INCREASING NITROGEN USE EFFICIENCY IN UPLAND SOILS

By

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THESIS

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DECLARATION

I hereby declare that this thesis entitled "Increasing nitrogen use efficiency in upland soils" is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship, or other similar title, of any other University or Society.

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Certified that this thesis entitled "Increasing nitrogen use efficiency in upland soils" is a record of research work done independently by Shri.K.M. Sathianathan, under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship, or associateship to him.

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To My Parents

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Introduction

INTRODUCTION

If mankind is to meet its greatest challenge of feeding an ever-burgeoning world population that is projected to reach 6.4 billion (Craswell and Vlek, 1982) by the year 2000 AD, crop yields are to be increased by at least 50 per cent to maintain even the present standards of nutrition.

Among the effective inputs for intensive and successful crop production, the fertilizers, which play a vital role, especially those supplying the most beneficial single factor - nitrogen, the deficiency of which almost universally limits crop production - have been one of the major concerns of soil scientists for many years.

About 40 per cent of the total energy input in agriculture is consumed for the production of nitrogenous fertilizers. At the current juncture of world wide energy crisis and ever increasing capital cost of fertilizer production, the rise in price of fertilizer nitrogen is inevitable. Any saving in the consumption of fertilizer, adopting low cost technology without sacrificing productivity of crops, will therefore be economically advantageous to the farmers.

The efficiency of applied fertilizer nitrogen is frustratingly low (Englestad and Russel, 1975; Sahrawat, 1979), especially under tropical conditions. Food crops, even under the best growing conditions, seldom recover more than 50 per cent of the applied nitrogen (Martin and Skyring, 1962). The alternate wetting and drying conditions in the humid tropics aggravate the situation, and register a recovery as low as 38.4 per cent only (Prasad, 1981).

Estimates show that 1 percent increase in the recovery of nitrogen fertilizer applied, would result in a saving of 1,50,000 tonnes of urea, which, in terms of additional crop response would be equivalent to one million tonnes of food grains (Swaminathan, 1980).

The recent energy squeeze, the high cost of the nutrient nitrogen and its low recovery, warrant that research should be directed towards measuring the magnitude of losses of nitrogen and identifying and/or developing products and practices that will curb losses and increase the efficiency.

The heavy losses of applied nitrogen are mainly through leaching, volatilization, surface run off and denitrification through various physical, biochemical and microbiological processes. Among the various approachos followed for conserving the nutrient, the use of slow release fertilizers and biological inhibitors, which reduce the activity of nitrogen in the soil solution, were found to be fairly effective.

Biological inhibitors are used to block particular transformations which lead to losses of nitrogen. It is thorefore essential to identify the loss mechanism that must be blocked before choosing an inhibitor. Inhibitors presently available are urease inhibitors and nitrification inhibitors.

The use of synthotic chemicals as nitrification retarders has been elaborately investigatcd during the past two decades (Gasser, 1970) and it has been recognised that if nitrification inhibitors are to be recommended for field application they have to be cheap and abundantly available, in addition to being effective in the retardation of the process at reasonable rates of application. Thus the search for cheap and effective inhibitors from indigenous resources has become a necessity, so that their use is economically viable, depending on the availability in different regions of the country.

The different non-edible oilcakes have been known to possess inhibitory properties. The oilseed crushing industry faces serious problems in the handling and disposal of bulky non-edible oilcakes, which have low manurial value. The future of the small scale (village) industry connected with the collection and crushing of non-edible oilseeds is at a stake, and its progress depends to a large extent on the utilization of this by-product.

Much work has been done on the use of neem cake as an inhibitor in submerged rice soils and also in some graden lands of low rainfall regions. In well aerated upland soils of Kerala, with its humid tropical climate, nitrification takes place at a much faster rate. Losses are also comparatively severe, due to heavy rainfall and undulating terrain. Thus a study has become necessary on the efficacy of the use of non-edible oilcakes in increasing N use efficiency in upland crops of Kerala.

Among the starchy staples, that are utilized for both human and animal nutrition, the cheapest source of calorie is Cassava (Manihot esculenta, Crantz) from which a sizeable section of the rural population of Kerala, derives their calorie intake. Cassava also enjoys the pride of place in textile, paper and food industries.

With an area of 2.4 lakh hectares, Kerala produces 4.04 million tonnes of tubers, which accounts for 80 per cent of the total production in the country. (Anon, 1982). However, the present cassava yield of the state is far below the known production potential of 50 t/ha or more. So researches in cassava have received an impetus in the last few decades. Significant response to nitrogen for tapioca, has been observed by many (Malavolta et al., 1955). Being a long duration crop grown in high rainfall tracts, the use of nitrification inhibitors would be a fruitful proposition for cassava.

In the light of the above, the present study embodying the following objectives, has become necessary.

1. To screen some of the commonly available non-edible oilcakes for their nitrification inhibition property.
2. To select the most efficient ratio of mixing oilcakes with urea for maximum nitrogen use efficiency.
3. To study the mineralisation pattern, so as to locate the stage of inhibition in the mineralisation process of urea in conjuction with various oilcakes.

4. To test the results of laboratory studies under field condition with one of the most popular upland crops of Kerala, Cassava.

5. To study the effect of using urea-oilcake blends on plant performance, nutrient uptake, tuber yield and quality of cassava tubers.

Review of Literature

REVIEW OF LITERATURE

Nitrogen is the prime nutrient added in attempting to achieve maximum yields of non legume crops. Stangel (1979) examined yield parameters of leading rice producing countries of the world and found that high national average yields positively correlated with irrigation, fertilizer responsive varieties and heavy doses of fertilizer nitrogen.

But recoveries of applied nitrogen have been found to be not more than 50-60 per cent in upland crops and 35-50 per cent for low land crops. Researches all over the world are being undertaken to retrieve the loss mechanism and recommend methods to improve the efficiency.

Most of the works done in this line have been in lowland (submerged/partly submerged) condition and hence literature regarding the loss mechanism and methods for improving the nitrogen use efficiency in upland condition is meagre. Some of the relevent literature pertaining to the present study are reviewed in this chapter. This includes recovery of nitrogen from applied nitrogen sources, losses of nitrogen, methods for increasing nitrogen use efficiency, and nitrogen nutrition of cassava.

2.1 Recovery of applied nitrogen

Data on the response of field crops to nitrogen are available from thousands of field experiments in agricultural experiment stations and in farmer's fields, conducted under the All India Co-ordinated Agronomic Research Project and several crop improvement projects of ICAR (Prasad, 1978; Tandon, 1980).

The recovery of applied fertilizer nitrogen from conventional fertilizers is quite low. Average recovery of only 10-50 per cent by rice was reported by many workers (Lakhdive and Prasad, 1971; Patric and Reddy, 1976; Prasad and De Datta, 1979; Mahapatra et al., 1980). But Mitsui (1956) obtained higher nitrogen recovery of 50-60 per cent in uplands, as against 30-40 per cent under water-logged condition.

