeding**

A good number of local strains of vegetable cowpea are available in India. Also some useful strains have been introduced from South-East Asian and western countries. The variety ‘Pusa Phalguni’ was selected from the Canadian variety ‘Dolique Du Tonkin’, whereas ‘Pusa Barsati’ was selected from a collection from the Philippines (Pal et al., 1956). Recently, ‘Pusa Dofasli’ was evolved by crossing ‘Pusa Phalguni’ and a Philippines selection at the IARI (Singh et al., 1968). Genetics of some of the economic characters and interspecific hybridization has also been studied (Premsekara et al., 1964; Singh and Mehndiratta, 1970). Jana et al. (1983) reported the highest magnitude of
direct effect of number of pods on pod yield. It had a high positive genetic correlation also with the yield. The number of primary branches had positive and the days to flower the negative indirect effects via number of pods per plant in vegetable podded cowpeas.

**Climatic and soil requirements**

It is a warm-season crop and cannot stand cold weather. It can be grown both in spring and rainy seasons in the plains, but it cannot tolerate heavy rainfall. Different varieties respond differently to temperature and day length and hence there are distinct varieties for spring and rainy seasons. It can be grown on practically all types of soils like French bean.

**Planting requirements**

Usually two crops of cowpea are taken in the plains but in places like Bangalore where summer and winter are not very extreme it grows throughout the year. It is usually sown in December-January in the southern plains and February-March in the northern plains to take the spring crop. For the rainy-season crop the sowing is done in June-July all over the plains. Most of the growers broadcast the seeds in a well-prepared field which interferes with the cultural practices. It requires 12 to 17 kg of seeds for a hectare of area depending on the spacing given. Usually the sowing is done behind the desi plough or may be drilled at a depth of 2 to 3 cm and later the excess seedlings are thinned out to provide proper spacing between the plants. To take a good crop and to facilitate cultural operations the sowing should be done in rows 45 to 60 cm apart and plants thinned to 10 to 15 cm in case of bushy varieties. In some cases the ridges are made for sowing in rows, particularly during rainy season.

**Manurial and fertilizer requirements**

Depending on the fertility status of the soil, the following recommendations have been made: 25 to 50 tonnes of FYM, 12 to 50 kg of nitrogen, 60 to 74 kg of phosphorus and 60 to 74 kg of potash per hectare (Mehta, 1959; Yawalkar *et al*., 1962). The complete dose of FYM may be applied in the soil at the time of field preparation and the complete dose of N, P and K may be applied to the soil before sowing.
Intercultural operations

The operations are more or less the same as that of the French bean. Choudhury and Ramphal (1960) reported that the spray of Maleic hydrazide at 50 to 200 ppm just before flower initiation increased the pod yield per plant significantly.

Harvesting

As in other beans the tender pods are harvested for marketing purpose. Frequent harvesting should be encouraged before the pods become fibrous and unfit for the market. The marketable pods are available from 45 days in the early varieties to 100 days in the late varieties. It produces about 75-100 q/ha of green pods and 10 to 18 q/ha of dry seed.

Improved varieties

The following varieties of vegetable cowpea were recommended by the IARI.

'Pusa Phalguni'. It is a bushy, dwarf variety best suited for spring sowing in the northern plains. The pods are dark green, about 12.5 cm long and appear in two flushes. The pods are ready in 60 days and the yield is about 90 q/ha.

'Pusa Barsati'. It is an early variety for the rainy season. The pods are about 25 to 27 cm long and appear in two to three flushes. The pods are ready in 45 days and the yield is 85 q/ha.

'Pusa Dofasli'. It is a bushy variety suited for both the spring and rainy seasons. The pod is about 18 cm long and gives the first picking about a week later than 'Pusa Phalguni' in the northern plains. It gives about 15 pickings in two months and produces 100 q/ha of green pods.

Recently, 'L-1552' (IARI) has been recommended by the All-India Co-ordinated Project for Cultivation. ‘Sel 61-B’ (IIHR), 'S-288' (Hebbal) and some selections from NBPGRE and IARI have been included for testing under All-India trials.

CLUSTER BEAN

Origin

The origin of cluster bean, *Cyamopsis tetragonoloba* (L.) Taub. is not definitely known but it has been grown since long in India, Africa, Sikkim, Peru and Java, where it is quite adapted for
commercial production.

Distribution and uses

It is a very hardy type of crop and survives well in the tropical plains. It is grown very commonly in the northern plains and an appreciable area has come under this crop in southern plains also. The pod is primarily used as a vegetable. Some of the fodder varieties are also available in different parts of the country. In the low rainfall areas of northern plains it is the most common poor man’s vegetable crop. The gum from its seeds is becoming an important commodity in international trade. The gum is a major component of adhesives including those widely used on postage stamps, to impart smoothness and stability to bakery products, as a foam stabilizer in beer, to impart lustre to silk and other fine textiles and many other uses (Anonymous, 1979).

Botany

It is a bush type herbaceous annual. Some of the varieties have single stem where the fruits are borne in clusters, whereas some other varieties produce branches and need more wider spacing for cultivation.

Plant breeding

A good number of useful indigenous strains are available in the northern plains. Some of the outstanding strains have been purified and selected as commercial varieties. The variety ‘Pusa Sadabahar’ was selected from a local strain of Rajasthan, whereas ‘Pusa Mausami’ was selected from another local strain (Pal et al., 1956). ‘Pusa Naubahar’ was evolved at the IARI by crossing the above two varieties with an ability to crop well in both spring and rainy seasons (Singh and Mital, 1966). Genetics of some of the economic characters have also been studied (Sanghi et al., 1964; Sanghi and Sharma, 1964).

Climatic and soil requirements

The cluster bean is a warm-season crop and grows well in summer as well as in the rainy season in the plains. It is very hardy and relatively resistant to drought. In regions with high summer temperature and low rainfall it has produced an excellent crop where no other important vegetable crop could be grown
successfully. It is adapted to all types of soils but thrives best in well-drained, sandy-loam soil. The land should be well prepared by few ploughings.

**Planting requirements**

The crop is sown during December-January in the southern plains, February-March in the northern plains and June-July all over the plains.

It requires 14 to 24 kg/ha of seeds. The seeds may be sown 2 to 3 cm deep in rows kept 60 cm apart and 20 to 30 cm apart in the rows. Most of the growers broadcast the seeds in the field which interferes with the cultural practices. In the rows the seeds may be dibbled behind the plough or drilled.

Seed germination takes place within a week depending on the soil moisture. The changes in chemical constituents during germination are reported by Nagpal and Bhatia (1970).

**Manurial and fertilizer requirements**

Being a leguminous crop it does not require much manuring especially when it is grown under rainfed conditions. However, when it is grown under irrigated condition to get maximum harvest it requires proper manuring and fertilization. The manurial and fertilizer requirements are as follows: 10 to 14 cartload of FYM, 12 to 24 kg of nitrogen, 60 to 74 kg of phosphorus and 60 to 74 kg of potash per hectare. The complete dose of FYM is incorporated in the soil at the time of field preparation, whereas the complete dose of N, P and K may be applied just before sowing.

**Harvesting**

The green pods for vegetable purpose are harvested when they attain the marketable stage. Only tender and non-fibrous pods should be hand-picked for market purpose. It produces 60 to 85 q/ha of green pods, whereas 6 to 8 q/ha of seed is produced.

**Improved varieties**

The following varieties of cluster bean are recommended by IARI.

*Pusa Sadabahar*. It is a variety with single stem and high yield. It does well in the summer and in the rainy season. The pods are green and about 12 to 13 cm long which are tender and
The first picking is done after 45 days of sowing during summer, whereas it takes about 55 days in the rainy season.

‘Pusa Mausami’. It is another high-yielding variety with smooth bright green pods about 10 to 12 cm long. It is a branched variety which is suitable for the rainy season. It is a late variety with first picking in about 65 to 80 days depending upon the weather and the region.

‘Pusa Naubahar’. It is a new variety with the pod quality of ‘Pusa Mausami’ and the growing habit of ‘Pusa Sadabahar’ and gives a good crop in both summer and rainy seasons.

WINGED BEAN

Origin

The centre of origin of winged bean (Psophocarpus tetragonolobus (L.) DC. is still uncertain. Vavilov (1951) claimed India as the centre of origin, though the likelihood of it is remote. Burkhill (1935) believes it to be of African origin, perhaps Madagascar. Khan (1976) reported that Papua New Guinea is the greatest centre of diversity though no other wild or cultivated species of this genus occurs in that country. Gopalakrishnan et al. (1981) suggested Kerala, Karnataka and part of Tamil Nadu to be the secondary centre of origin of winged bean.

Distribution and uses

The winged bean has been cultivated for generations in humid tropics of South and South-East Asia, particularly India, Sri Lanka, Bangladesh, Burma, Malaysia, Thailand, Vietnam, Laos, Kampuchea, the Philippines, Indonesia and Papua New Guinea. It is grown as a field crop in Papua New Guinea, Burma and Thailand. In India it is grown at least in eight states including Assam, Manipur, Mizoram, Kerala, Tamil Nadu and Karnataka by the tribals only as a backyard crop. The results of trials encourage to hope for its successful cultivation in north Indian plains also. The winged bean is used as a green vegetable of half-grown pods. The leaves, flowers, seeds, stem and tuberous roots are also eaten in a variety of preparations. It also forms an excellent source of dietary protein and oil. It has remarkably high protein content in most of the edible portions and is similar to soybean. Its dry seeds contain 30-40% protein
and 15-20% oil. The green tender pods contain 2-4% protein on fresh weight basis and 15% on dry weight basis. Its tubers also contain 11-15% protein content which is 5 to 10 times more than in potato, sweet potato, cassava, etc. In spite of reported presence of trypsin inhibitor in winged bean, it contains an antioxidant tocopherol that enhances utilization of vitamin A in the human body (Singh and Paroda, 1983). No adverse effects have been reported so far.

**Botany**

The winged bean is a twining perennial herb grown as annual. All the cultivars are indeterminate in growth and have the pods with longitudinal wings. It is also known as Goa bean, Manila bean, four-angled bean, etc.

*Psophocarpus* has about 9 species but only *tetragonolobus* is the common one. Though it is normally a self-pollinated crop, the cross-pollination occurs to the extent of 7.6% (Erskine, 1980). It has chromosome 2n=18. The flowering in winged bean occurs between 50 and 90 days after planting and the pods mature in 3-5 months.

**Plant breeding**

A very fast approach has been made to study various genetic and plant breeding facets of winged bean at international level. In India it is dealt under a separate All-India Co-ordinated Project on under-Utilized Crops. The active research is being co-ordinated at the International Research Centre in Sri Lanka. In India useful informations have been contributed from IIHR, Bangalore, NBPGR, Delhi, NBRI, Lucknow, at two International Symposia held during the past 5-6 years in the Philippines and Sri Lanka. Khan (1980), Singh (1981), Anonymous (1981) and Singh and Paroda (1983) contributed greatly by publishing monograph and review articles.

The winged bean exhibits a wide genetic variation in size, shape and colour of pods, leaves, flowers and seeds. No improved variety has been released in India though a selection was recommended from NBRI, Lucknow, for cultivation. With such a genetic variability available in India and the efforts being put, some useful high-yielding varieties may be available in near future. Certain varieties like ‘Bogor’, ‘Ribbon’, ‘Butterfly’,
'Mariposa', 'Lunita', 'Always', 'Alipasto', 'Dual', 'Chimbu', and 'Tinge' are available in markets of Puerto Rico and South-East Asia which can be tried in India also.

Cultivation

Except alkaline and sodic soils it can be grown on a range of soil types from sandy to clay with soil pH from 4.3 to 8.5. It can withstand high temperature but not the frost and water logging. The sowing is generally done from the end of July up to October at a spacing of about 1 m between rows and 25-70 cm between plants at a depth of 2-3 cm. Seeds germinate in 5-15 days. Plants flower during short days and between 18°C and 32°C. The varieties differ in sensitivity to day-length. The flowering can continue for about 8 months if green pods are removed periodically. While the rain destroys most other beans, winged beans flourish in rain. If rains are not frequent, irrigation will be necessary. Irrigation is required weekly until the plants are large and have roots deep enough to resist short droughts.

The twining vines (3-4 m long) require support from the beginning itself which can be provided by thick bamboo poles or a Y-shaped trellis connected by wires to get better yield. Yield is poor without staking. A fertilizer dose of 40 kg N, 100 kg P₂O₅ and 40 kg K₂O is applied. Except 50% nitrogen which is required at the time of flowering, the entire quantity may be applied at the time of sowing. The weeds are required to be controlled in the first month of its establishment after sowing.

There are not very serious pests on winged bean except nematodes and some viruses. Sandy soils should be avoided from cultivation to escape from nematodes.

The winged bean has prolific pod bearing capacity (up to 75 pods per vine). The yield per hectare up to 24-40 quintals of seeds or 250-350 quintals green pods and 8-11 tonnes of tubers has been reported.

Insect pests

Common insect pests are described below.

Bean weevil (Bruchus sp.). This beetle infests the pods when the crop is in the field and later on feeds on the seed in the stored condition. The weevils can be killed by fumigating carbon disulphide at the rate of 1.5 to 4 kg to each 28.31 m³ of
space. Heating the beans up to 54.4°C for 30 minutes also destroys the beetle. If the bean seeds are to be used for seed purpose only, they can be mixed with 3% DDT and then stored.

Bean aphids (Aphis and Macrosiphum sp.). These are very small green to black insects which suck the cell sap of the tender parts of the plant, mostly the leaves. It may be controlled by spraying nicotine sulphate (1 : 600), Lindane (0.1%) or Parathion (0.025%). If the fruit formation has not taken place, spraying with 50% Malathion at 3 ml in 5 litres of water may be done (Reddy, 1962, 1968). The edible pods may be harvested before spraying and the next harvest should be done after a week of spray. In case of Parathion spray harvesting after two weeks of spray is preferred.

Pod borer (Adisura sp.). Sometimes it becomes a serious pest of beans especially of dolichos bean, particularly in cold weather. The caterpillars are brownish green and the moths are yellowish brown. The caterpillars first feed on surface of the pod, bore into them and feed on the seeds. Hand-picking of the caterpillars in early stages of attack helps in reducing the intensity of the infestation. The affected mature pods may be sprayed with Pyrethrum (1 : 800) (Reddy, 1968). It can be controlled successfully by spraying the crop with 0.2% DDT or BHC (Dorge and Moghal, 1967).

Diseases

Commonly found diseases are given below.

Anthracnose (Colletotrichum sp.). The disease becomes severe when the weather is moderately cool, humid or rainy during the growing period. On the stems, leaves, pods and seeds elongated, sunken, dark-red cankers appear which ultimately cause defoliation and the seeds do not develop at times. Care should be taken to use disease-free seeds and proper crop rotation should be followed avoiding this crop in the rotation. It may also be controlled by treating the seeds with 0.125% solution of Ceresan wet or Captan at the rate of one tea-spoonful per kg of seed (Reddy, 1962, 1968). Spraying Benlate or Bavistin (0.1%) is also effective.

Powdery mildew. The common powdery mildew fungus affecting broad bean, double bean and peas is Erysiphe polygoni,
whereas the organism damaging cluster bean and dolichos bean is *Leveilulla* sp. The disease occurs on all parts of the plants, first on the leaves and later spreads on to stem and pods. Slightly dark areas appear on the leaves which later turn into powdery spots. The disease usually develops late in the season and early varieties escape it. It reaches its maximum intensity at the time of pod formation. The incidence may be reduced considerably if the field is kept clean and the alternate hosts from and around the field are removed. The disease may be controlled by dusting fine sulphur at the rate of 27 to 33 kg/ha at 10 to 15 days interval, or the wettable sulphur may be sprayed at the rate of 1 kg in 500 litres of water (Reddy, 1968).

*Bean rust* (*Uromyces* sp.). The disease occurs in regions of high relative humidity. The symptoms occur on the lower surface of the leaf in the form of minute dark brown spots which are slightly raised. Red to black pustules appear first on the lower surface of the leaves and the leaves turn yellow and drop. It can be controlled by dusting fine sulphur at the rate of 24 kg per hectare even before the infection takes place.

*Bean mosaic*. Three strains of the virus are involved in causing this disease. The leaves become ruffled, crinkled and have mottled yellow areas on the green leaf surface. The pods from infected plants may be rough and deformed. The common bean mosaic and its variants are carried in seed from diseased plants and may be transmitted from diseased to healthy plants by aphids. The only way to control this disease is by growing resistant varieties. Some of the varieties like ‘Contender’, ‘Kentucky Wonder’, ‘Rival’ and ‘Logan’ have been reported to be resistant varieties in the United States. It may be avoided by roguing some of the infected plants in the beginning itself.

*Root-knot nematode* (*Meloidogyne* sp.). In certain beans, in some regions, it becomes a serious pest. The attacked plants are pale, yellowish and somewhat dwarfed and have a tendency to wilt. The roots show typical galls which should not be confused with the bacterial nodules. It may be controlled by following long crop rotation or by soil fumigation with nematicides like DD or Nemagon.

**Seed production in beans**

Since all the beans are self-pollinated no appreciable contami-
nation is expected in seeds. But for the production of foundation seed it is necessary that the two varieties each of French bean, dolichos bean and cowpea are sown about 50 m apart (Anonymous, 1971a). The agronomic practices for the crop to be raised for seed production are more or less the same as that of the crop raised for vegetable purposes. The ripe and dry pods should be picked up by hand and threshed carefully without injuring the seeds. Singh et al. (1964) reported an average yield of 644 kg/ha in the French bean variety, 'Kentucky Wonder' (pole type), and 390 kg/ha in the bush French bean variety, 'Giant Stringless'.

In cluster bean the average seed yield was 6.0 to 7.4 q/ha, whereas in cowpea it was 14 to 18 q/ha.
9. **PEA**

**Origin**

It is said to be the native of Europe and western Asia (Thompson and Kelly, 1957).

**Distribution and uses**

Pea is a very common crop during winter throughout the plains in India. There is an appreciable acreage under this crop and the consumption is very high when compared with other vegetable crops. It is rich in protein, carbohydrates, vitamin A and C, calcium and phosphorus. It also contains a small quantity of iron. The green pod is edible and is usually cooked in various vegetable preparations in different regions of the country. It has a good market in the dehydrated and canned forms.

**Botany**

Pea (*Pisum sativum* L.) is a self-pollinated crop and belongs to the family Papilionaceae. The fruit which is eaten is a ‘pod’ botanically. The plant is a herbaceous annual with vining habit. The flower is hermaphrodite, papilionaceous in nature and borne in cymose inflorescences.

**Plant breeding**

Pea has been grown in this country for several decades and is quite adapted to this part of the world. There are a good number of local strains and exotic varieties are also available in this country. Most of the exotic varieties were introduced in India and used as commercial varieties and hence significant efforts were not made to breed varieties for various purposes. There has been an acute need for breeding varieties for high yield, better processing and cooking qualities and disease resistance. Some of the genetic informations with regard to economic characters and male sterility have been reported (Joshi and Singh, 1959; Singh *et al.*, 1964; Bhagmal, 1969; Singh and Singh, 1970; Sharma *et al.*, 1976, 1977; Brahmappa and Singh, 1977; Singh and Singh, 1979a; Narsinghani and Singh, 1979; Narsinghani *et al.*, 1979; Pal *et al.*, 1982). Incorporation of rust
and powdery mildew resistance has been taken up at IIHR, Bangalore, after isolating the source of resistance. A few advanced generation selections from intervarietal hybrids are also ready for large-scale multilocation testing for yield and processing qualities (Pal et al., 1982).

**Climatic and soil requirements**

It is a cool-weather crop and grows best at the optimum mean monthly temperature of 10° to 18.3°C. It is relatively tolerant to frost when compared with Solanaceous and Cucurbitaceous crops. Blossoms and pods are susceptible to frost, whereas leaves and stems are relatively tolerant. Seed germinates better at the soil temperature of 10° to 18.3°C.

It can be grown on all types of soils but the early crop is expected in light soils and higher yields in loose, friable and heavy soils. It grows best at the pH of 5.5 to 6.7. It does not thrive in highly acidic or alkaline soils. The field should be well prepared with 3 to 4 ploughings.

**Planting requirements**

Since it is a cool-season crop, mid-season varieties can be sown from the beginning of October to the middle of November in the plains. The early varieties can be sown in August-September. The cultivation of pea in Karnataka has been discussed (Pal and Nath, 1976). It can be sown in flat or in raised beds either by broadcasting or behind the plough. Depending upon maturity period and plant habit it is sown in rows 30 to 60 cm apart and within the rows 5 to 10 cm apart. In raised beds it can be sown on both the sides of the bed which are 120 to 150 cm wide with furrows between them. Seeds are sown about 2.5 cm deep. It requires 50 to 75 kg of seed per hectare for the mid-season varieties and 80-100 kg for early varieties depending on the size of seed. For better germination sometimes the wrinkled seeds are water-soaked overnight. In the new field where the pea crop has not been grown earlier the inoculation of *Rhizobium* sp. in the soil is recommended for better growth.

