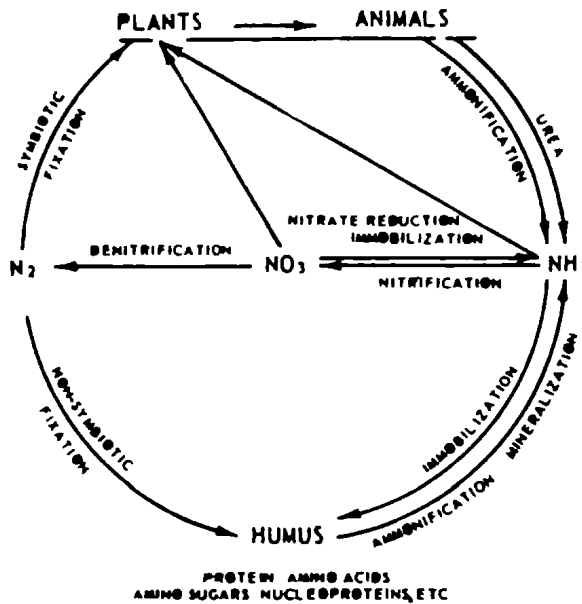


NITROGEN IN SOILS AND CROPS OF KARNATAKA

B V VENKATA RAO

AND

M K BADIGER



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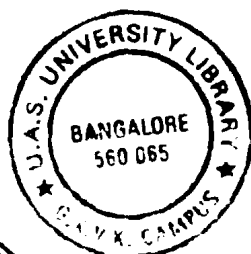


NITROGEN IN SOILS AND CROPS OF KARNATAKA

B. V. VENKATA RAO

AND

M. K. BADIGER



1977

UNIVERSITY OF AGRICULTURAL SCIENCES

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FOREWORD

NITROGEN is the most important of the three basic plant nutrients and is used in much larger quantities as compared to the other two. The world consumption of nitrogen in the fertiliser year of 1975-76 was at the level of 44 million tonnes. The increasingly critical importance of nitrogen is highlighted by the projections made of nitrogen consumption in the world in coming years by the Food and Agriculture Organisation, which indicates that the rates of annual increase is likely to be more than 6 per cent. It is believed that the future of world's food supply is closely linked to the ability to expand the output of this compound. Consumption in India has increased from few thousand tonnes some few years back to more than 2 million tonnes and the rate of increase has to be much more than the global level to ensure increase in agricultural production to meet the rising needs of the country.

Nitrogen is available in plenty in atmosphere and still there is dearth of it in soil. It is a good example of starvation amidst plenty. Every acre of earth's surface carries over it thousands of tonnes of nitrogen although the quantity in soil in an available form is small and varying from place to place. In nature, the cycle of nitrogen supply and use is well balanced. Due to the disturbance caused to the balance by man in his quest for increasing agricultural production the need for making nitrogen available artificially was felt and the process of combining nitrogen and hydrogen under heavy pressure and high temperature was evolved. The supply of nitrogen is being augmented through this process all over the world. The attempts to increase the supply through the activity of microbes although going on for a long time, have been intensified in recent years with hopeful results.

Although the use of various materials that supply this important nutrient element as manures and fertilisers is in vogue in the country for a long time, chemical fertilisers however, have been introduced to farmers on a large scale, only in recent years. Though there has been good progress in quantitative terms in the use of fertilisers, especially those which supply nitrogen, much remains to be done in the matter of improving fertiliser use efficiency.

In this publication, a critical appraisal of the work done on the several aspects of nitrogen in soils and crops in the State in the past over 40 years has been attempted. The data on the role of nitrogen in plant growth, nitrogen use efficiency in relation to source of nitrogen, biological transformations affecting nitrogen utilisation by crops, balanced nutrient supply, effects of heavy doses of nitrogen on soil and crops and similar work done in the various research stations located in the different agro-climatic conditions of the State has been critically discussed so as to project generalised thinking on aspects of practical significance. The senior author himself was involved in work on the several items of work reported. It is hoped that the material presented in the bulletin will be useful to those working in this important area of research.

H R ARAKERI

Vice-chancellor

CONTENTS

Introduction	1
Geographic features and agro-climatic conditions of Karnataka	10
Soils of Karnataka	12
Fertility status of soils of Karnataka	16
History of soil fertility and fertilizer use in Karnataka	18
Effect of nitrogen on the growth of field crops	22
Nitrogen Transformations	35
Rhizobial inoculations of legumes	44
Balanced supply of nutrients to crops	49
Effect of heavy doses of nitrogen on soil and crops	52
Effect of herbicides on the uptake of minerals	64
Effect of complex fertilisers on crops	66
Methods of application of nitrogen	68
Foliar application of nitrogen	75
Slow release nitrogenous fertilisers	85
Safe limit of biuret content in urea for crops	92
Effect of nitrogen on the quality of crops	96
Nitrates in seepage water and plants	97
Variety fertiliser interactions to assess the yield potential	98
Investigations under dryland farming	100
Fertiliser nitrogen under irrigation agriculture	103
Yield potential under resource constraints	109
Summary and projections	111
References	115

INTRODUCTION

NITROGEN is a major limiting factor in crop production world over. The consumption of nitrogen through chemical fertilisers is increasing year by year to meet the growing demands of intensive crop production. Increased irrigation facilities and introduction of fertiliser-responsive hybrid and high yielding varieties of crops have accelerated this demand. Crop yields under adequate moisture regime are largely determined by the supply of nitrogen than any other element.

Nitrogen is present in the atmosphere as elemental nitrogen constituting about 75 per cent by weight and 79 per cent by volume. Although it is abundant in nature, it exists as a free, inert gas—a form of no significance either to life or industry. Despite its inert nature, it is an essential constituent of life on earth. In fact, nitrogen is useful to living beings only in combined form.

Plants require nitrogen in relatively large quantities for growth and reproduction. It is an essential constituent of all proteins, all enzymes and is involved in synthesis, energy transfers and in the make up of genetic code.

Most of the nitrogen in soil, exists in organic combinations except for traces as a part of igneous rocks. It is considered as the most unpredictable nutrient element. It is subject to biological fixation by the activity of micro-organisms, biological mineralisation and immobilisation depending on the complex inter play of temperature, aeration, moisture, kind and amount of organic matter and losses through leaching and denitrification (Allison, 1965).

A fertile soil may contain as much as three tons of nitrogen per acre to plough depth while in the same area in atmosphere it is estimated to weigh about 35 000 tons in an uncombined state. However, the amount of nitrogen in soil in a situation is determined by the general influence of climate and the type of vegetation associated with it subject to modifying influences like, parent material, topography and man.

The nucleus of nitrogen atom has seven protons and seven neutrons with an atomic weight of 14.008. It is difficult to cause dissociation with nitrogen as the bond strength of N^{14} is estimated to be 7.5 million electron volts. The nitrogen exists in two isotopic forms. N^{14} is abundant in nature (99.63 per cent of the total) and the other form N^{15} is quite rare (Sauchelli, 1964).

MECHANISMS OF NITROGEN ADDITIONS TO SOIL

The major sources of nitrogen additions to soil are through biological fixation and crop and animal residues. The nitrogen supply to crops in aerable lands is mainly through plant and animal residues. The decomposed organic matter in soils is relatively stable and resistant to losses through leaching, volatilisation and denitrification but is often subject to losses by soil erosion. This complex form of nitrogen is slowly but continuously transformed into ammonia and nitrate by the action of microorganisms. The accumulation of soil nitrogen as nitrate to an extent of 5 to 10 per cent may take place over a period of six months under fallow and in the absence of leaching losses under most favourable conditions (Allison and Sterling, 1940). On the contrary the loss of nitrogen from the soil by crop removal as in the case of maize under humid temperate condition is estimated to be about 2 to 3 per cent annually and half of this quantity would be removed by small grain cereals like sorghum (Woodruff, 1949). In general, the return of nitrogen to soil under good soil management practices, would come mainly from the portion of organic nitrogen removed by the soil in the crop. If these plant residues contain less than one per cent nitrogen it is very likely it remains tied up in organic form for a considerable period of time and may even cause immobilisation of any available nitrogen in the soil. In situations where the residues contain more than 2 per cent nitrogen, losses of ammonia to the atmosphere during the initial decomposition may take place. Unless the residues are incorporated into the soil, losses of ammonia with bulky manures would be considerable during handling and composting (Allison, 1963).

The amount of nitrogen added on to soil annually through atmospheric precipitation is estimated to be in the range of 4 to 7 kg per ha in the form of ammonia and nitrates (Stevenson, 1965).

Biological nitrogen fixation The fixation of inert gaseous atmospheric nitrogen by the activity of microorganisms is one of the greatest gifts of nature to mankind. The combining ability of this inert elemental nitrogen by microorganisms into a useful and assimilable combined form to plants is a marvelous feat of nature and a great service to mankind. Hosts of microorganisms fix atmospheric nitrogen by living in symbiosis with certain plants or non-symbiotically in soil, water or on vegetation.

Symbiotic nitrogen fixation The symbiotic relationship between members of the bacterial genus *Rhizobium* and leguminous plants is well known. In spite of the tremendous production of chemical nitrogenous fertilisers, legumes are still the major suppliers of fixed nitrogen to soils to sustain crop production. The quantity of elemental nitrogen fixed per ha annually by legumes ranges from a few kg to 300 kg or more (Henzell and Noriss, 1962). The Nitrogen mobilised in kg/ha per season by some of the leguminous crops is alfalfa, 50-350, clovers 50-200, peas, 30-140, groundnut, 88 and other legumes 10-550 (Spector, 1966). After the legume-hosts die, the fixed nitrogen becomes available to other plants by the normal process of mineralisation. Some of the important species belonging to *Rhizobium* are *R. meliloti*, *R. Leguminosae*, *R. phaseoli*, *R. Lupini*, *R. Japonicum* and *R. trifoli*.

Non-symbiotic nitrogen fixation There are several other free living (non symbiotic) nitrogen fixing bacteria such as *Rhodospirillum*, an aerobic saprophyte *Clostridium* and aerobic saprophyte, *Azotobacter*. All these free living bacteria are mainly dependent on readily available energy sources and thus their activities under natural conditions is restricted. The capacity for nitrogen fixation of these non-symbiotic bacteria is estimated to be in the range of 0.1 to 6 kg of nitrogen per ha per year (Jensen, 1960, Lipman and Conybear, 1936).

Blue-green algae The nitrogen-fixing blue-green algae are autotrophic and can synthesise all their requirements in the presence of sunlight as the main source of energy. But they are not recognised as important in mineral soils because of inadequate moisture in the soil surface layer or highly acidic conditions and lack of adequate sunlight except in the surface layer. But they thrive in rice fields and have

been reported to fix about 44 kg nitrogen per ha per year. They are also recognised to be important source in increasing fixed nitrogen in lakes (Dudgdale and Neess, 1961). In India, blue green algae is known to play an important role in nitrogen economy of rice fields. The ability of our paddy soils to produce successive rice crops on the same land year after year is believed to be due to nitrogen fixation by algae (De and Mandal, 1956). The important species of blue green algae isolated are *Nostoc-punctiforme*, *N-musconum*, *N paludosum*, *Anaba-cana variabilis* and *Anabacana fertilissima*.

The hypothesis on nitrogen fixation proposed by Dhar (1960, 1961) though controversial is interesting. According to him nitrogen fixation in soil is essentially a photochemical reaction with the organic matter as substrata. His contention has been that the organic matter containing carbohydrates, cellulose, lignins and fats when added to soil undergo slow oxidation at the soil surface resulting in liberation of energy. This energy of oxidation can fix atmospheric nitrogen and thus enrich the soil with nitrogen. The increase in the total soil nitrogen obtained by Dhar may be perhaps due to the activity of nitrogen fixing algae.

AMMONIUM FIXATION

Ammonium fixation by clays When a granule of ammonium fertiliser is added to moist soil, the dissociated ammonium ion gets absorbed on the clay surface. The magnitude of ammonium absorption by clay minerals is a function of surface area and the nature of the exchangeable cations. Montmorillonite and illite type of clays are known to fix ammonium on their surface as well as in their interlattice structure. This kind of fixation is regarded as purely physical one. There is also a chemical absorption of ammonia that takes place on hydrogen saturated clays. Here, the ammonium ions are split into ammonia and hydrogen ions. Ammonia on absorption on acid clays, becomes ammonium ion as a result of chemical reaction. The ammonium ions fixed in the lattice and as well as on the clays surface are difficultly replaceable with other cations.

The fate of added fertilizer nitrogen to Indian soils was reviewed by Tandon (1974). He diagrammatically presented the dynamics of nitrogen

in a cropped soil (Fig 1) Several different reactions occur simultaneously in soil, the moment the fertilizer nitrogen is added to soil. The absorption and fixation of ammonium increases in relation to cation exchange capacity, clay content and water holding capacity (Sen, 1956). Fixation of ammonium in soil in a nonexchangeable form is not uncommon in our soils.

Fixation of ammonia by organic matter in non-exchangeable form The soil organic matter can also fix ammonia by chemical reaction (Mattson and Koutler, 1954, Anderson, 1956). This ammonium fixation involves an oxidation reaction which favours fixation under alkaline condition. There also exists a definite relationship between total nitrogen content and fixation of ammonia. Higher the nitrogen content, lesser will be the fixation of ammonia. Peat and muck soils can fix more nitrogen because of their higher state of oxidation of lignin compounds. The degree of ammonium fixation on lignin is a measure of its non-saturation with nitrogen (Nommik and Nelson, 1963). The exact nature of ammonia-lignin compounds is not known. Recent studies by Broadbent *et al* (1961) have shown that presence of oxygen is not necessary for ammonia fixation in soil. He demonstrated that polyphenolic compounds should undergo oxidation before ammonia fixation can occur. Functional groups like quinons produced by oxidation of polyphenols are believed to be responsible for ammonia fixation under anaerobic conditions. According to Janson (1960), ammonia is bound primarily to the phenolic and hydroxyl groups forming aminophenols. Since these compounds are unstable, they are converted to quinoneamines. These amino groups easily react with adjacent chains forming heterocyclic rings which offer resistance to treatments with strong acids and alkalies. It has been shown that higher the carbon content, greater is the fixation of ammonia in soil. One molecule of ammonia can fix 29 atoms of carbon under aerobic conditions and 45 atoms of the same in the absence of oxygen (Peech, 1948).

Chemistry of Soil Nitrogen Since most of the nitrogen in soil occurs in organic combinations any increase in the nitrogen content is closely associated with the accumulation of organic matter. The nitrogen content in soil tends to remain in equilibrium with "Soil forming" factors like climate, vegetation, nature of slope, physical

characteristics of soil, microflora and fauna in soil (Jenny, 1950) The soil nitrogen system is dynamic and any change in the system would alter the equilibrium and a new equilibrium sets in The soil nitrogen may vary from 0.01 per cent in light textured soils to 0.2 per cent in highly organic soils

Jenny, (1950) and Jenny and Raychaudhari, (1960), studying the relative importance of the "Soil forming" factors in determining the nitrogen content of soil rated them in general as climate ~ vegetation =- parent material > age Under a given climatic condition, keeping vegetation constant, the soil nitrogen content largely depends on the textural properties of soil The humic substances of organic mineral complexes serve to preserve soil nitrogen The heavy textured soils have higher nitrogen content than light textured soils Some constituents of organic matter in soil are quite resistant to oxidation by microorganisms and to removal by chemical extractants which suggest that the nitrogen present in soil is intimately associated with mineral matter

Numerous studies (Black 1957, Tisdale and Nelson, 1967) have shown that the nitrogen content is related to clay content Soils derived from basaltic rocks contain higher amounts of nitrogen than those derived from granitic material The soils formed from basalt are generally clay loams while those derived from granites are sandy or sandy loams The retention capacity of soils for nitrogen compounds is closely associated with the type of clay Montmorillonite clays are effective in protecting the absorbed nitrogen constituents against the attack of microorganisms Fine textured soils with high calcium content may often contain high organic matter and nitrogen than light textured soils, low in bases due to formation of calcium-humate-complexes which become less available to microorganisms Calcium coagulates humic substances and thus prevents dispersion (Cooke 1967, Stevenson, 1965)

Absorption and utilisation of nitrogen by plants Plants absorb nitrogen in the form of nitrates with the exception of rice which is known to absorb nitrogen in the ammoniacal form in early stages of growth The nitrogen so absorbed by plants is synthesised into protein through several intermediate steps The capacity of the plant to absorb

and store nitrogen during young stage is important since at fruiting stage the same is transported from vegetative part to grains. The ability and perhaps requirements of the plant to accumulate sufficient nitrogen during early stage of growth for subsequent translocation might be the possible cause in some instances for ineffectiveness of slow release nitrogenous fertilisers to some field and vegetable crops (Williams, 1955). Nitrogen when once absorbed by plants is protected against leaching and denitrification losses. The growing plant is thus a remarkable conservator of nitrogen.

TIME OF NITROGEN APPLICATION

In studies on time of application of nitrogen on nitrogen deficient soils, yields of grain are often greater when a portion of nitrogen is applied to plants when they have made half growth. The common belief is that the portion of nitrogen applied at a later stage is subject to less losses from leaching and denitrification and also contributing to higher grain straw ratio.

FOLIAR FEEDING OF NITROGEN

The nitrogen requirement of some crops can be met effectively and economically by spraying on the foliage with dilute solutions containing nitrogen. Among the chemicals used, urea has been found to be efficient because of its ability to penetrate rapidly into leaves. Nearly half of the urea applied through foliar spray could penetrate within one to six hours. Foliar feeding of crops is successful when fertilisation through soil becomes ineffective or inadequate. There is a practice of applying nitrogen along with micronutrients like iron and zinc in the form of foliar sprays at frequent intervals to pineapples in Hawaii (Stevenson, 1965). Likewise nitrogen, phosphorus, potassium and micronutrients are suitably combined and are sprayed on the foliage. But the amount of nitrogen applied is often in the range of 10 to 20 kg per ha per application. Foliar feeding of crop with nitrogen is considered as a supplement to the supply of native or added soil nitrogen (Witter *et al*, 1963).

The foliar feeding has not been found more efficient than soil application and the high requirement of nitrogen to crops and low tolerance of foliage to nitrogen demand many spray operations which

often become uneconomical. Absorption of urea, ammonium and nitrate by leaves take place both by active and passive processes similar to the absorption by roots. Urea enters the leaf very rapidly in un-ionised form. Transportation of these materials is first through phloem. Urea after hydrolysis into ammonia and nitrate in plants will go through the same metabolic pathways as nitrogen absorbed through roots. Absorption of urea is found more rapid during night due to favourable conditions of humidity. Foliar application of nitrogen, except for specific crops and under special situations, has not shown a spectacular success as obtained in case of foliar application of micronutrients which often get fixed up when applied to soils.

EFFECT OF NITROGEN ON PLANTS

As indicated earlier, nitrogen is essential to plants for growth and reproduction. The deficiency of this element manifests in many visible symptoms in the morphological make up of plants. Among such effects are pale green colour - an indicator of lack of chlorophyll, stunted growth of the top resulting in reduced cell division and cell enlargement as a consequence of inadequate protein synthesis, delayed maturity in some species, lack of tillering in cereals, a more acute angle between stem and leaf and premature death of lower leaves (Hewitt, 1963).

The effects of excessive nitrogen, though less obvious than those of deficiency, include excessive vegetative growth resulting in self competition for light, lodging in cereals, failure of development of colour in fruits and delayed flowering in some species.

The effects of excessive nitrogen on lodging in small cereal grains and breakage in maize stems are agronomically important. Lodging has been associated with excessive supply of nitrogen and becomes acute in situations of thick stand of crop. According to Welton and Moriss (1931), lodging was attributed to low dry matter content per unit length of plant induced by thick stand of crop. In case of maize, rootrot disease and damage caused by maize stem borer are contributory factors for lodging. In general, lodging effects are attributed to heavier ears, taller plants and greater ear heights which increase the momentum of wind force.

Optimum supply of nitrogen to crops often hastens maturity. Staying of leaves green for a longer time has been interpreted to be a sign of delay in maturity. According to Black (1957), maturity of grain crops involves two phases: 1) the rate of development of inflorescence and filling of the grains and 2) the dehydration of grains. Nitrogen deficiency may retard the inflorescence in small grains and grain filling in maize. On the contrary, excess of nitrogen may delay the dehydration phase of grains.

NITRATE ACCUMULATION IN PLANTS

Nitrogen in the form of nitrates accumulates in plants only when total nitrogen content becomes very high. Griffith (1960) demonstrated the accumulation of nitrates in forage crops fertilised with high doses of ammonium sulphate and cut for silage. The crude protein content of such crops exceeded 18 per cent (2.85 per cent N). Grasses with more than 21 per cent crude protein may be expected to contain excess of nitrates. When such crops are silaged, denitrification starts with the resultant release of gases like NO (colourless), NO₂ (brown) and N₂O₄ (yellow) which are heavier than air and are deadly poisonous to man and animals (Paterson *et al* 1958).

Stems and leaves of quite a few field and leafy vegetable crops contain more nitrates when grown under conditions of excess of nitrogen fertilisation. Consumption of such materials in raw condition may cause serious stomach disorders resulting in death. The nitrates are absorbed into the blood stream where they oxidise oxyhaemoglobin to methanoglobin which loses its capacity to carry oxygen into the system. This hazard is commonly called as nitrate cyanosis or methanoglobinemia disease in man and livestock. The poisoning effects of nitrates in drainage waters that contaminate well waters are causing great concern to public health. According to U.S. Public Health Association's standard, drinking water containing more than 45 ppm nitrate or 10 ppm nitrogen is considered to be unsafe for drinking purpose (McKee and Wolf 1963, Taras, 1972).

GEOGRAPHIC FEATURES AND AGROCLIMATIC CONDITIONS OF KARNATAKA

GEOGRAPHICALLY the State of Karnataka forms the South-Western part of Deccan peninsula lying between 11 5° and 16 5° N latitude and 74 2° and 78 4° E longitude with an area of 1 93 890 square kilometers. The State has a coast line of about 322 kilometers. Politically, the State is divided into 19 districts.

The whole of Karnataka State is a plateau with an altitude ranging from sea level along the Western Coast to 1 524 m in the Western Ghats and tapering off to east having an elevation of 304 m in the plains along the river valleys. All the rivers originate in the Western mountainous ranges parallel to the coast and flow west or east. The high hills are covered with dense evergreen forests.

Agro-climatically the State can be broadly divided into four regions primarily based on rainfall and associated factors. The first is the coastal region, along the Western Coast with a rainfall of over 2500 mm, the second is the hilly region including the Western Ghats running from north to south parallel to the sea coast with a rainfall range of 1,300 to 2,500 mm with points of heavy rainfall as high as 8,750 mm, the third is the transition zone, which is a narrow strip along the eastern slope of the hilly regions with reasonably assured rainfall, and lastly, the dry region in the north, central and south-eastern parts of Karnataka State (Fig 2 and 3, and Table 1)

Dry regions of Karnataka consists of the vast areas in the north of the State comprising districts of Bijapur, Gulbarga, Bellary and Raichur, eastern parts of Dharwar, Belgaum and north-eastern portion of Chitradurga with a rainfall of 635 mm. The rabi cropping programme is common in these parts.

Central belt comprises eastern part of Chickmagalur and Hassan districts, parts of Tumkur and southern portions of Chitradurga almost the whole of Mandya and the eastern portions of Kolar with an average

rainfall between 508 and 635 mm. At places in extreme eastern taluks of Kolar, the rainfall would be as low as 381–508 mm.

TABLE 1
Area under different rainfall zones of Karnataka State
(Total area of State 18 103 million ha)

Rainfall zone (mm)	Region	Geographic area (m ha)	Mean annual rainfall in (mm)
600	Dry farming zone	4 823 (25.51%)	508
600–800	Dry farming zone	7 839 (45.6%)	711
800–1,000	Transition tract	2 307 (12.2%)	914
1,000–2,000	Malnad tract	1 002 (5.3%)	1524
2,000–3 000	Mountainous region	0 851 (4.3%)	2540
3,000–4,000	Coastal region	1 08 (5.7%)	3556
4,000	Coastal region	0 202 (1.2%)	4064

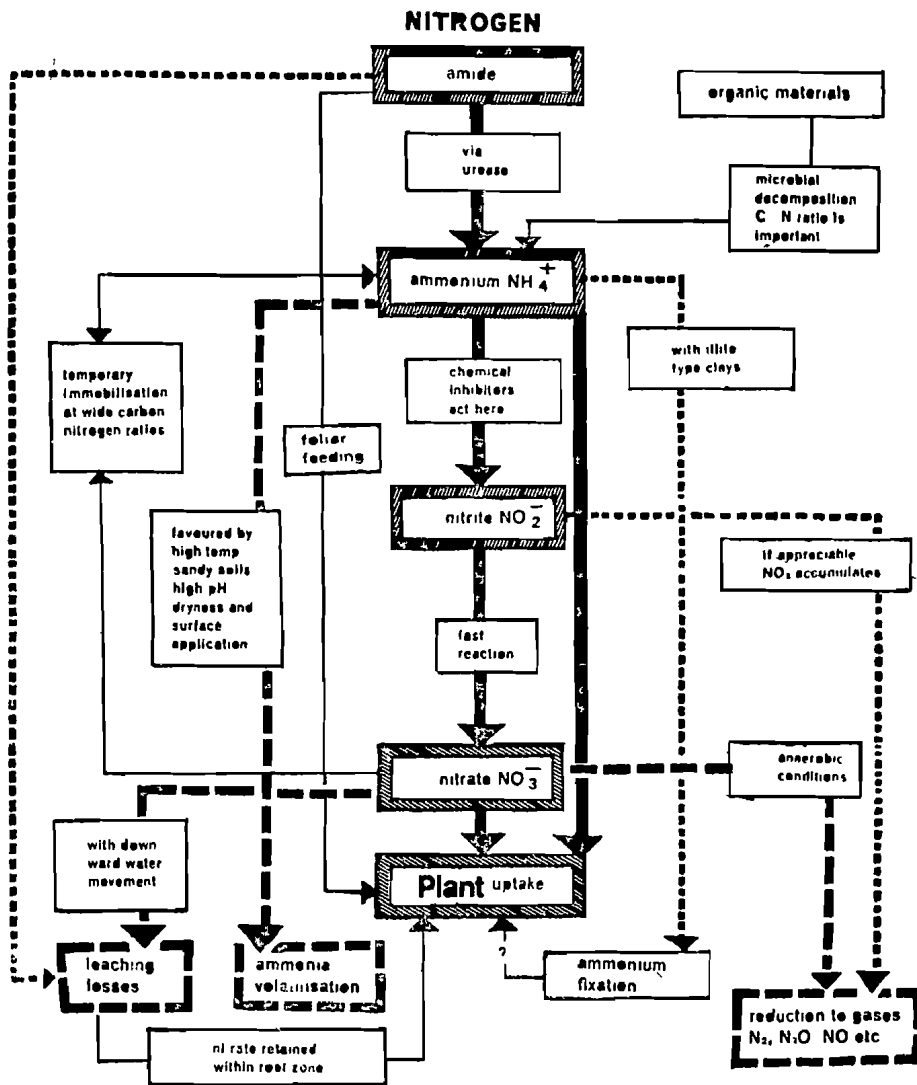
Southern region consists of parts of Kolar, Bangalore, South Western portions of Tumkur and north-western portions of Mandya. The rainfall here is of the order of 637 to 732 mm. Though the rainfall is slightly higher, because of the low water holding capacities of the soils, the problem is equally severe as in the northern districts. This is the belt which receives meagre rainfall for successful crop production and the problem of increasing the water resources for agriculture is of primary importance.