Plant recovery of applied nitrogen is dependent on factors such as natural conditions of the soil, as well as climatic and cultural practices (De Datta, 1977). In the uplands of the tropics the losses are more severe, as heavy rainfall at short intervals of time causes alternate wetting and drying condition, which lead to greater nitrogen losses (Wijler and Delwiche, 1954; Prasad, 1966; Prasad and Rajale, 1972).

In aerobic soil, the mineralisation of organic nitrogen is faster than in anaerobic situation (Alexander, 1977), and mineralised nitrogen is subjected to various types of loss mechanisms, and thus recovery is less.

2.2 Losses of nitrogen from applied nitrogen

2.2.1 NH_3 volatilization

Heavy losses of nitrogen through volatilization from surface applied nitrogenous fertilizers have been reported by many scientists from India and abroad (Basdeo and Gangwar, 1976; Bouldin and Alimango, 1976; Wetsellar et al., 1977; More and Varade, 1978; Vlek and Craswell, 1979; Jain et al., 1981; Frency et al., 1981; Aulakh and Rennie, 1982).

In uplands also volatilization losses were experienced by Gasser (1964) and Jain et al (1981). When dissolved urea penetrated into the soil, volatilization loss was found to be less. Blasco and Cornfield (1966) found that acid soils under aerobic conditions at 33-75 per cent water holding capacity lost six to twelve per cent of applied nitrogen within a period of three weeks of incubation. But under anaerobic condition two to four times greater loss was reported. Contrary to that Das and Khan (1967) found that soils kept submerged under about 5 mm water lost only 3.4 to 11.4 per cent of the applied nitrogen while at 40-60 per cent moisture saturation the loss was 21.6 to 33.1 per cent. Jain et al (1981) observed that nitrification retarders increased NH_3 volatilization losses.

2.2.2 Denitrification

Since the pioneering work of Shiori (1941), denitrification loss in water logged situation was studied by many in detail (Greenland, 1962; Prasad and Lakhdive, 1969; Prasad and Rajale, 1972; Daffardar, 1973; Smith and Tiedge, 1979).

In uplands there is easy gaseous exchange between soil and atmospheric air and when waterlogging occurs, O_2 dissappears and nitrates along with manganese enters first in the thermodynamic sequance of reduction of inorganic compounds (Turner and Patric, 1968).

Due to heavy rainfall and/or irrigation, in uplands also localised micro-anaerobic pockets develop, due to water logging, and hence denitrification losses cannot be ruled out. Broadbent et al (1952) and

Allison et al. (1960) have observed denitrification losses in uplands also.

Gaseous nitrogen products escape into the atmosphere chiefly as N_2 (Candy and Bartholomow, 1960; Cooper and Smith, 1963; Focht, 1979) and as either N_2, N_2O mixture (Pearsall, 1950; Shiori and Tonada, 1954) or as N_2, N_2O and NO mixture (Wijler and Delwich, 1954).

Reddy et al.(1976) produced a mathematical model of the process from which they concluded that the rate of NH_3 diffusion and nitrification determined the rate of nitrogen losses. Later in 1980, they evaluated the selected processes controlling nitrogen loss, by working out the diffusion and oxidation-reduction rates in different layers of the soil independently. They concluded from their studies that fast rate of NO_3^--N diffusion and rapid rate of NO_3^- reduction were likely to increase the nitrogen losses.

A close relation between soil aeration and nitrate reduction, and the influence of texture on soil aeration was noticed by Lue Pilot and Patric (1972). Focht (1979), from a mathematical model suggested that O_2 diffusion is the most important factor regulating nitrification-denitrification reaction processes in soil.

2.2.3 Leaching

This is the principal form of nitrogen loss from upland soils. Being an anion, NO_3^--N is less adsorbed on soil colloids and so lost from the root zone along with percolating water.

Volk and Sweet (1955) leached one foot layer of soil with 5 inches of water in 24 hours. The leachate removed 33 per cent of nitrate nitrogen and 15 per cent urea nitrogen, but no measureable amount of ammoniacal nitrogen.

The order of leachability of three forms of nitrogen was found to be $NO_3^- >$ Urea $> NH_4^+$ (Owens, 1960; Daftardar et al.,1980).

Dastane et al. (1967) obtained percolation losses of water in the order of 125 cm, from upland paddy soil (Sandy clay loam) during a five month period and he observed considerable losses of nitrogen as nitrates and nitrites.

Mohanty and Kibe (1968) showed that on coating a fertilizer with a material, the leaching losses were reduced from 50 to 5 per cent.

Leaching losses depends on soil texture and water control (Koshino, 1975).

The magnitude of nitrogen loss through leaching depends on crops grown and the form of fertilizer. It was greatest with flax and least with grasses and the fertilizer nitrogen contribution to the total nitrogen loss was estimated to be 3.7 per cent. It was found to be maximum with sodium nitrate application (Korenkov et al., 1979).

2.2.4 Run-off losses

The loss of nitrogen through run-off water poses a serious problem in tropical areas with undulating terrain receiving heavy rainfall and/or irrigation.

Timmons and Holt (1977) studied the loss of nutrients in run-off water and observed only 0.8 kg nitrogen loss per hectare in grass lands, but suggested that in fields planted to other crops it might be several times higher.

Padmaja and Koshy (1978) reported that on draining the surface water on the same day of fertilizer application, upto 70 per cent of the applied nitrogen is lost in run-off water.

2.3 Methods for increasing nitrogen use efficiency

The use of slow release nitrogen fertilizers and nitrification retarders was found to be the most effective method for increasing the efficiency of nitrogen.

Slow release could be achieved either through the coating of fertilizers with sulpur or materials such as oil-cakes, plastic, shellac and other inert materials (Rajale, 1970; Prasad et al., 1971; Prasad and Rajale, 1972; Prasad, 1974; 1979; 1981; Rajale and Prasad, 1974; 1975; Prasad and Reddy, 1977; Rao, 1977, Prasad et al., 1980) or by using compounds with inherently low solubility such as IBDU, CDU etc. (Hamamoto, 1966; Hughes, 1976). Among the slow release fertilizers, sulphur coated urea is the most widely tested one (Prasad and Rao, 1978; Crasswell and Vlek, 1982). In upland condition also sulphur coated urea was found to be promosing (Sander and Moline, 1980).

2.3.1 Efficiency of nitrification inhibitors in reducing nitrogen losses.

The research on the use of inhibitors for higher nitrogen efficiency in India was started by Prasad et al., (1966).

Prasad and co-workers have since continued their work and the results have clearly brought out that the use of nitrification inhibitors was advantageous for irrigated rice culture and well drained/partially drained soils (Prasad and Rao, 1978).