**Manurial and fertilizer requirements**

Depending on the fertility of the soil the following manures and fertilizers have been recommended per hectare: 10 to 15
tonnes of FYM, 20 to 50 kg of nitrogen in the form of ammonium sulphate, 30 to 80 kg of potash in the form of potassium sulphate and 50 to 60 kg of phosphorus in the form of single superphosphate (Purewal, 1957; Mehta, 1959; Yawalkar et al., 1962). It is suggested that the complete dose of FYM may be mixed up with the soil at the time of field preparation, whereas the complete dose of potash and phosphorus may be applied before sowing. The ammonium sulphate may be split in two doses with first dose at the early stage and the second at the flowering stage as top-dressing. Sharga and Jauhari (1970) reported that the foliar application of 0.1% ammonium molybdate significantly increased number of root nodules, TSS and the length, diameter, fresh weight and number of grains per pod.

Intercultural operations

As in other vegetable crops, pea also requires regular soil moisture but the frequency of irrigation is much less than other common vegetable crops. Usually the irrigation is given immediately after sowing in the light soils. In heavy soils the sowing should be done when enough of soil moisture is available. Frequent irrigation is always avoided but the pea plant must be provided with irrigation at the pod-filling stage or when frost is at hand. Hoeing should be done to keep down weeds and provide good aeration for proper development of the roots. In some places weed is controlled with the application of 3 kg/ha of dinitro material immediately after sowing. In case of tall indeterminate varieties it would be advisable to provide stakes to the plants to harvest better-quality pods.

Harvesting

The green pods of early varieties are ready for harvest in 45-60 days, while mid- and late-season varieties, which are generally indeterminate, take 70 to 100 days. As the pod attains marketing stage it turns dark to light green and the grains are well filled up in the pod. In the processing industry the maturity of pea is tested with the help of ‘tenderometer’. The high quality of pea is tested by its tenderness and high sugar content. Usually 3 to 4 pickings of pods are made during the season, which is spread over 2 to 4 weeks at 7 to 10 days interval. Mid- and late-season varieties require more number of pickings. The early
varieties produce 25 to 40 q/ha of edible pods, medium varieties 65 to 75 quintal and the late varieties 85 to 115 q/ha, where the shelling percentage is 40 to 45.

It cannot be stored for more than 2-3 days under ordinary conditions but it can be stored for about two weeks at 0°C and 85 to 90% relative humidity.

**Improved varieties**

**EARLY-SEASON VARIETIES**

*Arkel*. It is wrinkled-seeded, early variety introduced from Europe and is sweet with good pod quality and gives the first picking in about 65 days after sowing in Delhi.

*Meteor*. It is a round-seeded early variety introduced from England. It is also sweet and gives the first harvest in about 70 days in Delhi.

*Asauji*. It was selected at the IARI for sowing the early crop around the middle of September. It is a dwarf plant growing to a height of about 37.5 cm. The pods are dark green, curved, about 7.5 cm long and well filled with 6 to 7 smooth seeds per pod. The pods are ready for harvesting in about 60 days.

*Early Badger*. It is an American variety suitable for sowing in early October. It is a dwarf, wrinkled-seeded variety which gets ready for the first picking in 60 to 65 days. The pods are well-filled and the seeds are bold and sweet.

All-India Co-ordinated Project recommended *Arkel* (IARI) and *Jawahar Matar-4* (Gwalior) for early seasons. *Hara Bona* (Ludhiana) and some selections from Almora, Pantnagar and Jabalpur are under testing at present for identification of better early varieties.

**MID- AND LATE-SEASON VARIETIES**

*Bonneville*. This is an American variety, medium tall in growth and is a prolific bearer. The pods are about 8 cm long which get ready for the first picking in about 85 days after sowing. This wrinkled-seeded variety has performed well as a main season variety in most of the areas.

*Perfection New Line*. It is a heavy yielding mid-season variety introduced from America. The plant is medium tall and the pod is about 8 cm long, dark green, sweet and well-filled with wrinkled seeds. It is ready for first picking in about 80 to 85
days.

All-India Co-ordinated Project recommended 'Bonneville' (IARI) and 'Jawahar Matar-1' (Gwalior) for commercial cultivation for mid-season. Some selections from Ludhiana, Jabalpur, Kalianpur, Pantnagar and Almora are under test to find out better varieties than the already recommended ones.

**Seed production**

Since it is a self-pollinaited crop not much outcrossing is expected while producing pure seed of a variety. However, it is suggested that for producing the foundation seed, the two varieties should be kept about 20 m apart to avoid contamination (Anonymous, 1971a).

The agronomic practices which are followed for the cultivation for green pods are the same for the crop for seed production. The pea crop is well known for producing off-type plants which rapidly multiply and hence should be rogued out at the flowering or fruiting stage. The ripe fruits when they are dry are hand-picked and threshed easily. After grading the seeds by means of hand sifters the split seed or any foreign matter is hand-picked. Average seed yield is 20-25 q/ha.

**Insect pests**

Common insect pests and their control measures are described below.

*Pea aphids (Macrosiphum sp.)*. These are very small, green and soft-bodied insects which suck the cell sap of the young plant leaves, stems and pods. It can be controlled easily by the spray of 0.06% nicotine sulphate, 1 ml of Rogor or Nuvacron, or 2 ml of Metasystox per litre of water at fortnightly intervals.

*Pod borer (Heliothis sp.)*. It is a serious borer of the pods in some parts of the country. The young caterpillars first feed on the surface of the pod, bore into them and feed on the seeds rendering the pods unfit for consumption. It can be controlled if the egg masses, caterpillars and pupae are hand-picked in the beginning of the infestation. It can be controlled by spray of Sevin (0.2%), Malathion (0.1%), dusting 5% BHC at the rate of 18 to 25 kg/ha, or by spraying 0.2% DDT suspension at the rate of 675 to 900 litres/ha at regular intervals depending on the degree of infestation.
Pea weevil (*Bruchus pisorum*). The insect lays eggs on young pods and larvae bore into the pods. Spraying with 0.02% Thiodan at flowering stage can control this pest.

**Diseases**

Common diseases and their control measures are given as follows.

*Powdery mildew* (*Erysiphe polygoni*). It first attacks the leaves producing faint, slightly discoloured specks from which greyish-white powdery spots spread over leaf, stem and pod. The leaves become yellow and die whereas fruits either do not set or remain small. In severe cases defoliation occurs. The disease usually develops late in the season reaching its maximum intensity at the time of pod formation. The disease can be eliminated in the beginning itself by removing and burning the diseased plants. At several places the early varieties generally escape the incidence of this disease. It can easily be controlled by dusting the crop with fine sulphur at the rate of 27 to 32 kg/ha at the interval of 10 to 15 days, or by spraying Sulfex (0.2%) or Karathane, Bavistin or Benlate (0.1%) at weekly intervals. There is need for breeding a variety resistant to this disease.

*Rust* (*Uromyces* sp.). Red to black pustules appear first on the lower surface of the leaves, later the leaves turn yellow and drop. In some regions it becomes a very serious disease which may be controlled by spraying Benlate (0.1%) or Bordeaux mixture (5 : 5 : 50) at the early stage of the plant growth.

*Wilt* (*Fusarium* sp.). The disease spreads through the affected soil and in severe cases the whole plant wilts and stem shrivels. The affected seeds may carry the disease to the next season. The incidence of this disease can be reduced considerably by following the long rotation schedule. The seed treatment and drenching the plants with Brassicol (0.2%) or other fungicides may help in controlling this disease. The resistant variety like ‘Alaska’ may be grown (Choudhury, 1957).

*Near-wilt* (*Fusarium oxysporum* f. *pisi* race 2). The symptoms are more or less the same as that of the above mentioned wilt, most probably caused by race 1. One of the chief differences between the two is that it develops more slowly than wilt, a fact which is in part due to its higher optimum temperature. The vascular elements as ‘a rule are brick-red rather than orange-
brown in colour and the discolouration commonly extends to the growing tip. Most of the wilt-resistant varieties in the USA are susceptible to near-wilt (Walker, 1952). The varieties 'Delwiche Commando' and 'New Era' are resistant to both wilt and near-wilt (Choudhury, 1957).
10. ROOT CROPS

RADISH

Origin

It is one of the most common root crops grown all over the country. Probably it is a native of Europe or Asia (Thompson and Kelly, 1957), perhaps of China. It has been grown in our country for several decades.

Distribution and uses

It is widely cultivated in northern and southern plains as well as in the hills. It is consumed almost in every house whether rich or poor. Radish green is very rich in vitamin A, B and C with little of carbohydrate, iron and protein. It is eaten both raw as salad or cooked in various ways. It has a cooling effect and increases appetite. It has some medicinal values also.

Botany

Radish, *Raphanus sativus* L. belonging to the family Cruciferae, is a quick-growing herbaceous annual. The enlarged edible roots are fusiform botanically which may differ in colour from white to red. There are two distinct genetical groups in radish. The Asiatic varieties which are primarily for tropical climates produce edible roots in the first season and seed in the second season as a biennial crop, whereas the exotic or European varieties produce roots in the plains of tropical and subtropical climate and seeds in the hills of temperate climate.

Plant breeding

Some studies on pollen morphology and physiology in radish have been reported (Nath and Mehta, 1969). Different useful strains of Asiatic types have been reported from different regions of the country. A good number of temperate and Asiatic varieties were also introduced and some of them have been grown as commercial varieties for decades, but their seed production has been possible only in Kashmir, Kulu Valley and Nilgiri Hills. Usually the Asiatic types are more pungent than the temperate ones. Attempts have been made to improve upon the Asiatic strains by crossing with the exotic varieties to obtain
new varieties with root qualities of temperate types and ability to produce seeds in the plains (Singh et al., 1971; Dutta and Vijay, 1970). An important achievement in this direction has been the release of the new radish variety ‘Pusa Himani’ (Singh et al., 1971). Emphasis has also been laid on developing varieties resistant to diseases. Dutta and Vijay (1970) reported radish strain ‘IIHR-1’ to be highly resistant to white rust (Albugo candida). The new variety developed at the IIHR is ‘Arka Nishant’, which produces high yield with better-quality roots in the southern region.

Male sterile line has also been used for hybrid seed production in other countries (Ogura, 1968). Muthukrishnan and Arumugam (1977) reported that the root length has the most important contributory factor for yield.

Climatic and soil requirements

Commonly radish is a cool-season crop but the Asiatic varieties can resist more heat than the European or temperate varieties. It attains best flavour, texture and size at 10° to 15.6°C. A long day as well as high temperature lead to bolting without adequate root formation. During the hot weather the roots become tough and pungent before reaching the edible size and therefore should be harvested while young and small in size. The radish is more pungent at higher temperature. Pungency decreases with the advent of cooler temperature. The temperate types are generally small, mild in taste and mostly used as a salad.

It may be grown on all kinds of soil but the best results are obtained on sandy-loam soils which are friable and contain high amount of humus. Usually the heavy soils produce rough, ill-shaped roots with number of small fibrous laterals. The field should be prepared with at least 4 or 5 ploughings so as to make the soil very loose and smooth.

Planting requirements

Since it is a cool-season crop its cultivation is preferred during winter season in the plains. It can be sown any time between September to January in the northern plains as it is not affected either by frost or by extreme cold-weather conditions. It is grown from March to August in hills. In the regions where
summer is mild it can be grown throughout the year except few months of summer. In Bangalore, the radish roots are available practically for 8 to 10 months of the year but the best edible roots are available during November-December only. The temperate types are generally not planted till October.

It requires about 5.5 to 11.0 kg of seeds for one hectare of area. It is usually grown on ridges to facilitate good root production. It is grown as a single crop or as a companion crop. The plant rows or ridges about 22 cm high are kept about 45 cm apart, whereas the plants within the rows are about 8 cm apart. The temperate types can be sown in rows about 20-30 cm apart. Generally, the seed sowing is done 1.25 cm deep in succession to give continuous supply of the produce. It is sown directly in the field and not in nursery beds. The seed is mixed with fine soil or sand and placed in rows by hand and is covered with soil to make it firm around it.

Manurial and fertilizer requirements

Different recommendations made by various workers are: FYM 25-40 tonnes, nitrogen 18 to 50 kg in the form of ammonium sulphate, potash 50 kg in the form of muriate of potash and 50 kg of phosphorus in the form of superphosphate per hectare (Desai, 1948; Purewal, 1957; Yawalkar et al., 1962).

The FYM should be mixed up thoroughly at the time of field preparation, whereas the complete dose of potassic, phosphatic and one-half dose of nitrogenous fertilizers may be applied in rows before sowing. The second half dose of nitrogenous fertilizer should be applied as a top dressing along with the irrigation when the plant started growing vigorously.

Intercultural operations

It is necessary that enough of soil moisture is available to help uniform seed germination and growth of the plant. If enough soil moisture is not available at the time of sowing the first irrigation should be given immediately after sowing. It is advantageous in case of light soils but it hinders the germination in heavy soil where the soil surface has become dry with hard film formation before the seed has sprouted and broken through the soil. In this case it is always safer if the sowing is done when already enough of soil moisture is available for germination in the heavy soil. Depending on the season and the soil
moisture available it may be irrigated once or twice a week. It should not be irrigated very frequently, but care should be taken that the field may not become dry and compact so that the root development is not checked.

Weeding should be done at regular intervals to keep down the weeds. Shallow hoeing may be necessary to facilitate root growth. When the root has started growing, earthing up should be done for enlarged root production, otherwise the growing roots may come above the soil surface.

**Harvesting**

Depending on the variety the edible roots get ready within 25 to 60 days. The temperate varieties take lesser time than the Asiatic varieties. The maturity of the roots for marketing will depend on the size of the root as well as on the variety. It is necessary that the roots are harvested at the right stage because they tend to become fluffy and unmarketable thereafter.

The Asiatic improved varieties produce 150 to 250 q/ha of roots in 40-60 days, whereas the temperate varieties produce 50 to 80 q/ha in 25-30 days. The roots are washed and bunched together along with the shoots for marketing purposes.

It can be stored at room temperature for 3 to 4 days without impairing its quality much, and for two months in the cold storage at 0°C and 90 to 95% relative humidity.

**Improved varieties**

The following varieties are reported to be under commercial cultivation.

**Temperate Types**

*White Icicle*. It is a medium-short European variety which matures in 30 days. The skin is pure white, thin and tender whereas the flesh is icy white, crisp, juicy, mild and of sweet flavour with just enough pungency to appeal the appetite. The root is solid icicle-shaped straight and tapered. It has given a good harvest in the plains.

*Rapid Red White Tip*. It is a very early European variety which matures in 25 days. It has a short top with small bright red roots with white tip. The flesh is pure white and crisp with mild pungent flavour.
Asiatic Types

'Japanese White'. It is Asiatic variety which matures in 45-50 days. The root is cylindrical and about 20 to 30 cm long. The skin is pure white, smooth and the flesh is snow-white, crisp, solid and mildly pungent with top medium-large with deeply cut leaves.

'Pusa Himani'. The roots of 'Pusa Himani' are 30 to 35 cm long and 10 to 12 cm in girth with green stem end. They are semi-stumped to tapering with short stalks. The skin is pure white and the flesh is crisp and sweet flavoured with mild pungency. Though it is primarily a variety for the hilly region, it has been found to do well in milder climate of the plains also.

'Arka Nishant'. It is an Asiatic variety developed at IIHR, Bangalore, and matures within 45-55 days. Roots are medium-sized (25 cm x 3-4 cm), marble-white, crisp texture, pleasant aroma, free from early bolting, pithiness, splitting and forking, each root weighing 300-400 g (Fig. 15). Root and shoot length ratio is 1 : 1. Pungency is mild. It yields 200-300 q/ha.

Fig. 15. 'Arka Nishant', a high-yielding, good-quality Asiatic radish.
‘Pusa Chetki’. It has been developed at IARI. Roots are medium long, white, good textured, weighing 300-400 g each. It yields about 200-250 q/ha in 50-60 days.

‘Punjab Safed’. Developed at Ludhiana; roots are pure white, tapering, smooth, mild in taste, 30-40 cm long and 3-5 cm thick.

‘Pusa Reshmi’. Developed at IARI; it has white tapering roots of medium to long size.

Seed production

It is a cross-pollinated crop and hence requires isolation from other varieties to avoid any out-crossing with regard to purity of the seeds. It is recommended that the two varieties may be planted 1,600 m apart to produce pure seeds (Anonymous, 1971a). The planting is similar to that in turnip. The best roots of a particular variety are picked up at the marketable stage and are required to be transplanted in the well prepared field after giving proper root and shoot cuts through the stocklings. Some growers leave the plants with the roots in the field and allow it to produce seed stalks. It is not recommended, as the selection of good roots cannot be made and off-type plants which are not true to variety cannot be removed. Also the seed quality and yield are affected if transplanting method is not followed. Kalvi and Nath (1970a) reported that the plants with two-third top left and one-half root cut or one-fourth root cut proved to be superior to control with full-top and full-root in respect of new vegetative growth and seed-stalk emergence. Kalvi and Nath (1970b) confirmed that the plants with two-third top left and one-half root cut produced the highest seed yield of 7.4 q/ha. But the highest germination of 95.5 and 80% was recorded in plants with two-third top left and one-fourth root cut in ‘Kalyanpur’ and ‘Marwari’, respectively, than the control which gave 3.4 q/ha (Kalvi and Nath, 1970b). Further investigations on the performance of these seeds (obtained through various shoot and root cuts) on shoot growth and root production and again on its subsequent seed production revealed interesting results establishing the point that better seeds could be obtained through these simple techniques (Nath and Mehta, 1971; Mehta and Nath, 1971).

Singh et al. (1960) reported 4.9 to 5.9 q/ha of seed from ‘Japanese White’.
Insect pests and diseases

The common insect pests are given below.

_Aphids (Brevicoryne sp., Myzus sp.)._ This pest attacks most of the Cruciferous crops and persists on the alternate hosts throughout the year. The cloudy and humid conditions are favourable for their quick multiplication. In case of heavy infestation the plants are completely devitalized, leaves and shoots curl up, get yellowed and finally die. Malathion 50% in the ratio of 1:1,200 gave sufficient high per cent of kill with a residual effect of 2 to 3 weeks. Nicotine sulphate (1:800) also proved to be effective at higher temperature of about 18.3° to 21.1°C (Singh _et al._, 1960). Spraying Nuvacron (1.25 ml) or Metasystox (2 ml) per litre of water is also recommended.

_Mustard saw-fly (Athalia sp.)._ This is a common pest of radish and turnip. It appears when the crops are in flowering and at vegetative stage. The damage is done by the grub by biting holes in the leaves and fruits. It has been controlled by dusting 10% BHC at the rate of 15-20 kg/ha at the vegetative growth of the infestation crop and 35 to 40 kg/ha at the seed formation stage. Spraying of 4 g Sevin 50 WP per litre of water at weekly intervals can also control this fly.

_Flea beetle (Phyllotreta sp.)._ In some areas it becomes a very serious pest on the vegetative parts of the plant which are eaten by this pest. It can be controlled by spraying with Malathion (0.15%) or Sevin (0.4%) at 10 to 15 days interval.

_White rust (Albugo candida)._ In some areas it is a very serious disease of radish. It produces a white powdery substance in patches on the under-surface of the leaves. It mainly appears on the leaves and flowering shoots which get deformed and bear only malformed flowers. The disease can be controlled effectively by spraying Dithane Z-78 (0.3%).

CARROT

Origin

Carrot is a most common root crop grown all over the country. It is said to be the native of Europe, Asia and North Africa and possibly North and South America (Thompson and Kelly, 1957). It was probably cultivated by the ancients but was not a common food plant. Asiatic types probably
originated from central Asia.

Distribution and uses

The Asiatic carrots are generally red coloured because of anthocyanin pigment. The European types are orange because of carotene, a precursor of vitamin A. In India, mostly Asiatic carrots are grown probably due to appeal for red pigment. The carrots are grown throughout the country. It is taken as raw as well as a cooked vegetable. It has got some medicinal values also in ayurvedic medicines. A black type of carrot is used to prepare kanji, a beverage. Red type is good for preparing various types of sweets in India.

Botany

The carrot, *Daucus carota* L. belonging to the family Umbelliferae, has got fleshy edible root portion which is designated as conical root botanically. As in radish, the carrot also has two groups—Asiatic and European (temperate) types. The Asiatic-type carrots produce root and seed freely in the plains, whereas the European types produce good roots but fail to produce seeds in the plains. The Asiatic type has its root ends predominantly conical whereas it is blunt in European-type carrots. The other contrasting features of Asiatic types are: tropical and subtropical, annual, no chilling requirement for seed production, more anthocyanin, more core, heavy top, core is not coloured, early maturing and high sugar content.