SOILS OF KARNATAKA

THE soils of the State are as diverse as the agroclimatic pattern discussed earlier and in such a context the agriculture on nearly 9 million ha out of a net area of 10.04 million ha has to depend on the vagaries of monsoon (Naik *et al* 1971)

Naturally the crops grown in the State are equally varied. They consist of the common food crops like rice, ragi and jowar, commercial crops like cotton, sugarcane, chillies and groundnut, plantation crops like coffee, arecanut and coconut and spices like cardamon and pepper.

Soils are found to vary due to the combined effect of climate and associated vegetation on the geological parent material. Sirur describing the soils of the State (1958) identified seven broad soil groups. They are (i) the base saturated trap soils derived mainly from Deccan trap and occupying large areas in Belgaum, Bijapur, Gulbarga and Bidar Districts, being light in colour on sloping lands and dark and deep in low land areas. (ii) Mixed red and black soils occur side by side in the districts of Belgaum, Bijapur, Dharwar, Raichur and Bellary. These soils are derived either from gneisses and schists of Dharwar series of rocks, and also from sedimentary rock formations known as Cuddapah and Vindhya series which include sand-stones, shales, lime-stones and other altered products. (iii) Red soils derived from acidic granites showing no regular variation in depth are light in texture varying from sandy to gravelly, lying in Kolar, Bangalore, Tumkur, Mandya, Mysore and parts of Hassan, Chickmagalur, Shimoga and Chitradurga Districts. (iv) Deep black soils are characterised by great depth, deep dark colour and high clay contents. They are derived from a variety of parent materials such as trap, gneisses and schists and sedimentary rocks and often appear to be of mixed origin. They are mostly transported soils and found in the river basins. They are known for high base saturation, moderate to high alkaline reaction and show accumulation of lime and soluble salts in lower layers. (v) Red loams occur in a long narrow strips in the districts of Shimoga, Chickmagalur, Hassan and Coorg. They occur in valley portion adjacent to the foot-



DYNAMICS OF FERTILISER NITROGEN IN SOILS

Plant use
 SOURCE FERT NEWS
 FIG 1

Losses

SOIL MAP OF KARNATAKA STATE

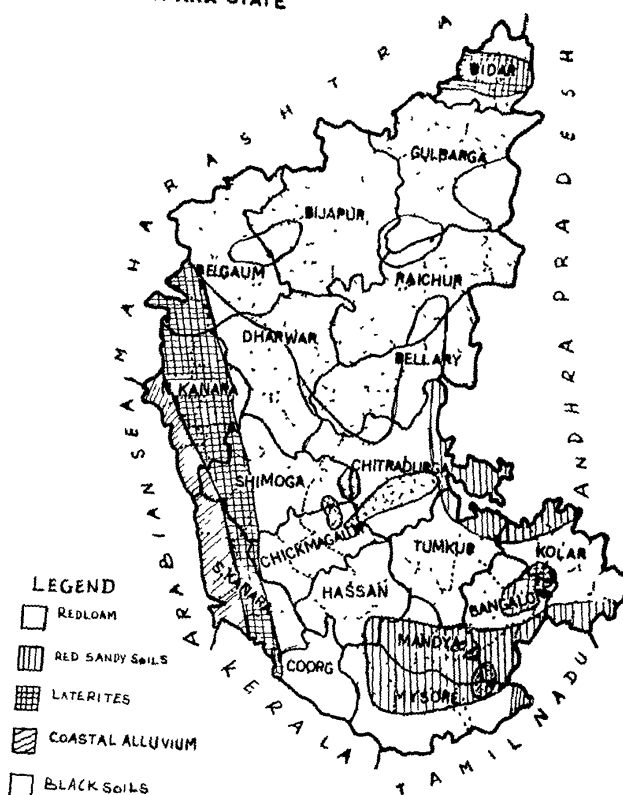


FIG-2...

AGROCLIMATIC REGIONS OF KARNATAKA STATE



FIG 3

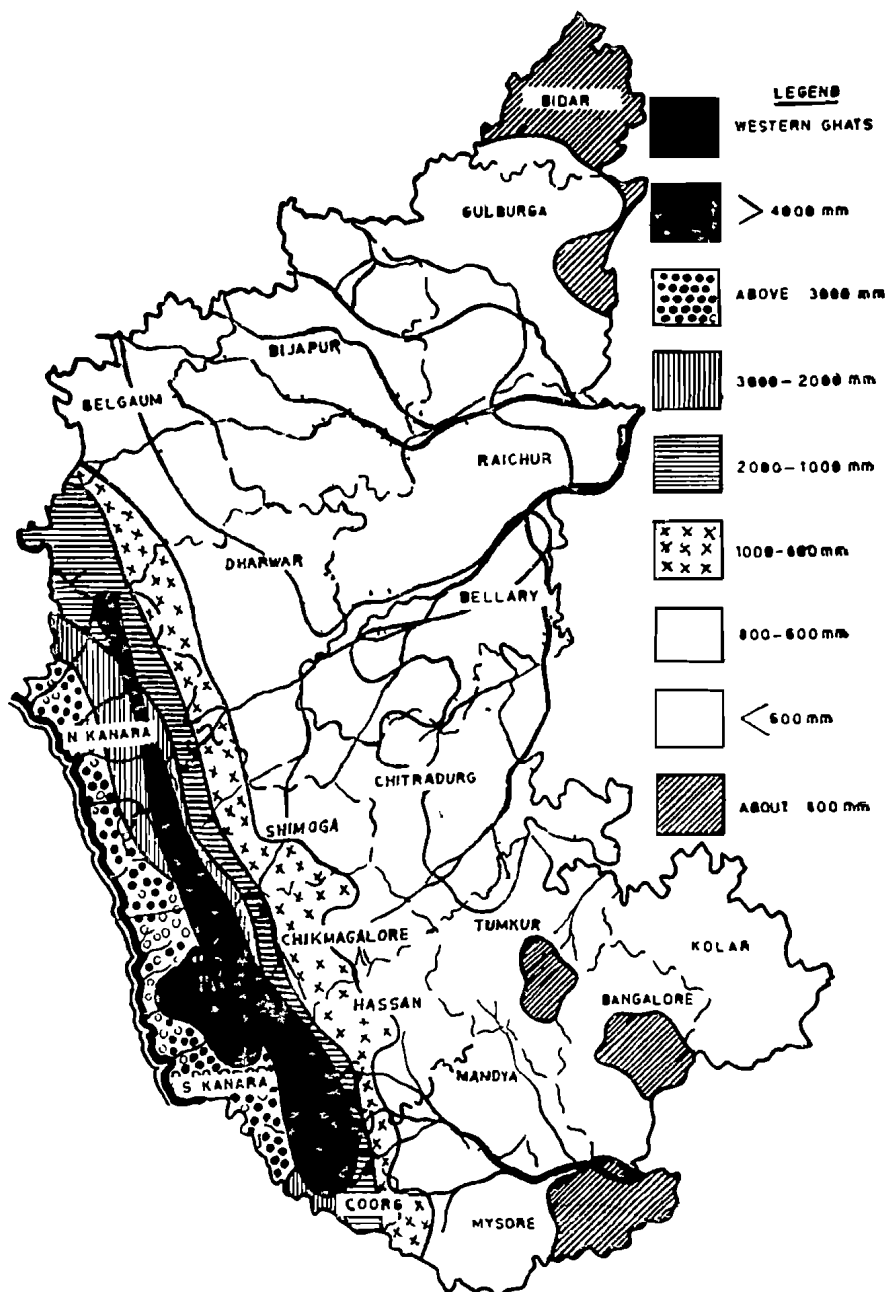


FIG. 4
RAINFALL PATTERN OF KARNATAKA

hills of Western Ghats supporting plantation crops (vi) Laterites and Lateritic soils are derived from laterite found in high rainfall regions of North and South Kanara, Belgaum, Western parts of Shimoga, Chickmagalur, Hassan and Coorg Districts. They are highly leached show low base saturation and are acidic in reaction and (vii) Dark brown soils occurs in a small area in the eastern parts of Coorg district and contiguous with similar dark coloured soil in the South Western parts of Mysore District which forms a forest belt. Venkata Rao (1968) broadly classified the soils into three groups, viz, (i) Red soils including red loams, red sandy soils and coastal red sandy alluvial soils, (ii) Black soils and (iii) Laterites and lateritic soils. The classification was based partly, on the specific soil surveys carried out in different areas of the State and partly on the experience and information gained in the course of agricultural extension activities (Fig 2). He presented a soil map showing regions of red loam, red sandy loam, laterites, coastal alluvium and black soils along with description of typical profiles including their physicochemical properties. The physical and chemical properties of some soils are presented in Table 2.

TABLE 2

Physical and chemical properties of some soils of Agricultural Stations of Karnataka

PHYSICAL					CHEMICAL						
Depth of soil (cm)	Texture	Max Water Holding capacity %	Bulk density g/cc	Available moisture %	pH	E C mmhos /cm	CEC -me per 100g -	Exch Ca+Mg	Total N %	Org C %	Available P ₂ O ₅ , K ₂ O -kg/ha-
Raichur (Black soil)											
0-15	Silty clay loam	45.2	1.32	15.4	8.2	0.2	51.0	48.0	0.028	0.34	12.1 33 600
15-30	Clay loam	49.3	1.31	19.3	8.3	0.2	48.0	44.0	0.020	0.27	11.5 16 674
Dharwar (Black soil)											
0-15	Clay loam	54.8	1.30	16.4	7.8	0.2	38.0	36.0	0.027	0.38	14.7 22 660
15-30	Clay loam	54.3	1.31	15.5	7.9	0.2	40.0	38.0	0.018	0.21	11.6 14 572
Hagari (Black soil)											
0-15	Clay loam	57.5	1.32	18.7	9.1	0.38	43.0	40.0	0.030	0.36	12.0 26 582
15-30	Clay loam	54.2	1.34	42.2	9.2	0.30	55.4	49.0	0.017	0.21	12.3 14 496
G K V K Bangalore (Red soil)											
0-15	Sandy clay loam	39.3	1.45	7.1	5.1	0.20	5.5	4.0	0.030	0.62	15.5 30 474
15-30	Sandy loam	37.3	1.40	6.5	5.2	0.20	7.4	6.1	0.024	0.28	11.6 13 372
Annigeri (Black soil)											
0-15	Clay loam	57.0	1.31	16.8	8.5	0.20	56.6	50.0	0.041	0.48	11.7 30 590
15-30	Clay loam	53.7	1.32	15.9	8.6	0.22	52.0	46.0	0.018	0.21	11.6 15 600

TABLE 2 (Continued)

[illegible]

FERTILITY STATUS OF SOILS OF KARNATAKA

BASED on soil test values from the State Soil Testing Laboratories Dathu Rao (1971) compiled the data on fertility status of soils in different agro-climatic regions in the State particularly of nitrogen, under irrigated and non-irrigated soils (Fig 5 & 6)

Coastal region As stated earlier, the region includes high mountains on one side and sea coast on the other and is covered with thick vegetation arising out of high rainfall. The soils consist of alluvium in low lying area and gravelly material in high upland area. The soils are acidic, high in nitrogen and mostly low in P and K.

Hilly region Soils are lateritic all over the region. They are acidic to normal in pH, normal in total salts, medium to high in nitrogen, low in P and low to medium in K. Due to high nitrogen content, soils respond well to P and K applications.

Transition North It lies to the east of hilly region towards the eastern plain where the rainfall goes on decreasing. The mean annual rainfall ranges between 635 and 1524 mm. The soils are reddish to medium black and nearly neutral in pH and medium in total salts, medium to high in nitrogen and low to medium in P and K.

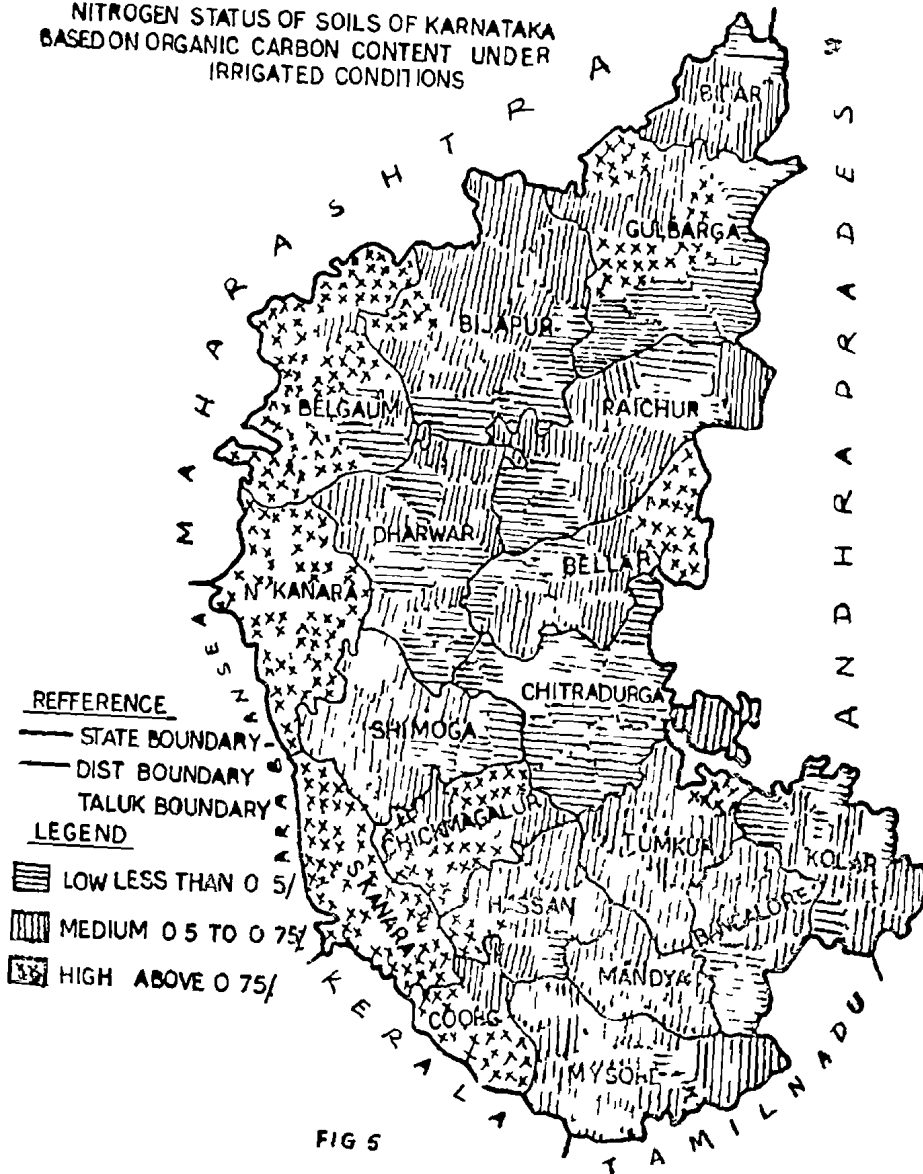
Transition South The characteristics are similar to those of transition North but it lies on the Southern side of the State. Soils are sandy, usually neutral in reaction and normal in total soluble salts, medium in nitrogen, low in phosphorus and medium in potassium.

Transition North-East Soils are lateritic and neutral to acidic in reaction, normal in total salts, low to medium in nitrogen and phosphorus and medium in potash.

Dry North region It comprises of vast area lying between transition north-east and transition north with a rainfall of 508 mm and consists mostly of deep black cotton soils with occasional patches of

KARNATAKA STATE

NITROGEN STATUS OF SOILS OF KARNATAKA
BASED ON ORGANIC CARBON CONTENT UNDER
IRRIGATED CONDITIONS



KARNATAKA STATE

NITROGEN STATUS OF SOILS OF KARNATAKA
BASED ON ORGANIC CARBON CONTENT UNDER
RAINFED CONDITIONS

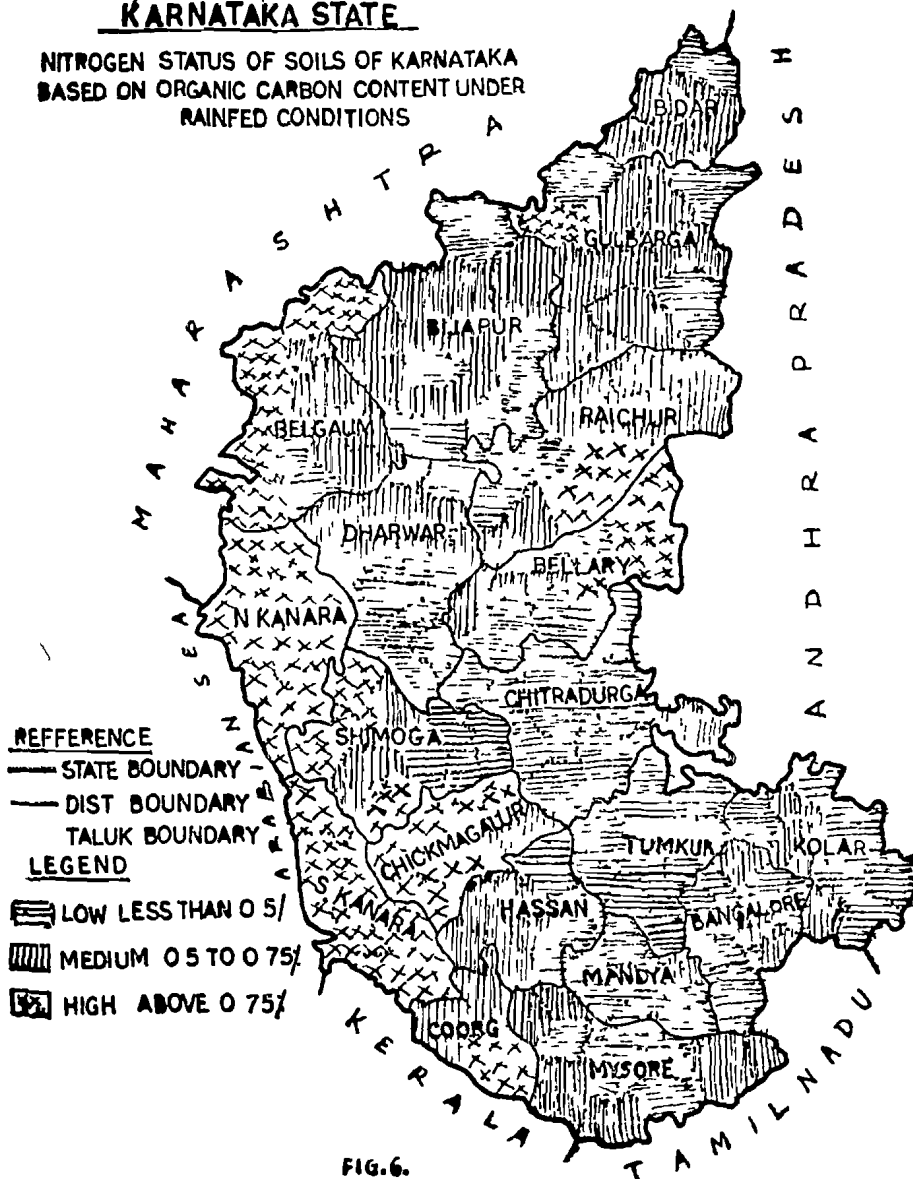


FIG.6.

sandy soils. They are alkaline in reaction, normal to excess in soluble salt content, low to medium in nitrogen, low in phosphorus and medium in potash.

Dry Central Region This tract lies to the east of the transition south and receives a rainfall in the range of 381–508 mm. The soils are sandy to loamy with poor retentive capacity. They are neutral to alkaline in reaction, normal in total soluble salts, medium in nitrogen, low in phosphorus but medium in potash.

Dry South Eastern Region It is a plateau receiving a rainfall of about 750 mm. Soils are mostly red loams with fairly good moisture retentive capacity. Soils are neutral in reaction, normal in soluble salts, medium in nitrogen but low in phosphorus and potash.

Kulkarni *et al* (1970) studied the fertility status of surface soils of Malnad tract which receives annual rainfall of 2000 to 5000 mm with a temperature range of 10–30° C and found that the soils from Mudigere and Chickmagalur are distinctly acidic in nature, rich in organic matter but low in available phosphorus and potassium.

HISTORY OF SOIL FERTILITY AND FERTILISER USE IN KARNATAKA

With increasing understanding of the soils situated in different agro-climatic conditions in the State, the need for improving the fertility status of soils to a level that would make it economically productive was felt. As far back as 1940's (Narayanan, 1944) pointed out that the productive efficiency of the lands was just under 50 per cent. This low fertility was attributed not to any inherent defect in the soils, but to a continued state of under-nourishment and often no nourishment combined with indifferent cultivation. Karnataka State can claim to be in forefront with a long period of activity in the study of soil-crop response dating back to 1899. Dr. Lehmann laid down the fundamental lines on which work on several problems concerned with soils and crops should be conducted and the manner in which the results should be conveyed to the farmers. He and his associates carried out comprehensive investigations using potculture and field experiments on both wet and dry lands on manurial requirements of several crops including important commercial crops such as coffee and sugarcane. Among the more notable and fundamental contribution was the investigations on 'Red soils and their manurial requirements' (Narasimha Iyengar, 1944). He demonstrated through his experiments on farmer's fields the necessity of both nitrogenous and phosphatic fertilisers in increasing the yields of ragi and paddy. The yield was found to have been trebled during the first year of manuring. From his experiments, he concluded that even with small quantities of N and P fertilisers with sustained and long continued application, it was possible to substantially increase the crop yields and build up soil fertility. He did not find any response to application of potash.

TESTING SOILS FOR NITROGEN

Crops suffer more often for want of nitrogen than any other nutrient. But there is not a single universally accepted method for testing available soil nitrogen. The validity of a method for determining the nitrogen status of soils should normally be based on the correlation of soil test with nitrogen and the nitrogen uptake by plants or yield.

response to nitrogen under green house or field conditions (Dahnke and Vasey, 1973) Indices of availability of nitrogen or the measure of the potentiality of soil to supply nitrogen to crops In the laboratory nitrogen availability in soil is determined by three methods viz , organic carbon, alkaline potassium permanganate and ammoniacal nitrogen, as advocated by the All India Co-ordinated Scheme on Correlation for Soil Test and Crop Responses Based on the results of these experiments conducted on black soil of Siruguppa and on red soils at Hebbal, organic carbon method was found to be correlated with crop responses while under laboratory studies, alkaline permanganate method appeared to be promising (Anon 1973) Based on potculture studies on rice (MR-136 variety) grown on 19 bulk soils of Bangalore district treated with four levels of nitrogen viz , 0 100,200 and 400 kg N per ha during *Kharif* 1973, critical levels of soil test values were evaluated by Cate and Nelson method (1968) (Table 3)

TABLE 3
Critical levels of organic carbon and percentage yields of rice grown on some soils of Bangalore District (Cate and Nelson method)

Soil test methods	Critical levels	Percentage yield	Predictability percentage
Organic carbon percentage vs percentage yield	0.7	42.5	84.2
Alkaline KMnO ₄ method vs percentage yield	142.5	42.5	94.4
NH ₄ -N vs percentage yield	180.0	50.0	100.0

The data (Table 3) show that crops did not respond to added nitrogen in soils whose soil test values were beyond the critical levels

The organic carbon and alkaline permanganate methods gave the same percentage yield (42.5) for nitrogen with critical soil test values of 0.7 and 442.5 respectively

TABLE 4

Correlation of percentage yield of rice with three methods of estimating available Nitrogen in the potculture studies

Method	"r" values	No of soils tested
Percentage yield vs organic carbon	0.159	19
Percentage yield vs alkaline permanganate method	0.349	19
Percentage yield vs ammoniacal nitrogen	0.768	16

The method of ammoniacal nitrogen for determining available nitrogen gave higher correlation co-efficient compared to other methods (Table 4). But during 1973 summer, this method gave surprisingly low correlation. Organic carbon had given consistently better correlation during the previous two years under field conditions.

The requirement of nutrients by crops and their contribution from the soil and the fertiliser was computed in order to work out the targeted yield as shown in Table 5.

TABLE 5

Nutrient requirement of crops and its contribution from the soil and fertiliser added

	Rice (IR-8) at Siruguppa			Rice (Jaya) at Hebbal		
	N	P ₂ O ₅	K ₂ O kg/ha	N	P ₂ O ₅	K ₂ O kg/ha
One quintal of grain required	1.85	0.154	2.60	1.51	0.31	1.58
Contribution from soil as percentage of available nutrient expressed in kg/ha	1.56	21.20	14.02	0.30	14.14	17.55
Contribution from fertiliser as percentage of the nutrient content of fertiliser	53.50	12.49	155.00	20.79	16.53	60.31

From the data (Table 5), it is apparent that the requirements of nutrients, their absorption and utilisation differed even in varieties of the same crop and also under similar soil conditions

EFFECT OF NITROGEN ON THE GROWTH OF CROPS

KRISHNA MURTHY *et al* (1972) studied the effects of fertiliser nitrogen on various stages of growth and yield of maize and jowar. Krishnamurthy, (1968) in his field studies observed the pattern of tillering in H 22 ragi (*Eleusine coraecana* Gaertn) by marking tillers arising at different times under different nitrogen levels and showed that the number of shoots and ears per plant were linearly related to the nitrogen applied.

The fertiliser requirements and the uptake of nutrient at different stages of growth of ragi were studied by Sadasivaiah and Ambadas Rao (1968). They found increases in the uptake of nitrogen by graded additions of nitrogen up to flowering stage after which it dropped. Nearly 80 per cent of nitrogen was absorbed from the tillering to flowering stage and the uptake was not associated with the seasonal conditions.

Before the advent of commercial fertilisers, the practice was to add farm yard manure to field crops to supply nutrients as well as maintain proper physical conditions of soil. The influence of such manuring on the root system under limited moisture conditions at the Research Station, Hagari was reported by Gopalakrishna Rao *et al* (1975).

TABLE 6
*Effect of different levels of FYM on development of roots of Jowar at the
Agricultural Research Station, Hagari (1938-1941)*
(Average of 3 seasons—length in cm)

Criteria	Farm Yard Manure (kg/ha)					
	3000		6000		9000	
	Root Number	Root Length	Root Number	Root Length	Root Number	Root Length
Primary roots	11	29.8	1	56.6	1	60.3
Secondary roots	146	327.8	358	880.0	391	991.0
Tertiary roots	467	540.0	912	995.0	1136	1072.0
Quaternary roots and roots of higher order	647	375.0	707	390.0	725	383.0

The observations were taken when the crops were 75 and 85 days old in all three seasons. The increase was manifested by roots of all orders, but particularly marked in the fine rootlets of the fourth order that constitute the real absorbing portion of the whole root system. It was noted (Table 6) that the root development was in proportion to the dose of manure applied and the differences between the effect of these doses were more marked as the plants grew older. The dose of 9,000 kg/ha of FYM was found better for development of roots than 6 000 kg FYM per ha.

Panchal *et al* (1972) studied the influence of fertiliser nitrogen on the growth and distribution of roots in two jowar varieties viz, CSH-1 and Swarna under irrigated conditions in black soils of Siruguppa with four levels of nitrogen viz, 0, 60, 120 and 180 kg/ha. A basal dressing of 60 kg P_2O_5 and 30 K_2O per ha was applied. It was observed that the density of roots in the initial stage of growth was more in surface layer up to 15 cm. But in CSH-1 variety, the growth of roots was more in lower depth on 90th day. The total dry weight of roots increased with increasing levels of nitrogen in both genotypes on the 45th and 90th day, but with no significant differences in root growth between them. The shoot/root ratio (S/R) was higher for CSH-1 than for Swarna but it increased with increase in nitrogen level in case of CSH-1 (Table 7) which showed greater efficiency of roots in promoting development of shoots because of the fact that the CSH-1 variety used metabolic sinks more towards the development of shoots.