The large body of literature on the use of nitrification inhibitors, that has been accumulated since then, is testimony to their growing importance in improving the efficiency of fertilizer for crop production (Hughes and Welch, 1970; Prasad et al., 1971; Hauck, 1972; Englestad and Russel, 1975; Sahrawat, 1978).

The discovery and the use of Dow chemical Company's Nitrapyrin or N-serve attracted the attention of scientists to this field (Gorin, 1962). Since then other similar chemicals were also tried such as AM, (Prasad and Lakhdive, 1969; Das and Chattergee, 1980) Dicyandiamide or Didin (Amberger, 1982) etc.

In upland conditions, nitrapyrin at the rate of 0.5 lb/acre gave increased yields of lettuce, celery and strawberry above those obtained with ammonium sulphate alone (Welch et al., 1979). Higher seed cotton yields were obtained with N-serve, by Swezey and Turner (1962) and Seshadri (1976). A saving of 15 kg nitrogen per hectare was reported in cotton by the use of N-serve (Shivaraj and Iruthayaraj, 1980).

2.3.2 <u>Non-edible oilcakes as nitrification inhibitors</u>

Nitrification inhibitors were found promising for improving the efficiency of applied nitrogen from the various trials conducted in India and abroad under different soil and climatic conditions. However, for wider applicability under field conditions, it has later been realised that they have to be cheap, abundantly available and effective at reasonable rates of application (Sahrwat et al., 1974).

Hence thereafter, attempts have been concentrated to develop products with nitrification inhibitory properties by the use of cheap indigenous materials. This endeavour has met with varying degrees of successes (Muthuswamy et al., 1977).

Non-edible oilcakes, particularly karinja, neem, maroti and mahua have been used as a manure since long. Their manurial value and nitrifiable properties were described by Plymann and Bal (1919) Yashwant et al. (1933) Pal and Rakshit (1937) and Khan (1952).

The microbicidal action and non-edible character, which are ascribed mainly to the presence of some non-fatty minor constituents of these oilcakes, drew attention of scientists searching for cheap source of nitrification inhibitors.

2.3.2.1 Neem(*Azadirachta indica*. *Juss*.) seed cake

The pioneering work of Bains et al. (1971) made a break through in this search and showed that the acetone extract of neem seed was on par with the proven synthetic nitrification inhibitors under field conditions. It was found even better than sulphur coated urea. He ascribed the inhibitory property to the presence of an acrid alkaloid.

Patil (1972) reported that neem oil contained two fractions, namely bitter and odourescent compounds which possessed the inhibitory property. He also observed that when the concentration of neem oil was increased from 1.5 to 12 per cent (by weight of fertilizer) there was a corresponding decrease in nitrification rate.

100 kg nitrogen supplied as urea coated with neem cake produced crop yields equivalent to that of 200 kg nitrogen as urea alone (Anjanaya Sharma, 1972). AICRIP trials also revealed the increased productive efficiency of neem cake treated urea (Anon., 1972 a).

Arunachalam and Morachan (1974) found the favourable influence of the treatment of urea with neem cake extract, in increasing the crude protein content of rice grain.

In both transplanted and direct sown crops the uptake of nitrogen and phosphorus was increased in treatments where urea was blended with neem cake, while the uptake of potassium was decreased at each level of nitrogen application, bringing out the adverse effect on the uptake of potassium exerted by neem (Shankar et al., 1976).

Oommen et al. (1977) observed the superiority of neem cake blended urea over untreated urea. Abraham et al. (1976) reported that application of 40 kg neem cake coated urea was equivalent to 80 kg naked urea.

Subbiah et al. (1979 a and b) reported that neem blended urea increased not only the grain and straw yield but also the uptake of nitrogen, phosphorus and potassium. Among the doses tried, the best result was obtained when the blend was prepared with neem at 40 per cent by weight of the fertilizer.

Enhanced crop yields through the use of neem cake was also obtained in sorghum (Anon, 1972 b), ragi (Subbiah et al., 1979 c; 1982), cotton (Shivaraj and Iruthayaraj, 1980), sugarcane (Ketkar, 1978) and in many other crops (Chatterjee et al., 1975; Ketkar, 1978; Krishnaiah and Shindo, 1979 a; Biddappa and Sarkunam, 1979; Subramoniam et al., 1979; Subramoniam and Venkitaraman, 1979; Charkravarthy, 1979; and Singh et al., 1980) under a wide range of soil and climatic conditions.

Biddappah and Sarkunam (1979) conducted laboratory incubation study under both flooded and moist aerobic condition. Neem cake troatment gave more extractable NH_4^+-N, under both conditions. NO_3^--N content was found to have increased with time.

Selective inhibition of <u>Nitrosomonas</u> <u>sp</u>. by neem was observed by Mishra et al. (1975) and Biddappah and Sarkunam (1979). The superiority of the single basal application of neem cake-urea-blend over split application of untreated urea was revealed by the higher recovery percentage of 46.5 obtained, in uncontrolled irrigated condition (Reddy and Shinde, 1981).

Blending of urea with neem cake resulted in increased NH_4^+-N in the soil (Subbiah and Kothandaraman, 1980; Sarkunam and Biddappah, 1980).

But Mohanty et al. (1974) found that neem coated urea was inferior to urea alone. Thirunavukkarasm et al. (1977) also did not obtain benefits from the coating of urea with neem.

2.3.2.2 Karinja (Pongamia glabra) seed cake.

As early as 1966, studies on the better utilization of non-edible oil seed cakes at I.A.R.I, revealed that the crude extracts from karinja and neem seed possessed nitrification inhibitory effect. In incubation experiments, inhibition effect was observed between 25 and 50 days of application by Singh (1966). Since then nitrification inhibitory effects of various constituents of karinja have been investigated. Karinja seed and bark have been found to be rich in karinjin, which is a potent nitrification inhibitor. Later Sahrawat et al. (1974) also observed inhibitory effect of karinja upto 45 days of incubation.

Karinjin, which is a major furanoflavnoid, isolated from karinja seed equals nitrapyrin in its performance and has given increased yield, nitrogen uptake and grain protein content, of rice in green house and pot culture studies. Inhibitory action was found to be imparted due to the furan ring in the molecule. Nonfatty minor constituents of karinja seed can be advantageously used for retarding nitrification (Saharawat, 1981).

Later Kuzvinzwa et al. (1982) tested various furano compounds for nitrification inhibition properties and were found to be active inhibitors.

2.3.2.3 Other non-edible oilcakes

Swaminathan (1979) suggested that nitrification inhibitory properties in various non-edible oilcakes could be explored and advantageously exploited.

Mahua cake (Kavathi - *Madhuca longifolia*) is poor in nitrogen and due to the presence of the toxic substance, saponin, it is unfit for use as a cattle feed or as a manure. But its nitrification inhibitory property has been observed.