Plant breeding

Carrot is a cross-pollinated crop with protandrous bisexual flowers. In Asiatic carrots a good number of local useful strains are available in various regions of the country, and some of them are very high yielding. Because of the pleasant flavour liked by the Indians it has large production and consumption than the European types which have a different flavour but excellent texture. In the plains at some of the research stations it has been possible to maintain and evaluate some of the useful strains for utilization in breeding programmes. Also efforts were made at IARI in Delhi and its substation in Kulu Valley to cross between the useful strains of the Asiatic and exotic strains, with an intention to incorporate good root qualities of European types into high-yielding Asiatic types. A carrot variety 'Pusa
Kesar' which has good qualities of both Asiatic and European types with an ability to produce seeds in the plains has been developed (Singh, 1963). Also information has been achieved on the genetics of various economic characters in Asiatic carrots. Bienz (1968) reported that splitting was a varietal characteristic and was governed partially by genetic factors in addition to the effect of spacing and nitrogen application. Dickson (1966) concluded that cracking susceptibility may be governed by a single dominant gene. Scibrjo and Zemoja (1969) were of the opinion that the carotene content was higher in varieties with orange-red colour. Efforts have been made to breed hybrid carrots by using male sterile lines.

**Climatic and soil requirements**

The climatic and soil requirements of carrot are more or less the same as that of radish but it requires a relatively long growing season than radish. Though it can tolerate higher temperature, but the optimum temperature is 7.2° to 23.9°C for germination and 18.3° to 23.9°C for better growth. Barnes (1936) reported that greenhouse-grown carrots produced longest root between 10° and 15.6°C with poor colour and between 15.6° and 21.1°C with good colour. However, 23.9° to 29.4°C temperature produced shortest root but the shape was not affected by the temperature. During the development of root the colour changes from white to yellowish white, whitish yellow, light yellow, dark yellow, orange and then dark-orange gradually. The carotene content is reduced below 15.6°C and above 21.1°C.

Deep, well-drained sandy-loam soil is preferred for an early crop. It does not grow well on highly acidic soil. Heavy soil may check the development of root and cause forked lateral roots.

**Planting requirements**

The time of sowing of carrot is more or less the same as that of radish. It requires 6 to 9 kg of seeds to plant an hectare of area. As in radish it is usually sown directly on ridges or in flat beds in light soils. Commonly the growers broadcast the seeds but the proper method is to sow them in rows spaced 30 cm apart. For sowing carrot on level surface the field is arranged in small plots, convenient for irrigation and the seed mixed with
fine soil or coarse sand is broadcasted and the soil surface is raked to cover the seed lightly. Depending on the moisture available, the seed germinates in 5 to 10 days. Initially thick sowing of seeds should be done. The thinning may be required after germination to maintain 5-7 cm distance between the plants within the rows.

Manurial and fertilizer requirements

This crop is a heavy feeder of fertilizers and manures. According to Thompson and Kelly (1957) a carrot crop yielding 106 to 114 quintal removes about 14 kg of nitrogen, 8 kg of phosphorus and 45 kg of potash. Depending on the fertility of the soil the following recommendations have been made in various regions: FYM 20 to 30 tonnes, nitrogen 25 to 60 kg, phosphorus 25 to 50 kg and potash 90 to 110 kg/ha. The complete dose of FYM may be mixed with the soil at the time of field preparation and the complete dose of potash and phosphorus may be applied to the soil before sowing. It is suggested that the application of nitrogen in the form of ammonium sulphate may be given as a top dressing to increase the yield.

Intercultural operations

In the light soils the first irrigation may be given soon after sowing which may be followed by next at 4 to 6 days interval depending on the soil moisture available. In the early stage the crop should be kept free of weeds which may be done by frequent hoeings. It facilitates in proper soil aeration and root development. Earthing up should be done to cover the developing roots with soil and thus to prevent discolouration of roots.

In order to check weed growth, Maloran 50 WP pre-emergence was observed to be superior than other treatments, whereas the highest root yield was recorded with both Maloran 50 WP and Gesagard 50 WP (Sharma and Bhagchandani, 1979).

Harvesting

As in radish, the carrot may be adjudged for harvesting at the marketable stage depending on the size of the root. Care should be taken that they should not grow beyond the marketable stage as they become fluffy and unfit for consumption. The common Asiatic varieties attain the marketable stage at 2.5 to 4 cm dia-
meter at the upper end. The roots which are grown on ridges are easy to be pulled out than those in flat beds. In both the cases it is advisable to give light irrigation before harvesting which facilitates pulling out the roots from the soil without any damage.

The Asiatic varieties yield higher than the European varieties. The yield varies in various regions ranging from 135 to 370 q/ha. The roots are washed, cleaned and bunched in a fixed number say half-a-dozen or one dozen together.

Carrots can be stored at room temperature for 3 to 4 days under ordinary conditions. At temperatures of 0° to 4.4°C with 93 to 96% relative humidity they can be stored for three to four months (Wright et al., 1954).

**Improved varieties**

The following varieties were recommended by the IARI:

*Nantes*. It is an European variety grown in plains for root production. Its seed is produced in hills. It is half long, slim, well-shaped with stump and forming a small thin tail. It has delicious flavour, fine grain texture and self-coloured core with orange-scarlet flesh colour.

*Chantaney*. It is also an European type having attractive roots with deep reddish orange colour. The root is smooth, half long with thick shoulders, gradually tapering towards a distinctly stumped end. The flesh is beautiful rich orange, tender, sweet and fine textured with indistinct core.

*Pusa Kesar*. This variety is selected from a cross between ‘Local Red’ and ‘Nantes’ half long (Singh, 1963). The leaf top is markedly shorter than that of the ‘Local Red’. The roots develop a narrow central core and the core is also sufficiently red coloured unlike the yellow or white core in ‘Local Red’. A notable feature of this variety is that the roots stay a month longer in the field than the ‘Local Red’ without showing any sign of bolting. It seeds freely in the plains but the seed crop matures about 15 days later. It has higher (38 mg) carotene when compared with ‘Local Red’ (26 mg).

Some promising selections have been developed at Katrain, Ludhiana and other places and are being tested for their yield potential at different centres.
Seed production

Only the Asiatic varieties produce seeds in the plains. The European varieties do not seed in the plains, hence their seed production is limited to the hills only. Since it is a cross-pollinated crop every care should be taken to keep the two varieties away from each other and the isolation distance given to produce foundation seed is about 1,000 m (Anonymous, 1971a).

The usual technique followed for the seed production is more or less the same as that of radish and turnip. Usually good-quality and high-yielding roots of a variety are selected at the root· marketable stage and transplanted to well-prepared fields after giving proper root and shoot cuts to ensure better quality and higher seed yield. The selected roots are planted at a distance of 75 cm X 20 cm. Nath and Kalvi (1969a) reported the maximum of 82.8% plant survival with two-third top cut and no root cut, or one-half root cut treatment and the minimum of 62.5% with no top cut and three-fourth root cut treatment in a local Rajasthan variety ‘Sharbati’. The seed stalk growth was delayed with the increase in the size of the root cut. The size of the plants in terms of height and width was not affected by any of the shoot and root cut treatments. In another report (Nath and Kalvi, 1969b) the maximum seed yield per hectare was recorded from the plants which received the treatment of one-third top cut and one-half root cut in the two varieties. The highest seed germination of 72.2% was obtained in the first order umbel, 59.7% in the second order umbel and there was no germination within a month of harvest in the third order umbel seeds. These observations suggested that the seedlings should be given the treatment of one-third shoot cut and one-fourth to one-half root cut to obtain better quality and higher seed yield in carrot. If possible, the seed growers may not harvest the seeds of third order umbel, which has poor seed germination, thereby ensuring better germination percentage from the seeds collected from the first two orders of umbel.

The off-type plants including premature bolters should be rogued out before flowering of the stalks. The harvesting is done when the secondary umbels are fully ripe and the third-order umbels have begun to turn brown. Shattering is not a serious
problem in carrots. The plants can be pulled and stacked for curing. Threshing is done by wooden rollers when the stem becomes brittle.

An yield of 330 to 550 kg of seed per hectare was obtained from the European variety ‘Nantes’ in the Kulu Valley (Singh et al., 1960), whereas an average seed yield of 2,054 kg/ha with proper root and shoot cut treatments was obtained from the Asiatic variety, but the plants with no treatment produced 1,461 kg of seed/ha only (Nath and Kalvi, 1969b). Malik and Kanwar (1969) recommended that all seeds smaller than 1.66 mm gathered from the late harvest should be eliminated from the seed stock because a good response to seed size was obtained by shoot growth, root development and yield. At the time of seed maturity a dry and hot weather is required.

**Insect pests and diseases**

The insect pests and diseases are more or less the same as those which attack radish and turnip crops. One or two sprays of Malathion (0.2%) before flowering will control the bugs eating embryo. Care should be taken at flowering stage, not to use excessive insecticides which may otherwise have adverse effect on pollinating agents.

**TURNIP**

**Origin**

It is not definitely known where the turnip originated but it is said to be known growing wild in Russia and Siberia (Thompson and Kelly, 1957). Some regard it to central and western China while others assign it to middle Asia, Punjab and Kashmir. It has been grown in this country since long.

**Distribution and uses**

This crop is grown in almost all the regions in northern plains along with radish and carrot. It is very popular specially in Jamnu & Kashmir, Punjab, Himachal Pradesh and western Uttar Pradesh. The turnip is primarily used as vegetable and to a limited extent it forms the ingredient of salad preparation.

**Turnip greens are sometimes used as vegetable but are extensively utilized as green fodder.** Turnip greens are good source of calcium, iron and vitamin A and C and contain appreciable
amount of vitamin B also. The roots contain vitamin B and C in appreciable quantities. Ascorbic acid, calcium, sugar and water contents are secured to be influenced by seeds obtained through various shoot and root cut techniques (Nath and Joshi, 1971). The roots should preferably be cooked along with the tender tops. European types of turnip are relatively sweet and more palatable and may be eaten sometimes raw. The Asiatic turnips prepare good pickles also. In Jammu & Kashmir it is used in several delicious dishes including with the meat.

Botany

Turnip (Brassica rapa L.) belongs to the Family Cruciferae. The turnip is grown primarily for its enlarged root which is napiform consisting of the hypocotyl, which swells and becomes spherical. It has hermaphrodite flowers and is highly cross-pollinated mainly due to self-incompatibility nature. It is a herbaceous annual for the root production, whereas it is biennial for the seed production. As in carrot and radish, this crop also has two distinct groups—Asiatic and European types. As in other two root crops, the Asiatic type seeds freely in the plains, whereas the European types do not produce seeds in the plains. Asiatic types are more pungent.

Plant breeding

A number of good genetic stocks of Asiatic and European types are available in India. Some of them are very good varieties. Efforts were made in the past to maintain some of the Asiatic strains, but no intensive breeding work was taken up. However, an interesting achievement has been the release of the new varieties ‘Pusa Kanchan’ (Singh, 1963), ‘Pusa Sweti’ (Asiatic type), ‘Pusa Chandrima’ (European type) (Singh et al., 1971) from the IARI, New Delhi. ‘Pusa Kanchan’ has been selected from cross between an Asiatic variety ‘Local Red Round’ and the European variety ‘Golden Ball’. It has good qualities of both Asiatic and European type of varieties with ability to produce seed freely in the plains.

Climatic and soil requirements

Its climatic and soil requirements are more or less the same as that of radish and carrot. Asiatic varieties are sown earlier,
requiring warmer conditions than the European types. Higher ascorbic acid content is obtained at higher light intensity.

**Planting requirements**

The planting requirements are more or less the same as that of radish. The seed requirement is about 2.5 to 3.5 kg per hectare. Sowing is done in hills from March to May and in the plains from July to September (Asiatic) and October to December (European). It is sown in rows 30 cm apart. After thick sowing within the row, plants are thinned to space them at 10-15 cm. It gives a maximum seed germination of 90 to 95% and the seed remains viable for four years under good storage conditions. Seed germination is quicker in turnip and it makes rapid growth.

**Manurial and fertilizer requirements**

Depending on the fertility status of the soil various fertilizer recommendations have been made (Sandhu et al., 1968) and the practices being followed are as follows (kg/ha): 20 to 25 tonnes of FYM, 70 to 100 kg of nitrogen, 44 kg of phosphorus and 44 kg of potash. The entire dose of FYM, phosphatic and potassic fertilizers should be applied to the soil at the time of field preparation. Half a dose of the nitrogenous fertilizer should be applied at the time of field preparation and the remaining dose as a top dressing at the time of knob formation.

**Intercultural practices**

The steps to be followed would be more or less the same as that of carrot and radish.

**Harvesting**

The turnip roots are harvested when they are tender and attain the marketable size depending on the variety. The size ranges from 5 to 10 cm in diameter. They soon become fibrous and hard if they are allowed to grow beyond the marketable stage. They need to be handled gently as in case of radish. It produces edible roots from 185 to 210 q/ha depending on the variety used. The edible roots could be stored for two to three days at room conditions, whereas they can be stored for a long period in the cold storage.
Improved varieties

EUROPEAN TYPES

‘Purple Top White Globe’. It is a large-rooted and heavy-yielding variety. The roots are nearly round, smooth and bright purplish red in the upper part which extends above the surface, whereas the lower portion is creamy. The flesh is white, firm, crisp and mildly sweet flavoured. The top is dark green, erect with cut leaves.

‘Golden Ball’. The roots are perfectly globe-shaped, medium-sized and smooth. It has bright creamy yellow skin and pale amber-coloured flesh of fine texture and flavour. The top is small erect with cut leaves.

‘Snowball’. It is an early variety with medium-sized roots. The roots are round, smooth with pure white skin, whereas the flesh is white, finely grained, sweet and tender. It has a small erect top with medium yellow green and cut leaves.

‘Early Milan Red Top’. It is an extra early 45-day variety. The roots are deep flat with purplish red tops and white underneath. The flesh is pure white, well-grained, crisp and mildly pungent. The tops are very small with only 4 to 6 sessile leaves. It is a very high-yielding variety.

‘Pusa Chandrima’. It is a temperate type and early maturing variety developed at the IARI. The roots are like that of ‘Snowball’ variety.

All the above varieties do not seed in the plains.

ASIATIC TYPES

‘Pusa Kanchan’. It was developed at IARI through selection from a cross between ‘Asiatic Red’ and ‘Golden Ball’. Its roots look just like the ‘Local Red Round’ turnip from which it differs in having creamy-yellow flesh. The roots stay longer in the field without getting spongy. The leaf top is shorter than the local. It produces seed satisfactorily in the plains, though the seed is harvested a fortnight later than the ‘Local Red’. It has excellent flavour and taste. It can produce the seeds in the plains.

‘Pusa Sweti’. It is an Asiatic type suited for August to October sowing and has attractive white roots. It produces seed in the plains (Choudhury et al., 1976).
Seed production

The only Asiatic varieties are able to produce seeds in the plains. As in the case of radish and turnip they require proper root and shoot cut to produce high-quality seeds. This is not preferred in case of the European varieties grown in the hills (Singh et al., 1960). Nath and Sachan (1969) obtained the maximum seed yield of 273.4 and 245.4 kg/ha in the treatments with two-third top left and one-half root cut and one-third top left with one-half root cut. These treated stecklings are immediately transplanted in the well-prepared beds in such a way that the whole root is covered under the soil leaving the crown exposed. This is followed by irrigation. The optimum spacing given is 60 cm × 60 cm or 45 cm. Turnip seeds are prone to shattering and is therefore advisable to cut the whole crop when 60 to 70% of it turns yellowish-brown but not dry. After 4 to 5 days it is turned upside down and allowed to cure for another 4 to 5 days. It is then threshed with ordinary sticks and sifted with hand-sifters. After thoroughly drying the seed in the sun it is graded by means of sifters and specified sieves thus separating the bad seeds. Sandhu et al. (1968) recommended 94 kg of nitrogen, 55 kg of phosphorus and 55 kg of potash which gave an average yield of 13 q seed/ha. However, the average seed yield in European varieties was 570 to 780 kg/ha (Singh et al., 1960).

Since it is a cross-pollinated crop the two varieties must be isolated by 1,600 m apart to avoid any out-crossing and to produce foundation seed (Anonymous, 1971a).

Insect pests and diseases

Aphids and mustard saw-fly are the common insect pests of turnip which have already been discussed under radish.

The diseases which are common to radish also damage turnip. However, the disease phyllody causes severe damage to the turnip crop meant for seed production in the hills. It shows malformation of flowering shoots and the entire plant may show this character. Such plants do not bear any normal pod. The 'Golden Ball' variety in particular is susceptible. Further spread of the disease can be checked by pulling out and burying down the affected plants.
ROOT CROPS

BETTROOT

Origin

Garden beet is probably a native of Europe (Thompson and Kelly, 1957), but some believe that it might have originated in Mediterranean region or Asia.

Distribution and uses

It is grown in almost all the states of India but not as common as radish, turnip and carrot. It is usually cooked as turnip and is commonly used with radish or carrot in salads. Sometimes it is used in the preparation of pickles and chutneys. It is rich in protein, carbohydrates, calcium and phosphorus.

Botany

The garden beet (Beta vulgaris L.) is a member of the family Chenopodiaceae. It is a wind cross-pollinated crop having protandrous flowers. The garden beet is different from the sugar beet where emphasis is laid more on the sugar content of the root, whereas the garden beet is used for salad and cooked vegetable purposes. Like radish and turnip it behaves as a biennial, producing a thickened root and a rosette of leaves first year, and flowers and seeds second year. The flower stalk grows to a height of about 1.2 m. The calyx continues to grow after flowering, becomes corky and completely covers the seeds. This forms what is commonly called the beet seed or ‘glomerule’ or multi-germ seed is in reality a fruit which contains usually 2 to 6 seeds. The true seeds are small, kidney-shaped and brown. The seeds are viable for 2-6 years under normal storage conditions.

Since it is a temperate type of crop it is only grown for edible roots in the plains and for seeds in the hills where temperate climate prevails.

Plant breeding

Garden beet is a cross-pollinated crop. It produces seed in the temperate climate. Hence no attempt was made to breed varieties in the plains. Some of the imported varieties were found to be suitable for commercial production in the plains. Recently efforts were made to select suitable sugar beet varieties for extracting sugar rather than beet varieties for vegetables.
Some of the male sterile lines and monogerm seed varieties have also been reported for commercial utilization in the foreign countries (Stewart, 1961).

**Climatic and soil requirements**

It is primarily a cool-season crop but grows well in warm weather and hence can be grown during winter all over the plains. Beetroot can withstand a bit high temperature but not the severe freezing. The root and colour development is better at 18.3°-21.1°C. The plants will go to seeding before attaining marketable size at the temperature below 10°C. The requirements are more or less the same as that of turnip and radish and need to be grown in nearly all types of soils but it thrives best on a fairly deep friable loam, moist but well-drained soil. The high yields have been obtained from deep rich alluvial soil such as silt loam. Heavy soils are not satisfactory because they produce asymmetrical roots in large quantities. It is very sensitive to acidic soil but thrives very well in alkaline soils with pH as high as 9 to 10.

**Planting requirements**

The time of sowing of garden beet is slightly later than of turnip or carrot. As a matter of fact all these root crops are sown at the same time during cool weather. In some parts like Bangalore it is sown in June-July also. As other root crops it is also preferred to be sown on ridges with rows 30 to 45 cm apart with plants about 15 to 22 cm apart. It requires 12 to 14 kg of seeds to sow one hectare of area. The seed is sown 1.5 to 2.5 cm deep and irrigated immediately after sowing in light soils. At some places the seeds are soaked for about 12 hours before sowing to facilitate better germination in the field.

**Manurial and fertilizer requirements**

It has been reported that one tonne of beetroot removes 2 kg of nitrogen, 4.5 kg of phosphorus and 4.5 kg of potash. Usually 60 to 70 kg of nitrogen, 100 to 120 kg of phosphorus and 60 to 70 kg of potash per hectare are applied to the soil at the time of field preparation (Choudhury, 1967). In addition, 10 to 15 cart-load of FYM may be mixed up thoroughly in the soil at the time of field preparation. The crop is susceptible to boron deficiency causing internal breakdown of roots. Hence Borax or boric acid
may be applied in such boron-deficient area.

The method of fertilizer application is more or less the same as that of other root crops mentioned earlier.

**Intercultural operations**

These operations are more or less the same as that of radish and turnip. Care should be taken to see that the young seedlings after germination are provided proper spacing between the plants by thinning the excess seedlings. Clean, shallow cultivation is needed to control weeds.

**Harvesting**

The harvesting operation is the same as that of radish or turnip. The marketable maturity is judged depending on the size ranging from 3 to 5 cm diameter. Usually the top is removed for marketing the roots. About 24 tonnes of roots are harvested from an hectare of area.

It can be stored for 2 to 3 days under ordinary conditions and for longer period under cold storage conditions at 0°C.