TABLE 7

Shoot-root ratio at 90 days after planting, weight of earhead and grains per earhead in two genotypes of jowar

Treatment (kg/ha)	Shoot g	Root g	S/R	Earhead g	Grain g
<i>CSH-1 Jowar</i>					
0	177.00	15.72	11.21	57.00	48.00
60	285.00	23.45	12.15	88.00	65.82
120	375.00	20.40	13.20	127.00	104.20
<i>Swarna Jowar</i>					
0	239.50	20.02	10.80	60.50	45.80
60	303.50	28.11	10.80	84.50	60.92
120	373.00	36.99	10.80	106.00	84.81
180	438.50	42.36	10.30	124.50	93.40

In CSH-1, ear weight and grain weight per ear also showed an increase with increased doses of nitrogen upto 20 kg N/ha which was almost the same (375 g in CSH-1 and 373 g in Swarna). The study indicated the greater ability of hybrid CSH-1 to accumulate dry matter in grains which may be primarily due to efficient root system developed as a result of nitrogen fertilisation. Krishnamurthy *et al* (1972) reported the pattern of response of ragi and jowar to nitrogen application. Based on ten trials on ragi in which nitrogen levels varied from 0 to 80 kg/ha. It was observed that the pattern of response to different levels of nitrogen remained almost the same. The response in the initial stage was high and at higher levels, the rate of increase in yield diminished. Linear trend was noticed up to 60 kg N/ha, and afterwards the response pattern was quadratic in nature. The response equation up to 60 kg N/ha was given by $Y = 4.0x - 0.0022x^2$ where Y is the yield of ragi in kg/ha and x is the amount of N added (kg/ha) and the quadratic equation at 20 kg standard dose was given by $Y = 14.46x - 0.0025x^2$.

The response pattern of jowar was studied based on four trials at experimental farms at Kaladagi and Saundathi. At Kaladagi, Fulgar-white variety of jowar was grown while M-35-1 was grown at Saundathi. Nitrogen levels varied from 0, 10, 20 and 30 kg/ha and FYM was applied at 0 and 5,000 kg/ha. The response equation indicated a high rate of increase in yield up to 30 kg N/ha and the response equation in the quadratic form was $Y = 13.05x + 0.105x^2$.

Based on three trials conducted at Dharwar on Nandyal variety of jowar, the response function was fitted for nitrogen application with an equation $Y = 57.62x - 1.044x^2$ (Krishnamurthy *et al*, 1972).

EFFICIENCY OF ORGANIC AND INORGANIC FORMS OF NITROGEN

The role of organic matter in the maintenance of soil fertility is well recognised and the application of green manures to many crops as a basal dose is a common practice. Results have shown that the responses of crops to green manures are practically similar to dose of ammonium sulphate and other nitrogenous fertilisers (Sethi *et al* 1952). A study was conducted at the Agricultural Research Station,

Nagenahalli for four seasons from 1954 onwards to ascertain the effects of green manure at higher doses over the recommended basal dressing of 3,000 kg/ha. The sandy loam soils of the station is acidic in reaction with low bases and has been under intensive cultivation since 1910's. The levels of green leaf manure applied were 3,000, 6,000, 9,000, 12,000 and 15,000 kg/ha over a basal dressing of 30 kg N/ha as ammonium sulphate applied in two equal doses, half at planting and the remaining at first weeding. Superphosphate at 20 kg P_2O_5 per ha was applied before planting. The results showed that rice yield was highest at 6,000 kg G M per ha and subsequently decreased at 9,000 kg level. There were no perceptible changes in the chemical composition of soil in regard to pH, organic carbon, C/N ratio and available phosphorus content. The plausible explanation offered for such a phenomenon was that the contribution of organic matter to soil was negligible as the green manures contained mostly succulent and easily decomposable plant tissues (Venkata Rao and Sirur, 1959).

The efficiency of different organic and inorganic manures was tested with rice on light textured soils of Tungabhadra Project Area (Ambadas Rao, 1972). Green manure (*Alvricidia*) FYM groundnut cake and ammonium sulphate were added at the rate of 50 kg N/ha with and without P_2O_5 at 25 kg per ha in the form of superphosphate. The study revealed that green manure and groundnut cake compared favourably with ammonium sulphate (Table 8) in increasing the rice yield on equal nitrogen basis.

TABLE 8
Extra yield of rice obtained for each kilogram of nitrogen added through different sources of nitrogen

Source of nitrogen	Additional yield of rice in kg for every kg of N added
Green manure	32
Ammonium sulphate	32
Groundnut cake	27
Farm yard manure	10

No cumulative effect of these manures was noticed on rice yield even after continuous application for six years. During the second

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post-war period, there was considerable shortage of fertilisers and bonemeal was freely recommended for use as a source of phosphorus to rice sugarcane and other field crops. Studies were conducted to ascertain the effect of bonemeal as an organic source of phosphorus with groundnut cake as a source of nitrogen on sugarcane at Hebbal, Babbur and V C Farms during 1946-47. The levels of nitrogen included were 200 kg N as groundnut cake + 100 kg N as ammonium sulphate with a common basal dressing of green manure at 3000 kg/ha. Three tons of compost were applied before planting of sugarcane. The indications were that the maximum yields in all treatments were obtained at Hebbal followed by V C farm and the lowest yields at Babbur but there were no significant differences between the treatments. The efficiency of nitrogen was more in conjunction with bonemeal rather than with superphosphate (Venkata Rao and Bhimsena Rao, 1960).

The effect of nitrogen in different inorganic and organic forms alone and in combinations with phosphorus and potash was studied at Hebbal on ragi under rainfed conditions during the period from 1927 to 1937. The results (Table 9) indicated uniform yield increases of the order of 20 per cent both in respect of grain and straw to application of moderate applications of 20 kg N, 20 kg P_2O_5 and 30 kg K_2O per ha. Nitrogen in the form of chilean nitrate was found to be better than ammonium sulphate. There was also a definite indication of the necessity of application of phosphorus and potash along with nitrogen for satisfactory yield (Venkata Rao, 1964 Venkata Rao and Sirur 1959).

Large scale trials in cultivators fields (Venkata Rao and Srinivasamurthy 1972) showed that ragi and maize under rainfed conditions responded generously to moderate levels of N along with P and also they survived better with fertilisers than without them under conditions of moisture stress.

Studying the efficiency of different sources of green manures like dhaincha (*Sesbania esculata*) and phillipsara (*Phaseolus trilobus*) with and without phosphoric acid on the yield of wheat in black cotton soil of Tungabhadra Project Area as compared to ammonium sulphate, Ambadas Rao (1972 b) observed that though green manure crops were

grown *in situ* with phosphoric acid, they were inferior to ammonium sulphate at 40 kg N per ha. Though dhaincha (50 kg N/ha) and phillipsera (75 kg N/ha) added nitrogen to soil, the response of wheat was better with dhaincha than phillipsera. The poor response of wheat to these organic sources of nitrogen was ascribed to incomplete decomposition of these green manures and immobilisation of nitrogen added through them. The severe competition for nitrogen between crops and enhanced microflora necessary for decomposition of added green manure might be another reason for depletion in yield.

TABLE 9

Effect of fertiliser application on the yield of rainfed ragi grown on red soils of Hebbal (1927 to 1937)
(Average of 10 years)

Treatments	Yield (kg/ha)	
	Grain	Straw
No fertiliser	960	1 27
N as ammonium sulphate + P + K	1,126	1,550
P + K	1,013	1,182
N as ammonium sulphate + K	1 034	1,471
N as ammonium sulphate + P	1,049	1,520
N as chilean nitrate + P + K	1 171	1,527
N as groundnut cake + P + K	1,060	1,409
$\frac{1}{2}$ N as groundnut cake + $\frac{1}{2}$ N as chilean nitrate + P + K	1,137	1,508
$\frac{1}{2}$ N as cake + $\frac{1}{2}$ N as ammonium sulphate + P + K	1,000	1 398

PHOSPHORUS APPLICATION INCREASES EFFICIENCY OF NITROGEN UTILISATION BY CROPS

It is well known that the responses to added nitrogen are generally spectacular in nitrogen-deficient soils. However, under conditions of balanced supply of nitrogen and phosphorus, the utilisation of nitrogen and crop responses were better (Venkata Rao and Govindarajan, 1956, Venkata Rao and Badiger, 1975).

A study was conducted at Gandhi Krishi Vijnana Kendra, U A S Bangalore to find out the effect of phosphorus on the efficient use of added nitrogen, on phosphorous deficient soils with ragi-maize-cowpea grown successively in rotation during 1972-1973 (Upadhyaya *et al* 1975). The fertiliser was applied on the basis of soil test values so as to give 0, 50, 100 and 150 percent of the recommended doses of N, P and K, along with treatments with only N and N + P. The normal recommended dose of fertilisers was taken as 100 per cent level.

The results showed that the yields of grains of ragi, maize and cowpea increased with increase in the levels of plant nutrients added, the maximum yields being recorded when 150 per cent N, P and K were applied, followed by 100 per cent N, P and K (Table 10).

TABLE 10
Effect of fertilisers on the grain yield (q/ha) and uptake of nitrogen (kg/ha) by Ragi-Maize and Cowpea crops in rotation

Treatment	Sept-Dec 1972 Ragi		Jan-May 1973 Maize		June-Sept 1973 Cowpea	
	Grain Yield	Uptake of N	Grain Yield	Uptake of N	Grain Yield	Uptake of N
50% of normal dose of NPK	9.55	18.44	16.62	47.79	4.71	51.67
100% normal dose	13.17	28.45	17.60	50.56	5.72	54.44
150% normal dose	19.34	38.19	24.88	71.11	6.86	55.46
100% of normal dose of N + P	11.40	26.43	18.73	53.88	5.57	54.45
100% of normal dose of N alone	1.62	3.34	1.74	9.22	0.64	23.89

Normal fertiliser doses

Ragi 100% = 100-60-25 kg N, P_2O_5 and K_2O /ha respectively

Maize 100% = 120-60-30 kg N, P_2O_5 and K_2O /ha respectively

Cowpea 100% = 25-50-25 kg N, P_2O_5 and K_2O /ha respectively

The uptake of nitrogen was highest at 150 per cent NPK level with all crops followed by 100 per cent N+P level except with ragi. The yields and uptake of nitrogen were drastically reduced at 100 per cent

nitrogen level indicating the necessity for balanced additions of P and K. With the application of nitrogen along with phosphorus at 100 per cent level, the uptake of nitrogen was more than that of 100 per cent nitrogen alone. Thus the study clearly demonstrates the role of phosphorus in increasing the efficiency of added nitrogen by plants.

Studies conducted by Venkata Rao and Sadasiviah (1968 b) on the nitrogen mobilisation through phosphate manuring of leguminous crops was another example illustrating this point. With increasing additions of P_2O_5 ranging from 0 to 320 kg per ha the increase in yield of green matter over control was of the order of 50 per cent at 40 kg and 200 per cent at 320 kg. The nitrogen mobilisation which was at 118 per cent with no phosphate rose to 190 per cent at 40 kg P_2O_5 and reached the maximum of 240 per cent at 320 kg P_2O_5 . Considering the fact that this crop was incorporated into the soil as green manure and the applied phosphorus and nitrogen contained therein became available to the succeeding crop. The results clearly indicate the immense potentialities of exploitation of unlimited resources of atmospheric nitrogen for the benefit of crop production.

EFFECT OF DIFFERENT SOURCES OF NITROGENOUS FERTILISERS

Bulk of the fertiliser material on the market, supply nitrogen in either ammoniacal or nitrate form and some in the amide form. Also, various high analysis and complex fertilisers are being manufactured in order to reduce the cost as well as minimise or obviate the need for imported sulphur. Many attempts have been made to supply nitrogen at comparatively less price on equivalent basis. Venkata Rao and Govindarajan (1955) were the pioneers in the country in using anhydrous ammonia for field crops through suitable technique. Anhydrous ammonia is a liquid under pressure and it is likely to be lost as a gas when pressure is released during incorporation into soil. Venkata Rao and Govindarajan (1970) report that the indigenous ammonia application equipment used by them was found to cause minimum loss of ammonia during injection into soil. Their results from the experiments on rice and sugarcane showed that on equivalent nitrogen basis ammonia was as effective as ammonium sulphate or any other

nitrogenous fertilisers and the applied ammonia was rapidly converted to nitrate form in soils

There are quite a few problems like storage and transportation encountered in the extensive use of anhydrous ammonia directly as a fertiliser which needs to be overcome before its use can be realised in the field on large scale. The State level committee that went into this question has made specific recommendations in this behalf (Anon, 1976)

TABLE 11
Yield of rice grain and straw under different fertilisers and water management treatments

Treatments		Yield (kg/ha)	
Fertilisers	No. of split application	Grain	Straw
<i>Submerged Condition</i>			
Ammonium sulphate	2	3 040	5 013
	3	3,327	5,580
Urea	2	2,773	4,773
	3	3,154	6,346
Ammonium sulphate-nitrate	2	2,317	3,993
	3	2,760	4,639
Calcium ammonium nitrate	2	2,707	4,333
	3	2,767	5,066
<i>Saturated Condition</i>			
Ammonium sulphate	2	3,133	5,200
	3	3,073	5,126
Urea	2	2,833	4,560
	3	2,895	4,946
Ammonium sulphate-nitrate	2	2,340	3,574
	3	2,607	4,346
Calcium ammonium nitrate	2	2,314	3,960
	3	2,500	4,593

Patil and Dashpande (1973) compared the efficiency of ammonium sulphate urea, ammonium nitrate and calcium ammonium nitrate for *Taichung-65* variety of rice grown under submergence upto 10 cm depth at field moisture saturation point. They applied fertilisers at 160 kg N per ha in two and three equal split doses with a basal dose of 100 kg P_2O_5 and 100 kg K_2O per ha. The study revealed (Table 11) that ammoniacal and amide forms of nitrogen were superior to nitrate form in increasing the yields of rice grain and straw.

The reasons they have put forward for the inferiority of nitrate fertilisers to rice are due to (i) greater losses through leaching and denitrification (ii) general inability of the rice plants to utilise nitrate form, (iii) nitrate toxicity to younger rice seedlings and (iv) selective permeability of the protoplasmic membrane of the root cells to NH_4^+ ions. They further demonstrated that nitrogen application in three equal splits gave significantly higher yields of grain and straw than the two equal splits. There was no difference between the two methods of irrigation.

In collaboration with the International Atomic Energy Agency, Datta *et al* (1970) used ammonium sulphate, ammonium nitrate urea and sodium nitrate for rice on heavy clayey soils of Cuttack and Hyderabad. The data on the uptake of fertiliser nitrogen and grain yield suggested the superiority of ammonium sulphate and urea applied as a basal dose and their performance was on par. Sodium nitrate was inferior as a source of nitrogen. The efficiency of ammonium nitrate was enhanced by applying it as a top dressing, a fortnight before primordial initiation compared to basal application. Uptake of phosphorus was found to be independent of the form of nitrogen used.

Complex fertilisers that are presently available in the market vary in their plant nutrient content, form, combination and degree of solubility as in the case of phosphorus, such as water soluble, citrate soluble and insoluble phosphorus. These fertilisers produce differential responses depending upon soil and its reaction. Work has shown that ammoniacal forms of nitrogen was preferable for lowland or flooded rice to nitrate forms (Englested and Parker, 1973; Shahi, 1973, and Rao *et al* 1972). Perur *et al* (1967) reported that nitrophosphates were

not superior to ammonium sulphate and superphosphate for paddy grown on acid soils. Kunte (1971) stated that nitrogen carriers like *suphala*, urea, anhydrous ammonia and nitrogen solutions had the same effect on the yield of rice on Trombay Farm. Based on this information, Maharudrappa *et al* (1974) studied the relative efficiency of complex fertilisers on low land rice under the Model Agronomy Scheme, during *rabi* seasons for two years on acid soils of Mangalore and during *kharif* seasons on alkaline soils of Siruguppa on jowar (CSH-1). Nitrophosphates (30 and 50 per cent water soluble P), urea, ammonium phosphate, ammonium phosphate-sulphate and diammonium phosphate were compared with urea *plus* superphosphate and ammonium sulphate *plus* superphosphate. Their results showed that there was no difference in yield due to different sources of nutrients. The return per rupee spent on fertiliser was the highest with diammonium phosphate which was also the cheapest source of nutrients.

Ambadas Rao (1972 c) demonstrated that there was no differential response in respect of yield of cotton when fertilised with different sources of nitrogen like urea, ammonium nitrate and ammonium sulphate with and without phosphoric acid and further showed that phosphorus in combination with nitrogen tended to depress the yield of cotton on black cotton soils of T B P area.

The results of the experiments, to study the effects of nitrogen in the form of ammoniacal, nitrate and in organic forms carried out at Hebbal Farm for ten years between 1927 and 1937 on rainfed ragi suggested that yield increase up to 20 per cent were obtained by application of 20, 30, 20 kg of N, P_2O_5 and K_2O per ha respectively. Nitrogen in the form of chilean nitrate was found to be better than ammonium sulphate. There was also an indication of the necessity of adding phosphatic and potassic fertilisers along with nitrogen to increase the yields of ragi (Venkata Rao and Sirur, 1959).

Viswanath and Perur (1969) tested the performance of ammonium nitrate, ammonium sulphate, ammonium sulphate-nitrate, calcium ammonium nitrate on ragi with split applications on coarse textured soils low in organic matter. Among the fertilisers tested nitrate forms of fertilisers were found better than ammoniacal, and amide forms of

fertilisers in increasing the yield of ragi. The efficiency of nitrate fertilisers was rated in order as, calcium ammonium nitrate > ammonium sulphate-nitrate > ammonium nitrate. Split applications of $\frac{1}{2} + \frac{1}{2}$ and $\frac{2}{3} + \frac{1}{3}$ in respect of ammonium sulphate-nitrate, ammonium sulphate and urea produced higher yields than application of the same in three equal splits, whereas ammonium nitrate and calcium ammonium nitrate proved better in three equal splits in increasing the ragi yields.

They further studied the effects of these fertilisers on the soil properties. Ammonium sulphate, though better, caused adverse effect on soil reaction. Physiologically acidic fertilisers such as ammonium sulphate, urea, ammonium sulphate-nitrate and ammonium nitrate increased soil acidity in light textured soils while calcium ammonium nitrate did not alter the pH.

Based on seven experiments conducted at Saundatti (1960-1961) and Bailhongal (1958 to 1960), it was found that yields were increased when nitrogen was applied as ammonium chloride and urea. In these trials, five different forms of nitrogen, were tried on *Fu'gar* white and BHU-1 varieties of jowar (Table 12).

TABLE 12

Responses of jowar to different forms of nitrogenous fertilisers

Fertilisers (33.6 kg N/ha)	Yield (kg/ha)	Percent increase over control
Calcium ammonium nitrate	1373	120
Ammonium chloride	1543	135
Urea	1507	131
Ammonium sulphate-nitrate	1409	123
Chilean Nitrate	1308	114
Ammonium sulphate	1493	131
Control	1142	100

In two trials at Bailhongal, nitrogen applied in the form of calcium cyanamide and calcium nitrate in two equal splits at 30 kg/ha yielded significantly more than 60 kg N/ha as ammonium sulphate and chilean nitrate (Krishnamurthy, *et al*, 1972).

In the two trials conducted at Bijapur during the years 1960 and 1961 to assess the comparative merits of different forms of nitrogenous fertilisers, Krishnamurthy *et al* (1972) (Table 13) found that the yield variations were mainly due to low rainfall (5-25cm) during the growing period. Such further studies are necessary to arrive at generalisations. In alkaline soils of Naragund, calcium nitrate gave 19 per cent more yield (406 kg/ha) compared to control while ammonium sulphate gave 6 per cent less yield than control (Krishnamurthy *et al* 1972) indicating volatilisation of ammonia from the fertiliser.

TABLE 13

Comparison of different forms of nitrogenous fertilisers on the yield of wheat grown on Black soil of Bijapur

Fertiliser	Yield (kg/ha)		
	N in kg/ha		
	0	15	30
1960			
Ammonium sulphate	360	482	375
Urea	329	344	390
Ammonium sulphate-nitrate	405	344	344
Calcium ammonium nitrate	314	390	482
Calcium ammonium chloride	314	336	374
1961			
Ammonium Sulphate	818	955	816
Urea	818	849	872
Ammonium sulphate-nitrate	902	803	888
Calcium ammonium nitrate	933	787	941
Calcium ammonium chloride	810	803	902

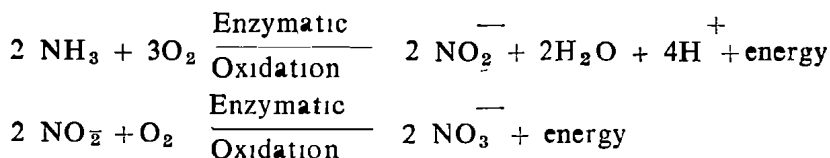
NITROGEN TRANSFORMATIONS

NITRIFICATION STUDIES

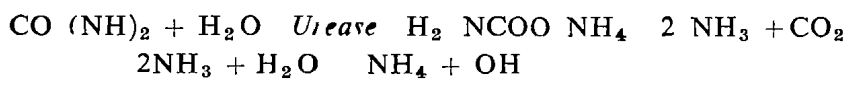
THE formation of nitrates by biological agencies in soil has been of great interest to agriculture and biology. The microbial conversion of ammonium compounds to nitrates has been recognised to be an indispensable transformation promoting plant growth. At the same time, this form of nitrogen is readily lost due to leaching and denitrification. In fact, nitrification consists of a series of biochemical changes by which native soil organic matter, crop residues and chemical fertilisers are converted to nitrite and then into nitrate.

The nitrification process is conditioned by pH, moisture and temperature of soil. Broadbent *et al* (1957) working on the nitrification of ammoniacal fertilisers in some California soils noticed that in acid and non-calcareous alkali soils, the rate of nitrification was in the order ammonium hydroxide > ammonium sulphate > ammonium nitrate, while in calcareous soils, ammonium sulphate and nitrate nitrified faster than ammonium hydroxide. Justics and Smith (1962) observed that nitrification of ammonium sulphate proceeded at a faster rate at 25°C in calcareous soils but declined when temperature was increased. Patil (1963) noticed that nitrification of urea in acid soil was faster than ammonium sulphate. Nitrification of urea was practically complete within eight weeks whereas in respect of ammonium sulphate, hardly 50 per cent of added nitrogen was nitrified. Nadagouda and Patil (1967) carried out an incubation study on the rate of nitrification of ammonium sulphate, ammonium phosphate, urea and calcium ammonium nitrate on four typical soils of Karnataka viz, black cotton soil, red sandy loam, Kari soil and rice alluvial soils. After eight weeks of incubation, they observed (Table 14) that in the beginning ammonium sulphate treatment lowered the pH value while with urea the pH was increased. There was a general decrease in soil pH upon incubation with all the fertilisers tested. The decrease in soil pH was associated with nitrification of ammonia resulting in the production of H⁺ ions (Alexander, 1971).

The reaction may be represented as follows



The initial increase in soil pH on addition of urea to moist soil was due to hydrolysis of urea and production of ammonia (Alexander, 1971)



The data presented in table 14 reveal the changes brought about in soil pH as a consequence of added chemical nitrogenous fertilisers to soils

From the data (Table 14 & 15), it is observed that in *Karl* soil, the oxidation was rapid and fairly complete in about four weeks. This may be due to the prevalence of high pH (8.5 to 8.8) very favourable for nitrifying bacteria like *Nitrosomonas* and *Nitrobacter* (Broadbent *et al*, 1957). The formation of nitrate was relatively rapid in well aerated red soils than in black clayey soils. In paddy soil also the nitrification was rapid possibly due to high organic matter content accompanied by high pH. The rate of nitrification with ammonium phosphate was comparatively faster while in case of calcium ammonium nitrate, it proceeded at a slow rate during the first three weeks.

Urease activity in soils The hydrolysis of urea to ammonia is an important pathway of converting organic nitrogen into inorganic form and it is catalysed by extra cellular urease that are absorbed on the soil particles in addition to viable urease active in soil organic matter. Ananthanarayana and Mithyantha (1970) studied the urease activity on surface soils of wet and dryland area of red soils of Hebbal farm. They measured two distinguishing activities of urease during hydrolysis and referred to them as "urease activity" the activity associated with extra cellular urease in soil which was independent of activity arising out of

metabolising ureolytic organisms. The term "total urease activity" connotes the sum of the two described above. The data (Table 16) indicate that higher urease activity in wetlands and Block A soils appears to be associated with high soil moisture content resulting in higher population of ureolytic organisms.

TABLE 14
*Effect of application of 400 ppm nitrogen from different sources
on soil reaction of four different soils of Karnataka*

Soils	Treatments	pH of soil at different intervals of time (Incubation in weeks)					
		0	1	2	3	4	5
Black clay loam	No fertiliser	7.40	6.90	7.00	7.00		7.25
	Ammonium sulphate	7.00	6.65	6.60	6.80		6.25
	Ammonium phosphate	7.30	6.80	6.70	7.00		6.05
	Urea	7.70	7.40	7.32	7.15		6.65
	Calcium ammonium nitrate	7.40	7.20	7.00	6.95		6.85
Red sandy loam	No fertiliser		6.00	6.15	5.82		6.00
	Ammonium sulphate		5.75	6.20	5.35		5.00
	Ammonium phosphate		6.05	6.20	5.35		5.32
	Urea		7.20	6.00	6.70		5.32
	Calcium ammonium nitrate		6.30	6.05	6.15		5.50
Karl Soil	No fertiliser	8.97		8.65	8.69	8.70	8.40
	Ammonium sulphate	8.60		8.00	8.18	8.10	7.92
	Ammonium phosphate	8.60		7.95	8.02	8.00	7.80
	Urea	9.07		8.10	8.35	8.30	8.06
	Calcium ammonium nitrate	8.75		8.22	8.25	8.20	8.06
Paddy alluvial soil	No fertiliser	7.30	7.30	7.40	7.12		7.10
	Ammonium sulphate	7.00	6.95	6.81	6.12		6.00
	Ammonium phosphate	7.25	7.20	6.73	6.57		6.20
	Urea	7.88	7.95	7.25	6.45		6.40
	Calcium ammonium nitrate	7.25	7.28	7.08	6.90		6.60

TABLE 15

Effect of application of 400 ppm nitrogen from different sources on nitrate nitrogen content in four different soils of Karnataka

Soils	Treatments	Nitrate nitrogen in ppm at different intervals of time						
		Incubation in weeks						
		0	1	2	3	4	5	6
Black clayloam	No fertiliser	10.4	18.3	21.4	12.4	17.4	25.6	26.6
		8.9	10.7	33.8	63.0	104.6	200.3	285.0
	Ammonium sulphate	10.0	10.4	50.4	113.0	224.5	278.5	315.4
	Urea	7.0	9.5	123.0	183.8	264.6	306.6	356.5
	Calcium ammonium nitrate	138.0	149.0	200.0	220.0	218.6	282.5	370.0
Red Sandy Loam	No fertiliser	7.9	15.4	16.6	6.0	13.6	15.3	13.8
	Ammonium sulphate	6.5	18.3	70.3	130.0	221.0	270.0	293.0
	Ammonium phosphate	2.8	23.1	73.0	136.0	240.3	268.5	300.6
	Urea	5.7	14.3	161.0	260.0	312.0	338.0	353.0
	Calcium ammonium nitrate	148.5	180.0	160.0	219.0	298.0	314.0	326.0
Karl soil	No fertiliser	7.5	8.5	20.6	26.0	31.0	25.0	26.3
	Ammonium sulphate	7.6	10.4	123.0	206.0	393.0	394.0	397.0
	Urea	5.9	14.2	119.0	189.0	364.0	398.2	400.3
	Calcium ammonium nitrate	165.0	153.0	159.0	292.0	354.0	394.4	393.6
Paddy alluvial soil	No fertiliser	7.8	4.0	6.8	10.5	6.2	10.4	10.8
	Ammonium sulphate	6.2	8.3	74.0	186.5	244.0	380.6	386.0
	Ammonium phosphate	7.4	10.0	74.0	175.0	248.3	401.6	412.5
	Urea	8.2	9.8	120.0	270.6	270.5	319.2	348.0
	Calcium ammonium nitrate	113.0	131.0	246.0	263.6	318.5	344.8	315.5

There was very little difference between urease activity and total urease activity, indicating the meagre contribution of ureolytic enzymes

to the hydrolysis of urea and the activities of the enzymes hydrolysing urea was related to the moisture and organic matter content of soil

TABLE 16

*Urease activity, organic carbon content and pH of soils of
M R S Hebhal, Bangalore*

Soil sample	pH	Organic carbon %	Urease activity	Total urease activity	Urease activity / Total urease activity
Wetland soil	6.7	0.98	45.5	57.8	0.785
Dryland- (plot 3, c range)	4.6	0.59	10.5	13.2	0.795
Dryland (plot 15 c range)	4.2	0.25	5.6	6.1	0.918
Grape orchard soil	4.8	0.29	05.9	7.5	0.787
Dryland (A block)	5.7	0.68	21.2	22.1	0.960
Dryland (Air dry soil)	5.2	0.24	5.9	7.6	0.775
Mean	—	—	15.75	19.08	0.825

Expressed as mg $\text{NH}_4\text{-N}$ hydrolysed in 6 hr per 100g of oven dry soil

Owing to increasing use of urea as a source of N for most of the field crops in the recent years studies were initiated to trace the fate of added urea in three soils of the State viz. red sandy loam, lateritic and black soils. These soils were applied with urea at 200, 400 and 800 ppm N and maintained at 40, 60 and 80 per cent of moisture holding capacity for a period of six weeks. From the study, it was found that at 60 per cent water holding capacity, maximum ammoniacal and nitrate nitrogen were produced. Transformation of urea was found most rapid in lateritic soil followed by red and black soils. The rate of transformation of urea increased linearly upto 400 ppm and there after tended to decline. The urease activity was highest in lateritic soil (5.0) followed by red sandy soil (7.4) and black soil (6.1). The Urease activity was expressed in ppm of urea hydrolysed per g of soil in 24 hr at 30°C (Siddaramappa and Rao, 1971).