Muthuswamy et al. (1977) studied the inhibitory properties of various materials including the extracts of non-edible oilcakes in garden land soil, at two levels of nitrogen application to ragi. The results showed that the efficacy of inhibitors was in the following order, viz. coal tar extract > sulphathiazol > mahua cake extract > neem cake extract > neem oil > whole neem cake.

He also observed complete inhibition of mineralisation upto 20 days of incubation . Better results were obtained with increase in the concentration of the inhibitors.

Krishnaiah and Shinde (1979 b) blended six non-edible cakes, namely neem (Azadirachta indica) mahua (Madhuca longifolia), undi (Calophyllum inophyllum) sal (Shorea robusta), karinja (Pongamia glabra) and kusum (Schleichera trijuga) cakes with urea at different rates of mixing and obtained higher rice yields. Maximum yield was reported for neem cake (50 per cent by weight of urea) and undi (30 per cent by weight of urea). Other cakes did not respond to the changes in the ratio of mixing to obtain the blend. Maximum yield response of 30 kg rice per kilogram fertilizer nitrogen was obtained with undi at 30 per cent mixing which recordod also the maximum uptake of nitrogen.

Sahrawat (1980) in an incubation study found maximum inhibition at three weeks after the application of treatments. The inhibition percentages were worked out to be 76 per cent for nitrapyrin, 63 per cent for karinjin, 54 per cent for AM and 46 per cent for Dicyandiamide (Didin). Sharp decline in percentage inhibition was observed after three weeks of application.

Hilgur and Shinde (1981) compared the application of urea alone with urea-blends using ether extracts of different oilcakes and whole cakes and found that neem cake, karinja cake and kunkum cake increased dry matter yield and nitrogen uptake, while mahua cako reduced the yield. But ether extracts of mahua cake possessed better inhibitory property.

Sinha et al. (1982) obtained the maximum response per unit nitrogen applied and the highest benefit/cost ratio in sal seed cake coated urea treatment at all levels of nitrogen tried (40, 80, 120 kg/ha) in wheat. The increase was more for higher doses. A yield increase of 39 to 74 per cent over naked urea was obtained at different levels of nitrogen application. The study established that sal seed cake, a cheap waste product of oil industry, can be profitably used as a coating agent for urea.

Howevor, Devi et al. (1980) did not find significant increase in rice yields through the use of oilcakes such as neem, maroti, punna and karingotta as nitrification inhibitors.

2.4 Nitrogen nutrition of Cassava

Cours (1953) found that a harvest of 50 tonnes of cassava tuber and 25 tonnes of wood, removed 253 kg nitrogen, 28 kg phosphorus, 250 kg potassium, 42 kg calcium and 29 kg magnesium from the soil.

Significant responses to nitrogen application on the tuber yield have been observed by many in different soil and climatic conditions (Chandha, 1958., Pillai, 1967; Takyi, 1974; Saraswat and Chattiar, 1976; Mohankumar and Mandal, 1977; Prabhakar et al., 1979).

Malavolta et al. (1955) reported that nitrogen and phosphorus were the most important nutrients for cassava. Abraham (1956) observed that cassava yields increased considerably by balanced NPK fertilization.

2.4.1 Effect of nitrogen on the growth and uptake of nutrients

High nitrogen rate tended to increase the weight of stems and leaves, total dry weight of plants, top to root ratio and plant height (Krochamal and Samuels, 1970; Cheo-Samut, 1973). However, Acosta and Pinto (1978) did not find any relation between fertilization and plant height and number of roots per plant.

Pillai (1967) also observed that nitrogen did not influence the leaf number and height of plants. Contrary to this Ramanujam and Indira (1979) and

Prabhakar et al. (1979) obtained increased leaf production, with incremental doses of nitrogen supply and found that shedding of leaves was proportional to the number of leaves produced.

According to Fox et al (1975) top growth responded more strongly to nitrogen application and roots, only moderately. In support of this finding Ratnanakul (1976) observed that nitrogen above 50 kg/ha increased the fresh weight of stems but not that of roots.

Response to nitrogen is very much dependent on the supply of other nutrients also, especially potassium which is the element removed in largest quantities by cassava (Hongsappan, 1962; Anon, 1975). Significant interaction of nitrogen and potassium on the yield was reported by Chadha (1958).

Ngongi (1976) observed that high rates of NPK reduced total dry matter which is very much correlated with root yield, apparently due to calcium and magnesium deficiencies.

Okeke et al. (1979) obtained increased nitrogen concentration in various plant parts but a reduced phosphorus and potassium concentration in leaves. Leaf blade nitrogen at three month stage was well correlated with the total plant dry weight at the same stage and tuber yield at harvest.

Nitrogen was found mostly concentrated in leaves, and potassium in stems (Kanapathy, 1974; Krochmal and Samuels, 1968).

2.4.2 <u>Quality of tubers in relation to nitrogen and potassium nutrition</u>

Pillai (1967) reported that nitrogen along with phosphorus and potassium significantly contributed to dry matter percentage and starch content of tubers.

According to Vijayan and Aiyer (1969) and Thampan (1979) balanced N, P and K supply was critical, which decided the quality of tubers.

Nitrogen supply increased crude protein content (Malavolta et al., 1955; Pillai, 1967; Hukkeri, 1968; Gomes and Howler, 1980; Muthuswamy and Rao, 1981) and hydrocyanic acid content (Sinha and Nair, 1968; Bruijn, 1971; Prema et al., 1975; Prabhakar et al., 1979) of tubers.

However, starch content presented a decreasing trend with increased nitrogen supply (Malavolta et al., 1955; Vijayan and Aiyer, 1969; Prema et al., 1975) assessed the cooking quality of tapioca tubers by a taste panel and found that it was significantly reduced by higher levels of nitrogen.

The effect of potassium on the quality attributes of tubers has been studied by several workers. Potassium supply enhanced dry matter, starch content and cooking quality of tubers, but depressed crude protein and HCN content (Bolhuis, 1954; Pillai, 1967; Degeus, 1967; Hukkeri, 1968; Kumar et al.,1971; Indira et al., 1972; Obigbesan, 1973; Natarajan, 1975; Pillai and George 1978 a; Pushpadas and Aiyer, 1976; Asokan and Sreedharan, 1977; 1978; Gomes and Howler, 1980; Muthuswamy and Rao, 1981).

Regular correlations have been obtained between starch percentage and dry matter (Anon , 1955; Thompson and Wholey, 1972) so much so, percentage of starch can be estimated in certain cases from the percentage of dry matter of the tubers (Jong, 1977).

2.4.3 Increasing the nitrogen use efficiency in cassava

Fox et al. (1975) obtained upto 68-69 per cent recovery of applied nitrogen in cassava.