**Improved varieties**

The following varieties were recommended by the IARI:

*Crimson Globe*. The roots are globular to flattened globe, medium red with little shoulders. The flesh is medium dark red with indistinct zones. The top is medium to tall with large, bright-green leaves having maroon shade. It is a heavy yielder.

*Detroit Dark Red*. The roots are perfectly round with deep-red skin, smooth, uniform and attractive with small collar and small tap-root. The flesh is dark red with light red zoning, tender and finely grained. The top is small with glossy dark green tinged with maroon leaves.

**Insect pests**

In most of the plains this crop has not been much affected by insect pests. However, some of the pests are discussed below.

*Semi-loopers (Plusia sp.)*. The green caterpillars damage the green foliage which may be controlled by the application of 50% wettable powder of DDT at the rate of 0.5 kg in 75 to 100 litres of water.

*Beet leaf miner (Pegomyia sp.)*. The larva is a white maggot
about 0.8 cm long which burrows in the tissue of the leaves between the upper layers and causes serious injury, and thereby checking the growth of the plant. Destruction of the fallen leaves and spraying the underside of the leaves with Parathion or TEPP is helpful in controlling the pest.

*Web worms (Loxostege sp. or Hymenia sp.).* They attack the beets by eating the leaves. The eggs are deposited on the leaves and the larvae attack the foliage either spinning small webs among the tender leaves or else feeding on the underside protected by a small web or with no protection. Spraying with DDT controls this insect.

*Aphids.* Same control measures as in radish.

**Diseases**

*Cercospora leaf-spot (Cercospora sp.).* It is readily identified by small brownish spots with reddish purple borders which give the leaf a speckled appearance. As the disease advances the spots enlarge and turn grey. The spots usually appear on older leaves and the fungus does not attack the root of the plant. In other countries, resistant varieties have been reported but the disease can easily be controlled by spraying Bordeaux mixture or by practising crop rotation.
11. BULB CROPS

ONION

Origin
ONION is probably a native of Asia perhaps from Palestine to India (Thompson and Kelly, 1957). It might have originated from North-West India, Afghanistan, the Soviet Republic of Tajik and Uzbek and Western Tien Sham (Choudhury, 1967). It is grown in India from very ancient times as mentioned in the ‘Charaka Samhita’, a famous early medicinal treatise of India.

Distribution and uses
The onion is grown all over India and is consumed by almost everybody either as raw in the salad form or as cooked along with the spices and vegetables. Primarily the ‘bulb’ is used as vegetable but in some places the green onions are also cooked. Sometimes the flowering shoot known as ‘scape’ is also used as vegetables. There are several local preparations of onion in different parts of the country. The production and demand of onion are relatively high. India is one of the exporters of onion. The important onion-producing states are Maharashtra, Tamil Nadu, Andhra Pradesh, Bihar and Assam. It is exported to Malaysia, Japan, Burma, Ceylon, Hong Kong, Iran and East African countries. It is rich in minerals like phosphorus and calcium and carbohydrates. It also contains protein and vitamin C. It has some useful medicinal properties also. White onions are generally preferred for dehydration. Multiplier onions are grown in Tamil Nadu especially to be used in sambar. Very small bulbs (2-3 cm diameter) with deep purple colour and high pungency are grown near Bangalore in Kolar district for export to Malaysia and Hong Kong.

Botany
Onion (Allium cepa L.) belongs to the family Alliaceae. It is a herbaceous annual for the edible bulb production, and biennial for the seed production. It has bisexual flowers and is highly cross-pollinated crop. The edible portion is a modified stem known as ‘bulb’, which develops underground. The
typical flavour of onion is owing to the presence of a volatile oil known as allyl propyl disulphide and the red colour is because of the pigment 'anthocyanin' and yellow colour because of 'quercetin'.

**Plant breeding**

Onion has been grown in India for a long time and some of its by-relatives are also available. Various useful strains are available in different growing areas of the country. At some places efforts were made to maintain and grow the useful indigenous strains. Some varieties were also introduced from other countries and few of them have proved to be promising and have been used for commercial production. Genetical studies on onion have been reported for better keeping quality and for suitability to dehydration (Singh and Joshi, 1975, 1978; Singh et al., 1976). Efforts have been made to study the genetics of various economic characters and to utilize the male sterile lines for the commercial hybrid seed production (Singh et al., 1979). But so far no hybrid onion has been made available commercially in our country. Male sterile lines have been extensively used in other countries for hybrid seed production (Jones and Clarke, 1947; Yen, 1959; Kazakova, 1965; Cohan and Weigle, 1966; Van der Meer and Van Bennekon, 1971). Recently IIHR, Bangalore, has taken a big stride in identifying useful cytoplasmic male sterility. The F₁ hybrids tested so far have given a very encouraging results (Singh et al., 1982).

**Climatic and soil requirements**

The onion is very sensitive to photoperiodic requirements. Generally it can be grown under a wide range of climatic conditions and is best suited as a tropical crop. It does best where the season is mild without the extremes of heat or cold or excessive rainfall. It requires a temperature of 12.5°C to 23.9°C before bulbing and for better bulb production it requires 15.6°C to 21.1°C for about 10 hours a day and about 70% relative humidity. In India mostly short-day onions are grown except in hills. The plant is quite hardy and in the young stage it can withstand freezing temperatures. It can be grown on various types of soils but it grows best in light soils which may be sandy loam or silt loam. Heavy or clay soils should
be avoided as they do not permit proper bulb development. The optimum pH range is between 5.8 and 6.5. In preparing the land for onion the field is ploughed to a fine tilth by giving four or five ploughings. The ploughings may be shallow because the roots do not penetrate deep in the soil.

**Planting requirements**

In the plains it is sown from September (in West Bengal) to mid-December (in Madhya Pradesh), but usually it is sown in October-November. Planting earlier than recommended may produce premature bolting in the bulb crop reducing the yield and quality of the bulb. Usually one crop is taken during winter but in Tamil Nadu, Maharashtra and Andhra Pradesh two crops are taken, but in areas near Bangalore in Karnataka almost three crops are taken, namely, monsoon crop (June to October), winter crop (October to January) and summer crop (January to June). *Kharif* crop has become quite popular in northern Indian plains also. In hills long-day varieties are grown during summer months.

The sowing is done in the nursery-bed and the seedlings get ready for transplanting in about 6 to 8 weeks. Patel *et al.* (1958) and Singh and Singh (1974) showed that the optimum age of seedlings for transplanting is 6 to 8 weeks, however, in case of *rabi* onion in Maharashtra, 8- to 10-week-old seedlings should be transplanted. It requires 8-10 kg seeds per hectare. Sometimes it is sown directly in the field and in that case the seed rate has to be doubled up. The healthy seedlings of 12-14 cm length are transplanted in the well-prepared fields in rows about 15-20 cm apart and plant-to-plant distance of 7 to 10 cm depending on the variety. In some areas growing onion by sets is popular especially for *kharif* season. It gives better plant stand and yield but takes longer duration of the crop.

**Manurial and fertilizer requirements**

The onion crop appears to be a heavy feeder of nitrogen and potash. The onion crop yielding 274 q/ha removes 81 kg of nitrogen, 40 kg of phosphorus and 35.5 kg of potash (Yawalkar *et al.*, 1962). Different recommendations have been made from time to time regarding the application of manures and fertilizers.
in different regions (Anonymous, 1954; Rao and Purewal, 1957; Yawalkar et al., 1962; Purewal and Dargan, 1962; Sandhu, 1964; Sachan and Nath, 1967; Singh and Singh, 1969; Pande et al., 1969). These are as follows. FYM 25 to 50 tonnes, nitrogen 50 to 110 kg, phosphorus 25 to 135 kg and potash 50 to 110 kg/ha. The FYM should be thoroughly mixed in the soil at the time of field preparation. Half of the nitrogen and full P$_2$O$_5$ and K$_2$O are applied at the time of transplanting. The remaining 50 % N is applied as top dressing 30-40 days after transplanting.

**Intercultural operations**

Onion is a shallow-rooted crop and deep tillage is likely to injure the roots and decrease the yield. To keep down the weeds very shallow cultural operations should be followed. Weedicides like Chloro-IPC at the rate of 5 to 6 kg/ha control the weeds (Choudhury, 1967). Stomp (2.5 litres) or Tenoran at 2.5 kg/ha in 800 litres of water three weeks after transplanting can also check broad-leaved weeds. Nitrofen (TOK E-25) @ 6 litres/ha along with one hand-weeding is useful in controlling weeds is kharif. Depending on the climatic and soil conditions the number of irrigations given will vary. The most important stage of irrigation is the bulb formation stage and the negligence at this stage results in cracking of the bulbs and low yield. Mandke and Arakeri (1956) obtained the highest yield of 395 q/ha when the crop was irrigated at 7 days interval with two-acre inches of water. Narang and Dasthane (1969) reported that the onion crop in all required 18 irrigations from transplanting to harvest.

**Harvesting**

Harvesting depends on the purpose for which it was grown and the maturity will depend on the variety being used. The green onions are harvested by pulling out by hand when there is little bulb formation and good, tender vegetative growth. The bulb crop is ready for harvest in three to five months after transplanting. When the bulb is ready for harvesting, about 70% of the top shoots get dry and fall over even when part of the leaves are green. At this time the foliage should be trampled, i.e. 1-2 weeks before harvesting. At the time of harvesting the bulbs, it is necessary that the soil is loose which may be
done by light irrigation some days back. The bulbs may be
dug out by shovel or *khurpi*. For marketing, the tops are
removed leaving bulb only. If the season is mild the bulb
after harvesting is left in the field for curing which makes it firm
and dry, whereas in hot weather the bulbs are removed to the
shade for curing. A good variety under favourable conditions
yields 250-400 q/ha marketable bulbs.

Under ordinary conditions it can be stored for several weeks,
whereas under cold storage conditions it can be kept for about
four months at 0° to 1.7°C and 80 to 85% relative humidity.
At 60% relative humidity it was possible to store even for 6 to
7 months. The work at CFTRI, Mysore, revealed that if
maleic hydrazide at 2,500 ppm is sprayed 15 days before
harvesting it checks the sprouting in the storage and the bulbs
remain healthy for about 8 months. Bulbs from *rahi* season
store better than those from *kharif* season.

**Improved varieties**

The following varieties are generally grown:

*Early Grano*. It is an American variety which produces
globular bulb of yellow colour and mild pungency and is most
suitable for salad purposes. Six average-sized bulbs weigh
about 1 kg. The bulb attains full size in about 95 days after
transplanting compared with the bulbs of the local red varieties
which take more than 100 days to attain a reasonable size.
The green onions can be uprooted in about 80 days after
transplanting. It has given an average yield of 475 q/ha. It does
not have a good keeping quality.

*Pusa Red*. It is a high-yielding selection from the local
red varieties at IARI. The bulb is of medium size, flattish in
shape and purplish red with 12 bulbs weighing about 1 kg. It is
less pungent than other red varieties. It is one of the most popular
varieties grown throughout the country for *rahi* season.

*Pusa Ratnar*. This variety was developed at IARI. The bulb
is large, round and deep-red in colour. It has a poor storage
quality. The yield is 500 q/ha (Anonymous, 1971b).

*Ninthad 53*. It is an improved strain of onion which has a
bright scarlet red colour, developed at Nasik/Pimpalgaon (M. S.).
It gives an yield of 197 q/ha (Kulkarni and Patil, 1966), and
is quite popular for *kharif* season cultivation.
Recently IIHR, Bangalore, has developed three very high-yielding, better-quality onion varieties through vigorous mass selection of Indian strains and released through Karnataka State Variety Release Committee. These varieties performed exceedingly well and all stood within the best three varieties during 1983, late *kharif* trial at Nasik.

‘Arka Kalyan’. Globe-shaped bulbs with deep-pink coloured outer scale, internal scales fleshy, succulent, concentric, high TSS (10.5 to 12%), suitable for *kharif* season having a yield of about 470 q/ha. It takes 140 days from seed to bulb.

‘Arka Niketan’. Globe-shaped bulb with thin neck and attractive pink-coloured outer scales. Inner scales are arranged in tight concentric rings. It has high pungency, high TSS (11-14%) and high dry-matter content. It has yield potential of about 420 q/ha. Suitable for both *kharif* as well as *rabi* season. It has an excellent keeping quality (Fig. 16).

‘Arka Pragati’. Globe-shaped, thin-necked and deep-pink bulb. It has fleshy scales with high pungency, TSS (10.5-12.5%). It has yield potential of about 450 q/ha. Suitable for both the seasons. It takes only 130 days from seed sowing to bulb harvesting (Fig. 17).

Besides, there are several other varieties developed at different research centres/stations/ agricultural universities which are being tested presently under the All-India Co-ordinated Project Trials. These include ‘VL-1’ and ‘VL-56’ F₁ hybrids (Almora), ‘N-2-4-1’ and ‘No.-780’ (Rahuri) and ‘Line 102’ (IARI) among red varieties and ‘Udaipur 102’ (Durgapur), ‘N-257-9-1’ (Rahuri) and ‘Pusa White Flat’ (IARI) among the white varieties. Several other varieties have been named after the names of the places where they are grown such as ‘Patna Red’, ‘Nasik Red’, ‘Patna White’, ‘Bellary Red’, and ‘Bombay Red’.

A good number of hybrid onions are being produced commercially in other countries, but they have not been grown here commercially because of relatively poor performance and of difficulties in producing hybrid seeds. Two F₁ hybrids developed at VPKAS (Almora) are being tested. IIHR, Bangalore, is developing hybrids using cytoplasmic male sterility which will be tested soon on large scale.
Fig. 16. A new high-yielding onion variety, ‘Arka Niketan’ with high TSS and excellent keeping quality.

**Seed production**

It is a biennial for the purpose of seed production. All the varieties produce seed freely in the plains.

*Seed-to-seed method.* The seeds are sown in the nursery-bed during September to November in the plains for bulb production which gets ready during summer. The selected bulbs for the seed purposes are usually planted in September-October in the plains which in turn produce seeds during summer next year. Thus seed-to-seed method takes about 1½ years from the sowing of the seed in nursery-bed to the actual harvesting of the seed from the new crop. In some regions like Bangalore with milder climate, the bulbs may be harvested from the monsoon crop (May to September) and may be planted immediately without storing, which in turn would produce the seed by next summer, i.e. within a year.

*Bulb-to-seed method.* The selected bulbs are planted in well-prepared field, the spacing of which would depend on the size of
the bulb. Arakeri and Patil (1956) reported the highest seed yield from large-sized bulbs with a spacing of about 30 cm between the two plants in a row. Solomon and Patil (1959) also supported this view indicating that the bulbs weighing 81 to 100 g produced the maximum seed yield of 760 kg/ha. Mital and Srivastava (1964) reported that the number of seed stalks influenced the seed yield and that the seed yield of 'Pusa Red' was 50% more than that of 'Early Grano'. Sandhu and Korla (1976), Dadlani and Bhagchandani (1978) and Singh et al. (1979) observed significant positive correlation between seed yield per plant and number of seed stalks per plant and also diameter of umbel by the latter.

Bulbs should be planted along one side of the ridge, 45 cm wide giving a space of about 30 cm from plant to plant. In flat beds the spacing of 45 cm × 30 cm may be given. Choudhury (1967) reported that 'Pusa Red' spaced 30 cm apart in the row produced more seeds than those plants which were spaced 45 cm
The after-care and irrigation for seed crop are the same as those for onion raised for bulbs. Within three months the flowering stalks are produced and in another 6 weeks the seed ripens for harvest. Since the ripening of the seed is not uniform it is desirable to cut the heads before the seeds are shed. The heads are dried in a well-ventilated shady place and then threshed. The seeds are then dried in the sun for a day or two before they are stored.

Kulkarni (1963) recommended an application of about 25 kg of superphosphate at the time of planting of bulbs and about 45 kg of ammonium sulphate per hectare as top dressing after about 1½ months. A light earthing up should also be given after two months of planting to facilitate better growth of bulbs.

For nucleus and foundation seed production the bulb-to-seed method should be followed because it provides opportunity for selection and rogueing. However, the seed-to-seed method may produce higher seed yield.

Since it is a cross-pollinated crop the two varieties should be isolated by about 1,000 ft in order to produce pure seeds (Anonymous, 1971a).

Diseases

Common diseases of onion are described below.

Purple blotch (Alternaria sp.). The disease is very serious and appears on the leaves, stem, bulbs and seed stalks as small, whitish, sunken lesions with purple centre that rapidly enlarges. The leaves or seed stalks fall over gradually. The infection of bulbs occurs late in the season when the plants are nearly mature. For control, dry infected leaves may be clipped and sprayed with Difolatan (0.3%) or Dithane Z-78 (0.2%) using a sticker. Bulbs should be harvested carefully to avoid injury. The resistant varieties reported from other countries are ‘Red Creole’ and ‘Yellow Globes’ (Jones and Mann, 1963). No source of resistance could be isolated so far in short-day onions.

Bottom-rot or basal-rot (Fusarium oxysporum Schlech). It is a serious disease of bulb crop. Field symptoms usually do not appear until the soil has become warm. At first, there is a progressive yellowing and dying back from the tips of the leaves. Plants that are infected when young may continue to
grow until harvest time. A semi-watery decay affecting the fresh scales starts from the base and progresses upward and with early infection decay may be almost complete by harvest time. The fungus is able to cause the disease at temperatures of 15° to 30°C and above. As a storage disease basal-rot is most active at or above room temperature. Use of healthy, disease-free planting material in disease-free plots is recommended. Sources of resistance have been identified which can be grown (Sokhi et al., 1974).

*Stemphylium blight (Stemphylium vesicarium).* This disease has become very serious like purple blotch and basal-rot. It causes burning tips of young seedlings and brown streaks on leaves. In seed crop it develops brown streaks and blight on flowering stalks due to which seed crop fails even to the extent of 100%. Dithane M-45 (0.25%) gives effective control (Anonymous, 1983).

*Bacterial soft-rot (Erwinia sp.)*. This disease can cause considerable loss in storage. The rot usually begins at the neck of the bulb. Later the bulb loses its firmness and it gives offensive smell through the neck when squeezed. It occurs most frequently in humid weather and specially in those varieties that have heavy green necks and do not cure well. Thorough and rapid drying at harvest time is essential and all the bulbs showing damage either mechanical or by insect pests may be discarded before storing.

*Onion smut (Urocystis cepulae F.).* Smut appears as elongated dark slightly thickened areas at the base of the seedling of leaf as it emerges from the soil. As new leaves are formed they become infected, swollen and bent downward. Raised black lesions appear near the base of the scales on plants starting to bulb. The fungus becomes inactive in soil temperature of 26.7°C and above. Most of the seedlings die within 3-5 days. The disease can be controlled by the application of 0.5 litre of 40% formaldehyde in 30 litres of water to be applied at the rate of 900 litres/ha (Jones and Mann, 1963). The disease may also be controlled by treating the seed with Thiram (3 g/kg of seed). *A. fistulosum* varieties are resistant to smut.

*Downy mildew (Peronospora sp.)*. The first indication is a furry violent growth covering outside the leaf or seed stalk. Later the
diseased portions become pale green, yellow and finally the leaves collapse. After a period of storage the infected bulbs become soft and shrivelled and the outer fleshy scale becomes partly or wholly amber in colour, wrinkled and watery. These bulbs must not be used for planting. However, the fungus in the bulbs can be destroyed by dry heating for four hours at 41°C (Yarwood, 1943). In the United States, the use of sprays or dust has generally not given satisfactory control on onion mildew (Jones and Mann, 1963). In Holland, the best results were obtained by spraying with 2% Zineb applied at the rate of 150 litres/ha with the addition of a commercial spreader (Doorn et al., 1954).

Black mould (*Aspergillus niger*). It is a serious disease during bulb storage. Rapid and thorough curing, good ventilation and temperature just above 0°C are important measures to control this disease.

**Insect pests**

The insect pests of the onion are as follows:

*Onion thrips* (*Thrips* sp.). It is a small, yellow sucking insect which causes white blotches on the leaves resulting in the browning of the tips. It is most injurious during dry weather and is seldom very destructive during rainy season. Dusts containing 3/4th of 1% Rotenone have proved satisfactory for use on bunching onions where the fresh green tops bring a marked preference (Thompson and Kelly, 1957). Whenever possible preventive measures should be used to restrict the thrip population. The cutting and burning of grass and weeds in waste places will destroy alternate hosts. DDT, Parathion, Toxophene, Heptachlor or Dieldrin should not be applied to onions which are to be eaten green. In this case Malathion should be used but it should not be applied within three days of harvest. The above chemicals may be used in case of the crop being grown for the bulbs. Jones *et al.* (1934) found some varieties like 'White Persian', 'Grano', 'Sweet Spanish', and 'Crystal Wax' to be fairly resistant than others.