Shankar and Venkata Rao (1966) examined the relation of soil phosphorus with nitrification on red sandy loam soils of Hebbal and concluded that the process of nitrification was independent of the soil phosphorus status

DECOMPOSITION OF ORGANIC MATERIALS IN SOILS OF KARNATAKA

Incubation studies on the rate of decomposition of organic materials and the rate of mineralisation of nutrients from them were conducted in red soil of Hebbal and black soil of Dharwar. FYM, pongamia cake, dhaincha, paddy husk and a mixture of pongamia cake and paddy husk were incorporated into soils at the rate of 0.5 per cent by weight of organic carbon content. The rate of mineralisation of carbon and the release of available nutrients were studied upto 30 weeks period of incubation. The results showed that there was increase in organic carbon content of soils upto the end of incubation period and FYM appeared to be the best amendment for increasing carbon content of soils. The rate of carbon mineralised was maximum in the case of dhaincha in red soil, while the mixture of pongamia cake and paddy husk gave maximum mineralisation in black soil. FYM and dhaincha significantly enhanced the total N content only in red soil. The mineralisation of nitrogen was maximum in red soil. Available phosphorus content of soils was increased by FYM and pongamia cake in red soil, while in black soil all organic materials added to soil enhanced the available P content. In general, the application of FYM resulted in maximum retention of organic matter in both red and black soils while pongamia cake recorded the maximum mineralisation of nitrogen. The release of phosphorus was marked in black soil than in red soil (Anon, 1973 a). The data on the microbial population of some typical soils of Karnataka presented in Table 17 reveal that black and lateritic soils generally contain more bacterial and actinomycetes population while red soil is rich in fungi. Wider variations in the number of different microflora in these soils indicate the profound influence of climate on microflora.

The effect of organic amendments to soil was quite marked on microflora. The data (Table 18) show that greater increase in fungal

population in black soil was observed in paddy husk and pongamia cake treatments. Greater Proliferation of bacteria in case of red soil was seen in pongamia cake and dhaincha treatments. In general, the bacterial population was more in black soils than in red soils. The organic amendments stimulated the bacterial population in red soil and the fungal, actinomycete and azotobacter population in black soil. Such enhancement was more due to dhaincha and pongamia cake application in red soil and pongamia cake in black soil. (Anon 1973)

TABLE 17

*Population of Bacteria, Actinomycetes, Fungi and Azotobacter
in some soils of Karnataka State*

Place	Bacteria (10 ⁶ /g)	Actino- mycetes (10 ⁵ /g)	Fungi (10 ⁶ /g)	Azotobacter (10 ² /g)
Hebbal (red Soil)	6.95	23.4	36.9	5.7
Dharwar (Black Soil)	8.50	36.4	10.6	4.5
Sirsi (Lateritic Soil)	9.50	37.8	15.8	—
T Narasipur (Alluvial Soil)	1.10	5.60	23.6	9.4

The data (Table 19) show that the mineralisation of nitrogen was maximum with the Pongamia cake treatment in both red and black soils but in different periods of time. In red soil, it was 4th week while it was 24th week in black soil. In regard to mineralisation of phosphorus, dhaincha treatment recorded maximum rate of mineralisation in red soil, while it was maximum in the paddy husk treatment in black soil at both stages of incubation.

The results indicate that the degradation processes of these organic materials are faster in red soils as compared to black soil and the release of nutrient was also faster in the former than in the latter.

TABLE 18

Changes in microbial population in the organic residues amended soils

Treatment	Soil	Bacteria (10 ⁶ /6g)	Fungi (10 ⁴ /g)	Actino- mycetes (10 ⁶ /g)	Azotobactor 6 (10 ⁶ /g)
Control	Red	2 47	1 42	1 40	0 08
		3 98	1 60	0 96	0 08
	Black	1 78	1 43	1 86	0 53
		6 05	3 42	0 73	0 82
F Y M	Red	2 72	2 50	0 99	0 09
		4 68	3 03	1 01	0 33
	Black	2 34	2 35	1 85	0 43
		10 95	6 48	1 00	1 24
Pongamia cake	Red	2 39	1 88	1 45	0 07
		53 37	14 64	1 67	0 08
	Black	2 09	1 97	2 22	0 42
		73 30	30 95	4 60	2 72
Dhamcha	Red	2 67	2 56	1 93	0 03
		28 83	37 05	2 74	0 28
	Black	2 25	2 65	1 87	0 51
		41 91	31 95	2 64	1 28
Paddy husk	Red	2 04	1 44	1 48	0 47
		14 07	12 05	2 32	0 34
	Black	2 17	1 88	1 80	0 48
		35 11	41 02	10 18	2 33
Pongamia cake + paddy husk	Red	2 13	1 47	1 29	0 06
		25 42	12 40	1 05	0 08
	Black	1 98	2 55	2 22	0 56
		53 32	27 14	10 19	1 59

Top and bottom figures indicate the initial and final populations

TABLE 19

*Rate of mineralisation of N and P₂ O₅ in soils
treated with organic materials*

Treatments	Red soil		Black soil	
	N	P ₂ O ₅	N	P ₂ O ₅
Control	9.65 (4)	2.65 (4)	4.64 (2)	4.06 (12)
FYM	7.89 (2)	2.73 (4)	4.27 (2)	4.56 (16)
Pongamia cake	13.60 (4)	2.57 (4)	7.55 (24)	5.36 (16)
Dhancha	7.71 (2)	4.87 (2)	7.18 (2)	3.66 (16)
Paddy husk	9.18 (4)	3.68 (4)	4.44 (8)	6.71 (16)
Pongamia cake + paddy husk (mixture)	8.48 (4)	3.98 (2)	7.32 (2)	5.24 (24)

Figures in parenthesis indicate period of incubation in weeks

RHIZOBIAL INOCULATION OF LEGUMES

NITROGEN fertilisers are not generally added to the leguminous crops. Research findings elsewhere have shown that yields could be increased to an extent of 35–100 per cent through symbiotic fixation of atmospheric nitrogen by the legumes inoculated with rhizobium.

From the field trials conducted under the All India Co-ordinated scheme on development of rhizobial inoculants for the principal legumes in Karnataka at Bangalore centre, isolate G-28 for groundnut, isolates B-29 and B-73 for black gram, isolate P-57 for peas were found uniformly effective. Isolate B-29 and B-73 recorded 59–4 per cent increased yield of blackgram as compared to the uninoculated control plants. p-57 isolate recorded 70 per cent increased yield in peas (Anon 1975).

TABLE 20

*Performance of rhizobium culture on groundnut at different locations
(1974-75)*

Treatment	No of nodules plant	Dry wt of nodules plant (mg)	Dry wt of plant top (g)	Yield (kg/ha)
<i>Bangalore</i>				
Control	6.81	10.00	2.64	162
G-28 isolate	11.62	14.69	3.56	166
CD at 5%	NS	4.54	NS	NS
<i>Dharwar</i>				
Control	19.7	148.6	6.05	—
G-28 isolate	71.6	82.9	5.69	—
CD at 5%	NS	51.99	NS	—
<i>Raichur</i>				
Control	119.75	72.19	7.55	563
G-28 isolate	106.67	52.50	7.68	695
CD at 5%	NS	NS	NS	65.07
<i>Bijapur</i>				
Control	45.08	38.13	1.91	472
G-28 isolate	42.81	48.25	2.62	511
CD at 5%	NS	NS	NS	NS

The data on the performance of strains of rhizobium culture for groundnut and blackgram on different soils of Karnataka are presented in Table 20

It is seen (Table 21) that isolate G-28 did well only at Raichur, by increasing the yield of groundnut by 23.4 per cent over control. In blackgram, culture B-29 and B-73 did not perform well at any of the places. This was due to unfavourable seasonal condition during crop growth (Anon, 1974)

TABLE 21

Performance of strains of rhizobium culture on blackgram (1974-75)

Treatment	No of nodules per plant	Dry wt of nodules per plant in mg	Dry wt of plant top in gm	Yield kg/ha
<i>Bangalore</i>				
Control	1.40	3.50	0.49	259
B-29 isolate	5.30	10.80	0.59	286
B-73 isolate	2.80	7.60	0.48	284
CD at 5%	NS	90.2	NS	NS
<i>Dharwar</i>				
Control	7.77	7.50	2.01	—
B-29 isolate	7.58	8.55	3.41	—
B-73 isolate	5.34	6.13	3.45	—
CD at 5%	NS	NS	NS	—
<i>Bijapur</i>				
Control	6.50	9.00	1.00	305
B-29 isolate	4.50	8.00	0.98	203
B-73 isolate	10.50	7.00	0.84	271
CD at 5%	NS	NS	NS	NS

TABLE 22

Release of available nitrogen and phosphorus during decomposition of organic materials in Hiriwar alkaline soil

Treatment	Ammoniacal - N (mg/100g)						Nitrate - (N mg/100g)						Available P ₂ O ₅ (mg/100 g)					
	1	2	4	8	12	30	1	2	4	8	12	30	1	4	12	30	1	4
Weeks	1	2	4	8	12	30	1	2	4	8	12	30	1	4	12	30	1	4
Soil (Control)	1 82	0 90	0 66	0 17	0 09	0 06	4 14	5 16	5 28	5 88	5 29	5 62	0 10	0 12	0 12	0 13		
„ + FYM 0 5% C	1 82	1 06	0 72	0 51	0 09	0 08	6 67	8 16	8 76	8 82	8 88	9 21	0 56	0 71	0 74	0 76		
„ + FYM 2 0% C	5 43	1 80	0 72	0 66	0 09	0 09	12 13	17 40	17 84	16 35	16 53	18 08	2 80	2 94	3 06	3 51		
„ + Jowar stalk																		
0 5% C	6 34	1 80	0 72	0 50	0 14	0 13	7 95	8 28	9 72	9 53	11 65	13 27	1 00	1 06	1 58	1 78		
„ + Jowar stalk																		
2 0% C	28 98	2 04	1 08	0 71	0 19	0 19	5 08	11 16	16 32	18 00	20 82	23 16	1 84	1 99	2 29	2 292		

TABLE 23

Effect of decomposition of organic matter on the carbon, nitrogen, humic and fulvic acid and CEC of Haryana alkaline soil at the end of 30 weeks incubation

Treatment	Organic C %	% increase or decrease over initial value	Total N %	% increase or decrease over initial value	Humic acid %	% increase or decrease over initial value	Fulvic acid %	% increase or decrease over initial value	CEC meq/100g	% increase or decrease over initial value		
Soil only	0.64	-	14.67	0.138	-	7.14	0.064	+ 14.29	0.060	+ 25.00	15.01	+ 5.19
„ + FYM												
at 0.5% C	0.81	+	28.00	0.133	-	5.00	0.070	+ 25.00	0.055	+ 14.58	25.26	+ 6.94
„ + FYM												
at 2.0% C	2.11	+	181.33	0.162	+	15.71	0.082	+ 46.43	0.065	+ 35.42	16.22	+ 13.66
„ + Jowar stalk												
at 0.5% C	0.70	-	6.67	0.131	-	6.43	0.086	+ 53.57	0.060	+ 24.99	15.81	+ 10.79
„ + Jowar stalk												
at 2.0% C	2.01	+	167.99	0.162	+	15.72	0.085	+ 51.79	0.062	+ 29.17	16.31	+ 14.29

In another study, the rate of decomposition, microbial changes and chemical transformations brought about by the addition of organic materials like FYM and jowar stalk at 0.5 and 2 per cent organic carbon levels were studied in the alkaline soil of Hiriyur (Balusubramanian *et al*, 1974). The CO₂ release and the microbial changes during the decomposition of organic residues were similar to normal soil. The positive relationship between CO₂ release from the soils amended with organic materials and the bacterial population was observed at the initial stages of decomposition. A decrease in the accumulation of ammoniacal nitrogen and an increase in the rate of nitrification and release of available phosphorus with the progress of incubation period was observed (Table 22). Net gains in the organic carbon, total nitrogen, humic and fulvic acid levels and CEC of the soil due to decomposition of FYM and jowar stalk at 2 per cent organic carbon was found to be significant (Table 23).

BALANCED SUPPLY OF NUTRIENTS

IMPORTANCE of balanced fertiliser application to crops has been recognised by many workers (Cooke, 1967, Black, 1957 and Bartholomew, 1972). It will ensure proper utilisation of applied nutrients and net return for the applied fertilisers through increased crop yields. Several experiments have been conducted in the State to work out the balanced supply of fertilisers for various crops under different soils and climatic conditions, (Sirur, 1958, Venkata Rao and Govinda Rajan, 1960, Kulkarni 1970 and Krishnamurthy, *et al*, 1972). Potculture trials in red sandy loam soil of Hebbal illustrates the adverse effects of imbalance fertiliser application to maize (Table 24)

TABLE 24

Effect of nitrogen and phosphorus on the yield of dry matter and composition of hybrid maize on red sandy soils of Hebbal

Treatment	Yield of dry matter g/pot	Soil after harvest		Uptake by maize [mg/pot]			
		pH	EC mmhos/cm	N	P	K	Ca + Mg
Control	10.75	7.0	0.26	4.58	3.29	13.45	10.31
N ₅₀ alone	10.98	6.8	0.30	8.50	2.40	12.85	11.15
P ₆₀ alone	11.75	7.0	0.28	7.50	4.12	13.10	15.04
K ₂₀ alone	10.70	7.0	0.32	7.30	2.67	17.20	11.14
N ₅₀ P ₆₀ K ₂₀	33.37	7.2	0.31	13.60	6.31	15.20	25.90
N ₁₀₀ P ₃₀ K ₂₀	15.70	6.8	0.38	8.00	3.78	15.00	25.74
N ₂₀₀ P ₁₅ K ₂₀	7.72	6.7	0.40	5.26	1.47	14.85	12.40
N ₂₅ P ₁₂₀ K ₂₀	14.82	7.0	0.34	5.21	4.76	15.20	23.80
N ₁₂₅ P ₂₄₀ K ₂₀	15.00	7.0	0.36	4.50	7.20	14.75	18.00
N ₁₀₀ P ₂₄₀ K ₂₀	22.05	6.9	0.37	10.65	7.36	14.35	30.87

The effect of imbalanced supply of nutrient to crops was associated with several factors. The differential absorption of nutrients caused many disorders within the plants which ultimately affected the yield. The application of N₂₀₀ P₁₅ K₂₀ caused great reduction in yield.

depressed soil pH and disturbed uptake of some nutrients (Badiger *et al*, 1975)

A study on balanced fertilisation of Jayadhar cotton (*Gossypium herbaceum*) was made during 1960-61 on black soil at A R S Saundatti in Belgaum district. The treatments consisted of three levels of N viz 0, 20 and 40 kg/ha, three levels of K_2O viz, 0, 15 and 30 kg/ha (Table 25). Application of N alone at 20 and 40 kg/ha increased the kapas yield of cotton by 19 and 40 per cent over no fertiliser level. But when these doses of N were combined with 15 kg P_2O_5 per ha, the yields were increased by about 40 and 75 per cent respectively over no fertiliser application.

TABLE 25

Effect of N, P and K levels on the kapas yield of Jayadhar cotton in kg/ha in black soil of A R S, Saundatti (1960-65)

Levels of P_2O_5 (kg/ha) - -	Levels of nitrogen (kg/ha)			mean for P-effect
	0	20	40	
0	251.0	315.3	370.0	312.1
15	273.0	343.3	395.0	337.1
30	255.3	328.6	374.3	319.4
Mean for N-effect	259.7	329.1	379.7	

Levels of K_2O kg/ha	Levels for nitrogen (kg/ha)			Mean for K-effect
	0	20	40	
0	252.3	313.3	395.0	320.2
15	258.3	330.0	366.0	318.1
30	268.6	344.0	378.3	330.3
Mean for N-effect	259.7	329.1	379.7	

Additions of P or K alone had no effect on the yield of kapas. Combined application of N, P and K had no better effect on yield than application of N with P. With increasing levels of K, the yield was not affected, indicating that the black soils of Saundatti were sufficient in regard to available potassium.

Patil and Havanagi (1960) reported that the application of 30 kg N with 15 kg P_2O_5 on black cotton soil of Dharwar increased the yield of Jayadhar cotton by 50 per cent, and also hastened the maturity of cotton.

EFFECT OF HEAVY DOSES OF NITROGEN ON SOIL AND CROPS

APPLICATION of high levels of fertilisers are a feature of hybrid and high yielding varieties of crops which have become increasingly popular in recent years. These fertilisers especially nitrogen carrying ones bring about significant influence on the physico-chemical properties of the soils when applied continuously over a period of years. Venkata Rao *et al* (1971) studied these changes, induced by the incremental levels of ammonium sulphate, calcium ammonium nitrate, ammonium chloride and urea under moist and submerged conditions on red sandy loam soils of Hebbal (Table 26). The soils were applied with these fertilisers at the rate of 50, 100, 250, 500 and 1,000 kg N per ha and incubated for a period of two weeks. Subsequently, soils were subdivided into three portions, One of which was subjected to submergence, while another was leached and still another was allowed to dry up for a fortnight. The results showed that no marked changes were noticed in the beginning in all the treatments. But later the soil pH decreased considerably as a consequence of leaching in the ammonium sulphate, ammonium chloride and urea treated samples, while calcium ammonium nitrate treated samples did not show any alteration in the soil pH. On submergence, the soil pH initially increased. However, in the case of ammonium sulphate, ammonium chloride and urea, the pH decreased with increased rate of added nitrogen. The depression in soil pH was associated with depletion of calcium and magnesium from the soil complex and consequent increase in hydrogen ion activity. The need for liming of such soils becomes evident.

A field study on the cumulative effects of application of high levels of nitrogen to an extent of 130 kg nitrogen per ha as ammonium sulphate with a common basal dressing of 45 kg each of P_2O_5 and K_2O per ha over a period of 6 seasons was carried out in microplots containing red sandy loam soils of Hebbal (Venkata Rao *et al*, 1972). The continuous application of ammonium sulphate caused considerable decrease in soil pH, and depletion of exchangeable bases, while significant increase in the population of bacteria and fungi and inhibition of nitrogen fixing bacteria (*Azotobacter*) were noticed (Table 26 and 27).

TABLE 26

Effects of application of nitrogenous fertilisers at high levels on some properties of red sandy loam soils of Bangalore

Treatment kg/ha	pH				Exchangeable cations (me/100g) leached after 21 days	
	15 days in cubation but unleached	Submer- gence	21 days leaching	Incubated one month but dried for 15 days	Ca + Mg	H
Ammonium sulphate						
50	5.80	6.50	5.70	5.60	5.4	0.08
100	5.45	6.20	5.55	5.60	5.2	0.10
250	5.50	5.80	5.30	5.40	3.4	0.13
500	5.75	5.10	4.85	5.00	2.8	0.15
1000	5.65	5.10	4.40	5.00	2.2	0.21
Calcium ammonium nitrate						
50	5.80	5.80	5.65	5.60	5.4	0.07
100	5.60	5.70	5.65	5.80	5.4	0.07
250	5.70	6.30	5.60	5.80	5.5	0.06
500	5.60	6.20	5.70	5.90	5.6	0.06
1000	6.10	6.20	5.80	6.00	5.8	0.06
Ammonium chloride						
50	5.60	6.40	5.60	5.70	5.3	0.09
100	5.60	6.30	5.55	5.60	4.8	0.11
250	5.60	6.30	5.30	5.60	3.0	0.16
500	5.55	5.80	5.10	5.40	2.1	0.19
1000	5.60	5.40	4.70	5.40	1.8	0.24
Urea						
50	5.80	7.00	5.70	5.00	5.5	0.09
100	6.20	6.40	5.60	5.50	5.4	0.09
250	6.80	6.50	5.60	6.20	5.2	0.11
500	6.20	6.80	5.40	6.60	4.6	0.12
1000	8.50	7.10	5.35	7.30	4.6	0.15
Control	5.80	6.20		5.80	5.6	0.09

TABLE 27

Effect of heavy application of ammonium sulphate on the physico chemical properties of red soils and on soil microflora

Characteristics	Treatment (kg/ha)				
	Control	N ₀	N ₄₅	N ₉₀	N ₁₈₀
pH	6.50	*6.35	5.75	5.25	4.30
Exch. Ca (me/100 g)	4.0	3.85	2.85	1.80	1.30
Organic Carbon %	0.49	0.44	0.50	0.58	0.49
Nitrogen %	0.07	0.08	0.09	0.09	0.08
Bacteria (10 ⁶ /g)	13.64	25.60	145.0	43.80	35.70
Actinomycetes (10 ⁶ /g)	0.16	1.74	2.49	3.81	0.71
Fungi (10 ⁴ /g)	3.02	7.08	10.85	14.28	17.18
Azotobacter (10 ² /g)	21.50	21.49	1.47	0.62	0.21

* A common dose of 45 kg each of P₂O₅ and K₂O per ha was applied to all treatments except control

TABLE 28

Yield of ragi in the first season and wheat in the fifth season by continuous application of nitrogen on red soil of Hebbal

Treatment	Ragi grain (g/m ²)	% Increase	Wheat grain (g/m ²)	% Increase
NO V ₁	633	—	225	—
N ₄₅ V ₁	774	22	250	11
N ₉₀ V ₁	827	29	228	1
N ₁₈₀ V ₁	946	50	220	-2.4
NO V ₂	518	—	170	—
N ₄₅ V ₂	559	8	210	21.4
N ₉₀ V ₂	643	24	174	2.4
N ₁₈₀ V ₂	712	38	167	-18
CD at 5%	157	—	42	

V₁ is 9-2-7 of ragi and CN 340 of wheat

V₂ is Purna of ragi and CN 423 of wheat

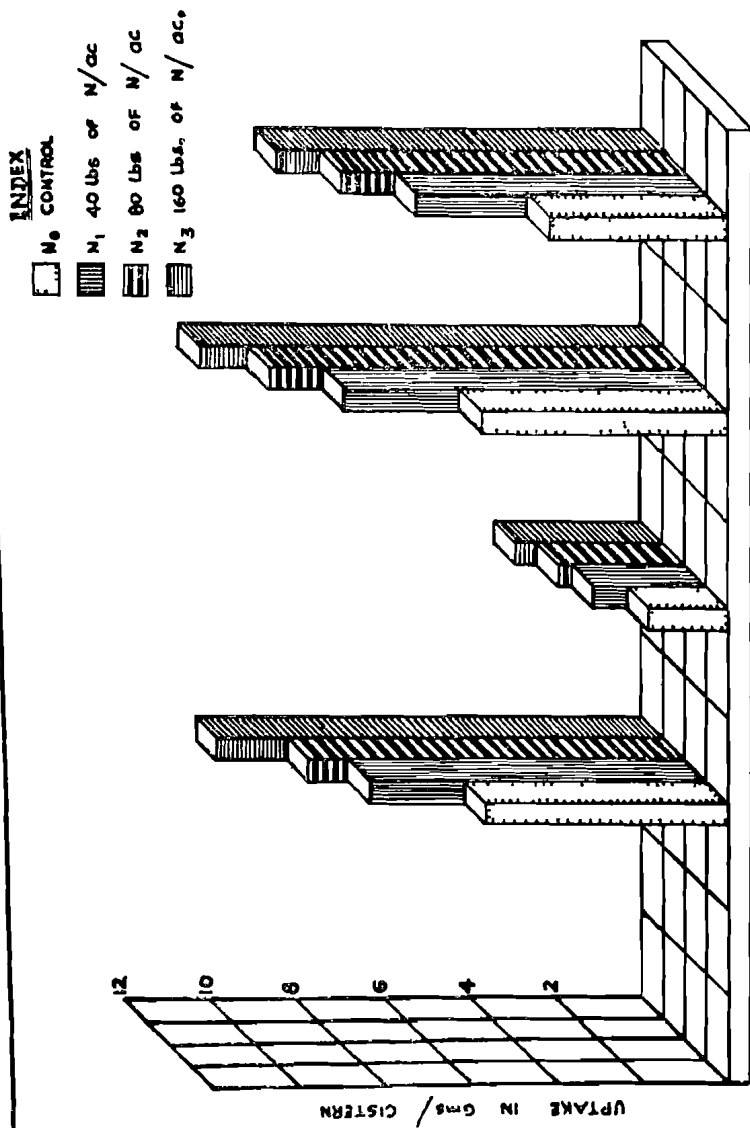
Viswanath and Perur (1975) studied the effect of heavy doses of fertilisers on physical and chemical properties of red sandy loam, black clayey and lateritic soils of Karnataka. The soil was treated with 200-80-40 kg N, P_2O_5 and K_2O per ha as urea, ammonium hydrogen phosphate and mutriate of potash. A crop of maize was raised and the uptake of N, P and K was studied. Overall recovery of added N, P and K in red soil was 55.46, 14.52 and 127.24 per cent respectively, in black soil, the corresponding recovery in red soil was 49.57, 10.27 and 195.12 per cent while in lateritic soil, it was 49.11, 6.64 and 104.43 per cent respectively. The uptake of Ca and Mg were also increased in these three soils and in all the seasons. Among the micronutrients, there was an increase in the uptake of Fe, Mn, Cu and Zn in all the soils. Maize plants showed deficiency of Mn and Zn on repeated applications of fertilisers and successive cropping in black soil. Heavy fertilisations with successive cropping caused reduction in bulk density, soil strength, pH and total bases in all the soils and increased hydraulic conductivity, aggregate distribution, aggregate stability, organic carbon and humus content and cation exchange capacity.

The deterioration of the productivity of the red sandy loam soils of Hebhal as a result of continuous heavy applications for over five seasons was demonstrated by Venkata Rao and Badiger (1971) in their studies on ragi and wheat. The experimental treatments consisted of four levels of nitrogen viz 0, 45, 90 and 180 kg/ha with a common basal dressing of 45 kg each of P_2O_5 and K_2O per ha. Two varieties of ragi viz, 927 and Purna were grown during first season (1968 monsoon) and wheat varieties viz CN 340 and CN 423 during fifth season (rabi 1969). The yields of 9-2-7 and Purna varieties of ragi (Table 28) grown in first season were increased to an extent of 50 and 38 per cent respectively as a result of additions of nitrogen while CN 340 and CN 423 varieties of wheat grown in fifth season in the same plots recorded very low yields in nitrogen treated plots and were in no way better than control (Table 28).