But under heavy rainfal conditions in Kerala the recovery is far below this level. Low fertilizer efficiency, due to leaching, in sandy soil planted to cassava was noticed and split application in 3 doses upto 150 days after planting has been recommended by Howler (1976).

Only in sandy soil with low organic matter content, with sufficient phosphorus and potassium supply slow release fertilizers gave good yields (Anonymous, 1965). Nopamorndordee et al., (1967) used Isobutylidene-diurea (IBDU), Ureaform compounds, Crotonylidine diurea, Guanyl urea phospnate salt (12-18-16) etc as slow release nitrogen sources for cassava. Though statistically not significant increased yields over ordinary urea were obtained in the experiments. Sulphur coated urea did not show any significant influence on cassava yield (Fox et al., 1975; Offori, 1976; Agboola and Obigbesan, 1976).

The use of nitrification inhibitors is yet to be attempted in increasing nitrogen use efficiency by cassava.

Materials and Methods

MATERIALS AND METHODS

The present work was undertaken to explore the feasibility of utilising non-edible oilcakes for increasing nitrogen use efficiency in rainfed upland conditions. Some of the locally available non-edible oilcakes which were known to exhibit nitrification inhibitory properties at varying degrees under different soil and climatic conditions, were tested in this study.

The particulars regarding collection of soil samples, details of experimental procedures, and analytical techniques employed in the investigation, are presented in this chapter.

The study comprises of two parts.

A. A laboratory incubation experiment to study the mineralisation pattern of blends prepared by mixing urea with oilcakes and to find out the best ratio of mixing them for effecting efficient nitrification inhibition.

B. A field experiment with tapioca to test the performance of the selected oilcakes at the most efficient ratio of mixing with urea, in prolonging the period of nitrogen availability, and its effect on the growth, uptake of nitrogen and potassium by the crop, yield and quality of tubers at three levels of nitrogen supply.

3.1 Laboratory incubation experiment

Incubation study was conducted in a typical red loam upland soil, collected from the instructional farm, College of Agriculture, Vellayani. The soil was air dried under shade, powdered gently with a wooden mallet and sieved through 2 mm sieve. Sub samples were drawn for the analysis of soil for the physico-chemical properties for reporting the basic data (Table 1 a and b).

The treatments consisted of five oilcakes mixed, in three ratios with urea which were compared with untreated urea in a completely randomised block design.

1. Treatments	(A) Oilcake	(B) Ratio of mixing urea to oilcakes)	
	(1) Neem cake	(1) 5:0	
	(2) Rubber cake	(2) 5:1	
	(3) Karinja cake	(3) 5:2	
	(4) Maroti cake	(4) 5:3	
	(5) Mahua cake		
2. Replication	- Two		
3. Design	- Completely randomised block		

Table 1. Characteristics of the Soil

(a) Physical characteristics

Sl.No.	Particulars	
1	Particle size distribution	
	(1) Coarse sand (%)	40.60
	(2) Fine sand (%)	24.60
	(3) Silt (%)	18.00
	(4) Clay (%)	13.50
	Textural classification - Sandy loam	
2	Apparent specific gravity	1.34
3	Absolute specific gravity	2.57
4	Porosity (%)	36.79
5	Volume Expansion on wetting (%)	1.21
6	Moisture (%)	9.17
7	Field moisture capacity (%)	39.71

(b) Chemical characteristics

Sl.No.	Particulars	
1	Soil Reaction (p^H)	4.700
2	Electrical conductivity of saturation extract (m mhos/cm)	0.100
3	Organic matter (%)	0.900
4	Total nitrogen (%)	0.052
5	Total Phosphorus (% P_2O_5)	0.111
6	Total Potassium (% K_2O)	0.051
7	Total Calcium (% CaO)	0.110
8	Total Magnesium (% MgO)	0.108
9	Available Nitrogen (kg/ha)	198.000
10	Available P_2O_5 (kg/ha)	52.000
11	Available potassium (kg/ha)	88.000
12	Available Calcium (me/100g)	0.800
13	Available Magnesium (me/100g)	0.400
14	Available Fe (ppm)	30.200
15	Available Mn (ppm)	28.900

Table 2. Analysis of oil cakes

No.	Oil cake	N%	P%	K%	Oil content %
1	Neem (*Azadirachta indica*. Juss) cake	3.276	0.688	1.010	4.700
2	Maroti (*Hydnocarpus wightiana*. Blume) cake	2.604	0.351	0.484	3.400
3	Mahua (*Madhuca longifolia*. Linn) cake	2.140	0.318	0.920	2.800
4	Rubber (*Hevea brasiliensis*. Muell) cake	1.930	0.300	0.720	6.800
5	Karinja (*Pongania glabra*. Vent) cake	3.200	0.690	0.816	4.000

4. Number of treatment combinations - 16

Plastic containers of three litre capacity were filled with 2 mm sieved air dried (2 kg) soil.

The moisture content of the soil was brought to 60 per cent of field capacity. Urea to supply 100 ppm N was weighed out and mixed with finely powdered oilcakes in different ratios as per the treatments. The nitrogen contents in the oilcakes were also taken into consideration while calculating the weights of urea and oilcakes for the different blends to give the same quantity of nitrogen.

Weight of each of the containers with the soil at 60 per cent field moisture capacity at the time of start of the experiment was recorded. Water was sprayed and well mixed with the soil on alternate days to maintain the moisture content throughout the period of incubation at constant level.

Samples were drawn at the time of application, and on the second, seventh, twelfth, seventeenth, twenty second and twenty seventh day of incubation.

The samples were extracted for NH_4^+-N, NO_2^--N, and NO_3^--N. Toluene was added to different extracts to arrest further microbial conversion of different forms. Colorimetric methods of analysis was adopted for fractionation of different inorganic nitrogen forms.

3.1.2 Rate of nitrification and inhibition percentage

Rates of nitrification at different periods of incubation were computed from the concentrations of NH_4^+-N, NO_2^--N and NO_3^--N at different periods of incubation of the soil treated with urea alone or urea-non-edible oilcake blends.

$$\text{Nitrification Rate (\%)} = \frac{NO_2^- \text{-N} + NO_3^- \text{-N}}{NH_4^+ \text{-N} + NO_2^- \text{-N} + NO_3^- \text{-N}} \times 100$$

(Sahrawat, 1980)

Nitrification inhibition percentages under different treatments were also calculated based on the following formula (Sahrawat, 1980).

$$\text{Percent Inhibition} = \frac{\left(\begin{array}{l}\text{Nitrification}\\ \text{Rate (\%) in the}\\ \text{untreated urea}\\ \text{pots}\end{array}\right) - \left(\begin{array}{l}\text{Nitrification}\\ \text{Rate (\%) in the}\\ \text{oilcake treated}\\ \text{urea pots}\end{array}\right)}{\text{(Nitrification Rate (\%) in the untreated urea pots)}} \times 100$$

3.2 Field Experiment

A field trial was laid out to test the efficacy of some of the selected non-edible-oilcake-urea blends in increasing the nitrogen use efficiency from the applied urea under the upland conditions of Kerala. Cassava, the long duration popular upland crop of Kerala was used as the test crop.