*Onion maggot* (*Hylemia* sp.). The maggot feeds upon onion plants of all ages from young seedlings to mature bulbs. They channel onion bulbs thus permitting bulb-rotting organisms to
enter. Where maggots are a problem, infected bulbs from storage-houses and packing-shades should be dumped to an isolated place and covered with at least 30 cm of soil in early spring before the adult emerges out. These burial places should then be dusted several times at 10 days intervals with 10% DDT to kill the adults, if any. Perron et al. (1958) reported that the varieties of *Allium fistulosum* were more resistant than those of *A. cepa*.

Sandhu et al. (1975) reported that application of granular insecticides like phorate 1 kg, carbofuran 0.3 kg, carbaryl 0.5 kg, dimethoate 1 kg and Lindane 1 kg a.i./ha control the pest effectively when broadcasted before light irrigation.

**GARLIC**

**Origin**

It is said to be the native of Central Asia and Southern Europe, especially the Mediterranean region (Thompson and Kelly, 1957).

**Distribution and uses**

This crop is grown throughout the plains of India and is consumed by most of the people. It acts as a flavouring and seasoning agent in various vegetable and meat preparations. It is rich in protein, minerals like phosphorus, potash, calcium and magnesium and carbohydrates. It also contains fat, vitamin C and sulphur. It has important medicinal values for digestive disorders, eye sore and ear ache.

**Botany**

Garlic (*Allium sativum* L.) belongs to the family Alliaceae. It is a herbaceous annual for the bulb production and a biennial for the seed production. The edible underground stem is the composite bulb made up of numerous smaller bulbs known as ‘coves’. If very small cloves are planted or if growing conditions are poor, a single small solid clove usually called a ‘round’ is produced. ‘Rounds’ if planted under favourable conditions give rise to usual composite bulb. Garlic has flat, longitudinally folded leaf blades, diverging at widely spaced intervals from its false ‘stem’. The ‘scape’ of garlic is smooth, round and solid for its entire length unlike onion which is
hollow. Many cloves of garlic do not produce flower stalk or the inflorescence may be partially or not at all exerted, its bulbils forming a swelling somewhere within the false stem, a few cm above the bulb.

Garlic contains a colourless, odourless, water-soluble amino acid (Alliin) in uninjured garlic. On injury of the cell, enzyme allinase changes it to Allicin. Allicin is the antibacterial substance of garlic and has typical odour of fresh garlic. It contains allyl radicle of disulphide.

**Plant breeding**

It is a cross-pollinated crop usually propagated by cloves. A good number of local strains are available in different regions of India. They vary in the number of cloves, which range from 16 to 50, and the size of the bulbs. There is very little variation in shape. Most of the strains have white colour, some have reddish tinge also. Though its production and consumption are high, no special effort has been made to improve upon these strains. Breeding is in progress by Associated Agricultural Development Foundation and other research institutions.

**Climatic and soil requirements**

These requirements are more or less the same as that of onion but it prefers a relatively moderate temperature in summer and winter. It is usually taken as a cool-season crop like onion. Garlic plants respond to day length and form bulbs under long days, regardless of the size of the plant.

**Planting requirements**

The garlic is propagated by cloves which are carefully detached from the composite bulbs at the time of planting. It is planted from August in Karnataka and Andhra Pradesh to November in the northern plains. In some localities the planting may be done twice (May and October) if the climatic conditions are favourable.

The cloves are dibbled in an upright position at a spacing of 15 cm from row to row and 7-8 cm from plant to plant. The field is divided into small plots as in onion to facilitate irrigation and other cultural operations. About 350 to 500 kg of cloves are required to plant one hectare of area. Hari Om and Srivastava (1977) observed that aerial bulbils can also be used as a planting
material though maximum net return was obtained from cloves planted at closer spacing (10 cm x 20 cm).

**Manurial and fertilizer requirements**

Various recommendations made are as follows: FYM 50 tonnes, nitrogen 110 to 220 kg, phosphorus 38 to 54 kg and potassium 50 to 120 kg/ha (Rao and Purewal, 1957; Purewal and Dargan, 1962; Joshi, 1961). The complete dose of FYM may be mixed up thoroughly in the soil at the time of field preparation, whereas the complete dose of phosphorus and potash and one-half dose of nitrogen may be applied before planting. Another half dose of nitrogen may be applied after one month of planting as a top dressing.

**Intercultural operations**

These are more or less the same as those for onion.

**Harvesting**

The crop may be harvested when the top turns yellowish or brownish and shows signs of drying up. The bulbs are cured for 3 to 4 days in shady places. Like onion, the tops are removed and bulbs kept for storing under ordinary room temperature for months together. Sometimes green garlic is also harvested like green onion. It produces 4 to 10 tonnes/ha of cured bulbs depending on the variety and the season.

Under ordinary conditions it can be stored for several weeks but under cold storage conditions at 0° to 2.2°C and 60% relative humidity it can be stored for many months.

**Improved varieties**

There are no improved varieties but 'Fawri' and 'Rajalle Gaddi', grown in Karnataka, are high yielders with good keeping quality.

**Diseases and insect pests**

They are the same as those of onion.

**Seed production**

Garlic is normally propagated by cloves. The well-grown, uniform-sized composite bulbs of a particular variety are selected and the cloves are separated. Healthy and uniform cloves are selected and used for planting. The planting followed for
the multiplication of bulbs is the same as that for the production of garlic bulbs for consumption. However, it has been recommended that the cloves may be sown 7.5 to 12.5 cm in rows which are spaced 40 cm apart.
12. LEAFY CROPS

SPINACH BEET

Origin
SPINACH beet or palak is probably the native of Indo-Chinese region. It was known in China as early as 647 A.D.

Distribution and uses
It is widely grown in the plains of northern states and is less common in the southern states. Primarily used as a cooked vegetable, it is highly rich in vitamin A and C and also contains good amount of protein, calcium and iron. Palak has been regarded as a rich yet cheap source of vitamins (Nath and Subramanyam, 1972). It has some medicinal values also.

Botany
The spinach beet (Beta vulgaris var. bengalensis Roxb.) belongs to the family Chenopodiaceae and is a close relative of beet root. The leaf of spinach beet is edible, whereas the root of beet root is used as vegetable. The spinach beet is different from spinach (Spinacia oleracea L.), the former is common palak with succulent leaves having entire margin, whereas the spinach is Vilayati palak with lobed leaf margin. The former is popular in northern states whereas the latter in southern states. The flowers are bisexual. The male and female parts are present in the same flower in spinach beet, whereas in the spinach the male and female flowers are usually borne separately. Studies on floral biology and pollen morphology and physiology in spinach beet have been reported (Purohit and Nath, 1969; Nath and Purohit, 1969).

It is a herbaceous annual for the edible leaf production while it is biennial for the seed production. It produces seed freely in the tropical plains. The seed is monogerm in spinach beet.

Plant breeding
It is a wind cross-pollinated crop. Efforts were made at the IARI to evolve high-yielding varieties, which resulted in the new varieties like 'All Green' (Singh and Joshi, 1960) and 'Pusa Jyoti' (Anonymous, 1971b). At the University of Udaipur a
high-yielding variety 'Jobner Green' suited to alkaline soil conditions was evolved (Nath, 1967, 1969a).

**Climatic and soil requirements**

It is a winter-season crop in the plains of India. It can withstand frost better than other vegetables. It can also tolerate warm weather but relatively hot weather will result in quick bolting making the plant unfit for producing edible leaves.

It can be grown in a wide range of well-drained fertile soils but it produces a good crop in lighter soils. It does very well in sandy-loam soil. Better results as regards quality and yield were obtained in the soils with pH 7, but the variety 'Jobner Green' gave excellent performance in soil with pH 7 to 10.5 (Nath, 1969a). The soil for this crop can best be prepared by 3 or 4 ploughings followed by levelling.

**Planting requirements**

The main sowing season in the plains is from the last week of August to second week of November. In places with milder climate it may grow throughout the year. It is sown from March to May in hilly tracts.

Sowing is usually done by broadcasting the seeds in the levelled plot. Sowing is also done in rows about 22 cm apart and later on thinning to 5-8 cm within the row. In both the cases seeds should be placed at a depth of about 4 cm. It requires about 25 to 30 kg/ha of seeds. The seed germinates in about 10 days if proper soil moisture and temperature are available.

**Manurial and fertilizer requirements**

The practices followed (Singh and Joshi, 1960; Nath, 1967; Yawalkar, 1969) are: 20 to 24 cartload of FYM, 50 to 190 kg of nitrogen, 88 kg of phosphorus and 88 kg of potash per hectare.

The FYM should be mixed thoroughly in the soil at the time of field preparation. The complete dose of phosphorus, potash and one-third dose of nitrogenous fertilizer are given just before sowing. The other two split doses of equal amount of nitrogen are applied after first and second cuttings.

Use of 1.5% foliar application of urea spray 15 days after germination and after each cutting up to third cutting gave the
highest yield of 438.80 q/ha in ‘Jobner Green’ (Khandelwal and Nath, 1971).

**Intercultural operations**

In light soils it is desirable to give irrigation soon after the sowing is complete, but in heavier soils the sowing should be done when enough soil moisture is available. Subsequent irrigations during winter should be given at 10 to 12 days interval depending on the soil moisture availability. Regular hoeing and weeding should be done.

**Harvesting**

It becomes ready for first cutting in about 3-4 weeks after sowing. Only well-grown, green, succulent and tender leaves should be trimmed at the height of 5 to 7.5 cm above the ground. Subsequent cuttings can be done at the interval of 15 to 18 days depending on the variety. Nath (1967) reported that ‘Jobner Green’ was ready for subsequent cuttings in 13 to 15 days, whereas ‘All Green’ took 15 to 18 days. If sown in the first week of September near Jaipur, ‘All Green’ allowed 6 to 7 cuttings whereas ‘Jobner Green’ produced 8 to 10 good cuttings.

The average yield of the green edible material is about 98 q/ha. It is not possible to store the fresh green leaves for more than few hours under ordinary conditions. It can be well stored at 0°C and 90 to 95% humidity for about 10 to 14 days.

**Improved varieties**

The improved varieties of spinach beet are as follows:

‘**All Green**’. This variety was released by the IARI (Singh and Joshi, 1960). It produces uniform green, tender leaves and yields about 123.5 q/ha of green material. As a winter crop it gives about 6 to 7 cuttings at 15 to 18 days interval.

‘**Jobner Green**’. This variety was released by the University of Udaipur (Nath, 1967). It is a high-yielding variety with thick large size, uniform green, succulent edible leaves. The average size of the edible leaves is about three times that of ‘All Green’ and is more succulent than the latter. It has recorded the highest yield of 197.6 q/ha of green leaf material even in an unusual soil pH condition of 7 to 10.5.

The seeds of the above two varieties are being multiplied by the National Seeds Corporation.
'Pusa Jyoti'. It is a selection from 'All Green' made at the IARI (Anonymous, 1971b). It has succulent, thick and tender leaves with higher content of potash, calcium, sodium, iron and ascorbic acid than the variety 'All Green'. 'Pusa Jyoti' has good regeneration capacity, late bolting habit and gives 6 to 8 cuttings.

**Seed production**

It is a wind cross-pollinated crop and the two varieties should be kept about 1,600 m apart to produce pure seeds (Anonymous, 1971a). The spinach beet does not cross with the spinach either way. Usually the plants are left to produce stalks after two to three cuttings. The variety 'All Green' produces seeds in about 80 days. The plants are cut after the seeds ripen and are left to dry. The seeds do not shed from the fruits and hence can be left on plant to become fully mature. The fruit balls, each of which contains 2 to 3 seeds, are collected after threshing, winnowing and cleaning. The variety 'All Green' produces about 980 kg/ha of seeds.

**SPINACH**

**Origin**

Spinach is probably originated in South-West Asia (Choudhury, 1967) and was used in Iran over 2,000 years ago. It was brought to Spain in 1,100 A.D. and taken to America by the early colonists.

**Distribution and uses**

The edible part of spinach is a compact rosette of leaves. Spinach or *Vilayati palak* is grown all over the plains. However, it is popular in the southern states also. Like spinach beet, it is liked by the common people as a cooked vegetable. It is a very cheap source of vitamin A, B and C. It also contains protein, carbohydrate and iron.

**Botany**

Spinach, *Spinacia oleracea* L. belongs to the family Chenopodiaceae and is a herbaceous plant which produces edible leaves as an annual and seed as a biennial crop in the plains. Secondary lateral branches arise from the leaf axils of both the central and the lateral stems. The flower clusters are borne
axially on both the larger stems and on the smaller branches, usually with dioecious flowers. Rosa (1925) described four types of plants with reference to sex expression which are: (1) extreme males, (2) vegetative males, (3) monoecious, and (4) females. The monoecious plant may be predominantly staminate, pistillate or pure pistillate, early but with some staminate flowers or almost equally staminate or pistillate throughout the season. The seed is multi-germ in spinach.

**Plant breeding**

No significant effort has been made to improve upon the old local strains available in various parts of the country. Some of the varieties introduced from the western countries are being grown in certain parts for commercial production. Bhagchandani et al. (1972) reported that additive gene effect was observed for leaf size and partial dominance for yield. The inheritance of leaf size depended on a minor gene group. Nine gene groups were involved in the inheritance of yield.

**Climatic and soil requirements**

It is strictly a winter-season crop and withstands freezing weather better than other crops. It tends to produce flower at the cost of leaves in long days, and warmer conditions further hasten the flowering response. Thus planting times are critical for this crop. The climatic and soil requirements are more or less the same as that of the spinach seed. The soil should be fertile and well drained. The optimum soil pH is 6 to 7.

**Planting requirements**

The requirements are more or less the same as that of the spinach beet. Usually the sowing is done during September to October all over the plains to get winter-season crop. The method of sowing is the same as that discussed in the case of spinach beet. It requires about 37 to 45 kg/ha of seeds. The seed rate is relatively high because about 50% of the plants come out to be of male type with poor growth and no seed which may be removed.

**Manurial and fertilizer requirements**

The manurial and fertilizer requirements and intercultural operations are more or less the same as that of the spinach beet.
Harvesting

It is ready for first trimming in about four weeks after sowing, and the subsequent trimmings may be done at 15 days interval. One crop in the season gives approximately 3 to 4 cuttings with the total yield of about 50 to 60 q/ha when compared with spinach beet where 8 to 10 cuttings are possible. In hills where growing season is short the entire plant is cut-off at the ground level about 5-6 weeks after seeding when plants have 5-6 leaves. Under ordinary conditions it is not possible to store it for more than few hours but under the cold storage conditions it can be stored for 10 to 14 days at 0°C and 90 to 95% relative humidity.

Improved varieties

Depending on the seed surface the varieties have been divided into two: (i) prickly seeded, and (ii) round seeded. Round-seeded variety does well in the plains, whereas the prickly seeded does better in the hills.

The following varieties were recommended by the IARI:

‘Virginia Savoy’. It is smooth-seeded variety which is easy in threshing and grading. The leaves are blistered, crumpled, thick and dark green with round tips. The plants are upright and vigorous.

‘Early Smooth Leaf’. It is also a smooth-seeded variety. The leaves are thin, yellowish green, smooth with a pointed apex.

Seed production

The method of seed production is similar to the spinach beet but care has to be taken to remove the male plants which do not produce seed. However, some of the male plants should be left to pollinate the females. The isolation distance maintained is about 1,600 m in production of the foundation seed (Anonymous, 1971a). It produces seeds in about 150 days. Ripening of seed is fairly uniform and there is less danger of shedding seed in the field. The entire seed-bearing plant should be collected, dried and threshed. The average yield of spinach seed is about 740 kg/ha in the plains. However, the late varieties have produced about 100 kg in the hills (Singh et al., 1962). The seeds of both spinach and spinach beet remain viable for 3 to 4 years under proper storage conditions.
AMARANTH

Origin

Some species of green Amaranths, especially *Amaranthus gangeticus*, *A. mangostanus*, *A. paniculatus*, *A. angustifolius* are supposed to have originated in India or Indo-Chinese region. Other species have originated in various other centres like North America, Central America, Mexico, South America and Mediterranean region (Zeven and Zhukovsky, 1975).

Distribution and uses

It is a common leafy vegetable grown in most of the parts in India. The fresh tender leaves and stem give delicious preparation on cooking as in the case of other fresh leafy vegetables. Cooked similar to spinach or spinach beet, it is a cheap vegetable for the common people and is highly rich in vitamin A and C. Besides having the highest protein contents among leafy vegetables, it also contains carbohydrates, calcium and iron. The vitamin A content in different species varies from 23,000 to 54,110 I.U. (Martin and Telek, 1979).

Botany

*Amaranthus* spp. belong to family Amaranthaceae. There are several species of *Amaranthus* used for leaves, grains or for both. There is a taxonomic confusion because species are quickly adapted in any environment, differences among various species are small, many specific and common names have been used throughout the world, almost interchangeably and also due to quick intergradation of a species in the region itself where it thrives when cultivated and appears adapted. In spite of this confusion, some species are sufficiently recognized to merit universal acceptance. The best of the species for grains is *A. hypochondriacus* L. and for edible leaves *A. gangeticus* L., *A. cruentus* L. and *A. dubius* Mart ex Thell. *A. hypochondriacus* was used as a grain in India and Sri Lanka in the 18th century. It became prevalent in the foot-hills of Himalayas during the 19th century, where it became a staple food. It is important now in Nepal, China, Manchuria, Uganda, etc. In India, *A. hypochondriacus* and *A. caudatus* (grains) and *A. gangeticus* (leaves) are of major importance. *A. mangostanus* (Syn. *A. tricolor* var. *mangostanus*), *A. lividus* and *A. dubius* (a recognized tetraploid)
are grown on a limited scale in Orissa and other states. A
variety named ‘Chhoti Chaulai’ had been released by IARI,
which is claimed to be of *A. blitum* but does not appear to be
amongst the recognized species.

**Plant breeding**

It is a wind cross-pollinated crop. Though it is rich in nutri-
tive value, it has received relatively less attention as regards the
work on its maintenance and improvement is concerned. So far
collections have been superfluous and no attempt has been made
to determine the range of variation with each species. Most of
the species are diploids and rapid progress can be expected from
traditional techniques. The IARI has recommended the varieties,
‘Badi Chaulai’ and ‘Chhoti Chaulai’ (Singh and Joshi, 1960).
Certain varieties, both grain type as well as leaf type, have been
developed at Coimbatore. Hauptle (1977) initiated active
investigation on the potential of grain amaranthus. While yield,
quality and flavour are generally acknowledged for suitability
in existing varieties, there is a great need to develop varieties
with low oxalic acid content and with insect and disease
resistance.

**Climatic and soil requirements**

Amaranth is a warm-season crop adapted to the conditions of
hot, humid tropics, but are also suitable for temperate climate
during summer. It belongs to a group of plants called C 4
plants, species with efficient photosynthetic abilities that respond
best to full sunlight. It has rapid, short growth cycles, high
net assimilation rates, a low CO₂ compensation point and a low
transpiration coefficient (Martin and Telek, 1979).

It grows in every type of soil but the best crop is harvested
from fertile loamy soils. The proper drainage system in the field
is necessary, because this crop is susceptible to water-logging.
The best growing soil pH range is between 5.5 and 7.5, but some
of the strains are successfully grown in soils with the pH up to
10. The soil should be brought to a fine tilth by ploughing 3 or
4 times and levelling.

**Planting requirements**

In the plains of northern India it is normally sown in
February-March to take a summer crop. The rainy-season crop
is sown in June-July or at the break of monsoon. In southern states where the climate is favourable it is sown throughout the year. The seeds are very small and are sown shallow at the depth of 1 cm in rows about 20 cm to 30 cm apart in flat beds if repeated cuttings are to be made. The seeds are usually broadcasted in flat bed. Sometimes seeds are germinated in a highly fertile seed bed and then transplanted after 3-4 weeks of sowing. If plants are to be uprooted 10 cm spacing is sufficient. The seed requirement will be 2-3 kg per hectare.

**Manurial and fertilizer requirements**

It grows on residual fertility of the previous crop taken in the field. However, the basal application of 25 to 30 tonnes of FYM per hectare at the time of field preparation ensures a good crop. Some of the fertilizer recommendations are as follows: 27 kg of nitrogen, 27 kg of phosphorus and 54 kg of potash per hectare. Three top dressings of ammonium sulphate can be done, first one month after the sowing and the subsequent dressings soon after the first and second cuttings. Amaranth is highly adapted and quite efficient at extracting necessary minerals even from a poor soil. Nevertheless, it has a high potassium requirement.

**Intercultural operations**

Moisture in soil is very necessary at the time of sowing in heavy soils, and in light soils a light irrigation should be given soon after sowing if soil moisture is insufficient. During summer it is necessary to irrigate the crop at 3 to 5 days interval. Unlike spinach beet this crop is erect in growth allowing enough of weed growth which may be removed from time to time. Hoeing is easy in the plots with row sowing.