It was further shown (Table 29) that the depressive effect of high dose of nitrogen on the yields of wheat was due to deterioration in the chemical make up of soil. The soil pH and exchangeable calcium were depleted upon heavy application of nitrogenous fertilisers to soils over a period of five seasons.

In order to improve these soils, lime was applied to half the plots and jowar and san hemp crops were grown. There were profound changes brought about in the chemical make up of soil (Table 30) as a result of liming. Repeated heavy application of nitrogenous fertilisers to soil brought down pH and exchangeable bases with concomitant increase in exchangeable acidity, exchangeable aluminium, iron and manganese in soil. The ameliorative effect of lime on soil was evidenced by increase in pH, exchangeable bases and lowering of the total and exchangeable acidity, aluminium, iron and manganese.

A more detailed study on the major changes brought about in the chemical properties of soil as a result of continuous heavy applications of nitrogenous fertilisers was made by Vasuki and Venkata Rao (1973) in microplots at the Agricultural College, Hebbal. This study was in continuation of the work of Venkata Rao and Sadashiviah (1968 a). The treatments consisted of 0, 40, 80 and 160 lb N/ac and the investigation was carried out in the tenth season. In all, the maximum amount of N added at the highest level was 1600 lb N/ac. The results (Table 31) show profound changes brought about in the chemical characteristics of soil like pH, alkaline earth carbonates and exchangeable bases as a result of repeated applications of nitrogen in the form of ammonium sulphate. The availability of copper and easily reducible manganese contents depressed while the zinc and water soluble manganese increased. It is therefore suggested that for proper maintenance of soil fertility, the use of nonacid forming nitrogenous fertilisers like calcium ammonium nitrate under dry or semi irrigated conditions or periodic liming in the case of acid residue fertilisers have to be practiced. The study on the uptake of nitrogen, phosphorus, calcium, copper, manganese and zinc (Fig 7 and 8) by ragi due to continuous heavy applications of nitrogen indicate the differences in the availability of these nutrients in soil.



EFFECT OF CONTINUOUS APPLICATION OF AMMONIUM SULPHATE ON THE
 UPTAKE OF N P K AND Ca BY RAGI CROP
FIG.7

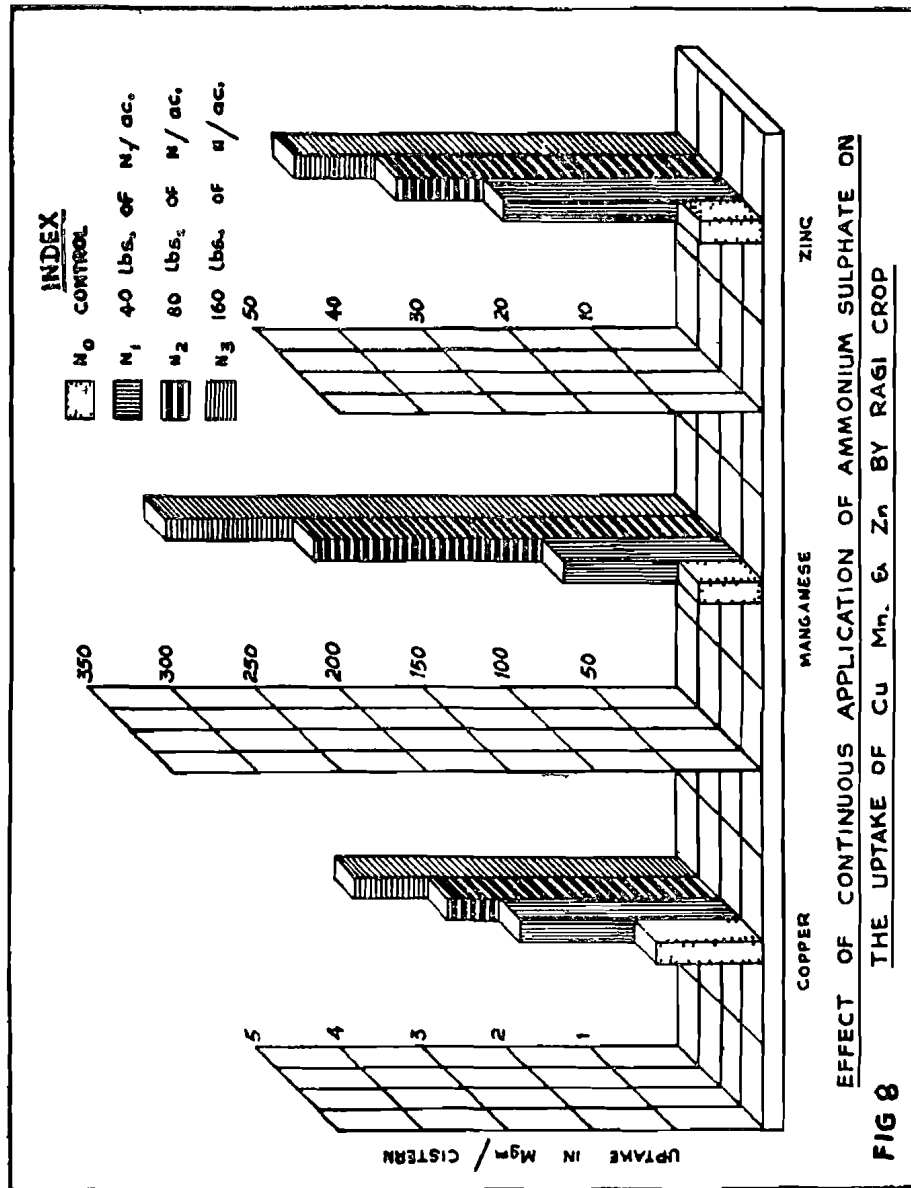


TABLE 29

Analysis of red sandy loam soils at the end of five seasons

Treatments		pH	Exch Ca me/100g	Organic Carbon %	Nitrogen %	C/N ratio
NO	V ₁	6.4	3.9	0.45	0.081	5.51
N ₄₅	V ₁	5.7	2.9	0.49	0.091	5.36
N ₉₀	V ₁	5.6	1.8	0.52	0.092	5.66
N ₁₈₀	V ₁	4.3	1.3	0.50	0.074	6.73
N ₀	V ₂	6.4	3.8	0.43	0.079	5.51
N ₄₅	V ₂	5.8	2.8	0.51	0.092	5.53
N ₉₀	V ₂	4.9	1.8	0.54	0.082	6.58
N ₁₈₀	V ₂	4.3	1.3	0.48	0.082	5.85
CD at 5%		0.21	—	NS	NS	NS

This indicates the necessity of application of suitable amendments like lime coupled with good soil management practices especially for low buffered soils

TABLE 30

Effect of repeated heavy applications of nitrogen and subsequent liming on the nature of soil acidity in red sandy loam soils of Hebhal

Treatments		pH (water Extract)	pH	me/100g					
				KCl Extr acidity	Exch Al	Exch acidity	Exch Fe	Exch Mn	Exch Ca + Mg
N ₀	L ₀	6.88	6.05	0.37	0.31	17.04	7.77	10.51	6.37
N ₄₅	L ₀	5.52	4.0	0.77	0.54	18.82	9.31	43.28	5.25
N ₄₅	L ₁	7.32	6.62	0.43	0.30	18.50	9.73	8.76	9.27
N ₉₀	L ₀	4.50	3.40	1.55	1.05	20.42	11.76	51.07	4.70
N ₉₀	L ₁	7.32	6.17	0.49	0.25	16.25	8.61	05.25	7.83
N ₁₈₀	L ₀	4.37	3.17	2.21	1.43	21.18	15.96	58.25	3.00
N ₁₈₀	L ₁	6.88	5.68	0.53	0.29	17.75	9.38	10.51	6.20
SE		0.27	0.17	0.18	0.06	1.31	2.21	9.54	1.04
CD (5%)		0.59	0.38	0.39	0.14	2.86	4.82	20.78	2.37

TABLE 31
Effect of continuous application of ammonium sulphate on the chemical properties of red sandy loam soils of Hebbal

Treat- ments	Depth (cm)	pH	EC mmhos/ cm	Alkaline				Exchangeable		Total nitrogen %	Available nitrogen %	Available phosphorus ppm
				Organic carbon %	earth carbonate %	Ca	Mg K me per 100 g					
N ₀	0-15	7.05	0.18	0.370	0.61	4.06	0.60	0.62	0.088	0.0089	15.16	
	15-30	6.96	0.17	0.333	0.63	4.11	0.48	0.54	0.0886	0.0386	4.91	
N ₄₀	0-15	6.30	0.19	0.370	0.58	3.96	0.46	0.60	0.094	0.0092	14.28	
	15-30	6.95	0.17	0.355	0.64	4.70	0.43	0.53	0.091	0.0096	4.58	
N ₈₀	0-15	5.51	0.19	0.378	0.50	3.71	0.43	0.60	0.099	0.0101	13.95	
	15-30	6.43	0.19	0.360	0.58	4.63	0.46	0.51	0.093	0.0098	4.37	
N ₁₆₀	0-15	4.51	0.20	0.403	0.36	2.26	0.30	0.58	0.010	0.0104	13.20	
	15-30	5.18	0.19	0.368	0.39	3.46	0.46	0.50	0.095	0.0099	4.58	
CD	0-15	0.60			0.108	0.436	0.06	0.0009	0.0004			
CD	15-30	0.14			0.101	0.44		0.0004	0.00049			

EFFECT OF NITROGEN ON SOIL MICROBES

The effects of application of high levels of nitrogen on the chemical composition of soils, studied by Venkata Rao and his associates have already been referred to earlier. With the changes in the chemical composition of soil the composition and activities of soil microorganisms are also affected. In India where intensive monocropping system is practiced, the need to study the soil microbial status as a result of intensive cropping assumes great importance. With this in view, studies were taken up to assess the changes brought about in the population of soil microbes as a result of heavy applications of nitrogenous fertilisers especially ammonium sulphate to red sandy loam soils with low buffering capacity. The red sandy loam soils that were heavily fertilised with nitrogen and on which ragi crop was grown were examined for the populations of bacteria, actinomycetes, fungi and azotobacter (Bagvaraj and Rangaswami, 1967 and Venkata Rao *et al.*, 1972). The study revealed that heavy additions of nitrogen did not affect the populations of actinomycetes and fungi to any great extent but drastically affected the bacterial population.

The study was continued (Emmimath and Rangaswami, 1971) on Tainchung-65 rice (*Oryza sativa L.*) grown under submergence to assess the qualitative and quantitative changes in the microflora of soil and rhizosphere of rice with heavy additions of nitrogen. Significant changes in the number and quality of bacteria, actinomycetes and fungi were observed. In the early stages of crop growth, selective stimulations of bacteria and fungi in rice rhizosphere were observed but such effects were absent during crop maturity. Fertiliser nitrogen decreased, gram-positive and spore forming bacteria, while the application of phosphorus and potassium enhanced the populations of actinomycetes and azotobacter in rice rhizosphere. Higher doses of nitrogen to soil under water logged conditions inhibited *azotobacter* particularly during the early stages of crop growth.

Balasubramanya *et al.* (1973) further reported the drastic chemical changes that occurred in red sandy loam soils as a result of continuous heavy additions of nitrogen. There was greater reduction in microbial populations. The dehydrogenase activity which is an index of overall

biological activity of soil was also decreased due to reduction in soil pH. Liming these experimental plots, reverted the chemical changes like pH and exchangeable bases and enhanced bacterial and azotobacter population.

Another effective method of mobilising nitrogen is through the symbiotic fixation. Use of rhizobia strains of known nitrogen fixing capacity was made through culture inoculation to many field crops to enhance nitrogen supply by nodulation. Study conducted on legumes inoculated with cowpea rhizobia strains revealed profuse nodulation on *Mimosa invisa*. The total amount of nitrogen recovered ranged from 35 kg N per ha per year with *M. Pudica*, and 110 kg N per ha per year with *M. invisa*. Although the experiment was of an exploratory nature, the data in Table 32 indicate the probable quantity of nitrogen that would accrue to the soil-plant system through symbiotic fixation by well nodulated legume crop and the same is sizeable (Setty *et al*, 1974).

TABLE 32
Nitrogen and dry matter yields of some wild and cultivated legume
(Kg/ha/year)

Name of legume	Yield of dry matter	Nitrogen yield
<i>Mimosa pudica</i>	5874	35
<i>Mimosa invisa</i>	12945	110
<i>Cryanc javanica</i>	13378	90
<i>Calopoqonium nucunordes</i>	10901	110
<i>Centrosema pubeseens</i>	8809	55

Deshpande *et al* (1971) studied the influence of lime and nitrogenous fertilisers on soil biology of lateritic soils of Mudigere. They observed that ammonium sulphate reduced the pH of the soil during incubation period while urea showed increased soil pH initially and subsequently which decreased with time. The decrease in pH was due to rapid nitrification of ammonia resulting in the release of H⁺ ions. Increase in pH of urea treated soil in the early period was associated with the hydrolysis of urea, forming ammonia. Ammonium sulphate depressed the bacterial population. Liming showed continuously high rate of

nitrification in all the treatments. It was suggested that in the lateritic soils of Mudigere where cardamom is extensively grown, urea is a better source of nitrogen.

3. *Effects of nitrogen fertilisers in relation to insects attack:* Mutalik Desai *et al* (1973) demonstrated that the higher levels of fertilisers and narrow spacing of plants would cause infestation of cutworms in case of potato. The study revealed that infestation percentage increased due to higher rate of fertilisers (250-150-150) to an extent of 11.8 per cent over control. They noticed that spacings of 30 cm to 45 cm between rows in both the experiments did not affect the percentage infestation to any appreciable extent. However, spacing of 60 cm in between rows of potato brought down reduction in the infestation to an extent of 10 per cent. The wider spacing in case of potato would provide added advantage in reducing the damage by cutworms.

4. *Phytotoxic substances in soil due to high fertilisation:* The red sandy loam soils of Hebbal were reported to contain 9 ppm of p-hydroxy benzoic acid and 12 ppm of dihydroxy stearic acid and the ragi seedlings would tolerate the concentration of p-hydroxy benzoic acid upto 20 ppm and dihydroxy stearic acid upto 10 ppm (Lilaram, 1970). Further, the effects of high additions of nitrogenous fertilisers on the phytotoxicity levels in red sandy loam soils were studied. It was observed that there was reduction in the p-hydroxy benzoic acid content while the presence of dihydroxy stearic acid was not observed. (Lilaram and Venkata Rao 1971).

5. *Effect of nitrogen on incidence of Virus disease of Crops:* Incidence of virus disease in ragi was noticed in all varieties and was extensive in the ragi growing areas of Karnataka. Resistance or susceptibility to disease in plants is governed to a certain extent by the degree of availability of nitrogen. Nitrogen supply in excess would tend to make the plant succulent and the plants thus become susceptible to diseases. A virus disease of ragi transmitted by two leaf hopper species and a Delphacid was reported by Krishnamurthy and Yaraguntaiah (1969). This disease produced characteristic streaking, mottling and mosaic symptoms.

Reddy *et al* (1975) studied the effect of graded levels of nitrogen on the incidence of the disease on four varieties of ragi grown on balck soil of Hiriyur. The observations made on the incidence of the disease at the earhead stage revealed a significant effect of nitrogen applications on the incidence of virus disease. Interaction of varieties with nitrogen levels was nonsignificant. Purna ragi was found to be more susceptible to disease as against EC-4840 with least incidence (Table 33).

TABLE 33

Effect of fertiliser nitrogen on the incidence of virus disease on ragi crop. (Ous of 200 plants per plot)

Ragi varieties	Incidence of Virus disease				
	Nitrogen levels (Kg/ha)				
	0	40	80	120	Mean
Purna	6.66	6.60	14.00	23.00	12.41
IE-28	5.66	8.33	14.33	12.33	10.16
IE-776	5.00	7.33	12.33	12.33	9.25
EC-4840	2.66	8.33	9.66	14.00	8.66
Mean	5.00	7.50	12.58	15.41	...

C.D. for subtreatments at 1% is 6.57.

Effect of heavy additions of nitrogen on brown leaf shoot of rice soils, with high fertility may also be one of the causative factors in inducing diseases to plants. More often, high nitrogen level in soil causes high incidence of disease but potassium reduces it. Hiremath and Hegde (1975) demonstrated the effect of fertiliser application on the grain infection of rice by *Drechslera Oryzae* (Breda De haan) Subram. and Jain. This brown leaf spot of rice is known to be affected appreciably by high soil fertility status. The incidence of this disease was studied on red sandy loamy soils of R.R.S. Mandya using five levels of nitrogen with two levels of potassium and phosphorus.

TABLE 34

Effect of fertiliser on grain infection by D. Oryzae

Fertiliser level (kg/ha).			Mean percent disease incidence on grain.
N	P	K	34.49
0	0	0	
40	20	20	38.39
60	0	0	43.26
60	20	0	42.70
60	0	20	39.18
60	20	20	36.26
80	0	0	48.42
80	20	0	50.57
80	0	20	43.49
100	0	0	55.86

It is evident (Table 34) that increased level of nitrogen had the greatest effect on the incidence of disease. At any given level of nitrogen, disease incidence was found to be reduced with potassium while phosphorus did not alter the incidence of disease.

EFFECT OF HERBICIDES ON THE UPTAKE OF MINERALS

Herbicides are known to contain heavy metals along with some nutrients. A preliminary study was initiated to ascertain the effects of some common herbicides on the uptake of nutrients by some field crops (Rajanna *et al*, 1974). The plants were raised for three weeks on pure complete nutrient solution and solutions containing respective herbicides. Plants grown on pure nutrient solution served as standards for purpose of comparison. The study revealed (Table 35) that the herbicides like simazine, Tok-E20 and 2, 4-D would enhance the uptake of nitrogen in maize, groundnut and paddy respectively.

TABLE 35

Effect of herbicides on the chemical composition of plants grown in nutrient solutions for three weeks

Crops	Herbicide dose	Composition of Seedlings (%)			
		Nitrogen		Phosphorus	
		Nutrient	Herbicide	Nutrient	Herbicide
Jowar-CSH-1	Atrazine 350 g/ha	1.855	1.578	0.493	0.640
Maize-Amber	Simazine 1 kg/ha	1.640	2.125	0.763	0.537
Groundnut-TMV ₂	Tok-E20	1.100	0.098	0.334	0.365
Paddy-MR-138	2,4-D	0.320	1.328	0.476	0.402

Attrazine (2-chloro-4-ethyl amino-6-iso-propylamine-S-triazine) compound is commonly used to control weeds in maize, sorghum and other cereal crops. Setty *et al* (1970) studied the effect of atrazine on the nitrification process on black clay loam soils. Since this chemical contained chlorine, it would possibly reduce the rate of nitrification.

The chemical was found to be highly toxic to nitrifying bacteria. Nitrogen was applied at the rate of 60 kg/ha in the form of ammonium sulphate, and atrazine was added at the rate of 10, 50 and 100 ppm to each flask. The study revealed that atrazine applied at higher doses lowered the rate of nitrification in the beginning, while at lower level the rate of nitrification increased initially and later slowed down.

EFFECT OF COMPLEX FERTILISERS ON CROPS

AN experiment was initiated to study the relative efficiency of different complex fertilisers on rice (Jaya) grown on lateritic soils at Mangalore and Jowar (CSH-1) on black clayey soils at Siruguppa. The chemical characteristics of soils were

	Mangalore	Siruguppa
pH	5.3	8.1
EC (mmhos/cm)	0.21	0.44
Organic Carbon %	0.49	0.51
Available Nitrogen kg/ha	429.0	292.0
Available P ₂ O ₅ (kg/ha)	22.0	36.9
Available K ₂ O (kg/ha)	537.0	840.0

From the data (Table 36) it is evident that all complex fertilisers gave more or less equal yields of rice as compared with that of ammonium sulphate *plus* superphosphate — Higher doses of phosphorous did not increase the grain yield. As regards uptake of nitrogen, ammonium phosphate, and ammonium sulphate treatment appeared to be a poor source of nitrogen and ammonium sulphate *plus* superphosphate as for the uptake of phosphorous is concerned. The study on lateritic soils at Mangalore demonstrated the equal efficiency of soluble and insoluble forms of fertilisers in acid soils for rice crop.

At Siruguppa, urea *plus* superphosphate and ammonium phosphate sulphate (20-20) were efficient in increasing the grain yield of jowar. Surprisingly, ammonium sulphate and superphosphate proved to be a poor source as evidenced by lowest yields. The uptake of nitrogen by jowar was highest in urea plus superphosphate treatment and least in diammonium phosphate. In regard to the uptake of phosphorous maximum response was obtained in diammonium phosphate and least with ammonium phosphate-sulphate.

TABLE 36

Effect of different complex fertilisers on the yield and composition of rice at Mangalore, and Jowar at Sruguppa during 1971

Treatments	Rate kg/ha N P K	Grain yield kg/ha		Uptake (kg/ha)			
				Rice		Jowar	
		Rice	Jowar	N	P	N	P
Urea + Super-phosphate	60-30-0	3158	5018	60 01	2 37	59 01	5 39
Urea + Super-phosphate	60-50-0	3335	5063	55 11	2 60	53 88	4 18
Ammonium sulphate + Superphosphate	60-30-0	3145	3770	62 52	2 36	46 46	4 05
Ammonium sulphate + Superphosphate	60-60-0	3109	4667	60 07	2 43	50 31	4 78
Nitrophosphate (20-20)	60-60-0	3049	4808	51 22	2 59	51 85	3 49
Urea Ammonium Phosphate (28-28)	60-60-0	2980	4638	56 74	2 47	46 75	3 59
Ammonium phosphate sulphate (20-20)	60-60-0	2861	5086	48 87	2 52	51 26	3 43
Diammonium Phosphate (18-46)	23-60-0	3366	4300	60 81	2 69	42 14	6 02
Control	—	2392	2486	34 83	2 03	24 71	3 23
CD at 5%	—	489	999	—	—	—	—

METHODS OF APPLICATION OF NITROGEN

EFFICIENCY of fertilisers increase with their proper placement in soil in relation to plant. This has become increasingly important in the case of high analysis fertilisers. Proper placement of fertilisers will help in better use of nutrients from the emergence of seedlings to maturity as also in preventing salt injury to the seedlings and from the point of agronomic convenience. Reports have shown that the greatest efficiency of applied nitrogen results when a portion of it along with P and K are placed in close proximity of the seed. Placement of fertiliser nitrogen at $1\frac{1}{2}$ to 2 inches to the side of the seed or below it is considered safe for normal germination (Donald *et al*, 1963)

Koraddi *et al* (1967) compared different methods of fertiliser applications for rainfed wheat (*Bijaga red var*) on deep black soils of Bijapur for three years. Fertiliser nitrogen was added at different rates through seed-cum fertiliser drill and iron plow besides application of nitrogen as foliar spray.

TABLE 37

Effect of different methods of applications of fertiliser nitrogen on the yield of wheat (Bijaga Red) (Kg/ha) grown on black soil of Bijapur (1962-65)

Treatment	Yield of Wheat grains	Per/cent Increase
Control	605 335	—
16 80 kg N/ha by seed-cum-fertiliser drill	852 525	40 83
11 20 kg N/ha by iron plow + 5 60 kg N/ha by foliar spray	752 652	24 33
11 20 kg N/ha by seed-cum drill + 5 60 kg N/ha by foliar spray	804 307	32 85
5 60 kg N/ha by seed-cum-fertiliser drill + 5 60 kg N/ha by foliar spray	766 226	26 57
16 80 kg N/ha by wooden plow	819 275	35 34

The results (Table 37) indicate that the application of 16.80 kg N/ha at sowing by seed-cum-fertiliser drill which placed the fertiliser 5.98 to 7.62 cm deep was found to be best, giving 4 per cent increase in grain yield than no fertiliser application. Shallow placement (3.81 to 5.08 cm) by iron plow without mouldboard or deep placement (7.60 to 10.16 cm) by wooden plow was found to be undesirable under rainfed conditions. Even a small dose (11.2 kg N/ha) applied through seed-cum-fertiliser drill at the time of sowing, supplemented by foliar spray of 5.60 kg N/ha seemed better than application of fertiliser by plow. But this did not compare well with 16.80 kg N/ha applied by seed drill.

Studies on the methods of fertiliser placement were carried out on ragi at Hebbal during 1951-1953. Nitrogen (80 kg N/ha) as ammonium sulphate and phosphorus (60 kg P_2O_5 /ha) in the form of superphosphate were applied by three methods as indicated (Table 38). There was no significant difference between the methods of applications of fertilisers. However, the pooled means given in Table 38 show that in the two methods, N+P at a depth of 7.5 to 10 cm below surface gave better yields than applying nitrogen alone at surface (Kushnamurthy *et al* 1972).

TABLE 38

Response of ragi to different methods of application of nitrogen and phosphorus in red soils of Hebbal (1951-53)

Methods of application	Mean yield of 4 years (kg/ha)
1 Control	820
2 N only at planting	720
3 N + P broadcast at surface	986
4 N + P at depth of 7.5 to 10 cm below surface	1014

The Research Station at Hagari (Bellary) is situated in drought prone area of Karnataka State. The low and erratic distribution of rain accompanied by high temperature, account for inadequate supply of moisture for crop production. In order to increase the efficiency of added fertiliser to soil, a fertiliser placement-cum-sowing experiment was

conducted for three years (1967-68 to 1969-70) on Jowar on typical black clayey soil (Gopalkrishna Rao *et al*, 1975)

TABLE 39

Effect of fertiliser-placement-cum-sowing method on the grain and straw yields of Jowar (kg/ha)
Average of three years

Treatments	Yield (kg/ha)	
	Grain	Straw
No fertiliser, Jowar sown with 18" spacing	982	2264
30 kg N + 20 kg P per ha applied deep by plow sole & seed sown through attached tube on the same line behind the plow	996	2622
Seeds and fertilisers (30 kg N + 20 kg P per ha) sown with seed-cum-fertiliser drill (seed line was above the fertiliser/band)	1164	2522
30 kg N + 20 kg P per ha sown deep 15 days prior to sowing by drill and later seeds sown 2" away from the fertiliser	1164	2522
30 kg N + 20 kg P applied 15 days prior to sowing by plow sole and then seeds sown with drill on the same line	1048	2622

From the perusal of data (Table 39), it is seen that the use of seed-cum-fertiliser drill for sowing seeds and fertilisers gave maximum grain yields of jowar (1164 kg/ha) which was 18.7 per cent higher over control. It was followed by placing fertiliser deep by drill, 15 days prior to sowing and later, seeds sown 2 inches away from the fertiliser.

Spacing-cum-fertiliser trials carried out at the Agricultural Research Station, Nargund between 1966 and 1968 revealed (Table 40) that spacing of 17 cm was found superior to 34 cm row spacing. The increase in grain yield was 22 per cent over 34 cm row spacing. Application of 35 kg N and 25 kg P_2O_5 per ha with 17 cm row spacing gave the highest grain and fodder yield than the other treatment combinations on *Karl* soils of Nargund.