3.2.1 Experimental site

The experiment was laid out in the Instructional Farm of the College of Agriculture, Vellayani, from where soil samples were collected for the incubation study.

3.2.2 Season

The crop was grown from July 1981 to May 1982, which is the regular growing season for tapioca in the rainfed uplands of Kerala.

3.2.3 Weather conditions

The maximum and minimum temperature, rainfall and relative humidity during the entire cropping season, were recorded from the meteorological observatory of the department of Agronomy and presented as monthly averages in Appendix-I and Fig.I.

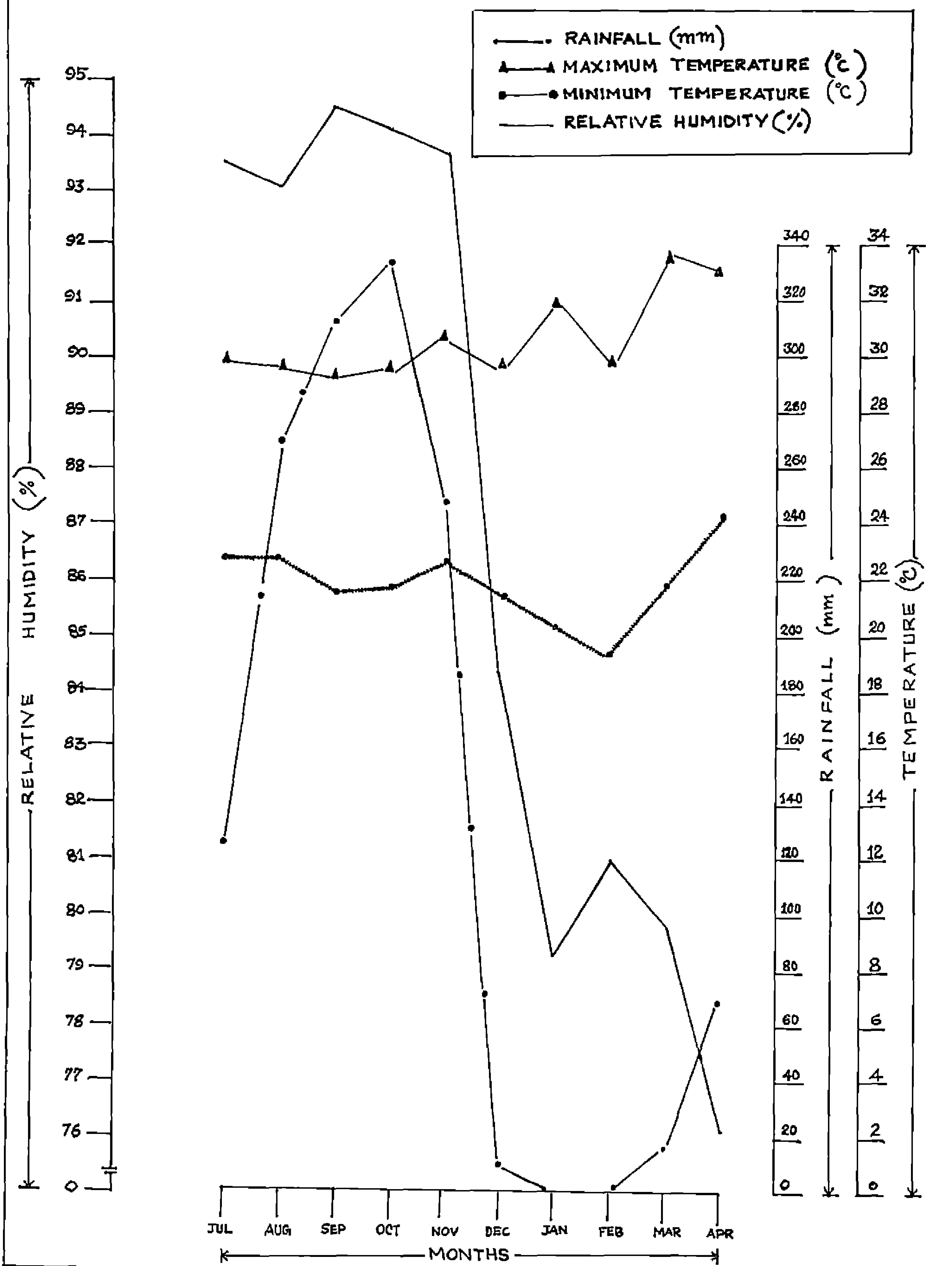
MATERIALS

3.2.4 Planting material

The introduced exotic variety from Malaya, Malayan-4 (M_4), noted for its good palatability and culinary qualities, was used for the study. Mature stems

FIG 1

WEATHER CONDITIONS DURING THE CROP SEASON



harvested and preserved in shade, were cut to get setts of 8-9 inches from the middle portion of the stems having more or less uniform girth.

3.2.5 Fertilizers

Urea, Superphosphate and Muriate of Potash were used as the sources of N, P and K. The fertilizer samples used were found to contain 46.01% N, 15.61% P_2O_5 and 54.00% K_2O respectively.

3.2.6 Oilcakes

The various non-edible oilcakes used as inhibitors were analysed for nitrogen, potassium, phosphorus and oil content and the results are presented in Table 2. Adjustments in the amounts of urea were made, considering the nitrogen content of the oilcakes so that nitrogen supply by the urea-oilcake-blends were in accordance with the treatments fixed.

Neem, mahua and karinja cakes used in their study were supplied by the Directorate of non-edible oils and soap industry, Khadi and Village Industries Commission, Pune. Rubber and maroti cakes were purchased from the local market at Ernakulam. The oilcakes were finely powdered and mixed with urea granules, prior to soil application to give a proper coating over the granules.

3.2.7 Layout (Fig.2)

Design - Randemised block design in factorial structure.

Replication - Three

Treatments - Three levels of nitrogen, supplied as untreated urea and as urea-oilcake blends (Selection of the oilcakes at the most efficient ratio of mixing with urea was made from the results of the incubation study).

Levels of Nitrogen:-

(n_3)- 50 kg N/ha (Full recommended dose of nitrogen as per the package of practices recommendation of KAU, 1980).