**Harvesting**

Unlike *palak* the young seedlings of amaranths are pulled out with roots but it is advantageous to make periodical cuttings of this crop. The first cutting is made 3 to 4 weeks after sowing or transplanting and subsequent cuttings are made at weekly intervals in ‘Chhoti Chaulai’ and at 10-days interval in ‘Badi Chaulai’. The average yield of green leaves is about 74 to 94 q/ha.

It does not stand storage for more than a few hours under
ordinary conditions.

Improved varieties

AT IARI

‘Badi Chaulai’ (A. tricolor = A. tricolor var. mangostanus). It has thick tender stem and large leaves. It is best suited for summer season. When sown early in summer it continues to give cuttings up to the end of the rainy season.

‘Chhoti Chaulai’ (A. blitum). It is a quick-growing variety with slight dwarf erect plants. The stem is thinner and leaves are smaller than in the case of ‘Badi Chaulai’. It is best suited as an early summer crop and if sown as a rainy-season crop it flowers early unlike ‘Badi Chaulai’ which gives good cuttings even in that season.

AT COIMBATORE

‘Co-I’. It is dark green in colour which grows vigorously and produces very high yield. It is the variety released by the TNAU, Coimbatore. Besides, ‘Co-I’, TNAU has released several other varieties of amaranths suitable for grains or dual purpose.

‘Lal Sag’. It is grown quite popularly in many states of the country. It belongs perhaps to A. mangostanus and is a high-yielding Indian amaranth variety. It produces seed early but has small flowers. Many other locally named varieties are grown in different regions.

Seed production

Since it is a cross-pollinated crop, an isolation distance of about 400 m has been recommended between two varieties (Anonymous, 1971a). It is a quick-growing crop and forms seed in about 10 to 12 weeks. This is advantageous because after taking a number of leaf cuttings, only few last cuttings can be omitted to produce seeds well in June. The seed yield is about 200 kg/ha and is slightly higher in ‘Badi Chaulai’.

FENUGREEK

Origin

Fenugreek or methi is native of Eastern Europe and Ethiopia. Its wild forms are found growing wild in North-Western India
Distribution and uses

It is grown throughout the country for its green leaves, young pods and dry seeds. But it does well in northern India. The seeds are used as condiments in several vegetables, as well as in pickle preparations. These are used in indigenous medicines also like diuretic, tonic carminative, astringent and aphrodisiac. Its leaves are used in making poultice for external and internal swellings. Dry leaves are used for flavouring and seasoning also. Leaves are rich in protein, iron and vitamin A.

Botany

Fenugreek or methi (Trigonella foenum-graecum L.) belongs to the family Papilionaceae. Champa or kasuri methi is T. cori- nculata. Both the types differ in several ways. Common methi is quick-growing, produces upright shoots, giving 2-3 cuttings; pinkish-white bigger flowers borne in axils of leaves; 6-7 cm long straight pods; leaf simple palmate; seed and flower size bigger than those of kasuri type. In contrast, kasuri methi is slow growing, remaining in a rosette condition during most of its vegetative growth period, gives 5-6 cuttings; flowers bright orange-yellow borne on long stalks; pods 2-3 cm sickle shaped; leaf bilobed; flowers and seeds smaller (scented).

Plant breeding

Fenugreek is a self-pollinated crop. It is a herbaceous annual which produces seed freely. Very little efforts have been made in collecting, maintaining or utilization of different genotypes for the improvement of this crop.

Climatic and soil requirements

It is a cool-season crop and tolerates frost and freezing weather. It can be grown on various types of soils but well-drained loamy soil is best suited. The soil should be brought to fine tilth by ploughing three or four times.

Planting requirements

Seeds are sown from September to the middle of November for seed purpose and for leaves it can be sown up to March in the plains of northern India. In the hills it is sown in March-April and October. Kasuri is sown in December. The seed
rate is 40-45 kg of common *methi* and 30-35 kg of *kasuri* per hectare. Seeds are generally broadcasted uniformly. The surface is raked thereafter to cover the seeds well. The germination is fast and complete within 6-10 days depending upon temperature and the variety. Sufficient soil moisture should be there to get uniform germination.

**Manurial and fertilizer requirements**

The crop being a legume does not require heavy quantity of nutrients. However, the soil should be fertile enough for getting succulent foliage and early growth. FYM (15 tonnes), 40 kg N and 20 kg P$_2$O$_5$ are applied at the time of ploughing and before sowing. Two to three top dressings of nitrogen, 20 kg each time, should be done preferably after alternate cuttings in *kasuri methi*. In common *methi* one top dressing can be done if it is kept for cuttings.

**Intercultural operations**

To obtain quick and good growth frequent irrigations at weekly intervals are necessary depending upon weather conditions. One or two weedings can be done if necessary. Occasional weeds are suppressed by this crop. Broad-leaved weeds should be pulled out at the time of first cutting.

**Harvesting**

The first cutting is made by sickle after 25-30 days of sowing when the plants are 15-20 cm high leaving 2-3 cm stabs for the production of new stalks. The old leaves become bitter and unfit for consumption. The young plants are nipped at the ground level in common *methi* after 20 days of sowing. After another 15-20 days the plants are often uprooted, bunched and marketed. *Kasuri methi* can give 5-6 cuttings at an interval of 15-20 days. The produce is kept in shade and moist conditions. It does not stand storage for more than a few hours. The common *methi* yields about 70-80 quintals and *kasuri* 90-100 quintals of leaves per hectare.

**Improved varieties**

The improved varieties of fenugreek are given below:

‘*Pusa Early Bunching*’ (*T. foenum-graecum*). Developed at IARI, quick growing, produce upright shoots, good yielder,
suitable for 2-3 cuttings.

‘Kasuri’ (*T. corniculata*). A late-flowering variety, rosette type leaves, gives 5-6 cuttings, heavy yielder, leaves with special fragrance. Developed at IARI.

‘Methi No. 47’. Released by Maharashtra State. Leaves are broad, succulent and rich in vitamin C.

**Seed production**

*Methi* is a self-pollinated crop and both the types produce seeds freely in the plains of India. Seed yield is higher if no cuttings are made and left entirely for seed production. ‘Pusa Early Bunching’ may yield 12-15 q/ha and ‘Kasuri’ 6-7 q/ha seeds by this method. Seed yield will be reduced if certain cuttings are permitted before leaving the crop for seed production. The seed crop matures in 155-165 days respectively.

Stray plants of wild *methi, senji* or sweet clover should be rogued out from the seed-production plots before flowering and harvesting.

**Diseases**

Some of the common diseases of leafy vegetables are as follows.

*Leaf-spot disease*. There are three different leaf-spot diseases caused by different fungi on spinach beet, spinach, amaranths and fenugreek.

(a) **Leaf-spot**. This is caused by the fungus *Cercospora beticola* which attacks spinach beet only. Fenugreek is affected by *C. traversinia*, and amaranths is affected by another *Cercospora* sp. The disease is characterized by the presence of numerous small, brown, circular spots on the leaves. In the beginning the spots are small, roundish with concentric rings but later on these spots increase in size and sometimes they coalesce. It may be controlled by spraying Bordeaux mixture (5 : 5 : 50) or 0.3% Blitox three times at an interval of 15 days.

(b) **Leaf-spot**. It is caused by the fungus *Cladosporium variable* which is restricted to prickly seeded varieties of spinach only. The disease is characterized by the appearance of numerous dirty-white, water-soaked, sharply-defined circular spots which usually appear on the upper half of the leaves. It can be controlled by the application of Bordeaux mixture (5 : 5 : 50) or
Cupravit.

(c) LEAF-SPOT. This is caused by the fungus *Phyllosticta spinacia* which is specific to spinach beet only. In early stage the infection appears as light yellow specks which later increases into spots and coalesce resulting in shrivelling and drying up of the leaves. The effective control measure is the spraying of fungicides like Shell copper, Blitox or Cupramar (0.3%) at 15 to 20 days interval.

White rust. *Albugo occidentalis* causes white rust in spinach, and *A. blightii* is the causal organism in amaranths. The white rust is characterized by the white, blister-like, circular or irregular pustules on the lower surface of the leaf and opposite to each postule on the upper surface a yellow patch develops. Heavy infection causes leaves to die and turn brown, giving the field a frosted or blighted look. The disease can be controlled by keeping the field and surrounding areas clean by crop rotation or by spraying Bordeaux mixture (5 : 5 : 50).

Downy mildew (*Peronospora* sp.). Spinach is affected by *P. affusa* while fenugreek is affected by *P. trigonella*. The first symptoms are noted as large yellow spots on the leaf, the underside of the blotches is covered with a fuzzy growth which is white in the beginning but turns bluish purple at the later stages. If the infection occurs at the seedling stage, the leaves may be stunted, crinkled and pale. The disease may be controlled by spraying Dithane Z-78 (0.3%) thrice at an interval of 15 days.

Insect pests

No serious pest on leafy vegetables has been reported. However, aphids and caterpillars sometimes do considerable damage. Insect may be a limiting factor on the use of leafy vegetables. Leaves with holes may be nutritious, but they are not attractive, and are seldom salable. Suitable insecticides like Malathion, Metasystox or Sevin, or resistant varieties should be used.
13. SALAD CROP

LETTUCE

Origin

LETTUCE is probably the native of Europe and Asia-Minor and has been in cultivation for over 2,500 years. It was grown by Persian Kings in 500 B.C.

Distribution and uses

The crop is grown in almost all the states of India. It is popular salad crop mostly in cities. It is rich in vitamin A and minerals like calcium, phosphorus, sodium, sulphur, magnesium and potassium. It also contains protein, carbohydrates and vitamin C.

Botany

Lettuce (Lactuca sativa L.) belongs to the family Compositae. It is a herbaceous annual which produces seed freely in the plains. It is an annual for leaf or head and is a biennial for seed production. It is a self-pollinated crop having cleistogamous flowers. What most people call the seed is really a fruit an ‘achene’ carrying a pappus of fine silky hair.

There are four types of lettuce which are recognized as subspecies of L. sativa.

Head type (var. capitata). It is of two types:

(a) Butterhead—Butterhead or Bibb lettuce is a head type in which the leaves are loosely folded. The inner leaves are cream or yellow, and outer leaves green, e.g. ‘White Boston’, ‘Bibb’, etc.

(b) Crisphead—Crisphead or Iceburg is quite common in the USA and Europe. Leaves are thin, crisp and frequently have curled and serrate edges. Heads are hard and durable, e.g. ‘Great Lakes’, ‘Crisphead’, ‘Imperial’, etc.

Leaf type (var. crispa). It is also called loose-leaf or loose-head lettuce. Plants do not form a head and leaves may be serrated, deeply lobed, or crinkled. Leaf colour varies from light green to red, e.g. ‘Chinese Yellow’, ‘Grand Rapids’, ‘Slobolt’ (resistant to heat).
**Cos type** (var. longifolia). Cos or Romaine lettuce is an upright plant which grows about 25 cm high. The outer leaves are smooth and green, the inner leaves are whitish green. The leaves are more crisp than other types, e.g. ‘Dark Green’.

**Stem type** (var. asparagina). Stem or asparagus can be used like celery and lettuce. The young leaves can be used like lettuce. The plant produces an edible seed stalk which is eaten raw like celery or cooked in Chinese dishes, e.g. Celtuce.

**Plant breeding**

Since several varieties introduced from outside performed well and the demand is not too great, no serious efforts have been made on studying variation, gene action for further improvement of the crop. There are certain known heat-resistant varieties available which need to be introduced and evaluated in India. Such varieties are ‘Summerlong Buttercrunch’ and ‘Bibb’ (Butterhead) and ‘Green Ice’ (Leaf). Some small varieties like ‘Tom Thumb’ (Butterhead), ‘Sweet Midget’ (Cos) and ‘Ruby’ (Leaf) should also be tried for growing in containers.

**Climatic and soil requirements**

It is a cool-season crop and is usually grown at the time when cabbage and cauliflower are grown. It thrives best in a relatively cool-growing season with a monthly mean temperature of 12.8° to 15.6°C. High temperature promotes seed stalk and causes a bitter taste in the leaves and accelerates the development of ‘tip burn’. The seeds become dormant and do not germinate properly when the soil temperature is above 22°-30°C.

It does best in sandy loam and silt loam, well supplied with organic matter. Where earliness is important, the sandy loam is preferred but where earliness is not important silt loam is preferred. The optimum soil pH is 5.8 to 6.6.

**Planting requirements**

Since it is a cool-season crop it is sown during September-November in the plains. It is sown in nursery-beds where the seedlings get ready for transplanting in about a month. About 500 g of seeds are required for a hectare. The seedlings are transplanted 4-6 weeks after sowing in well-prepared plots at the distance of 20-25 cm in the rows and the rows are kept 30 to 45
cm apart. The sowing is done in small flat beds but sometimes it is transplanted on ridges depending on the soil and the irrigation facilities. Sometimes it is sown directly in the fine bed in rows at 15-20 cm apart. The plants are thinned to 3 cm when crowded. The sowing/transplanting of lettuce in hilly areas is done from March to June.

**Manurial and fertilizer requirements**

The common practices followed (Mehta, 1959; Yawalkar, 1969) are: farmyard manure 18 to 36 tonnes, 50 to 86 kg of nitrogen, 24 to 50 kg of phosphorus and 50 to 54 kg of potash per hectare. Choudhury (1967) reported good results with 100 kg nitrogen, 60 kg each of phosphorus and potassium per hectare.

The complete dose of farmyard manure may be applied to the soil at the time of field preparation and the entire dose of phosphorus and potash and half the dose of nitrogen may be applied just before transplanting. The remaining half the dose of nitrogen may be applied as a top dressing after a month of transplanting.

**Intercultural operations**

Since it is a shallow-rooted crop, shallow cultivation is recommended. In the plains, irrigation at frequent intervals is essential for rapid development of leaves. Excess irrigation in heavy soils causes the rot and burning of leaf edges.

**Harvesting**

The leafy varieties are harvested in 50-60 days when the leaves are immature and tender but large enough to use. In head varieties it is harvested on attaining a good size and solid head in about 60-70 days. While marketing, care should be taken that no wrapper leaves are damaged. The fresh leaves cannot be stored under ordinary conditions because they lose their moisture very soon. However, the head lettuce can be stored for a few days under ordinary room conditions. Under cold storage conditions it can be kept at 0°C and 90 to 95% relative humidity for about two to three weeks. The average yield per hectare of head type ranges from 10 to 14 tonnes (Sharma and Pandey, 1963). It is more in leaf type.
Improved varieties

The following introduced varieties were recommended by the IARI:

‘Great Lakes’ (Crisphead type). The head is large, firm with green leaves and the outer leaves being blistered. It is fairly resistant to ‘tip burn’ but susceptible to powdery mildew.

‘Slobolt’ (Leaf type). The leaf is broad, frilled, slight yellowish green. It is very late in bolting and is an ideal variety for home gardens. It is a leafy type.

‘Chinese Yellow’ (Leaf type). It is an early variety with light-green crisp and tender leaves. It is highly productive and produces white seeds. It is a leafy type.

‘Imperial 859’ (Crisphead type). The head is medium large, solid and well covered by heavily blistered outer leaves. It stands well in summer weather.

‘White Boston’ (Butterhead type). It has soft solid heads, inner leaves have oily, soft, greasy texture.

‘Dark Green’ (Cos type). It has narrow leaves with elongated upright heads.

Seed production

The early flowering varieties produce good seeds in the northern plains. It is a self-pollinated crop with cleistogamous flowers but some amount of cross-pollination has also been reported. It is suggested that the two varieties may be kept 50 m apart (Anonymous, 1971a). The agronomic practices to be followed are more or less the same as that of the crop to be raised for the leaf or head production purposes.

Harvesting for seeds should be taken up when a substantial number of heads have burst and shown the pappus which is in the form of white hair on the seeds, and a good number of heads after opening have turned brown or dark brown but have not shown out the pappus.

White leaf-type lettuce has no problem in producing flowering stalks. The outer leaves should be turned open by hand and provide a slight cut in head type for facilitating flowering stalk to emerge easily. It produces an average of 595 kg/ha of seeds in ‘Chinese Yellow’ (leaf) and as low as 30 kg/ha in ‘May King’ (butterhead) (Singh et al., 1962). ‘Great Lakes’ (crisphead) produces about 100-125 kg seeds/ha.
Diseases

Some common diseases are described below:

*Slimy soft rot* (*Erwinia* sp.). This is a sort of bacterial rot which first appears as water-soaked, greasy, soft lesions, which spread rapidly and later turn dark brown and slimy. The disease causes considerable damage in head lettuce and can be controlled by the removal of the heads and also keeping the soil surface relatively dry.

*Downy mildew* (*Bremia lactuceae* Regel). The disease appears as light green or pale yellow lesions on the upper surface of the leaves. On the reverse side a downy white growth is seen. The lesions may join and eventually the entire leaf turns yellow and brown. The disease can be controlled by spraying or drenching the young plants with Dithane (Walker, 1952). Certain varieties like 'Imperial 17' are resistant to the disease (Choudhury, 1967).

*Mosaic.* Lettuce mosaic is a widespread seed-borne and aphid-transmitted virus disease and causes considerable damage. The leaves get distorted by inward rolling and mottling. There may be severe stunting and the whole plant turns yellow and discoloured. Use of disease-free seed and control of aphids is suggested.

Insect pests

The insect pests of salad crops is given below:

*Aphids* (*Aphis* sp.) Aphids cause considerable damage to the lettuce crop. The use of 3 to 4% nicotine dust gives satisfactory control if applied when the temperature is around 18° to 21°C (Choudhury, 1967). Knott (1955) recommended spray of Malathion, Parathion, Metacid or TEPP for effective control.
14. COLE CROPS

CABBAGE

Origin
It is probably the native of western Europe and the northern shore of the Mediterranean region (Thompson and Kelly, 1957). All cole crops (cabbage, cauliflower, knol-khol, sprouting broccoli, Brussels sprouts, etc.) have originated from a single ancestor *Brassica oleracea* var. *sylvestris*. It was in general use in 2,000 to 2,500 B.C.

Distribution and uses
Cabbage is an introduced vegetable crop in India, but it has adapted itself well and is grown all over the country. It is the most common vegetable crop available during winter all over India. It is a rich source of vitamin A, B and C. It also contains phosphorus, potassium, calcium, sodium and iron.

The heads vary from flat-topped to long-oval. Preference is generally given to varieties with compact, round heads though pointed-head varieties are also grown.

The tender leaves are primarily used as cooked vegetables, more in raw than in processed forms.

Botany
The common cabbage grown in India is white cabbage. The red cabbage has the same botanical name except form is *rubra* (L.) Thell. The Savoy cabbage is *B. oleracea* var. *sabauda* L. The last two types are not so popular.

Cabbage (*Brassica oleracea* var. *capitata* L. f. *alba* DC) belongs to the family Cruciferae. It is a herbaceous annual for vegetable, whereas for seed production it is biennial. It has bisexual flowers and the edible portion is made up of numerous thick overlapping smooth leaves covering a terminal bud, known as ‘head’. The cabbage varieties differ in size, shape and colour of the head. The flowers are protogynous. Most of the varieties show self-incompatibility.

Plant breeding
It is a temperate crop which does not produce seeds in the
plains and hence no work either on breeding or on seed production has been taken up in the plains. It can produce only the edible heads in the plains, the seeds for which are produced in the temperate hilly regions. There inheritance and hybrid vigour studies have been made on the available genetic stocks (Swarup and Singh, 1963; Swarup and Sharma, 1965; Swarup et al., 1968; Morgan, 1969; Bhagchandani et al., 1977; Gill et al., 1979). Watson and Baker (1969) have given an account of the possible gene centres for resistance in the genus *Brassica* to *Plasmодиophора brassica*. The resistance to black-rot, *Xanthomonas campestris* was observed to be dominant and governed by polygenes (Tewari et al., 1979).

'Dania' variety was developed as self-compatible line for late season. Male sterility has been reported which may be used in the production of hybrid seeds. Swarup and Gill (1964) suggested the use of purple pigmentation in hybrid seed production of cabbage.

**Climatic and soil requirements**

It is a cool-season crop which thrives best in a relatively cool moist climate. It can withstand extreme cold and frost relatively better than cauliflower. It loses its flavour in dry warm weather. The optimum seed germination is obtained at 12.8°C to 15.6°C soil temperature.

It can be grown on all types of soils from light to heavy soil. In clay loam or silt soils larger yield may be obtained from the late crop. It does not grow well on a highly acidic soil and the maximum phosphorus availability to the plants is between pH 5.5 and 6.5. Higher acidity can be reduced by liming but it should not be reduced beyond 6.5 pH.

**Planting requirements**

Since it is a cool-season crop the sowing is done in the plains usually in August, September and October for the early, main season and late varieties respectively. In some parts two crops of cabbage are taken. Sowing is done in the nursery-beds. The seedlings become ready for transplanting in 4 to 6 weeks depending on the weather conditions. The field is prepared by 3 or 4 ploughings. The early and main varieties are transplanted at the distance of about 45 cm and 60 to 70 cm from row to row.
and 45 cm and 45 to 60 cm plant to plant respectively.