TABLE 40

Effect of spacing and fertiliser levels on the yield wheat grown on Karl soils under dry farming at Agricultural Research Station, Neragund

Treatments	Yield of wheat in kg/ha			
	1966-67		1967-68	
	Grain	Straw	Grain	Straw
1 No fertiliser with 17 cm spacing	683 84	1196 20	490 96	854 30
2 No fertiliser with 34 cm spacing	496 19	770 01	510 96	886 68
3 35 kg N + 25 kg P ₂ O ₅ per ha with 17 cm spacing	948 44	1608 60	717 62	1252 40
4 35 kg N + 25 kg P ₂ O ₅ per ha with 34 cm spacing	652 39	1104 78	635 24	966 20
5 70 kg N + 25 kg P ₂ O ₅ per ha with 17 cm spacing	880 49	1357 64	772 88	1262 80
6 70 kg N + 25 kg P ₂ O ₅ per ha with 34 cm spacing	515 24	781 44	602 86	992 39

Time of Application Several experiments were carried out in the past, in order to increase the efficiency of fertiliser nitrogen by split doses. Patil *et al*, (1959) reported the effectiveness of split applications of nitrogen on the yield of Kharif Jowar grown on light red and medium black soils of Agricultural College Dharwar. The increase in grain yields of Kharif Jowar was of the order of 49.5 and 72.1 per cent in light red and black soil respectively. Application of 15 kg nitrogen per ha in two split doses was found economical for *Kharif* Jowar. With this dose, about Rs 3-00 cash return was obtained for every rupee spent on fertiliser. The maximum return was obtained when nitrogen at the rate of 22 kg/ha was applied in conjunction with 15 kg P₂O₅ / ha in red soil while, 22 kg N and 22 kg P₂O₅ per ha was found best for medium black soil.

Setty (1971) studied the effects of different levels of fertilisers and time of application of nitrogen on the growth, nitrogen uptake and yield

of jowar (CSH-1) on medium black soils of Dharwar. He concluded that the application of nitrogen in graded doses increased the yield linearly and reduced the number of days required for 50 per cent flowering by 5 to 15 days. Nitrogen application in three split doses had greater effect on the growth and uptake of nitrogen by plant and grain yield than application of nitrogen in two splits. The maximum additional income per rupee spent on fertiliser was found to be at 66.74 kg N/ha but decreased when nitrogen applied was higher than 66.74 kg N/ha.

Similar experiments on split application of nitrogen at various fertiliser levels (100-50-50, 200-100-100 and 300-150-150) of NPK to Jowar (CSH-1) was carried out at the Agricultural College Farm Dharwar on black clay loam soils (Patil *et al*, 1972). Nitrogen at all levels tried, was applied in two split doses *i.e.*, 60 per cent at sowing and 40 per cent at one month stage and three split doses 60 per cent N at sowing, 20 per cent N at one month stage and the remaining 20 per cent N at flag leaf stage. Entire quantity of P and K was applied along with the basal dose of nitrogen. Application of nitrogen in two split doses (60 per cent at sowing and 40 per cent at one month stage) was better than single and three split applications at all levels of fertiliser applications. Highest net profit of Rs. 1310-50 per ha with the grain yield of 35 q per ha, was obtained with two split application of nitrogen at the fertiliser level of 100-50-50 kg NPK/ha.

Studying the effect of different seed sizes and split application of nitrogen at different growth stages of Decan hybrid maize at the main research station at Hebbal in order to understand their implications on the structure of yield, Krishnamurthy *et al* (1973), observed that the grain and other yield attributes did not increase significantly due to the increase either in seed size and split application of nitrogen. Planting large sized seeds and application of nitrogen in one or two splits respectively contributed to 6 and 4 per cent higher yield as compared to planting smaller size seeds.

The relative efficiency of different sources of nitrogen with different split applications by broadcasting on IR-8 rice was studied on black soils of Siruguppa during 1969-70 (Anon). The investigation revealed that the application of 120 kg N/ha produced higher grain yields over

TABLE 41

*Trials on the optimum time of application of ammonium sulphate to paddy
(Yield of paddy in kg/ha)*

Treatments	1947-48 Grain	1948-49 Grain	1949-50 Grain (Average of 3 years)	Increase over treatment Grain
V C Farm, Mandya (Red sandy loam soil)				
At planting	2782	1280		—
At the end of 1st fortnight	2355	1344		—
At the end of 2nd fortnight	2988	1376		156
At the end of 3rd fortnight	3002	1488		215
At the end of 4th fortnight	3098	1216		126
Paddy Breeding Station, Nagenahally (Red gravelly soil)				
At planting	2040	1840	2107	—
At the end of 1st fortnight	2246	1893	2320	159
At the end of 2nd fortnight	2226	1833	2347	139
At the end of 3rd fortnight	2160	1713	2173	19
At the end of 4th fortnight	2133	1727	2187	20
Babbur Farms (Base saturated black soil)				
At planting	832	1952	1408	—
At the end of 1st fortnight	704	1648	1464	—
At the end of 2nd fortnight	968	2040	1808	208
At the end of 3rd fortnight	736	1384	1824	—
At the end of 4th fortnight	880	1736	1584	—

Basal dressing 1947-48 3,000 kg green leaves 3 weeks before and 15 kg N and 12 kg P₂O₅ as bonemeal per ha applied at planting, and another 15 kg N applied later as specified in the treatment in the above trials

60 kg N/ha Application of fertilisers by broadcasting 2/3 at planting and 1/3 at boot leaf stage and application of half dose before puddling and transplanting and remaining half in the form of pellets produced significantly higher yields over broadcasting full dose at planting and broadcasting half before puddling and half after 25 to 30 days of transplanting There was no significant differences in rice yields due to sources of nitrogen except in calcium ammonium nitrate treatment

Govindaraj and Venkata Rao (1952) conducted studies on the optimum time of application of nitrogenous fertilisers to paddy at the experimental farms at Mandya, Nagenhalli (Red soils) and Babbur (Black soil) The yield data in table 41 indicate that the application of half the dose of N viz 15 kg N/ha as ammonium sulphate to paddy after an interval of 4 to 6 weeks after transplanting gave more yield than application of the entire dose at the time of planting However, a basal dose of 3000 to 4000 kg FYM or compost or green manure per ha three weeks before planting along with 20 kg P_2O_5 per ha was recommended

FOLIAR APPLICATION OF NITROGEN

FOLIAR feeding of plant nutrients has become a common practice in modern farming to supplement soil application. This practice is followed extensively to minimise leaching losses of nitrogen applied to soil and to reduce the cost on fertilisers (Witter *et al*, 1963)

In an experiment to study the time of application of nitrogen at 100 kg N/ha through soil in different splits and foliar spray of urea as a supplemental dose, conducted in 1967-68 on IR-8 and Tiachung rice in red sandy loams at V C Farm, Veeraraj Urs and Havangi (1969), observed that the application of 50 kg N/ha through soil at transplanting and 50 kg N/ha as foliar spray of urea four times, at 12.5 kg N/ha each spray produced the highest grain yield. The increase in yield was attributed to increase in 1000-grain weight and to some extent reduction in spikelet sterility. This treatment was found better than applying 100 kg N/ha all to soil at transplanting or in two or three splits. They further report that split applications through soil at 50 kg N at transplanting and 25 kg N/ha at tillering and 25 kg N/ha at floral initiation, gave better yield than application of all nitrogen at transplanting or in two splits. IR-8 rice had greater length of panicle than T-65 but the latter had less spikelet sterility.

Hiremath *et al* (1974) reported that foliar application of urea as top dressing at 15, 30 and 45 kg N/ha along with a basal dose of nitrogen at 30 kg N/ha increased the yields of cotton by 44, 113 and 162 per cent respectively over application of the same total quantity to black cotton soils at Dharwar and Gadag but not at Bagalkot. Top dressing through soil did not increase the yield of cotton both at Dharwar and Bagalkot. At Gadag top dressing through soil at the rate of 30 and 45 kg N/ha increased the yield.

Effect of foliar applications on wheat and rice was studied in the Co-ordinated Agronomic Experiments Scheme sponsored by I C A R during 1969-70. Wheat crop (*Safed leima*) was grown on black calyey soil of Sinuguppa in rabi and rice (Jaya) on red lateritic soil of Mangalore.

TABLE 42

Effect of foliar application of nitrogen on the yield of wheat and rice (kg/ha) during rabi 1969 at Siruguppa

Treatments	Wheat (Siruguppa)		Rice (Mangalore)	
	Grain	Straw	Grain	Straw
Control (No fertiliser)	1394 10	1541 67	3385 86	5151 52
Basal dressing only	2341 32	2625 00	4196 97	6388 89
Top dressing at 15 kg N/ha	2389 03	2305 56	4391 92	6767 68
Foliar spray at 15 kg N/ha (one spray)	2348 20	2402 73	3935 35	5757 58
Top dressing at 30 kg N/ha	2214 38	2944 45	4592 93	7297 98
Foliar spray at 30 kg N/ha (Two sprays)	1844 65	2416 67	4075 76	7020 20
Top dressing at 60 kg N/ha	1967 15	2458 34	4876 77	7676 77
Water spray only	2335 07	2583 34	3380 81	5075 76
CD at 5%	366 14	413 97	328 38	955 96

Basal application of 60 Kg each of N, P and K/ha was given to all the treatments except control. Top dressing was done one month after sowing. At Siruguppa, spraying of 30 Kg N/ha in two sprays or top dressing at 60 Kg N/ha at one month after sowing gave significantly lower yields over application of basal dressing of 60 Kg each of N, P and K per ha (Table 42). As far straw yield, basal dressing of 60 kg each of N, P and K per ha and top dressing of nitrogen at 30 kg per ha were found better as evidenced by increased yields. Foliar sprays of nitrogen were not found advantageous in increasing the yield of jowar at Siruguppa.

Maximum yield of rice was recorded at Mangalore with top dressing at 60 Kg N/ha followed by top dressing at 30 Kg N/ha. Foliar sprays at 15 and 30 kg N/ha were found to depress the yields. There was no differences in yields of grain between control viz with no fertiliser and only water spray. Similar trend was observed in straw yields also. The study revealed that the foliar feeding of nitrogen was not advantageous over soil application as top dressing.

TABLE 43

Effect of liquid foliar fertiliser and growth regulators on yield and other attributes of K-1 Cowpea

Treatments	Pod Weight g/plant	Seed Weight g/plant	Pods/ plant	Branches/ plant	Seeds/ plant	Percent seed Weight	100 seed Weight	Pod length cm	Plant height cm
Planotix at 10 ppm	10 61	6 53	6 81	3 83	13 3	82 2	9 63	17 38	20 26
at 15 ppm	11 26	7 06	7 43	4 17	15 0	86 2	10 71	16 73	30 96
Tiba at 10 ppm	10 60	6 51	7 09	3 69	15 1	86 3	9 99	17 03	26 33
at 15 ppm	11 69	7 76	7 87	3 89	16 2	89 2	10 39	16 77	30 06
Navaras at 0 25%	12 29	8 24	7 82	4 14	16 6	89 3	10 45	16 76	30 52
Water spray	10 13	6 26	6 50	3 38	16 0	80 4	9 20	13 65	25 89
CD (P = 0 05)	1 12	0 99	NS	NS	0 72	2 79	0 77	0 96	3 76

Poliar fertilisers on field crops In recent years liquid foliar fertilisers stated to contain all essential nutrients including vitamins and growth harmones, blended in optimum proportion for ideal crop growth are being put out on the market. One such product by name *Navaras** Stated to contain 9 per cent each of N, P_2O_5 & K_2O and several other micronutrients has gained popularity in the past 2-3 years.

In order to ascertain the usefulness of such fertiliser materials, the Agronomy Division at Hebbal initiated a number of field trials (Thimmegowda *et al*, 1974) on potato to test the effectiveness of spray with this material at 0.25 and 0.50 per cent respectively during flower initiation as supplement to soil application of 125 N, 100 P_2O_5 and 125 K_2O in kg/ha on wet land soils of Hebbal. Besides a combination of 'Navaras' at 0.25 per cent concentration with Tiba (2, 3, 5-tri-iodobenzoic acid)—a vegetative growth retarder at 10 ppm was also compared. These were compared with water spray as control where a basal soil application of N P K was given.

The product at 0.50 per cent concentration gave the maximum tuber yield (32762 kg/ha) as compared to 0.25 per cent concentration (32170 kg/ha). Control treatment gave the lowest yield (21973 kg/ha). There was no improvement on yield of potato tuber due to combined effect of 'Navaras' with 'Tiba' as it gave (31457kg/ha) yield lower than 'Navaras' alone.

Another study with this product on the yield and other attributes on K-1 variety of cowpea already with growth regulators was made at M R S Hebbal during Kharif 1974. The effects of this product at 0.25 per cent concentration on yields of cowpea was compared with a hormone Planofix (α-naphthylacetic acid) and a growth suppressor, Tiba (2, 3, 5-tri-iodobenzoic acid) at 10 and 15 ppm levels. They were compared with water spray as control. These sprays were given before flower initiation. The results (Table 43) show that the maximum yield of cowpea (32 per cent over control) was obtained at 0.25 per cent

* "*Navaras*" is a product of Panchajanya Enterprise Bangalore

concentration. The hormone Planofix and Tiba gave 11.26 and 11.69 per cent more yield than control. Foliar spray with this liquid fertiliser gave greater seed weight per plant (8.249) and more number of seeds per pod (16.6) than Planofix and Tiba treatments. In addition, podlength (16.76) and plant height (30.52) were better in this treatment as compared to only water spray.

The effect of different levels of the same foliar fertilizer on the yield of HG-8 groundnut was studied at Hebbal during Kharif 1974 (Timmegowda, *et al*, 1975). A basal dressing of 25 N, 75 P_2O_5 and 48 K_2O kg/ha was given and spraying was done around 45 days after sowing. The results (Table 44) indicate that the groundnut, sprayed with 0.25 and 0.50 per cent nutrient concentrations gave significant increases in yield over the control.

TABLE 44

Effect of different Concentrations of foliar fertiliser on the yield and yield components of HG-8 groundnut

Yield and its components	Concentration of foliar fertiliser				Water spray	CD(P = 0.05)
	0.125%	0.25%	0.50%	0.75%		
Pod weight, g/plant	22.1	28.5	25.0	23.3	19.9	1.99
Kernel weight, g/plant	15.0	18.9	17.9	16.7	13.2	2.68
Pods /plant	32.5	37.0	35.5	34.8	31.3	NS
Branches/plant	7.5	7.9	7.6	7.7	7.1	NS
Per cent unfilled pods	44.4	41.7	42.6	45.9	47.0	NS
Per cent two seeded pods	79.9	82.2	80.7	79.0	75.1	NS
Per cent two seeded						
Kernel weight	90.7	93.8	91.6	91.0	86.8	2.62
100 kernel weight, g	31.2	33.4	32.5	32.9	30.1	NS
Plant height, cm	38.5	39.5	39.4	40.4	36.0	NS

NS – No significant at F = 0.05 per cent

(19.9 and 17.9 g/plant i.e. 43 and 36 per cent respectively over control)

The favourable effect was observed at 0.25 per cent concentration

TABLE 45
Yield and yield components of wheat varieties in relation to foliar fertiliser application at different stages of growth

Treatments	Grain yield, kg/ha	Shoots number/ m row	Ears number/ m row	Grain yield/ m row, g	Mean dry weight/ ear, g	Mean grain weight/ ear, g	Ear length cm	Spikelet number/ ear	Grain no / ear	100 gram weight
<i>Genotypes</i>										
Choti larma	3062	119	103	66.5	1.3	1.0	0.6	11.9	26.2	30.7
safed larma	2966	86	82	58.1	1.7	1.3	0.7	13.1	28.8	40.3
Gamut	3737	155	108	72.0*	1.5	1.2	0.7*	12.3	26.3	36.2
<i>Stage of spray</i>										
Heading	2975	115	89	57.3	1.4	1.0	0.6	11.8	24.1	35.1
Grain-filling	3029	126	99	68.1	1.3	1.0	0.7	12.6	27.0	34.9
Heading and grain-filling	3761	120	104	72.3	1.5	1.2	0.7*	13.0	30.2	37.2*
CD (P = 0.05)	313	4.1	9.8	12.9	0.05	0.02	—	0.22	0.48	5.1
<i>Concentration of liquid fertiliser</i>										
0.25%	3045	117	96	61.6	1.3	1.0	0.7	12.7	27.6	36.1
0.50%	3149*	122+	102*	64.9*	1.4+	1.0*	0.7*	12.2	25.3+	34.5+
Water spray	2009	120	83	46.2	1.2'	0.9	0.7	11.3	21.8	32.6

* No significant at P = 0.05

+ = Significant at P = 0.01

In another experiment the effect of this liquid fertiliser was tried on different varieties of wheat on sandy loam soils of Hebbal during 1974 (Thimmegowda, *et al*, 1975). The foliar application at 0.25 and 0.50 per cent concentrations at heading, grain filling and heading *plus* grain filling stages on wheat varieties—*Chotilerma*, *Safed lerma* and *Gamut* with the applications of 150, 100 and 75 kg N, P_2O_5 and K_2O respectively/ha was done. Nitrogen was applied in three equal splits at sowing, tillering and heading. Third split application of nitrogen was omitted wherever foliar nutrition or water spray was used.

The results (Table 45) indicated that foliar applications increased the grain yields of wheat (3045 to 3149 kg/ha) as against control treatment (2099 kg/ha). The relative performances of these varieties of wheat to foliar spray of this liquid fertiliser in terms of grain yields (kg/ha) were *Gamut* (3737) > *Chotilerma* (3062) > *safed lerma* (2966). The superiority of *Gamut* variety of wheat was stated to be due to its capacity to produce more number of tillers and also ear heads. There was no significant differences between the yields at 0.25 and 0.50 per cent concentration. Spraying at heading and grain filling stage of wheat was found to be advantageous over spraying at heading and grain filling alone.

Similar experiment was conducted on MR-30 and IR-30 varieties of rice at M R S Hebbal during summer 1975. Fifty per cent of the recommended N and entire dose of P_2O_5 and K_2O at the rate of 125-63-63 NPK kg/ha were applied before planting in all the treatments. Top dressing of the remaining 50 per cent N was given through four sprays, 0.25 per cent each time coinciding with the growth stages of tillering, flag leaf stage and grain filling, anthesis respectively. The results (Table 46) indicated the differential response of wheat varieties to foliar spray. IR-20 variety recorded maximum yield of 70 q/ha at four sprays as against 46 q/ha in control treatment. The corresponding values for MR-301 were 64 q/ha and 47 q/ha respectively. The other growth attributes like 1000 grain weight, number of panicles, spikes and shoots were more in IR-20 than in MR-301.

The study was repeated with Laxmi cotton also at Hebbal. The liquid fertiliser at 0.25 and 0.50 per cent concentrations was sprayed. The crop was fertilised at 30 N, 15 P_2O_5 and 15 K_2O (kg/ha) at sowing.

TABLE 46

Effect of liquid fertiliser on growth and yield MR-301 and IR-20 varieties of paddy

Treatment	Basal application of 63-63-63 NPK kg/ha	One spray with basal application of 63-63-63 NPK kg/ha	Two sprays with basal application of 63-63-63 NPK kg/ha	Three sprays with basal application of 63-63-63 NPK kg/ha	Four sprays with basal application of 63-63-63 NPK kg/ha	Mean at 5%	C D
Plant height cm							
MI-301	65.0	67.1	70.7	72.3	74.3	69.9	0.4
IR-20	64.5	66.1	66.6	69.0	70.0	67.2	0.4
Number of shoots per plant							
MR-301	10.3	10.7	11.4	12.6	13.2	11.6	N S
IR-20	11.7	11.9	12.3	13.5	13.9	12.7	N S
Number of panicles per plant							
MR-301	9.3	9.8	10.4	11.7	12.5	10.7	1.9
IR-20	9.6	10.1	10.8	11.9	12.8	11.0	1.9
Number of spikes per panicle							
MR-301	8.0	8.6	8.8	9.0	9.5	8.8	N S
IR-20	8.3	8.8	9.4	9.5	9.8	9.2	N S

Length of panicle in cm										
MR-301	23 0	23 9	24 3	24 7	25 4	24 3	1 7			
IR-20	20 7	21 3	21 6	22 7	23 0	21 9	1 7			
Number of developed grains/panicle										
MR-321	100	115	125	132	143	123	28			
IR-20	92	101	114	120	124	110	28			
Grain weight per panicle, g										
MR-301	2 1	2 5	2 7	2 9	3 0	2 6	0 4			83
IR-20	2 2	2 6	2 7	3 0	3 1	2 7	0 4			
10000 grain weight, g										
MR-301	20 47	20 98	21 03	21 85	22 23	21 31	3 1			
IR-20	25 16	25 25	26 21	27 51	28 98	26 62	3 1			
Grain yield kg/ha										
MR-301	4682	5454	5838	6218	6400	5718	754			
IR-20	4990	5790	6194	6794	6993	6152	754			

N S = Not Significant

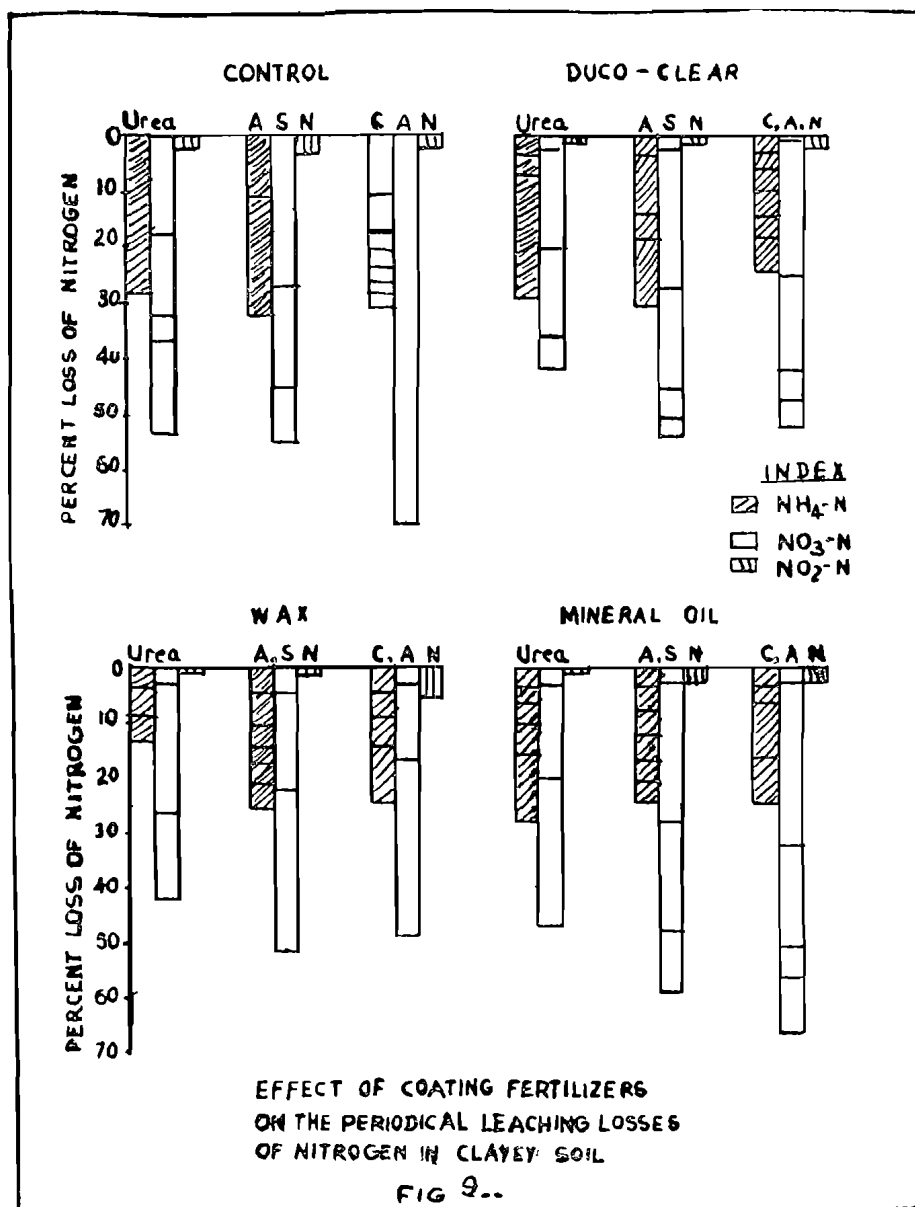
However, this 30 kg nitrogen was applied in two splits viz 20 kg N at seedings and the second 10 kg N at 30 days after seeding. The spray at 0.5 per cent concentration recorded maximum yield of 4226 kg/ha of Kapas over 0.25 per cent concentration (4208 kg/ha) and water spray (2963 kg/ha) (Table 47)

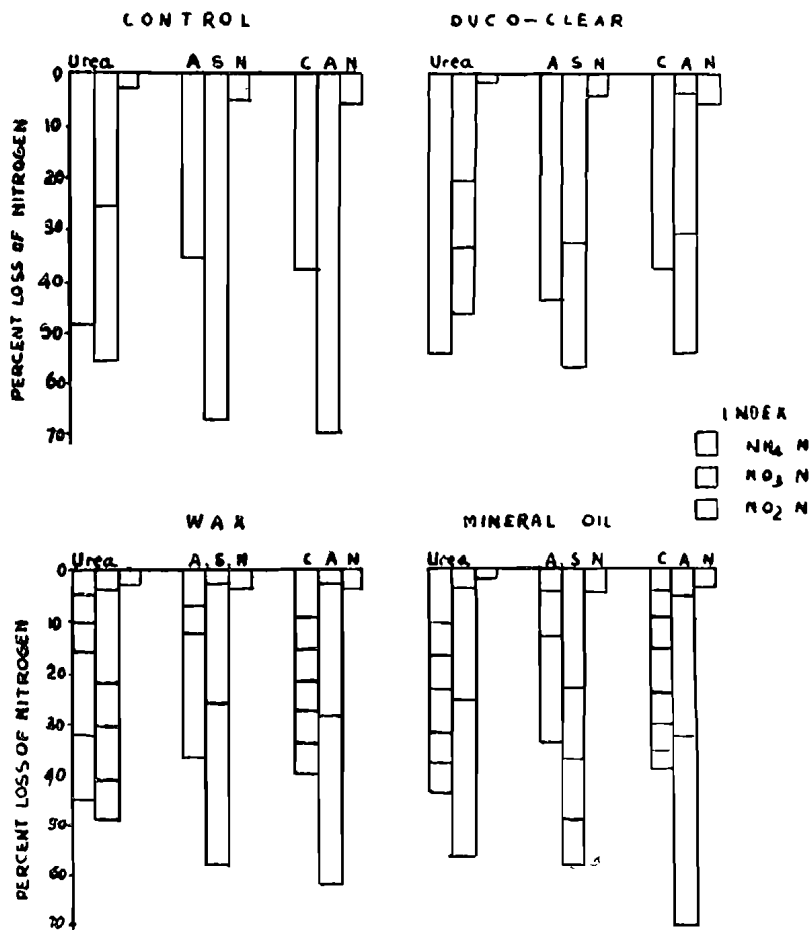
TABLE 47

Influence of foliar fertiliser treatment on the yield and yield components of Laxmi Cotton

Treatment (concentration)	Kappas kg/ha	Kappas/ Plant, g	Kappas/ Boll, g	No of Bolls/plant	No of Seeds Boll
Control	2963	134.2	3.7	40.0	24.2
0.25%	4208	190.6	3.9	49.9	30.7
0.50%	4226	191.4	4.0	52.77	30.1
'F' Test	**	**	**	**	**
C D at 5%	70.84	3.22	0.06	1.61	1.42