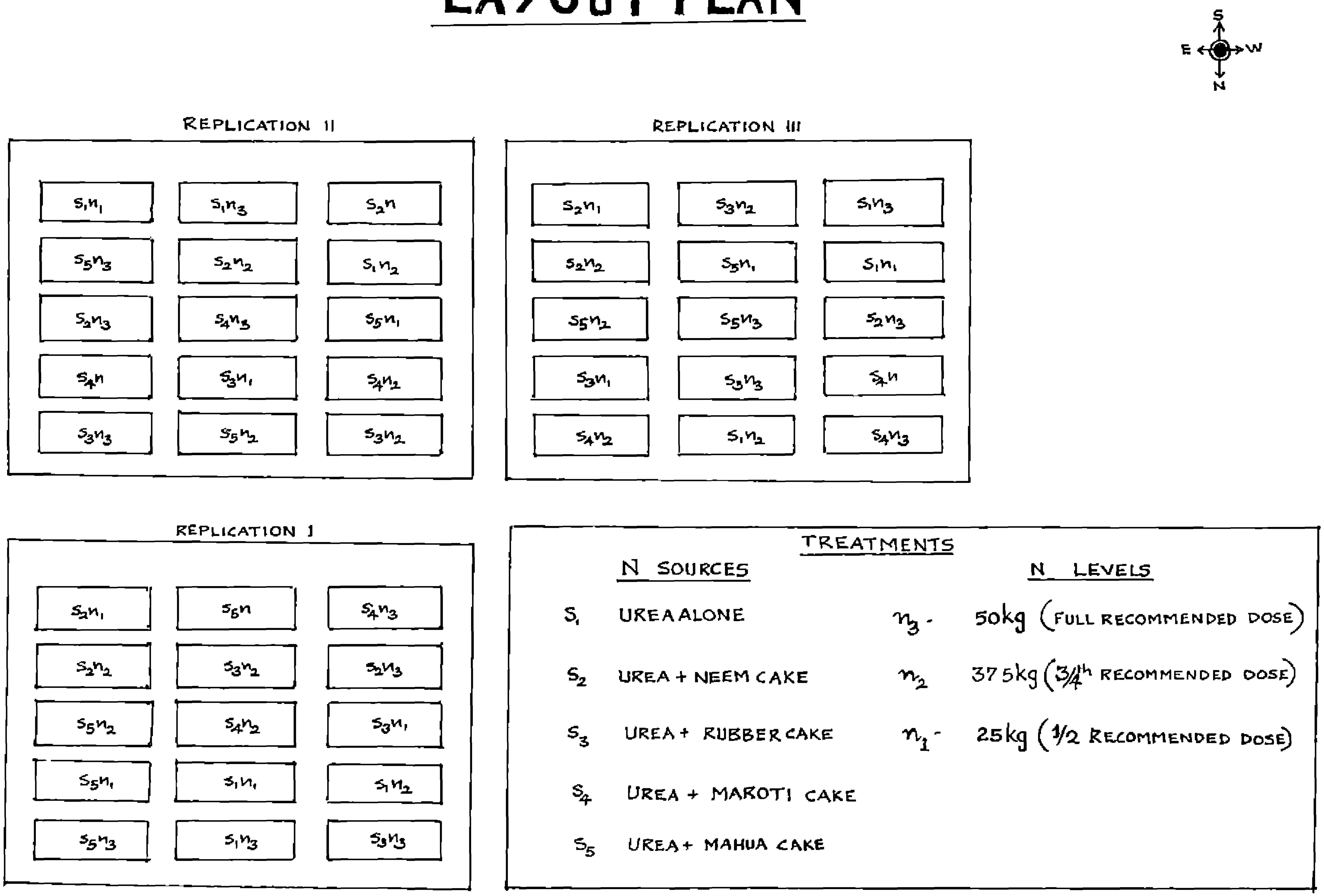
(n_2)- 37.5 kg N/ha (3/4 recommended dose).

(n_1)- 25 kg N/ha (1/2 recommended dose).

			Dose	Ratio of mixing
Treatmont Combinations	(1)	Urea alone	50 kg N/ha (n_3)	(5:0)
	(2)	Urea + neem cake	"	(5:3)
	(3)	Urea + rubber cake	"	(5:3)
	(4)	Urea + maroti cake	"	(5:2)
	(5)	Urea + mahua cake	"	(5:3)

FIG
2

LAYOUT PLAN



		Dose	Ratio of mixing
(6)	Urea alone	37.5 kg N/ha (n_2)	(5:0)
(7)	Urea + *neem* cake	"	(5:3)
(8)	Urea + rubber cake	"	(5:3)
(9)	Urea + *maroti* cake	"	(5:2)
(10)	Urea + *mahua* cake	"	(5:3)
(11)	Urea alone	25 kg N/ha (n_1)	(5:0)
(12)	Urea + *neem* cake	"	(5:3)
(13)	Urea + rubber cake	"	(5:3)
(14)	Urea + *maroti* cake	"	(5:2)
(15)	Urea + *mahua* cake	"	(5:3)

Plot size: Gross : 6.3 m x 4.5 m (35 plants)

Net : 4.5 m x 2.7 m (15 plants)

Spacing : 90 cm x 90 cm

Total number of plots: 45

3.2.8 Field culture

The cultural practices recommended in the package of practices (1980) prepared by Kerala Agricultural University were followed.

(1) Land preparation

The experimental area was dug thrice and was divided into three blocks. Plots of size 6.3 m x 4.5 m were laid out, separated by bunds of about 50 cm width and 25 cm height. The plots were once again dug, the soil was mixed thoroughly and levelled to ensure uniformity within the plots. Mounds of 45 cm height were taken in lines, 90 cm apart on either way.

(2) Planting

Planting was done on 8th July 1981. The cuttings were planted vertically at the rate of one sett/mound on the centre of the mounds, inserting the tip 4 cm below the soil.

(3) Fertilizer application

Nitrogen was given according to the treatments fixed, in two equal split doses, viz.the first at the time of planting and the second two months later. All plots received a uniform dose of 50 kg/ha of P_2O_5 and K_2O. The entire phosphorus was supplied as basal dose and potassium in two equal splits along with the nitrogen supply.

Extra care was taken in the application of urea-oilcake blends to ensure uniformity of application. Measured amounts of urea or urea-oilcake blends for each mound were separately given which enabled to get representative soil samples from each plot for the periodic chemical analysis to study the retention of NH_4^+-N in various treatments.

(4) After cultivation

Sprouting of setts was satisfactory. Gap filling was done ten days after planting. Weeding and earthing up operations were given twice, at an interval of two months in the initial stages of growth. No plant protection measures were necessitated. In general the crop growth was satisfactory.

3.2.9 Periodic soil analysis

After the basal application and top dressing of fertilizers, soil samples were analysed for NH_4^+-N content to know the release pattern of nitrogen from the various urea oilcake blends. Soil samples were taken immediately after fertilizer application (o time) and at weekly intervals thereafter.