An average of 500 to 750 g of seeds are required per hectare.

**Manurial and fertilizer requirements**

Cabbage is a heavy feeder especially of nitrogen and potash. The nutrient removal by a crop of 700 q heads, 350 q leaves and 50 q stalks per hectare is recorded as 230 kg nitrogen, 85 kg phosphorus, 320 kg potash and 426 kg calcium (Bauer, 1932).

The amount and type of fertilizer used vary in different parts of the country depending on the soil and the climatic conditions. The recommendations made so far (Yawalkar et al., 1962; Lal, 1938; Mehta, 1959) are as follows: FYM 20 to 50 cartload, 50 to 70 kg of nitrogen, 45 to 120 kg of phosphorus and 45 to 90 kg of potash/ha. The complete dose of FYM should be incorporated in the soil at the time of field preparation. The entire dose of phosphatic and potassic fertilizers along with half the dose of nitrogen should be mixed in the soil before transplanting. The remaining dose of nitrogenous fertilizer should be top-dressed around the plants one month after transplanting.

Chhonkar and Jha (1963) recommended the application of starter solution to seedlings immediately after transplanting to help increased production. They reported that the starter solution containing urea (1 part), potassium sulphate (1 part) and single superphosphate (2 parts) applied immediately after transplanting the seedlings at the rate of 0.25 litres and again after 15 days of first application at the same rate gave the highest yield of 700 q/ha of heads. Prakash and Bhardwaj (1965) reported that the foliar application of molybdenum and cobalt may help the increased production of cabbage heads.

**Intercultural operations**

A continuous supply of moisture is necessary for the proper development of the heads. The first irrigation should be given immediately after transplanting. Heavy irrigation is avoided at the time of marketable maturity of heads.

Very shallow hoeing should be done in order to remove the weeds and loosen the soil for better aeration. In order to produce solid heads the plants are earthed up after 5 to 6 weeks of transplanting.

Chhonkar and Singh (1964) reported that two sprays of GA
at 5 ppm to the seedlings gave the maximum increase in yield and quality of cabbage heads. Singh and Chhonkar (1965) recorded the highest yield per unit area with two sprays of 0.05 ppm of NAA after two and three weeks of transplanting.

**Harvesting**

Cabbage heads should be harvested when they attain the full size depending on the variety used. They have a tendency to burst or loosen the leaves beyond the marketable stage. In the plains usually the heads are harvested from December to April, the early varieties take 60 to 80 days while the late varieties take 100 to 120 days for harvesting after transplanting. The early varieties yield low than main and late varieties. However, the yield differs with the season, variety and locality. The yield of early cabbage ranges between 330 and 350 q/ha, while that of late varieties between 350 and 450 q/ha in northern India. It is at least 25% less in southern region, especially because the winter is mild and of shorter duration than in the northern region.

The marketable heads can be stored for four to five days under ordinary conditions, whereas they can be stored for several weeks in the cold storage at 0°C to 1.7°C with 85 to 87% relative humidity.

**Improved varieties**

The following varieties are commonly grown in India.

*Golden Acre*. It is an early variety with heads very uniform, solid and round. The plant is small and compact with a few outer leaves, short stem and small cup-shaped leaves. Interior portion of the head is clear white and of excellent quality.

*Pride of India*. Early, round headed, solid, medium sized and weighing 1 to 1.5 kg each.

*Copenhagen Market*. It is an early variety with round head which is compact with a few outer leaves, small core and large in size. The stem is short and the leaves are light green.

*September*. An early, high-yielding variety recommended from the Indo-German Nilgiri Project, Ooty.

*Pusa Drumhead*. It is a new cabbage variety selected from 'EC-6774' (Japan) and evolved at Katrain (IARI). It has uniform, flat, solid, small-framed and short-stalked head which, weighs about 1.5 to 2 kg. It yields about 495 to 540 q/ha. It is
resistant to black-leg or dry-rot (Phoma lingam), common in hills and often in Delhi (Swarup et al., 1968).

Other varieties of white cabbage grown in India are 'Golden Ball', 'Early Drumhead'.

'Drumhead Savoy'. It has a dark green foliage which is much blistered or wrinkled. The quality is superior but it is not commercially acceptable in our country.

'Red Cabbage'. The leaves are deep purplish red. The yield is usually low.

In general the round head varieties mature the earliest followed by the conical varieties, whereas Drumhead varieties with flat head and Savoy varieties are usually late. A number of varieties are available with various nurseries.

Seed production

It requires a temperate climate and chilling for flowering and seed production. It produces only 'head' in the plains and fails to produce any flower and seed in the plains and hence its seed production is not being discussed here.

CAULIFLOWER

Origin

Cauliflower was introduced to India in 1822 by Dr Jemson at Saharanpur during the period of East-India Company. Since then it has undergone acclimatization and selection as a result of which the Indian cauliflower today has attained a characteristically different form compared to other temperate types of the world. The main points of difference are tolerance to high temperature and rainfall and earliness. After originating in Cyprus, the cauliflower got established around Mediterranean region, particularly in Italy. Its further development and improvement were achieved in North and North-Western Europe extending its cultivation to 60° N. The development of Indian cauliflower types made it possible to extend its growing area in the tropics and subtropics of the world. The crop is presently cultivated from 11° N to 60° N. The different types of cauliflowers like Cornish, Northernns, Roscoff, Angers and Erfurts originated from the Italians independently in different regions like Cornish and Northernns in England, Roscoff and Angers in France and Erfurts or Snowball in Germany and the Netherlands. Cornish
type, perhaps the first to be introduced in India, has itself gone out of cultivation after contributing many genes to Indian varieties like resistance to black-rot, self-incompatibility, curd flavour, open plant habit, exposed yellow loose curds, etc. (Swarup and Chatterjee, 1972).

**Distribution and uses**

Cauliflower is grown on a larger acreage than cabbage in India. Though it is grown throughout the country from 11°N to 35°N latitude, the most important extensive growing locations are around Calcutta (West Bengal); Hajipur, Ranchi and Patna (Bihar); Varanasi, Faizabad, Lucknow, Aligarh and Meerut (U.P.); around Delhi; Panipat, Sonepat and Karnal (Haryana); Ludhiana, Jullundur and Amritsar (Punjab); Ajmer, Ganganagar and Jaipur (Rajasthan); Kolar, Bangalore, Mysore and Hassan (Karnataka). Cauliflowers from Ranchi and Hajipur are available as early as May. Besides, Snowball types are grown in hills of Himachal Pradesh, Uttar Pradesh, Ooty (Tamil Nadu), etc. during summer months.

Cauliflower is cooked like cabbage, solo or in combination of peas, potato, etc. and is liked by both rich and poor. During glut period, cauliflowers are sun-dried for later use. It is used in pickles also.

Cauliflower is rich in minerals like potassium, sodium, calcium, iron, phosphorus, magnesium. It also contains vitamin A and C.

**Botany**

Cauliflower (*Brassica oleracea* var. *botrytis* L.) belongs to the family Cruciferae and is a close relative of cabbage and knol-khol. Heading broccoli resembles with the late cauliflower except that the former requires chilling for seed production and the cauliflower does not. Cauliflower has longer and narrower leaves than the cabbage. Similarly the cauliflowers differ from the sprouting broccoli in the following contrasting features:

Sprouting broccoli has wavy and shorter leaves, axillary sprouts and having apparent reproductive buds, while cauliflower has long and linear leaves, curd is the early stage of inflorescence development without any axillary sprouts. Cauliflower is very exacting in soil and climatic requirements. In cauliflower only the curd is harvested while in sprouting broccoli it is harvested
along with the stem. The edible portion of plant is the ‘curd’, which is made up of numerous divided hypertrophic branches which terminates the main stem of the plant and is highly suppressed with no part of flower apparent there.

Cauliflower is herbaceous annual for vegetable production and biennial for seed production.

**Plant breeding**

‘Early’ and ‘Main Crop Patna’ and ‘Early’ and ‘Main Crop Banaras’ were the first four listed Indian varieties, perhaps the earliest in the world and have greatly contributed in developing improved varieties adapted to hot-weather conditions in different countries, viz. ‘Pua Kea’ in Hawaii, ‘Compinus’ in Brazil, ‘Improved Japanese’ and ‘96-D’ in Israel and ‘Extra Early’ in Taiwan. Singh (1971) and Swarup and Chatterjee (1972) classified cauliflowers into four distinct maturity groups and four plant types. Extensive genetics and plant-breeding work was initiated by Singh *et al.* (1966) at IARI on Indian cauliflowers (Singh, 1971). Information on these aspects is available (Singh *et al.*, 1975, 1976a,b, 1981b). The same authors suggested and developed for the first time the synthetic varieties in Indian cauliflowers of Maturity Group II and III (Singh *et al.*, 1981a). An excellent genetic and breeding work is going on at IARI. This work has resulted in the development of some very high-yielding varieties like ‘Pusa Deepali’, ‘Early Synthetic’, ‘Synthetic II’, ‘Line 328’, ‘Line 12C’, ‘Synthetic III’, etc. Work taken up later on at Pantnagar and Ludhiana is also quite appreciable. The other informations on Indian cauliflowers and Snowball type are also available (Chatterjee and Mukherjee, 1964, 1965; Pal *et al.*, 1956; Pal and Swarup, 1966; Sandhu *et al.*, 1977; Kale *et al.*, 1979).

**Climatic and soil requirements**

The varieties of cauliflower are very much sensitive to temperature and photoperiodic requirements. It is therefore essential to choose the proper variety to be sown at the proper time. Cauliflower generally requires a cool and moist growing season. It cannot withstand so low temperature or so much heat as cabbage does. Dry weather and low humidity cause curds to be small and hard. For good seed germination,
temperature of 10° to 21.1°C is required. High temperatures produce poor-quality curds like ricey, leafy, fuzzy, loose and yellow coloured ones. Temperature below the optimum during growing period delays maturity, and undersized, small, unmarketable ‘buttons’ may be formed. The optimum monthly average temperature ranges from 15° to 25°C for varieties of different maturity groups, for curd formation. To varieties of early-maturity groups require higher temperature and longer day lengths. Cauliflower thus makes heavy demands on the professional skills of the growers, and its cultivation often fails under less favourable growing conditions than are normally required.

It can be grown on a wide range of well drained soils. However, the early varieties prefer sandy loam, whereas for the late varieties loam or clay loam are preferred. It requires an average pH range of 5.5 to 6.6, and below pH 5.5, it would be necessary to do liming at the rate of 4 to 8 tonnes/ha. As in cabbage, the field can be prepared well with 3 or 4 ploughings.

**Planting requirements**

In the plains the seeds of early varieties of maturity group-I (a and b) are sown in May-June, the mid-season or maturity group-II in July, maturity group-III (mid late) in August and maturity group-IV (Snowball type) in September-October in the well-prepared nursery-beds where the seedlings become ready for transplanting in about 4-6 weeks. The seedlings are transplanted usually in the flat beds or on ridges at a distance of 45 cm x 30 cm in case of early varieties and 60 cm x 45 cm in case of medium and late varieties. The transplanting should generally be done in the evening avoiding hot sun, and followed by light irrigation. Singh *et al.* (1977) observed that transplanting of seedlings of the ‘Snowball-16’ variety of cauliflower by 15th October proved beneficial over other dates of transplanting in N.E. Indian conditions. It requires an average of 495 to 740 g of seeds for the early varieties and 300 to 370 g for medium and late varieties to raise the nursery for the planting of one hectare land.

**Manurial and fertilizer requirements**

Like cabbage, the cauliflower is also a heavy feeder. An average crop of cauliflower giving 16 tonnes/ha of marketable
Curd removes 46 kg of nitrogen, 16 kg of phosphorus and 55 kg of potash. Depending on the climatic and soil conditions the following recommendations have been made from time to time: FYM 30 to 40 tonnes, nitrogen 54 to 120 kg, phosphorus 40 to 45 kg, and potash 40 kg/ha (Purewal, 1957; Yawalkar et al., 1962; Patel and Jyotishi, 1969; Randhawa and Bhaii, 1976). There is good response to nitrogen up to 150 kg/ha.

The complete dose of FYM should be applied thoroughly in the soil at the time of field preparation and the complete dose of phosphorus and potash is applied before transplanting. Half the dose of ammonium sulphate may be applied along with the potash and phosphorus before transplanting and the other half in bands around the well established plants one month after transplanting followed by irrigation. Chhonkar and Sharma (1966) reported that the application of starter containing ammonium sulphate and single superphosphate (1.2: 1.8 kg of mixture in 225 litres of water) in liquid form in combination with 0.1 ppm IBA was most effective in increasing the total yield of cauliflower.

Deficiency of boron has been reported at several places in India. About 10-20 kg/ha of boric acid should be applied along with the basal dose of fertilizer followed by 2-3 sprays (0.3-0.4%) up to curd formation.

Intercultural operations

Intercultural operations are more or less the same as that of cabbage. Patel and Jyotishi (1969) found 10-cm thick mulching with paddy husk to be beneficial in increasing the growth and yield of cauliflower over no mulch. The curd is protected against sun-burning and yellowing by covering the curd which is known as ‘blanching’ (Mehta, 1959; Srivastava, 1960). However, some of the varieties retain white colour even if exposed to the sun.

Harvesting

Cauliflower should be harvested when the curd has attained the proper size, bright colour and compactness. The plant is cut off well below the curd so that the stub thus left protects the curd during transport.

It produces an average of 20 to 30 tonnes curd containing 12,000-24,000 curds per hectare depending upon the maturity.
group of the varieties. Early varieties generally produce lower yield than the mid-season or late-season varieties. The edible curds can be stored for 3 to 4 days at ordinary temperature, whereas it can be stored for 30 days at 0°C with 85 to 90% relative humidity.

It gives a net profit of Rs 860 to 2,400 per hectare depending on the season and the market price. Datta (1961) calculated the cost of cultivation to be Rs 1,384 near Delhi and Rs 808.60 per hectare near Agra.

**Improved varieties**

The following important varieties are grown in India for different maturity groups:

* Maturity group-I (a) (September maturity). ‘Early Kunwari’ (Ludhiana) as a recommended and ‘Early Synthetic’ and ‘Line 327’ (IARI), ‘78-1 S’ and ‘234 S’ (Pantnagar), ‘Early Patna’, ‘Early Banaras’, etc. are promising.

* Maturity group-I (b) (October maturity). ‘Pusa Deepal’ (IARI) as recommended and ‘Pusa Katki’ and ‘Line 328’ (IARI), ‘75-IC’, ‘75-2C’ and ‘75-3C’ (Pantnagar), etc. are promising.

* Maturity group-II (November maturity). ‘Improved Japanese’ (NSC) as recommended and ‘12 C’ and ‘Synthetic-II’ (IARI), ‘235-S’ and ‘74-6C’ (Pantnagar), ‘Agahgni’, ‘Poosi’ and ‘Main Crop Patna’ are promising.

* Maturity group-III (December maturity). ‘Synthetic-III’ (IARI) and ‘114 S-1’ (Pantnagar) as recommended and ‘PG 25’, ‘PG 26’ (Ludhiana), ‘Hisar-1’ (Hisar), ‘Sel-7’ (Kattain) and ‘236 S-1’ (Pantnagar), ‘D-96’ (Israel) and ‘Early Snowball’ (Japan), etc. are promising.

* Maturity group-IV (January maturity). ‘Pusa Snowball’ and ‘K-1’ (IARI), ‘Indian Snowball’ (Suttons), ‘Snowball-16’ (Holland), ‘Dania’ (Denmark), ‘Dania Kalimpong’, etc. are promising.

Several strains of early-, medium- and late-season crops of cauliflower are available with various seed companies in India.

**Seed production**

It is possible to produce the seeds of the varieties of first three maturity groups, i.e. Indian cauliflower varieties in different parts of the plains. The usual method is to leave the plants
with good curd in the field which later produce flower stalks and flowers and the seed ripens from March to May. But this method occupies lot of area because plants for seed production are left here and there in the field. It is recommended that the selected plants with best curds may be uprooted carefully and replanted in a compact block for seed production. In this process the curd of the stecklings before transplanting or at the time of transplanting is given scooping or incision in the middle of the curd to facilitate the growth of the side seed stalks which permit better quality seed production. High yield of seeds, however, has been obtained from the plants which were left in situ and not transplanted (Choudhury and Ramphal, 1961).

While transplanting the stecklings may be spaced at 75 cm × 75 cm. It is necessary that the field is well prepared and manured before transplanting. The bee activities for efficient pollination should be encouraged. Use of insecticide spray at the flowering time should be avoided.

The seed gets ready from March to May depending upon the maturity group. It should be cured, threshed, cleaned, graded and stored before the onset of rains.

Since it is a cross-pollinated crop it is necessary that the two varieties are kept 1000 m apart so as to avoid contamination (Anonymous, 1971a).

In early- and mid-season varieties (up to III maturity group) excellent seed-set is observed in the plains and on an average seed yield of 500-650 kg/ha is not uncommon. On an average about 220 kg of seeds/ha in ‘Snowball’ variety were produced in the hills (Singh et al., 1959).

**KNOL-KHOL**

**Origin**

Knol-khol is reported to have originated in the coastal countries of northern Europe. It was introduced in India long back.

**Distribution and uses**

Like cabbage and cauliflower, knol-khol is also cultivated commonly during winter in several parts of the country. It is liked very much in Kashmir and Karnataka regions. However, its acreage is very limited. In other countries also only German
speaking countries have interest in this crop. It is primarily used as a cooked vegetable. Its tuber is normally harvested for food, though of the earlier strains the young leaves may also be cooked. The late varieties are sometimes used for animal fodder. It is high in minerals like calcium, magnesium, potassium, phosphorus, sodium and sulphur. It also contains vitamin A and C.

**Botany**

Knol-khol or kohlrabi (*Brassica oleracea* L. var. *gongylodes* L.) belongs to the family Cruciferae and is a close relative of cabbage and cauliflower. It is a herbaceous plant of which the swollen stem just above the ground is the edible portion. The small leaves grow out of this stem arranged in a compressed spiral on the bulbous part. It is a temperate crop which produces edible vegetable as an annual in the plains and in the hills. For seed production it is biennial in the hills.

**Plant breeding**

It is a cross-pollinated crop like cabbage and cauliflower with bisexual flowers. Since it fails to produce seed in the plains, no effort was made either to maintain or to improve upon the available strains. Most of the varieties were introduced from European or American countries.

**Climatic and soil requirements**

These requirements are more or less the same as that of cabbage. Varieties differ in their response to low temperature (below 10°C) for premature bolting. Susceptible varieties if exposed after germination to temperature below 10°C, even for one week of low temperature, may produce bolting. High temperature after planting can delay the bolting of plants.

**Planting requirements**

It is a cool-season crop and is usually grown at the time when cabbage and cauliflower are grown. The planting system is the same as that of cabbage where the seedlings are raised in the nursery-bed from August to November and transplanted usually in the flat beds in the well prepared field. The planting distance kept is 30 cm between the rows and 20 cm from plant to plant in a row. It requires about 1 kg of seeds to raise the seedlings
for one hectare land. Kohlrabi is sometimes planted in between other vegetable crops that are maturing.

**Manurial and fertilizer requirements**

Backer (1956) reported that the nutrient removal from a hectare of knol-khol crop was 100 kg of nitrogen, 80 kg of phosphorus, 160 kg of potash and 60 kg of calcium. Chaudhuri and Som (1959) studied the response of knol-khol variety ‘Early White Vienna’ to nitrogen (0 to 120 kg/ha) and phosphorus (0 to 60 kg/ha) in sandy-loam soil with low available nitrogen and phosphorus. Best yield was obtained with 100.7 kg nitrogen and 60 kg phosphorus/ha.

FYM may be incorporated in the soil at the time of field preparation whereas the complete dose of potash and phosphorus and half the dose of nitrogen may be applied before transplanting as in cabbage. The rest half dose of nitrogen may be applied after a month of transplanting.

**Intercultural operations**

Same as that of cabbage and cauliflower. It requires frequent watering to establish the plants. If growth is slowed or checked, the edible tuber becomes woody, tough and fibrous. At the same time, too rapid growth may cause the tubers to crack, especially when the initial growth was slow.

**Harvesting**

The harvesting of knol-khol is made when it attains its marketable size (5 to 7 cm diameter) and bright colour depending on the variety. The harvesting should be done twice or thrice a week. At this stage the edible portion is tender and non-fibrous. For its marketing the main root is cut off and the enlarged stem along with the leaves are tied up. The average yield is 20 to 24 tonnes/ha depending on the region and the variety. Late varieties are usually higher yielding than early ones.

Under ordinary conditions it can be stored for two to three days but under cold storage conditions it can be kept for relatively longer period.