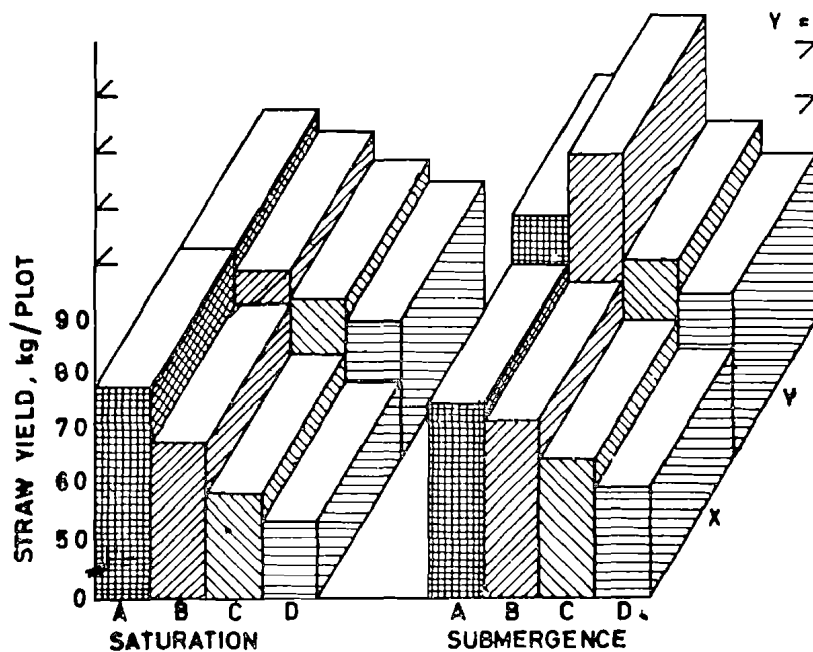
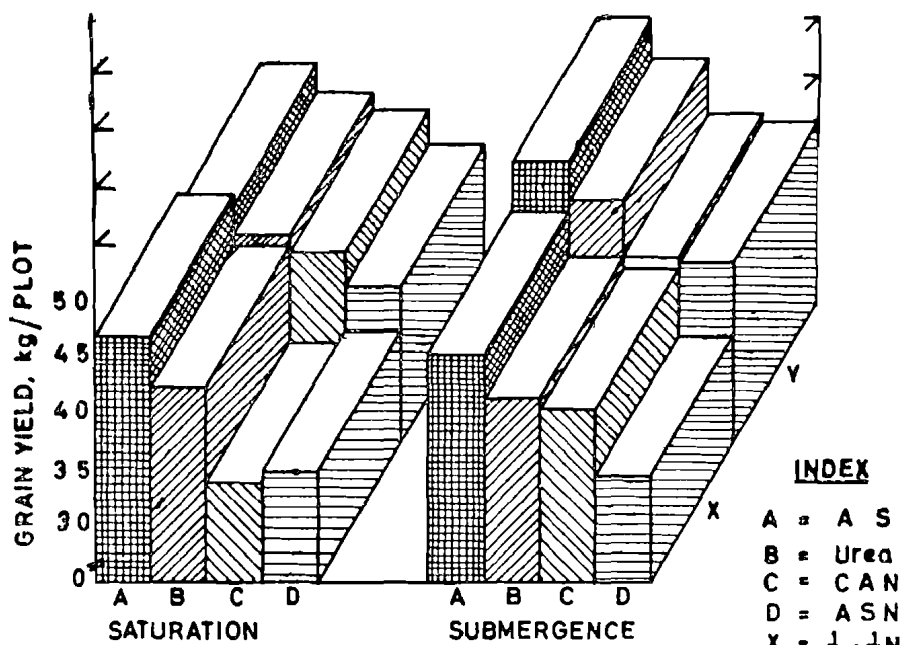
The major factor contributing to higher yield due to spray of this liquid complete fertiliser was due to the increase in the number of bolls per plant (40 to 53), weight of bolls (3.7 to 4.0 g), Kapas/boll and the number of seeds/boll (24.0 to 30.0)





EFFECT OF COATING FERTILIZERS ON THE PERIODICAL
LEACHING LOSSES OF NITROGEN IN SANDY CLAY LOAM
SOIL

FIG 10



EFFECT OF SOURCE OF NITROGEN,
THEIR SPLIT APPLICATION AND SOIL
WATER MANAGEMENT ON PADDY YIELD

FIG 11

SLOW RELEASE NITROGENOUS FERTILISERS

THE possibilities of reducing nitrogen losses from added fertilisers in soil may be accomplished by coating the fertilisers with inert materials which prevent rapid dissolution of fertilisers. Another way is to coat the fertiliser with nitrification retarders like neem cake, mahua cake and karanja cake. Patil and Deshpande (1972) studied the effects of three different coating materials on fertilisers, to serve as physical barriers for rapid dissolution of fertilisers in red and black clayey soils. Urea, ammonium sulphate-nitrate and calcium ammonium nitrate fertilisers were coated uniformly with 2 per cent solution with 'Ducoclear'-diluted in Duco-thinner, mineral oil diluted with Ducoclear and with polishing wax dissolved in benzene. The leaching losses of various forms of nitrogen under submerged conditions in wetland and black soil are given in Table 48.

The efficiency of these different coating materials in reducing leaching losses of ammoniacal nitrogen in red soil under Hebbal wetland conditions with control as 100 per cent were in the increasing order: mineral oil (96 per cent) > wax (100 per cent) > Ducoclear (107 per cent), while in black soil, the order was: wax (81 per cent) > mineral oil (85 per cent) > Ducoclear (93.5 per cent) (Figs 9 and 10).

In case of leaching losses of nitrate nitrogen, the relative efficiency in reducing leaching losses in wetland red soils was: wax (78 per cent) > Ducoclear = mineral oil (78.5 per cent), while in black soil the order was: wax (80.0 per cent) > Ducoclear (81.5 per cent) > mineral oil (95 per cent). The losses of ammoniacal and nitrate nitrogen were lesser to an extent of 23 and 10 per cent respectively in case of black soil than in red soil.

The rate of release and dissolution of fertilisers are also influenced to a large extent by the type and thickness of coating materials on fertiliser granules. Among the coating materials studied, wax and Ducoclear were found effective in regulating the release of nitrogen and retarded the leaching losses of nitrogen to an extent of 16.0 and 10.4 per cent over control and mineral oil coating respectively.

TABLE 48

Effect of coating of nitrogenous carriers on the losses of ammonium, nitrate and nitrites in the leachate collected in a period of two months from Hebbal wetland soil and black soil

Treatments		NH ₄ -4 (ppm)	NO ₃ -N (ppm)	NO ₂ -N (ppm)
<i>Hebbal Wetland soil</i>				
Urea	Control	55 36	63 04	2 34
	Ducoclear	62 00	52 90	1 44
	Wax	50 49	56 38	2 47
	Mineral Oil	49 56	65 14	1 69
Ammonium sulphate- nitrate	Control	39 37	76 44	5 38
	Ducoclear	50 04	65 32	4 33
	Wax	41 98	66 52	3 76
	Mineral Oil	38 60	66 76	4 73
Calcium ammonium nitrate	Control	42 65	81 78	6 07
	Ducoclear	43 36	62 92	5 10
	Wax	45 51	70 66	4 12
	Mineral Oil	44 72	80 78	4 47
<i>Black Soil</i>				
Urea	Control	32 26	61 28	2 49
	Ducoclear	33 42	47 46	1 00
	Wax	27 13	47 88	0 99
	Mineral Oil	31 70	54 26	0 84
Ammonium sulphate- nitrate	Control	36 58	63 06	3 51
	Ducoclear	35 41	62 00	1 80
	Wax	28 66	58 70	1 51
	Mineral Oil	28 37	67 46	2 29
Calcium ammonium nitrate	Control	34 79	82 38	2 59
	Ducoclear	28 07	59 76	3 08
	Wax	28 22	56 26	5 68
	Mineral Oil	27 94	75 58	2 70

TABLE 49
Chemical analysis of soil samples collected from the plots before planting and after the harvest of rice

Treatments	No of split applications	Soil pH		EC mmho/cm 25°C		Organic carbon per cent		Available P ₂ O ₅ Kg/hectare		Available K ₂ O Kg/hectare		Exch Ca me per 100 g	
		Before	After	Before	After	Before	After	Before	After	Before	After	Before	After
		Average of four replications											
<i>Submerged</i>													
Ammonium sulphate	2	6.53	5.65	0.285	0.328	1.02	1.01	38.6	41.6	52.8	49.2	3.04	2.81
	3	6.65	5.75	0.235	0.329	1.02	1.03	34.0	40.4	53.3	46.5	2.87	2.67
Urea	2	6.68	5.95	0.258	0.300	1.00	1.03	26.7	33.6	47.7	44.3	3.09	2.75
	3	6.50	5.66	0.345	0.310	1.04	1.03	22.3	36.3	48.7	49.9	3.04	2.71
Ammonium sulphate-nitrate	2	6.63	5.85	0.273	0.290	1.06	1.08	37.5	39.6	44.7	45.5	2.93	2.75
	3	6.60	5.85	0.263	0.315	1.01	1.04	33.2	36.5	46.2	42.7	3.00	2.73
<i>Saturated</i>													
Calcium ammonium nitrate	2	6.65	6.03	0.270	0.308	1.00	1.03	35.2	34.1	48.4	42.6	2.94	3.16
	3	6.55	6.03	0.278	0.295	1.05	1.00	38.6	36.3	50.0	43.0	2.87	3.30
Ammonium sulphate	2	6.45	5.60	0.345	0.380	1.02	1.00	39.0	42.8	48.6	45.6	3.02	2.61
	3	6.60	5.80	0.423	0.373	1.04	0.97	45.0	45.8	54.9	46.4	2.91	2.55
Urea	2	6.43	5.73	0.290	0.333	1.04	0.97	31.2	32.0	49.1	46.7	3.14	2.55
	3	6.35	5.75	0.335	0.330	1.05	0.97	35.2	42.1	51.9	46.0	2.73	2.43
Ammonium sulphate-nitrate	2	6.38	5.70	0.250	0.285	1.03	1.03	32.8	34.0	51.7	46.9	3.02	2.67
	3	6.60	5.90	0.240	0.300	1.06	1.01	36.8	40.3	45.2	42.0	2.81	2.59
Calcium ammonium nitrate	2	6.50	5.58	0.295	0.288	1.02	0.98	37.4	38.0	53.3	42.8	2.96	3.16
	3	6.48	5.95	0.253	0.289	1.04	1.00	28.3	32.8	49.6	42.2	2.91	3.32

The rapid release of nitrogen in the above experiments indicate that coating the fertilisers with 2 per cent coating materials failed to prevent the losses of nitrogen to any desired level since the rate of release of nitrogen is universally related to the coating thickness (Ahmed, 1962 and Lunt and Oerthli, 1962). The poor performance of mineral oil in controlling the release of nitrogen might be due to its failure to form a firm membrane over the granule, and the mineral oil coated fertilisers tended to float on the surface of water.

The effects of different nitrogenous fertilisers on chemical composition of soil (Table 49) revealed that soil pH, exchangeable calcium and potassium were depleted while soluble salts and available phosphorus were increased.

The relative performances of different nitrogenous sources such as ammonium sulphate, urea, ammonium sulphate-nitrate and calcium ammonium nitrate on Taichung-65 rice grown on wetland soil at Hebbal and black soil of Dharwar under submergence (10 cm depth) and moisture at field saturation was studied by Patil and Deshpande (1972). The yields of rice (Fig. 1) revealed that ammonium and amide forms of nitrogen were superior sources in increasing the yields. Application of nitrogen in three equal splits, first at planting, second 25 days after and the third 45 days after planting significantly enhanced the rice yields than two split application.

In order to test the efficacy of direct application of slow release nitrogenous fertilisers and also their residual effect on succeeding crops, an experiment was conducted at Siruguppa under Model Agronomy Scheme on irrigated jowar (CSH-1) during kharif and wheat (*Kalyan Sona*) during rabi of 1972-73 (Anon, 1973a). The slow release fertilisers listed in Table 50 were applied at 100 kg N/ha and were compared with 50, 100, 150 and 200 kg N/ha as urea. A basal dose of 100 kg each of P_2O_5 and K_2O /ha was applied before planting.

The results (Table 50) indicate that none of the urea coated fertilisers except neem-coated-urea were superior to urea on equal nitrogen basis in increasing the yields. On the contrary, in most of the cases, the yields from the coated urea were depressed. However, neem cake

coated urea treatment gave the maximum yields of jowar. As regards the residual effect of these fertilisers, I B D U (10-0-10) treatment significantly increased the yield of wheat (*Kalyan sona*) followed by sulphur coated urea (S 2) in the absence of nitrogen. But they were obliterated when nitrogen was applied uniformly at 20 kg N/ha.

The investigation was continued further during 1973-74 (Anon, 1974a) at Siruguppa with the inclusion of some more treatments such as urea coated with *karanja* cake and *mahua* cake applied at 50 and 100 kg N/ha on two rice varieties-IR-8 during *Kharif* and MR-136 during *rabi* seasons. The data on grain yield (Table 51) reveal that during *kharif*, at 50 kg N/ha, lac-coated urea and neem coated urea produced significantly higher yields over ordinary urea. The rest of the treatments were on par with ordinary urea. *Mahua* cake at 100 kg N/ha produced the highest yield almost equal to ordinary urea at 100 kg N/ha and was significantly on par with sulphur coated or lac coated urea.

As for, uptake of nitrogen by the crop (Table 52), none of the urea coated fertilisers were superior to ordinary urea at 50 kg N/ha while at 100 kg N/ha *mahua* cake coated urea was equal to ordinary urea. In general the uptake of nitrogen by rice grain was reduced considerably. However, the lac coated urea at 50 Kg N/ha recorded the highest uptake of nitrogen in the residual effect trials followed by ordinary urea.

Kulkarni *et al* (1975) studied the effect of split applications of urea treated with nitrification retardants such as neem cake, *karanja* cake and *mahua* cake with *CSH-1* Jowar and *IR-8* and *Java* rice varieties at Siruguppa and Mangalore centres respectively.

In terms of rice yield as well as uptake of nitrogen sulphur coated urea at 50 kg N/ha was found better when half the N was applied as sulphur coated urea and the remaining half as top dressing in the form of ordinary urea at 50 Kg N/ha. Rice yields were on par with ordinary urea at three splits. The sulphur coated urea did not have any residual effect on the succeeding rice crop indicating that most of the applied nitrogen was released and taken up by plants. With *CSH-1* variety of jowars, urea treated with neem cake at 20 per cent by weight applied in one dose

appeared to be on par or better than ordinary urea applied in two splits at 100 kg N/ha, both in respect of grain yield and uptake of nitrogen. Neem cake treated urea did not indicate any residual effect on wheat.

TABLE 50

Direct and residual effect of slow release nitrogenous fertilisers on yield of jowar (CSH-1) and wheat (Kalyan sona) on black soils at Siruguppa

Treatment	Yield (kg/ha)		
	Jowar direct effect during Kharif	Residual effect on wheat during rabi	
		Without N	with 20 kg N/ha
Urea at 50 kg N/ha	4494	469	775
Urea at 100 kg N/ha	5399	198	710
Urea at 150 kg N/ha	5541	588	790
Urea at 200 kg N/ha	5849	471	696
Sulphur coated urea at 100 kg N/ha	4914	249	789
Sulphur coated urea at 100 kg N/ha	4569	670	913
I B D U (10-10-10) at 100 kg N/ha	4549	1103	820
I B D U (16-10-14) at 100 kg N/ha	5366	296	825
Lac coated urea at 100 kg N/ha	4394	328	836
fertilisers at 100 kg N/ha	5011	234	828
Neem cake coated urea at 100 kg N/ha	5872	474	648
Control-no nitrogen	2391	274	778
Mean	4826	450	748
CD at 5 per cent	1106	315	N S

TABLE 51

Direct effect of slow release nitrogenous fertilisers on the grain yield of IR-8 rice during Kharif and residual effect on MR-136 rice during Rabi on black soils of Sruguppa

Treatments	Grain yield of rice (Kg/ha)			
	Direct—	Kharif	Residual—	Rabi
	50 Kg N/ha	100 Kg N/ha	50 Kg N/ha	100 Kg N/ha
Urea	3818 33	4911 67	2283 33	1925 83
Sulphur coated urea	4092 50	4583 33	1849 17	1875 00
Lac coated urea	4260 00	4540 00	2799 17	1903 33
Neem cake coated urea	4310 00	4329 17	2175 00	1987 50
Karanja cake coated urea	3978 33	3852 50	1946 67	1785 83
Mahua cake coated urea	3904 17	4920 00	1852 50	1839 17
Urea S T	4062 51	4510 83	2096 67	1780 00

TABLE 52

Uptake of nitrogen from slow release fertilisers by grains of IR-8 rice during Kharif and MR-136 rice during Rabi (kg/ha) on black soils at Sruguppa

Treatments	Nitrogen uptake by rice (Kg/ha)			
	Direct—	Kharif	Residual—	Rabi
	50 Kg N/ha	100 Kg N/ha	50 Kg N/ha	100 Kg N/ha
Urea	44 71	46 71	23 52	18 68
Sulphur coated urea	37 24	40 79	20 90	18 94
Lac coated urea	36 64	41 77	27 15	18 65
Neem cake coated urea	37 93	41 08	21 32	19 68
Karanja cake coated urea	35 14	45 76	20 93	18 58
Mahua cake coated urea				
Urea S T	35 75	39 70	22 02	17 09

SAFE LIMIT OF BIURET CONTENT IN UREA FOR CROPS

THE efficiency of urea is partly dependent on the biuret content which sometimes becomes toxic to seedlings. Biuret ($\text{NH}_2\text{CO-NH-CO-NH}_2$) occurs in urea as a result of over heating during the manufacture. Ordinarily, it may be present in such low amounts that it may neither prove harmful to young seedlings nor cause damage to foliage when used as spray. Biuret up to 5 per cent in urea may not affect its ammonification and nitrification in soil (Low and Piper, 1961).

An experiment was conducted on black clayey soil of Siruguppa to study the safe limit of biuret content in urea used for foliar spray on wheat (*Safed Lerma*) during rabi season of 1970. A foliar level of nitrogen as urea at the rate of 20 kg N per ha was applied in which biuret content was calibrated to contain 0, 5, 10, 15, 20, 25 and 30 per cent with a basal dressing of 60 kg each of N, P_2O_5 and K_2O /ha. From the data (Table 53), it is seen that the soil application of nitrogen was found to be more effective than that applied as foliar spray. But in the case of straw yield, the trend was almost reverse. This may be due to the fact that the plants might have utilised the foliar applied nitrogen for dry matter production rather than grain formation.

The nitrogen content of grains increased by foliar spray of urea containing biuret upto 3 per cent whereas the nitrogen content of straw decreased. The possible explanation for such phenomenon is that the metabolised nitrogen in leaves and stems as a result of foliar feeding was translocated to grain, contributing to increase in its nitrogen content. Foliar application of nitrogen appears to influence the phosphorus content of grains.

In both the cases, the concentration of phosphorus increased from 0.0975 to 0.1050 per cent when sprayed with urea containing biuret upto 1.5 per cent. The study revealed that the biuret upto 3 per cent in urea does not cause any adverse effect on the yield of wheat. The foliar feeding of nitrogen had no advantage over its application through soil.

TABLE 53

*Effect of biuret in urea as a foliar spray on the yield and composition of wheat (Safed Lerma)
grown on black soil of Siruguppa*

Treatments	Yields (Kg/ha)			Composition of grain %			Composition of Straw %		
	Grain	Straw	N	P	K	N	P	K	
Control (No Nitrogen)	707	1342	2 464	0 1025	0 48	0 350	0 040		3 4
Control (Nitrogen applied to soil)	2431	3620	2 394	0 0975	0 52	0 392	0 028		3 2
Commercial grade low biuret urea	2396	3955	2 422	0 0975	0 52	0 322	0 030		3 2
0 5 per cent biuret urea	2063	3906	2 380	0 0975	0 49	0 350	0 030		3 3
1 0 per cent biuret urea	2431	3770	2 450	0 1000	0 48	0 280	0 035		3 1
1 5 per cent biuret urea	2376	4000	2 422	0 1050	0 56	0 322	0 023		3 2
2 0 per cent biuret urea	2425	3775	2 454	0 0900	0 49	0 280	0 023		3 2
2 5 per cent biuret urea	2122	3503	2 350	0 0900	0 48	0 336	0 033		3 4
3 0 per cent biuret urea	2386	3741	2 473	0 0825	0 46	0 392	0 033		3 3

TABLE 54

Effect of nitrogen on the nutritive composition of some common cereal grains of Karnataka

Treatment	Proximate composition			Mineral composition			Vitamins (mg/100g)			Amino acid mg/100g protein
	Moisture %	Curde Protein %	Mineral matter %	Carbo- hydrates %	Phos- phorus %	Iron (ppm)	Thia- mine	Ribo- flavin	Niacin	
<i>Wheat (Bijaga Yellow)</i>										
Control (No fertiliser)	9.96	14.70	1.58	69.89	0.341	47.03	0.463	0.38	3.11	1.50
N ₀	9.83	15.33	2.03	68.95	0.299	35.99	0.461	1.76	2.90	2.15
N ₁₀	9.86	13.96	2.13	70.60	0.337	39.89	0.402	1.74	4.99	2.43
N ₂₀	9.52	14.90	1.80	70.80	0.346	45.91	0.390	0.36	4.95	2.28
N ₃₀	9.14	15.18	1.82	70.24	0.350	45.75	0.373	0.28	5.95	2.01
N ₄₀	9.46	15.40	2.13	69.37	0.366	45.97	0.362	0.22	5.99	2.01
<i>Jowar (Muguti vai)</i>										
Control (No fertiliser)	8.45	9.49	1.24	76.36	0.215	30.54	0.457	0.022	2.05	3.79
N ₀	7.43	7.65	1.22	79.44	0.202	20.32	0.460	0.020-	2.00	3.92
N ₁₀	7.55	8.45	1.28	78.78	0.212	21.27	0.460	0.024	2.10	3.67
N ₂₀	7.83	8.61	1.34	77.84	0.215	22.64	0.480	0.026	2.25	3.83
N ₃₀	8.65	9.14	1.37	78.23	0.225	26.51	0.500	0.026	2.25	3.72

<i>Ragi (I E 267)</i>										
N ₀	10 50	7 00	2 30	76 30	0 300	48 00	0 450	0 105	2 100	3 71
N ₆₀	9 77	7 48	2 59	76 31	0 307	48 99	0 475	0 113	2 137	3 60
N ₁₀₀	11 93	7 56	2 64	73 40	0 297	43 65	0 686	0 119	2 844	4 17
N ₁₄₀	12 13	7 68	2 84	73 32	0 265	40 55	0 635	0 120	2 850	3 99
<i>Rice (I R -8)</i>										
Control (No fertiliser)	2 37	8 60	0 135	81 26	0 290	90 50	0 211	0 020	3 02	3 72
60-30-30	2 37	8 95	0 136	80 17	0 280	92 73	0 220	0 019	3 50	3 69
90-45-45	2 38	9 19	0 137	80 71	0 291	82 93	0 220	0 019	3 64	4 13
120-60-60	2 39	9 29	0 141	80 74	0 381	82 31	0 263	0 020	6 03	3 52
150-75-75	2 41	9 76	0 143	79 87	0 389	72 97	0 630	0 021	6 83	3 38

EFFECT OF NITROGEN ON THE QUALITY OF CROPS

GREEN revolution has contributed to bumper harvests. In a country like India where hunger and malnutrition are prevalent, there is need to improve the quality of food grains we produce, in order to increase the nutritional standard of food of common people. Investigations have shown that nitrogen application to crops improve the quality of crops. A study was undertaken to ascertain the influence of Nitrogen fertilisation on some of the most important cereal grains like rice, jowar, wheat and ragi commonly grown in the State. Jowar and wheat crops were grown on black clayey soils at Bijapur, rice on black soils at Hivru and ragi on red soils of Hebbal. The data (Table 54) reveal that the crude protein mineral matter, niacin riboflavin and lysine contents increased with nitrogen applications. There was reduction in iron content in all the grain samples (Kavalappa 1976).

It has been shown by many workers that nitrogen application to crops tend to increase protein content in grains (Chandrashekar *et al*, 1953, Gupta & Das 1954, Modgal and Das, 1963). It has been further demonstrated that applied nitrogen at higher rates would improve the quality rather than the yield of produce. Arakeri *et al*, (1972) observed that the split application of nitrogen at the rate of 150 kg/N per ha improved the protein content of rice from 8.6 to 9.6 per cent as compared to single application at planting.

Protein content of sorghum grains was found to increase by the application of nitrogen (Deosthale, *et al*, 1972). Similar observations were made in respect of four varieties of ragi at 80 Kg N/ha by Krishna murthy (1968). But a reverse trend was noticed by Venkata Rao and Sadasivaiah (1968) in their studies on ragi. Their studies revealed that nitrogen applied at 40 kg per ha enhanced the protein content, but the same was found to be depressed beyond 80 kg N/ha. The plausible reason for decrease in protein content at nitrogen level beyond 40 kg/ha was due to decrease in pH of low buffered soils as a consequence of higher rates of nitrogen (160 kg N/ha) applied as ammonium sulphate.

NITRATES IN SEEPAGE WATER AND PLANTS

WITH the expansion of irrigation facilities, cultivation of crops like sugarcane and rice with high fertiliser levels has become common. Often, the fertiliser nitrogen added to such soils tends to leach down resulting in the enrichment of seepage water with nitrates (Ayers and Bransan, 1973). A cursory check of canal waters and seepage waters through black soils of Siruguppa clearly show the possible hazard of nitrates in the near future (Bhadiapur and Rao, 1972). The canal water contained nitrates in the range of 0.62 to 2.48 ppm during the year but the drainage water found to contain as much as 12.38 ppm nitrates. A more serious situation was observed at R. R. S. Mandya where the seepage water from the sugarcane fields contained nitrates to the extent of 52 ppm. Though such waters are good for irrigation, their possible use for drinking either by cattle or human beings would pose a health hazard.

With increasing awareness of nitrate poisoning to cattle in recent years, there has been great interest in the study of inhibitory effect on the digestibility of straw or forage. Uthappa (1967) studied the digestion of cellulose in *Cynodon dactylon* (*Vai Coastal Broom* grass) grown under nitrogen levels ranging from 0 to 720 kg N/ha. The technique adopted was *in vitro* bacterial digestion using the rumen fluid from steer as inoculum. At levels from 0 to 240 kg N/ha there was no appreciable difference in cellulose digestion of the grass samples but the samples from plots which received 720 kg N/ha gave very low digestion percentage. The digestion of cellulose was highest in the samples from first cutting from plots receiving nitrogen at 0 to 240 kg per ha. There were also not much differences among the four cuttings in respect of quality as referred to digestibility.

VARIETY FERTILISER INTERACTIONS TO ASSESS THE YIELD POTENTIAL

NUMEROUS experiments were carried out in the past to study the response of different varieties of crops to fertilisers. In recent years owing to the introduction of high yielding and hybrid varieties of crops, several field studies were taken up to find out their yield potentials in relation to fertiliser applications.

Two high yielding varieties of ragi *Viz*, 9-2-7 and *Purna* were tested for their responses to graded additions of nitrogen upto 160 kg N/ha on red sandy loam soils of Hebbal. Yields of both the varieties increased with increasing levels of nitrogen. The response of 9-2-7 variety of ragi was more pronounced, than *Purna* ragi though it was found to contain higher nitrogen when fertilised at higher levels of nitrogen (Venkata Rao and Sadasiviah, 1968b).

Bajra (HB-1) was grown on black soil of Siruguppa with 30, 60 and 120 kg N/ha. It was found that the application of nitrogen at 120 kg N/ha produced significantly higher yields (1993.50 kg/ha) of grain over 60 kg N/ha (Anon, 1970).

A study on the fertiliser requirements of new varieties of paddy conducted at Mangalore under Model Agronomy Scheme during Rabi 1972 and Kharif 1974, indicated that the relative yield potentials of paddy varieties to fertiliser nitrogen in terms of grain yields were: *Jaya* (3909 kg/ha) > IET-1966 (3514 kg/ha) > IR-8 (3159 kg/ha) > MR-272 (1665 kg/ha). The interaction of varieties with nitrogen revealed that *Jaya* was capable of giving increased yields up to 180 kg N/ha while those of IR-8 and IET-1996 responded only upto 60 kg N/ha.

In the same experiment in *Kharif* season at Siruguppa centre, the relative yields of *Kharif* Jowar varieties were: 2219 Axes 3541 (3123 kg/ha) > CSH-1 (3124 kg/ha) > 604 (1909 kg/ha) > 302 (1670 kg/ha). The response of *Kharif* Jowar to nitrogen upto 120 kg N/ha was increasing and thereafter it showed a depressing effect.

New varieties of wheat i.e., *Kalyana Sona*, *Sonalika*, *UP-301*, and *HDI-739* were tested during rabi 1974 for their responses to fertiliser nitrogen upto 180 kg N/ha. Their relative performances in terms of grain yields were *HDI-739* (1882 kg/ha) > *Kalyana sona* (1626.10 kg/ha) > *Sonalika* (1554.37 kg/ha) > *UP-301* (1549.79 kg/ha). The response to added nitrogen was linear upto 180 kg N/ha for all the varieties tested except *HDI-739* which gave the highest yield of 2546.67 kg/ha at 120 kg N/ha (Anon 1974 a)

Singlachar (1972) from his study on the yield potentials of promising rice varieties under different nitrogen levels at the Regional Research Station at Mandya reported that variety *Jaya* outyielded (8.0 tonnes/ha) all the varieties, showing highest response upto 150 kg N/ha followed by *IR-20* (7.2 tonnes/ha). Based on average responses, he stated that yield increase of 2 tonnes/ha over zero level of nitrogen was obtained at 150 kg N/ha in terms of kg grain per kg nitrogen added. Application of 100 kg N produced 26 kg grain extra followed by 19 kg grain at 150 kg N/ha.

Panchaksariya *et al* (1972) studied three varieties of rice viz., *Jaya*, *Padma* and *5-705* for their performances to added nitrogen upto 160 kg N/ha during kharif and summer 1962. *Jaya* and *Padma* rice varieties responded upto 160 kg N/ha though 120 kg N/ha was found economical.

Deccan hybrid, Amber composite and Arabhavi local maize genotypes were compared with three levels of nitrogen (100, 150 and 200 kg N/ha) and two levels of population (55,000 and 83,000 plants per ha) for two seasons in order to ascertain their relative performances. Deccan hybrid (8054 kg/ha) yielded 15 per cent more than Amber composite (6845 kg/ha) and 42 per cent more than Arabhavi local. This was due to the ability of hybrids to produce more number of cobs per ha (13 and 5 per cent more than composite and local respectively) with the highest grain weight per cob. Increase in the dose of nitrogen or plant population did not increase the grain yield significantly and eventually application of 100 kg N/ha with a population of 55,000 plants per ha appeared to be optimum (Krishnamurthy, *et al*, 1973).

INVESTIGATIONS UNDER DRYLAND FARMING

THE scheme on Dryland Agriculture sponsored by the I C A R started functioning from 1971 at Gandhi Krishi Vignana Kendra, the new campus of University of Agricultural Sciences, Bangalore as the main centre for investigating the various problems on dryland farming. Some of the important findings related to fertiliser nitrogen are

The soils are red sandy loam to clay loam and are distinctly acidic in reaction. They are also low in organic carbon and available phosphoric acid but rich in potassium.

Studies on placement of fertilisers for Ragi. Treatments consisted of four levels of nitrogen viz 0, 30, 60 and 90 Kg N per ha and three methods of applications viz, broadcasting, placing at 10 cm depth and placing half the amount of N at 10 cm depth and remaining half as top dressing. A basal application of 50 kg P_2O_5 and 25 kg K_2O per ha was done.

TABLE 55

*Influence of methods of applications of nitrogen on the yield of ragi
(Sharada) (q/ha)*

Treatments	Broadcast	Placed at 10 cm	$\frac{1}{2}$ Placed and $\frac{1}{2}$ top dressed	Mean
N ₀	17.45 (24.8)	18.91 (26.1)	17.90 (25.9)	18.10 (25.6)
N ₃₀	23.11 (32.5)	21.86 (30.3)	22.79 (32.7)	22.58 (31.8)
N ₆₀	28.36 (41.8)	25.01 (45.2)	28.12 (40.0)	27.23 (42.3)
N ₉₀	28.32 (44.4)	29.25 (47.5)	29.37 (40.4)	28.97 (44.1)
Mean	24.32 (35.9)	23.76 (37.2)	24.61 (34.8)	

(Figures in parenthesis indicate straw yield)

The results (Table 55) indicate that the placement of fertiliser had no effect on the yield of ragi. However ragi responded to fertiliser nitrogen upto 90 kg N/ha.

Time of application of nitrogen to crops It was shown conclusively that the yields of ragi and maize were improved by the application of nitrogen in three equal splits. Ragi yielded maximum when 50 kg nitrogen per ha was applied over basal dressing of 50 kg P_2O_5 and 25 kg K_2O in three equal splits viz before sowing and one month and two months after sowing. In case of maize, application of 75 kg nitrogen per ha in three equal splits with the same basal dressing proved better in respect of yield potential. The split applications were made at sowing time, at knee stage and at tasselling stage.

Studies on the role of FYM in reducing the fertiliser requirement of ragi crop Results indicated that FYM could not completely replace fertiliser nitrogen in increasing the yield of ragi. Adding FYM with fertiliser phosphorus was found to be better in increasing the yields through efficient use of applied phosphorus.

Influence of legumes and green manures on the economy of fertiliser nitrogen for ragi The study revealed that the yield of ragi grain was reduced when grown after cowpea without phosphorus and potash. Though FYM and green manures were superior sources of nitrogen for ragi, the yield differences among the two were negligible. The interaction effects between FYM, green manure and fertiliser nitrogen were not observed.

Study on the optimum doses of N and P for different crops Ragi, cowpea, maize and groundnut were tested with four levels of nitrogen and four levels of phosphoric acid. For ragi 50 kg N and 60 kg P_2O_5 per ha appeared to be economical while a dose of 37.5 kg N and 60 kg P_2O_5 per ha for cowpea and groundnut was found optimum. Maize required the application of 75 kg N and 60 kg P_2O_5 per ha for maximising the yield.

Studies on foliar application of nitrogen to leguminous crops The solutions of urea (0.155 per cent), potassium nitrate (0.5 per cent) and

ammonium nitrate (0.25 per cent) were sprayed on groundnut, cowpea and blackgram over a basal dressing of 20-60-25 kg per ha of N, P_2O_5 and K_2O respectively

The data (Table 56) reveal that the leguminous crops did not respond to foliar application of nitrogen during flowering

TABLE 56

Effect of foliar application of nitrogen on the yield of leguminous crops (q/ha)

Treatments	Yield of grain (q/ha)		
	Groundnut	Cowpea	Blackgram
Urea (0.155%)	8.00	8.10	4.96
Potassium nitrate (0.5%)	8.52	9.18	5.48
Ammonium nitrate (0.25%)	7.63	8.74	4.00
Control	6.37	8.15	4.44
S Em	0.67	0.88	0.47

A number of fertilisers trials were conducted on different crops in cultivators fields under dryland conditions and they have created an awareness among farmers on the beneficial effects of fertilisers on crops under limited moisture conditions. Venkata Rao and Srinivasamurthy (1972), and Srinivasamurthy and Aswatharath (1958) based on extensive experiments and demonstrations on farmers fields indicated that there was an increase of 30 to 50 per cent in grain and 50 to 100 per cent in straw yield with the application of 30 and 15 kg N and P_2O_5 per ha respectively with dryland ragi and maize in Kolar and Bangalore districts. In Siddlaghatta area of Kolar district, the yield of ragi increased from 50 to 100 per cent in lean rainfall years and 100 per cent in normal rainfall years. Kulkarni (1970) reported responses of locally improved varieties of Jowar and Cotton to application of 30 kg N/ha at the research stations, Kaladgi in Bijapur district and Saundatti in Belgaum district. The yield increase was of the order of 32 and 34 per cent respectively. The results at Nargund (Dharwar district) indicated that the application of 30 kg N and 20 kg P_2O_5 per ha was best for crops like Jowar, Cotton, Wheat and bajra.

FERTILISER NITROGEN UNDER IRRIGATION AGRICULTURE

IRRIGATION under favourable soil conditions is a guarantee for a stable and prosperous agriculture. With the opening of large scale irrigation facilities in the State, many crop varieties are being grown. The fertiliser requirements of these crops are certainly different from those under rainfed conditions. In the past, many investigations have been carried out to work out the fertiliser needs of different crop varieties. The Research Stations at Siruguppa and Gangavati have been in existence for the past 40 years. Some of the highlights of research carried out at these stations before 1965 as reviewed by Patil and Venkata Rao (1968) are

The soils at Siruguppa and Gangavati are deep black and are highly deficient in nitrogen and available phosphorus but are well supplied with available potash to an extent of 500 kg K_2O /ha. In general, marked responses of crops to nitrogen and phosphorus applications have been noticed.

Studies on the possibilities of replacing groundnut cake and FYM in part or full with fertilisers for sugarcane, rice and cotton showed no perceptible beneficial effect of FYM in conjunction with fertilisers on these crops.

Trials on the efficiency of nitrogenous fertilisers like ammonium sulphate, urea, ammonium sulphate-nitrate, ammonium chloride, calcium ammonium nitrate and chilean nitrate applied to sugarcane showed negligible effect on the yield and quality of cane. However, in the case of rice, ammonium sulphate and ammonium chloride showed better results than other forms. Nitrate containing fertilizers were found inferior for rice.

Green manures applied in conjunction with fertilisers were not suitable for light irrigated crops. Cotton yields were increased with the application of green manures. The effects of green manures were more marked in case of rice particularly when it was applied with fertilisers.

Karad local *Kharif* Jowar variety gave 3 to 4 times higher yield over no fertiliser when fertilised with 40 kg N and 20 kg P_2O_5 per ha. Under light irrigation, the same *kharif* Jowar recorded further increase in yields at 60 kg N and 80 kg P_2O_5 . For hybrid jowar, a dose of 100 kg N and 60 kg P_2O_5 per ha was recommended for higher yields.

A dose of 60 kg N and 30 kg P_2O_5 per ha was found optimum for higher yields of Navane (*Setaria italica*). For maize (*Zea mays L.*) a dose of 100-60-30 N, P_2O_5 and K_2O was recommended. Good response of wheat was observed at 60 kg N and 30 kg P_2O_5 per ha. Numerous trials conducted on the fertiliser requirements of cotton revealed that the yields of cotton were doubled with 60 kg N and 30 kg P_2O_5 over no fertiliser addition. Nitrogen in ammonium sulphate was found superior to nitrogen supplied through cake, FYM and green manure. Application of nitrogen in three splits, the first at sowing, the second at one month and the third at two months after gave higher yields than entire application at sowing. Based on this, a dose of 60-30-20 N, P_2O_5 and K_2O per ha was recommended for cotton. Entire quantity of P and K may be applied at the time of sowing whereas nitrogen has to be supplied in three splits.

In the case of rice, heavy doses of fertilisers caused considerable lodging. Application of green manures at 6000 kg/ha before planting was advantageous in getting higher yields. A dose of 60 kg N and 30 kg P_2O_5 per ha along with 6000 kg per ha of green manure was recommended for rice.

Sugarcane (CO-419) has covered a large area under Tungabhadra Project. Varieties like CO-740, 775 and 995 were also found promising. Application of 300 kg N per ha for cane planted in January was found suitable. This gave 6 tons higher cane yields as compared to 150 Kg N per ha. A dose 300 kg N, 100 Kg P_2O_5 and 50 kg K_2O per ha was found optimum for January cane, while 400 kg N, 125 kg P_2O_5 and 50 kg K_2O per ha were recommended for Adasali (Planted in July) sugarcane.

With the transfer of the Agricultural Research Station at Sruguppa to the University of Agricultural Sciences, Bangalore in 1965, the programmes at this centre were remodelled under the "All India Co-ordinated Scheme for Research on Water Management and Soil salinity". Main findings of the studies are (Anon, 1974).

Water requirement of important crop rotation at different intensities of irrigation and fertiliser (rice-rice rotation) application are being worked out. Irrigation to rice at 5 cm submergence was found to result in maximum yield. Irrigation between saturation and hair cracking of soil no doubt saved about 8.5 per cent of water in Kharif and 38.4 per cent in summer but caused reduction in yield to an extent of 15.8 per cent when compared to maintaining water at 5 cm depth of submergence. IR-8 rice gave maximum yield with 180 kg N/ha at 5 cm submergence. High levels of nitrogen induced greater susceptibility to blast in IR-8 rice.

Ragi recorded maximum yield when irrigated at 50 per cent depletion in available soil moisture with nitrogen at 120 to 180 kg per ha.

It was found that bajra should be irrigated at 50 per cent depletion in available moisture and that the crop responded upto 180 kg N/ha. Cotton (Hampi var) needed irrigation at 50 to 70 per cent depletion in available moisture. It also gave maximum yield at 120 kg N per ha. Hybrid cotton (Varalaxmi) was superior to H-4 cotton for a given level of nitrogen. Varalaxmi yielded highest (25.82 q/ha) with a dose of 180 kg N/ha.

Wheat was found to respond best to irrigation at 75 per cent depletion in available moisture when combined with nitrogen level of 120 kg N/ha for *Kalyan sona*, 180 kg N/ha for UP-301 and for *Safed Lerma* at 150 kg N/ha.

Setaria recorded highest yield when irrigated at 50 per cent depletion in available moisture with the application of 150 kg N/ha. CSH-1 Jowar responded upto 180 kg N/ha and gave higher yields than *Swarna* variety of Jowar.

Kulkarni *et al* (1975) reported that in transition tract under conditions of sufficient soil moisture, application of 50 kg N/ha in one dose at sowing was adequate for a short duration variety of jowar like CSH-1 during *Kharif*. For *rabi* jowar grown in scarcity areas under limited soil moisture conditions, addition of 25 kg N/ha to soil, half at sowing and the remaining half one month after as urea spray were found advantageous. Foliar applications to crop yielded about two quintals of additional grain per ha over an application of entire dose at planting.

Irrigated wheat varieties like *Safed Lerma* and *Bijga yellow* were tested for their responses to fertilisers in terms of grain yield during 1969-72 on cultivators fields in Raichur district (Chandrashekaraiya *et al*, 1975). The response pattern of crops to different nutrients and their interactions were identical for both the varieties, except that the yields of *Bijga yellow* were slightly lower than *Safed Lerma* at every level of fertiliser added. Combined applications of N and P_2O_5 at 60-30, 120-30 and 120-60 kg/ha produced higher yields than their additions separately.

In a study on the responses of newly introduced cotton varieties to fertiliser nitrogen under irrigation at Siruguppa and Arabhavi with different spacings, Gururaj Hunsigi and Katarki (1974) observed that the response of cotton to added nitrogen was quadratic in form and maximum yield was obtained at 90 kg N/ha. Cotton absorbs nitrogen both in the form of NH_4 and NO_3 ions but the latter is preferred.

An experiment to ascertain the influence of graded additions of nitrogen on newly introduced varieties of cotton was conducted at Dharwar under irrigation during 1968-69. The results (Table 57) show highly significant yield differences due to varieties in respect of nitrogen applied. The optimum level of nitrogen was found to be between 90 and 120 kg N/ha.

TABLE 57

Yield of seed cotton (q/ha) as influenced by varieties and nitrogen applications

Variety	Levels of nitrogen, kg/ha					CD at 5%
	0	60	90	120	Mean	
Varalaxmi	12.76	17.52	18.68	19.34	17.07	3.49
JK-78	4.19	8.27	10.83	12.02	8.83	
Hybrid-4	5.59	10.09	11.57	10.96	9.54	
Laxmi	11.07	15.23	17.60	17.96	15.46	
Mean	8.40	12.77	14.67	15.00		

The study further demonstrated that early ripening of cotton bolls took place with increase in applied nitrogen. Maturity of bolls was hastened (Table 58) when nitrogen was applied up to 90 kg N/ha and further delayed at higher levels.

TABLE 58

Effect of nitrogen levels on maturity of cotton bolls

Nitrogen (kg/ha)	Percentage of first two pickings
0	33.88
60	41.83
90	42.38
120	39.72

The common belief that nitrogen application would delay maturity is not supported by the data in Table 51 when the proportion of total yield at first two pickings is used as a measure of crop maturity. The same authors also studied the effect of nitrogen levels in relation to population of cotton plants at Siruguppa and Arabhavi during 1968-71. They reported that close spacing of 75×15 cm (89,000 plant population per ha) yielded 3.3 per cent more over wide spacing of 75×25 cm (53,000 plant population per ha) at Siruguppa, while at Arabhavi, wider spacing of 75×25 cm gave increased yield of 2.4 per cent over close spacing.

In a study on the interactions between spacing and nitrogen levels, it was found that closer spacing of 75×15 cm with addition of 90 kg N/ha gave high response at Siruguppa while at Arabhavi wider spacing of 75×35 cm (38,000 plant population per ha) with 90 kg N per ha produced the highest yield of 15.90 q/ha. It was also noticed that closer spacing without nitrogen depressed the yield at both the locations.

Working on irrigation and nitrogen requirements of different varieties of wheat viz, PW_3 , PW_5 , NP_{710} and NP_{718} grown on black soils of Raichur, Ambadas Rao (1972 c) observed that NP_{718} variety produced (402 kg/ha) of grain at 40 kg N/ha which was almost double that without fertiliser (292 kg/ha). The relative yield potential of these varieties was rated in decreasing order as NP_{715} (358 kg/ha) > NP_{710} (227 kg/ha) > PW_5 (221 kg/ha) > PW_3 (203 kg/ha). He further observed the significant interactions between irrigation and manuring. The results indicated (Table 59) that interactions between them were seen at higher levels of fertilisers (20 and 40 kg N/ha) with four and six irrigations.

TABLE 59
Interactions between irrigations and the fertiliser levels on yield of wheat (1958-61)

Fertiliser levels (kg/ha)	Yield of wheat grain (kg/ha)				
	Frequency of Irrigations				Mean
	I ₀	I ₂	I ₄	I ₆	
N ₀	106	227	231	328	223
N ₂₀	114	230	292	397	258
N ₄₀	119	243	317	426	276
Mean	113	233	280	384	

In general, four frequent irrigations with application of nitrogen at 20 kg N/ha appeared to be optimum for the wheat varieties studied

Similar studies were made on cotton under Tunga Bhadra Project, Raichur district, on black soils by Ambadas Rao (1972 d). He observed that cotton response was linear to nitrogen applications upto 90 kg N/ha. Irrigation tended to increase the yields of seed cotton upto nine irrigations. The interaction between irrigation and nitrogen was significant at 90 kg N per ha with nine irrigations (Table 60).

TABLE 60
Interactions between nitrogen and levels of irrigation on the yield of seed cotton (kg/ha) 1955-1958 *Yield of seed cotton (kg/ha)*

Irrigation levels	Fertilisers levels (kg/ha)				Mean
	N ₀	N ₃₀	N ₆₀	N ₉₀	
I ₀	472	698	570	640	595
I ₃	625	634	637	812	677
I ₆	563	699	686	840	697
I ₉	568	709	792	885	739
I ₁₂	610	627	759	824	705
Mean	568	675	689	800	

A level of 30 kg N/ha appeared to be better for cotton without irrigation and it was also found to respond to three irrigations in the absence of fertilisers. The yield of seed cotton increased upto nine irrigations but decreased beyond it. Maximum yield of seed cotton (885 kg/ha) was obtained at 90 kg N/ha with nine irrigations.

YIELD POTENTIAL UNDER RESOURCE CONSTRAINTS

ESSENTIAL agricultural inputs like fertilisers, plant protection measures and irrigations for maximising agricultural productions have become very expensive. High costs of these inputs necessitate an examination of package of practices so as to ascertain whether any reduction in cost through applications of these inputs at lower levels than recommended would maintain the yield of crops at reasonably higher level.

This study was undertaken during 1972-74 for selected crop sequences like rice-rice at Mangalore centre and jowar-wheat at Siruguppa centre, under the Model Agronomy Scheme. At Mangalore, fertilisers and plant protection measures were the constraints studied. And at Siruguppa, the constraints looked into were fertiliser and plant protection for jowar and fertiliser and irrigation for wheat.

Studies at Mangalore Plant protection measures consisted of three levels viz, (i) No plant protection (ii) Full plant protection and (iii) Plant protection in part. Three fertilisers levels were tried F_1 Full dose of fertilisers as recommended by the University viz 100 75 85 kg N/ha P_2O_5 and K_2O respectively, F_2 75 per cent of the full dose, F_3 50 per cent of the full dose.

Studies at Siruguppa The levels of plant protection measures remained same. Fertiliser levels tried were (i) Full dose recommended by the University (F_1) viz 125 75 37.5 kg/ha of N, P_2O_5 and K_2O respectively (ii) F_2 75 per cent of the full recommended dose (3) F_3 50 per cent of the full recommended dose. Full quantities of P_2O_5 and K_2O and fifty per cent of N were applied at sowing and remaining nitrogen in two splits at fourth week and at flag leaf stage.

Irrigation was tried at three levels viz

I_1 = Five irrigations at sowing, crown root initiation, late tillering, flowering and dough stages

I_2 = Four irrigations, Same as I_1 Except no irrigation at dough stage

I_3 = Three irrigations, Same as I_1 except no irrigation at late tillering and dough stage

The investigation carried out at Mangalore Centre revealed that the yields of Jaya variety rice were drastically reduced by eliminating plant protection measures rather than applying fertilisers at 50 per cent of the full recommended dose. The uptake of nitrogen by the crop was more at full plant protection measure level than at no plant protection measure, at all levels of fertiliser added.

The study with Kharif Jowar grown at Siruguppa, indicated that grain yield was severely affected by omitting plant protection measures. Though the fertiliser dose at 50 per cent level depressed the yields, not much differences in yield were observed between 100 and 75 per cent levels of fertilisers. As regards wheat (*Kalyan Sona*) grown at Siruguppa, application of 50 per cent of recommended dose of fertilisers with four irrigations were found optimum for maximising yields of wheat grain.

SUMMARY AND PROJECTIONS

THE importance of nitrogenous fertilisers in obtaining good harvests was recognised by the earlier workers in Karnataka. Based on manurial trials, optimum and economic doses of nitrogen were included in the successive manurial recommendations made by the Department of Agriculture.

As for innovative work, the demonstration of the feasibility of direct application of anhydrous ammonia to field crops through the fabrication of simple applicators that could be used with indigenous equipment like bullock drawn plough and bullock carts deserve mention.

The soils of Karnataka are generally low in nitrogen. Additions of small quantities of nitrogenous fertilisers have often given spectacular increase in yields. This additional yield was found to be due to higher accumulation of dry matter arising out of proliferation of roots.

Balanced application of nitrogen with phosphorus and potash has been found to produce increased yields in respect of all field crops. For example, a dose of 40 kg N, 20 kg P_2O_5 and 20 kg K_2O per ha is the recommended package of practice for ragi and jowar even under dryland farming. The effects of green manures or oil cakes on the yield of crops have been found to be similar to those of inorganic fertilisers when supplied on equal nitrogen basis.

Nitrogen use efficiency has been found to increase in the presence of phosphorus in cereal-legume rotations. Though, the influence of straight and complex fertilisers on crop yields has been found to be the same, the latter are less expensive and more economical. Ammonium form of nitrogen has been shown to be more efficient over nitrate forms for lowland or flooded rice. Nitrogen carriers containing ammonia in different forms like complex fertilisers, urea, anhydrous ammonia and nitrogen solutions have shown the same effect on rice.

Urea and ammonium sulphate have been found to be efficient in calcareous and alkaline soils. It has been demonstrated that nitrate forms of fertilisers are better sources in increasing yields of ragi and other crops where underground leaching is minimum. The relative efficiency of nitrate fertilisers applied to ragi was rated in the decreasing order: Calcium ammonium nitrate > ammonium sulphate nitrate > ammonium nitrate. In regard to the rapidity of nitrification of different sources of N in soils, urea was seen to nitrify faster in acid soils than ammonium sulphate. The nitrification of urea was complete within eight weeks of application whereas hardly 50 per cent of nitrogen in ammonium sulphate was nitrified.

Applications of heavy doses of nitrogenous fertilisers like ammonium sulphate and urea were found to result in drastic changes in many chemical properties of soils. The main effects were decrease in pH, reduction in exchangeable bases and increase in aluminium, iron and manganese. Under such conditions occasional liming was found to restore the soil to normal conditions for good growth of crops.

Other side-effects of continuous heavy applications of nitrogen were found to be the alteration in the composition of soil microflora. The population of bacteria and other microbes were found to depress while those of fungi and actinomycetes remained unaffected. The hydrogenase enzyme activity was depressed due to lowering of soil pH.

Increased crop incidence of insects, virus and other bacterial diseases were found to be associated with heavy fertiliser nitrogen, the reason attributed to such conditions being that the plants would become succulent and susceptible to diseases.

Since nitrogenous fertilisers are generally water soluble, broadcasting and sometimes placement as in the case of urea, 10 cm deep by seed-cum-fertiliser drill was found to be advantageous. Three split applications of nitrogenous fertilisers to jowar were generally found to be preferable to single application in order to minimise leaching losses of nitrogen and better utilisation of applied nitrogen. Usually split applications were found to favour early flowering by about two weeks.

Foliar application of urea to cotton as a supplement to basal soil applications increased the yield of seed cotton. The yields of rice were also increased by split applications through foliar sprays. In general, foliar feeding of plants is feasible under specific conditions where nitrogen application to soil has become inadequate or ineffective. Soil applications of nitrogen generally appeared to be better than foliar sprays.

Coated fertilisers of urea, ammonium sulphate nitrate, and calcium ammonium nitrate with 'duco clear' mineral oil or wax could be used with advantage for rice in wetlands. As for their effectiveness, mineral oil coating was found to be better than wax coating followed by 'duco clear' in red soils but wax coating proved superior to mineral oil coating in black soils. In red soils under wet conditions, wax coating showed minimal leaching losses of nitrate nitrogen. 'Duco clear' and mineral oil coatings showed almost the same effectiveness in red soils in minimising leaching losses, while in black soils, 'duco clear' produced better results.

Among the different nitrification retardants such as neem cake, mahua cake, Karanj cake, used for coating urea, none of them was found superior to urea or sulphur-coated urea when applied to jowar, wheat and rice crops.

Foliar spray of urea containing biuret upto 3 per cent was not found to depress the yield of wheat grown on black soils.

The yield potential of high yielding varieties like Purna and 9-2-7 varieties of ragi was found to enhance with the application of nitrogen up to 160 kg/ha and for HB 1 bajra up to 120 kg N/ha. The yield potential of rice varieties like Jaya, IET-1996, IR-8 and MR-2 were substantially increased at 60 kg N/ha.

Under dryland farming at G K V K, Bangalore, a dose of 90 kg N per ha, applied in three splits viz before sowing, one month and two months after sowing was found to be effective in maximising the yield of ragi and maize. Under light irrigations, 40 kg N and 20 kg P_2O_5 for Karad-local Khairif jowar, 100 kg N and 60 kg P_2O_5 for hybrid jowar,

60 kg N and 30 kg P_2O_5 for *sataria*, 100 kg N, 60 kg P_2O_5 and 30 kg K_2O for maize were some of the recommended levels for economic yield

Work done so far has demonstrated the dominant role of nitrogen in crop production in soils of Karnataka. There is need for increasing use of nitrogen, particularly, in the context of expansion of area under improved high yielding and hybrid crop varieties. More concerted work on nitrogen use efficiency so as to get maximum returns for applied fertilisers is necessary. Studies on new and inexpensive fertilisers sources have to be taken up on a priority basis. Steps to popularise the use of anhydrous ammonia under our conditions as has been done elsewhere in the world needs to be taken up in earnest.

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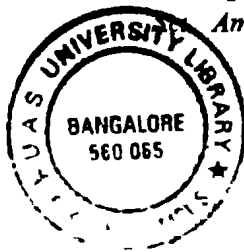
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