**Seed production**

It does not produce seeds in the plains.
Improved varieties

The improved varieties of kohlrabi are given below:

'White Vienna'. It is an introduced early variety with dwarf growth habit. The modified stems are globular, light green and very smooth. The flesh is creamy white, tender with delicate flavour.

Other varieties grown by the cultivators are 'Purple Vienna', 'Kyote No. 3' and some others. The factors which determine the value of a kohlrabi variety are earliness, productivity and resistance to bolting.

Physiological disorders of cauliflowers

There are certain physiological disorders which are generally encountered in cauliflowers.

Whip tail. The leaf blades do not develop properly and become strap-like. The growing point is severely deformed and no marketable head is formed. This results because of the deficiency of molybdenum which occurs in acidic soil below 4.5 pH. It may be controlled by liming the soil which reduces acidity and increases pH up to 6.5. It may also be controlled by the application of 1-2 kg/ha of sodium or ammonium molybdate. Sharma and Singh (1963) demonstrated the effect of different levels of N, P and molybdenum on cauliflower.

Browning. It is common in cauliflower where the stem becomes hollow and the curd becomes brown because of the deficiency of boron (Venkataratnam, 1961). Later the edges of older leaves develop purple colour. It may be controlled by the application of borax (sodium tetraborate) at the rate of 5 to 7 kg in acidic soil and a heavier dose in neutral or alkaline soils.

Buttoning. This is identified by the development of small curd or 'button' while the plants are small and consequently the curd gets open. This is caused usually due to the deficiency of nitrogen, by planting older seedlings than 6 weeks, or any other factor that causes check in growth in early stage of seedlings of plants. Such other factors may be insufficient moisture supply, water-logging, hot and dry weather, carelessness in proper and timely weeding and a pest and disease attack.

If an early variety is grown late, its growth is checked due to lower temperature and the curd remains undersized, or 'buttoned'.
Such factors should be avoided to get proper size of the curd.

**Riceyness.** The peduncle elongates and the curd becomes granular and loose. If late variety of cauliflower is planted early it occurs due to higher temperature. Rampant growth, heavy nitrogen dressing and high relative humidity also have unfavourable effect. It may appear when the harvesting of curds is delayed and they become over mature.

**Blindness.** In some cases the terminal bud does not develop or gets broken or eaten away by the insects. In other words, the plant grows without a terminal bud with no curd or head. The leaves become large, dark green and leathery. These types of plants should be removed.

**Diseases**

The common diseases are as follows:

- **Damping off** (*Pythium* sp., *Rizoctonia* sp., *Fusarium* sp.). It is a common disease in the nursery-bed where the rotting starts in the collar region of the seedlings. In the nursery it may be controlled by drenching the bed with 0.1% solution of Brassicol, Captan or Fytolon. The infection may also be reduced if the seed is treated with Agrosan GN or Ceresan at the rate of 2 g/kg of seed.

- **Black-rot** (*Xanthomonas* or *Pseudomonas* sp.). The margin of the leaves turn yellow. The veins become dark and vascular region of the main stem becomes discoloured. The cauliflower curds and cabbage heads get discoloured. The disease may be controlled to a great extent by following proper crop rotation. The hot-water treatment of seeds at 48.9°C for 30 minutes has given a good control (Rao and Srivastava, 1964).

- **Leaf-spot and blight** (*Alternaria* sp.). The small dark-coloured spots appear on the leaves which spread rapidly to form circular lesions. In humid weather concentric dark rings appear. In severe cases the cauliflower develops brown colour, whereas the cabbage develops black, moldy appearance after harvest. The hot-water treatment as in the case of black-rot gives a satisfactory control of this disease.

- **Club-root** (*Plasmodiophora brassicae*). In severe cases malformed roots present a clubed appearance. The foliage wilts on sunny days and recovers towards the evenings. The infected areas should be abandoned for growing cruciferous crops. The
contamination of implements, farm animals, plants and surface drainage water should be avoided. Since the disease is prevalent in the acidic soils efforts should be made to treat the seedlings before transplanting with mercuric chloride solution (1 in 1500).

**Black-leg (Phoma lingam).** The young plants in the nursery-bed are affected usually. The fungus attacks at the base of stem and roots and the plant wilts. The disease may be controlled by proper crop rotation, seed treatment by fungicides and hot-water treatment.

**Cabbage Yellows (Fusarium sp.).** The fungus enters the host through the root system and grows throughout the plant. The plants become yellow in two to four weeks. The growth remains stunted and defoliation occurs. No proper control measure is available but in foreign countries some resistant varieties are available.

**Insect pests and nematodes**

Commonly found insect pests are given below:

**Mustard saw-fly (Athalia sp.).** The adult is a minute black fly that lays eggs inside the leaf tissues. The caterpillar feeds on the leaves of young seedlings. This black caterpillar attacks almost all cruciferous vegetables. It may be controlled by the fortnightly spray of 0.02% Malathion but in case of light infestation the caterpillars may be hand picked and destroyed.

**Mustard aphid (Brevicoryne sp., Myzus sp., Rhopalosiphum sp.).** The greenish or black aphids damage the leaves by sucking the cell sap. The affected leaves get curled and plant wither away and die. It may be controlled by the spray of 0.5% nicotine or 0.5% Malathion. Source of resistance to this aphid has been reported in *Brassica* plants (Thompson, 1963).

**Cabbage butterfly (Pieris sp.).** The young green caterpillars feed on the surface of the leaves and skeletonise them. In case of heavy infestation the leaves, tender shoots, flowers and fruits are completely destroyed resulting in the rugged appearance of the attacked plants. It may be controlled by the insecticides as used for controlling the mustard saw-fly. After the head formation persistent insecticides should not be used. If needed 0.05% of nicotine sulphate may be sprayed.

**Semi-looper (Plutia sp.).** The green caterpillars, which are identified by the characteristic loop while moving, attack cruci-
ferous crops resulting in serious damage. The nature of damage and control measures are similar to those of cabbage butterfly.

_root-knot nematodes* (*Meloidogyne* sp.). Sometimes these minute worms become serious causing check of growth and proper development of curd or head. This may be easily identified by the formation of galls on the roots. It may be controlled by proper crop rotation with other crops. It may also be controlled by fumigating the soil with nematicides with ethylene di- or tri-bromide which requires about 165 to 275 litres/ha.
15. **BHINDI (LADY'S FINGER)**

**Origin**

*LADY'S FINGER* is said to be the native of South Africa or Asia and has been predominantly a vegetable of the Tropics (Thompson and Kelly, 1957). It has found its place in India for more than a century.

**Distribution and uses**

It is commonly grown in almost all parts of the plains and is consumed by the common people in all the states.

The tender fruits are cooked as vegetables. It contains vitamin A, B and C with little iron. It has several other economic uses. Matured fruits and stem containing crude fibre are used in the paper industry. In some places the plants are soaked in water and the resulting solution is used as clarifier in the manufacture of jaggery.

**Botany**

*Bhindí, Abelmoschus esculentus* (L.) Moench, belonging to the family Malvaceae is a herbaceous annual with bisexual flowers and erect vegetative growth with or without branches. The fruit is a capsule which may be light green, green or sometimes red. Sistrunk *et al.* (1960) reported that the greatest increase in fruit weight, length and diameter occurred during fourth to sixth day after flowering. At this stage the quality was also high in all the varieties. Usually the fibre formation in the pod starts from the fifth to sixth day of formation and a sudden increase in fibre content from the ninth day was seen. Dutta (1971a) observed that the new strain ‘IIHR-20-31’ retained its tenderness up to the tenth day.

**Plant breeding**

Earlier attempts were made to study the inheritance of various economic characters (Richharia, 1949; Kalia and Padda, 1962; Nath and, Dutta, 1970c; Lal *et al.*, 1977; Kulkarni *et al.*, 1978; Armugam and Muthukrishnan, 1979, 1981; Misra and Chhonkar, 1979; Singh and Singh, 1979b; Elangovan *et al.*, 1981b) and up till now inheritance of almost all characters have been studied.
Attempts were also made to achieve interspecific crosses (Gadwal et al., 1968) to the best advantage of the useful characters especially the source of resistance to diseases and pests to be incorporated in the cultivated species. Singh et al. (1962) evolved a new variety 'Pusa Sawani' which was highly tolerant to the yellow-vein mosaic virus but now it has become susceptible. Efforts are being made at the IIHR to breed a variety which is highly resistant to YVMV. Almost immune source to YVMV has been recorded in the wild species, Abelmoschus manihot (Dutta and Singh, 1979). Interspecific relationship among different species of okra was studied by Pal et al. (1951).

Efforts were also made to exploit hybrid vigour and as much as 60% increased yield was reported (Joshi et al., 1958). Induction of male sterility by use of chemical (Dubey and Singh, 1968) and by irradiation (Dutta, 1971b) was made possible to exploit commercial hybrid seed production. A recent study on heterosis for yield and yield components using 56 F₁ hybrids involving 14 female lines and 4 testers indicated that manifestation of heterosis over the mid and better parent was evident over all the characters studied (Elangoven et al., 1981a).

Climatic and soil requirements

It is a warm-season crop and thrives best during warm humid seasons, although it grows fairly well in the hottest summer.

It grows best in comparatively lighter soils ranging from sandy loam to loam though it gives a normal crop in relatively heavier soils also. The land should be well prepared with 2 or 3 ploughings and should have proper drainage system.

Planting requirements

This crop can be grown throughout the year where frost and severe winters are absent. In the plains and frost-free areas the first sowing is done around January, the second during June-July, and the third during September-October. In regions where frost occurs the third sowing in September-October is not done.

It requires about 18 to 22 kg/ha of seeds during summer and 8 to 10 kg/ha for the rainy season. During summer the vegetative growth is relatively less and hence rows are kept about 30 cm apart with plants about 13 to 15 cm apart. During
the rainy season where growth is vigorous, rows are kept 60 cm apart and plants 30 cm apart.

One ounce of seed contains about 500 seeds with average germination of 50 to 60% (Sundaraj et al., 1965). The optimum temperature for germination is 26.7° to 30°C and it does not germinate below 15.6°C.

The seeds are sown directly in the field in rows either in flat beds or on ridges depending on the type of soil and irrigation facilities available.

**Manurial and fertilizer requirements**

Depending on the type of soil and its fertility status the following recommendations were made: 20 to 24 cartload of FYM, 44 kg of nitrogen, 22 kg of phosphorus and 22 kg of potash/ha (Yawalkar et al., 1962; Ahmad and Tullock Reid, 1968; Kamalanathan et al., 1970). FYM is thoroughly mixed in the soil at the time of field preparation and the complete dose of phosphatic and potassic fertilizers is applied in bands before sowing. The nitrogenous fertilizer is usually applied in two split doses, the first to be top dressed one month after sowing and the second two months after sowing.

Gupta and Rao (1979) reported that the nitrogen application significantly increased the fruit size and fruit yield in both the years of study. The optimum level was 116.9 kg N/ha, yielding 112.1 q/ha of marketable fruits. Further it was possible to grow okra as a rainfed crop around Bangalore if sown during August.

**Intercultural operations**

Depending on the soil moisture available the crop should be irrigated at frequent intervals. At the time of sowing enough of moisture should be available to help germination. For a continuous growth and pod formation the crop should be irrigated every 5th or 6th day during hot season and every fortnight during cold season. Hoeing and weeding should be done at regular intervals depending upon the need. Care must be taken to drain off excess irrigation or rain water, because it adversely affects the plant growth.

Nandpuri et al. (1969) reported increased yield of okra with the application of 100 ppm gibberellic acid.
Only the tender, young pods free from fibre should be harvested at every three or four days interval. Frequent picking is necessary to help picking the tender pods and to help increase in fruiting and yield. It yields about 54 to 60 q/ha in summer while the rainy-season crop yields 80 to 92 q/ha. After picking, the fruits are kept in shade and care should be taken to avoid bruises and injury. The crop matures in about 90 to 100 days in rainy season and 80 to 90 days in summer. The fresh vegetables are stored at temperature below 10°C with a high humidity to prevent damage.

**Improved varieties**

Commonly grown varieties are given below:

'Pusa Makhmali'. It has 15-20 cm long, straight, smooth and attractive green fruits. In the beginning when it was selected from West Bengal it proved to be superior to all the indigenous and foreign materials under Delhi conditions. During summer the first harvest is taken in 50 days whereas in monsoon crop it takes about 10 days more.

'Pusa Sawani'. It is a cross between 'IC-1542' and 'Pusa Makhmali'. It has dark green, smooth fruits with five ridges. The fruits are about 10 to 15 cm long at the marketable stage. It is a very high-yielding variety during rainy season but is suitable for growing throughout the year. It has adapted in almost all the parts of the country and in fact is the only commercial variety grown extensively throughout.

'Red Bhindi'. The fruits are red with longer size and are slender, fleshy and have fewer seeds than 'Pusa Sawani'. Its yield is the same as the latter one in southern plains (Anonymous, 1967).

'IIHR 20-31'. It produces long pods (24 cm x 8 cm) with thick flesh and lush-green skin (Dutta and Singh, 1970). Average number of pods per plant varies from 20 to 25, giving an average yield of 350 to 375 g/plant. The variety remains free from the attack of YVMV. Pods are five-ribbed and are ready for harvest 8 to 10 days after flower opening.

Due to serious nature of yellow vein mosaic virus on okra and to breaking of its hidden tolerance in the variety 'Pusa Sawani', active research work has been initiated at NBPGR and...
Ludhiana to develop variety resistant to this disease.

Seed production

It is an often cross-pollinated crop and a considerable extent of cross-pollination has been recorded. The two varieties may be grown 400 m apart for producing pure seeds (Anonymous, 1971a).

No special agronomic practices need to be followed for the crop raised for seed production. For economic seed production of okra during spring-summer season, the soil may be fertilized with 92 kg N/ha and plants be placed 45 cm by 15 cm apart with irrigation at 60 mm CPE (Cumulative Pan Evaporation) under agroclimatic condition of Agra (Pandey and Singh, 1979). The variety ‘Perkins Long Green’ gave a seed yield of 10.3 q/ha, whereas ‘Pusa Makhmali’ reported a seed yield of 27 q/ha (Singh et al., 1964).

Insect pests

Common insect pests are described below:

Jassids (Empoasca sp.). The adults and nymphs suck the sap of the plant which wither and in severe attacks the leaf curls. The pest can be controlled by 0.02 % Malathion, which can be repeated 2 to 3 times. Harvesting is done prior to each spray and fruits should not be harvested within two to three days after the spray. Reddy and Gupta (1967) found spraying 0.04 % Malathion to be effective in controlling this pest in addition to other insecticides.

Spotted bollworm (Earias sp.). The larvae with black and brown spots bore into the shoots and fruits of bhindi and cotton plants. The growth of the plant remains stunted and the fruits are rendered unfit for consumption. Frequent picking also minimizes the insect incidence. In case of seed crop where the fruits are not to be used for consumption 0.25 % DDT emulsion may be sprayed to control the infestation. Dieldrin (0.1 %) effectively controlled this pest (Srinivasan and Gowder, 1957).

Red cotton bug (Dysdercus sp.). The clusters of nymphs and adults suck the sap from bhindi fruits at the maturity stage. It can easily be sprayed with 0.2 % DDT emulsion to control the pest.
Diseases

Common diseases of bhindi are given below:

Yellow vein mosaic virus. It is a very common virus disease and limits the cultivation of this crop in some seasons. When the disease appears very early, all the leaves become completely yellow, later on turn brown, dry up and shed. Such plants hardly bear flowers and the plant dies prematurely. If the infection takes place at the later stage, the earlier formed leaves on the main stem remain green whereas the top leaves and the flowering part as also the secondary branches show clear symptoms. On such plants although the fruits are formed in good numbers, they are uniformly yellow at the picking stage and as such are unmarketable. In the beginning, the few infested plants may be uprooted and destroyed. The alternate host plants near the bhindi plot should be removed. Singh et al. (1977) have suggested minimizing the vector (white fly, Bemisia tabaci Gen.) population with the help of insecticides. Resistant lines developed at IIHR may be tried.

Powdery mildew (Erysiphe sp.). White greyish powdery coating is seen on the under-surface of the leaves. Leaves which are severely affected turn yellow and drop. It may be controlled by the wettable sulphur (0.2%) at one to two weeks interval. Ramakrishnan (1977) suggested Benlate (0.1%) or Morestan (0.05%) at 15 days interval for its effective control.


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## APPENDIX A

**NUTRITIVE VALUE OF VARIOUS VEGETABLES PER 100 G OF EDIBLE PORTION**

<table>
<thead>
<tr>
<th>Name of the vegetable</th>
<th>Moisture content (%&lt;sup&gt;1&lt;/sup&gt;)</th>
<th>Carbohydrate (g)</th>
<th>Protein (g)</th>
<th>Fat (g)</th>
<th>Vitamin A (I.U.)</th>
<th>Vitamin B (mg)</th>
<th>Vitamin C (mg)</th>
<th>Total (g)</th>
<th>Ca (mg)</th>
<th>P (mg)</th>
<th>Fe (mg)</th>
<th>K (mg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amaranth</td>
<td>85.7</td>
<td>6.3</td>
<td>4.0</td>
<td>0.5</td>
<td>9,200</td>
<td>0.03</td>
<td>0.10</td>
<td>99</td>
<td>2.7</td>
<td>397</td>
<td>83</td>
<td>25.5</td>
</tr>
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<td>85</td>
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(Continued)
## APPENDIX A (Contd)

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<tr>
<th>Name of the vegetable</th>
<th>Moisture content (%)</th>
<th>Carbohydrate (g)</th>
<th>Protein (g)</th>
<th>Fat (g)</th>
<th>Vitamin A (I.U.)</th>
<th>Vitamin B (mg)</th>
<th>Vitamin C (mg)</th>
<th>Total (g)</th>
<th>Ca (mg)</th>
<th>P (mg)</th>
<th>Fe (mg)</th>
<th>K (mg)</th>
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<td>0.01</td>
<td>11</td>
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<td>180</td>
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<td>0.01</td>
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<td>73</td>
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<td>8</td>
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<td>0.07</td>
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*After Aykroyd (1963).
# APPENDIX B

## FAVOURABLE TEMPERATURE RANGE AND DAYS FOR MATURITY OF VARIOUS VEGETABLE CROPS

### A. Cool-season crops

<table>
<thead>
<tr>
<th>Crop</th>
<th>Maturity</th>
<th>Radish*</th>
<th>Green onion*</th>
<th>Spinach*</th>
<th>Spinach beet*</th>
<th>Turnip*</th>
<th>Pea*</th>
<th>Beet*</th>
<th>Average temperature °C (2)</th>
<th>Minimum</th>
<th>Optimum</th>
<th>Maximum</th>
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<tbody>
<tr>
<td>Cauliflower</td>
<td>(30-60)</td>
<td></td>
<td>(35-45)</td>
<td>(40-45)</td>
<td>(40-90) Knol-khol</td>
<td>(50-70)</td>
<td>(60-70)</td>
<td></td>
<td>4.5</td>
<td>10-18</td>
<td>21</td>
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</tr>
<tr>
<td>Cabbage</td>
<td>(60-80)</td>
<td></td>
<td></td>
<td></td>
<td>(Perennial) Onion (90-110)</td>
<td>(60-75) Garlic (90-110)</td>
<td>French bean (60-90)</td>
<td></td>
<td>10</td>
<td>16-18</td>
<td>21</td>
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<tr>
<td>(70-100)</td>
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### B. Summer-season and rainy-season crops

<table>
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<th>Crop</th>
<th>Maturity</th>
<th>Tomato (60-90)</th>
<th>Pepper (65-80)</th>
<th>Cucumber (60-70)</th>
<th>French bean Okra</th>
<th>Chillies (80-100)</th>
<th>Spongegourd (60-90)</th>
<th>Ridgegourd (75-180)</th>
<th>Pumpkin (18.3)</th>
<th>Roundmelon (18.3)</th>
<th>Bittergowd (55-110)</th>
<th>Bottlegowd (60-100)</th>
<th>Longmelon (70-90)</th>
<th>Snapmellon (70-90)</th>
<th>Ashgourd (75-120)</th>
<th>Pointedgourd (80-60)</th>
<th>Squash (75-100)</th>
<th>Amaranth (25-50)</th>
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<td>(50-70) Cluster bean (50-70)</td>
<td>(0-110) Cluster bean (50-70)</td>
<td>(60-110)</td>
<td>(60-90)</td>
<td>Ridgegourd (60-90)</td>
<td>(75-180)</td>
<td>18.3</td>
<td>24-27</td>
<td>35</td>
<td>(75-100) Bottlegourd (60-100)</td>
<td>(55-90) Snakegourd (60-100)</td>
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<td>Watermelon</td>
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</table>

*Will stand frost.

1 From time of transplanting. Rest of the days are from sowing to harvest.

2 Below the minimum and above the maximum the growth and reproduction will be checked.