A composite sample from around the base of the central plant of each plot was quartered from there itself, and about 15 g of soil was removed each time from the base. The samples were quickly brought to laboratory and a part used for moisture determination, and from the other,,

NH_4^+-N was extracted using KCl solution (2 M). Toluene was added to the extract to prevent the further microbial conversion of NH_4^+-N.

At the three month stage of the crop, available nitrogen and available potassium in the soil were also determined.

3.2.10 Pre-harvest observations

1. Height and number of leaves

Three plants in the net plots were selected at random from each plot for taking biometric observations. Averages of the observations were recorded.

The number of fully opened leaves, and height of the tallest stems of each plant measured from the base of the sprouts to the top of the unopened bud, were recorded at 3 months, 6 month and harvest stages of the crop.

2. Dry weight of plant and uptake of nitrogen and potassium.

One plant from the first inner row of each plot, was uprooted at 3 month, 6 months and harvest stages of the crop. From each plant, the lamina, petioles, stem and tubers were separated and their fresh weights recorded separately. Representative samples from each of the plant parts were obtained, wiped with damp cloth to remove adhering dust particles and were dried in an air-oven at 70°C, till constant weights were recorded. Having obtained the sample dry weight of plant parts, the total plant dry weight was computed. Dried samples were powdered and analysed for nitrogen and potassium.

Uptake of nitrogen and potassium were computed from the dry weight and nutrient concentrations in the different plant parts. The total plant uptake was then worked out.

3.2.11 Post harvest observations

(1) Number of tubers per plant

Total number of tubers from three observational plants was recorded and the average per plant was worked out.

(2) Tuber yield

After the harvest of the crop, the tubers were separated the adhering soil removed, and the fresh weights

(3) Root to shoot dry weight ratio

From the sample plant uprooted at the harvest stage, the ratio of the dry matter, accumulated in the roots to that in the top (stem and leaves) was determined.

(4) Quality attributes

On the same day of harvest, the HCN content of the tubers was analysed.

To determine the dry matter content of tuber flesh, uniform quantities of flesh from the tubers were taken from each plot and chopped into small pieces and dried to constant weight in an air-oven at 105°C. The weight of the dry matter obtained was expressed as a percentage on the fresh weight of tuber flesh (Anon, 1969).

Dried flesh was powdered and analysed for starch and crude protein content.

3.3 Analytical procedures

3.3.1 Methods used for soil analysis

1. Physical properties

(a) Particle size distribution

Mechanical analysis of the soil was carried out by the Robinson's international pipette method, after oxidation of organic matter with 6% H_2O_2 as described by Piper (1950). Soil was classified into textural group using I.S.S.S.System.

(b) Specific gravity and Pore space

Apparent specific gravity and absolute specific gravity (Particle density) were determined using Keen Raczowski brass cup measurements (Piper, 1959) and the percentage pore space was then calculated.

(c) Moisture content of soil

5 g of soil was taken in a weighing bottle and dried in an air oven at 105°C to constant weight. Moisture percentage was calculated from the weight loss on oven drying (Hesse, 1971).

(d) Maximum water holding capacity and volume expansion on wetting

Maximum water holding capacity and volume expansion on wetting of the soil sample were determined, using Keen Raczowski brass cups by the method described by Wright (1934).

3.3.1.2 Electrochemical properties

(a) Soil reaction

The pH of the soil water suspension (1:2.5, soil:water ratio) was determined using a Perkin Elmer pH meter with glass and calomel electrodes (Hesse, 1971).

(b) Electrical conductivity

Electrical conductivity of saturation extract was determined as described by Hesse (1971).

3.3.1.3 Chemical parameters

(a) Organic carbon

Organic carbon was estimated by Walkley and Black's rapid titration method (Walkley and Black, 1952).

(b) Total nitrogen

Total nitrogen was determined by the macro-kjeldahl method (Jackson, 1973).

(c) Total phosphorus

The soil was digested with, HNO_3 and perchloric acid and made upto a constant volume (Jackson, 1973). Total phosphorus was estimated from an aliquot by the vanadomolybdate yellow colour method (Jackson, 1973).

(d) Total potassium

The soil was fused with sodium carbonate and the fusion cake was extracted with HCl. Total potassium was determined from an aliquot of fusion extract using EEL Flame photometer (Jackson, 1973).

(e) Total calcium and magnesium

From an aliquot of the fusion extract, total calcium and magnesium were also determined. (Jackson, 1973).

(f) Available nitrogen

Available nitrogen in the soil was determined by the alkaline permanganate method, described by Subbiah and Asija (1956).

(g) Available phosphorus

Available phosphorus in the soil was extracted in Bray No.1 dilute acid flouride solution (0.03 N, NH_4F and 0.025 N, HCl) - (Bray and Kurtz, 1945) and colorimetric determination of phosphorus in the extract by the chlorostannous reduced molybdophosphoric blue colour method in hydrochloric acid system (Jackson, 1973).

(h) Cation exchange capacity

The cation exchange capacity of the soil was determined by leaching the soil with neutral normal ammonium acetate solution and estimating the NH_4^+-N adsorbed, by distillation using MgO. (Peech et al., 1947).

(i) Exchangeable potassium

Ammonium acetate extract of the soil was treated with aquaregia, evaporated to dryness, and dissolved in o.1N HCl and potassium in the extract was determined using EEL Flame photometer (Jackson, 1973).

(j) Available calcium, magnesium, iron and Manganeese

From the aquaregia treated ammonium acetate extract, calcium and magnesium were determined by the versenate titration method (Chang and Bray, 1951). Available Fe and Mn were read in an atomic absorption spectrophotometer (Jackson, 1973).

3.3.1.4 Estimation of inorganic forms of nitrogen

(a) Ammoniacal nitrogen

(1) Colorimetric method was adopted for incubation study.

Soil samples were extracted with 10 per cent sodium chloride solution acidified to pH 2.5 with HCl. Ammoniacal nitrogen in the extract was estimated using Nessler's reagent by measuring the colour intensity at

410 nm using a photoelectric colorimeter. The NH_4^+-N concentration read from the standard curve was expressed as ppm in the soil on oven dry basis. For the field study, NH_4^+-N was estimated by the Semimicrokjeldahl distillation method as described by Hessee (1971).

(b) Nitrite nitrogen

Nitrite nitrogen accumulated at different periods of incubation was determined by the method described by Black (1965) using diazotizing reagent (Sulphanilamide in 2.4 N, HCl) and coupling reagent (N-(1-naphthyl) ethylene diamine hydro-chloride in 0.12 N, HCl. The colour intensity was measured at 520 nm using a Photoelectric colorimeter.

(c) Nitrate nitrogen

Nitrate nitrogen was estimated, by the phenoldisulphonic acid yellow colour method as described by Jackson (1973) and the colour intensity was read at 420 nm using a photo-electric colorimeter.

3.3.2 Methods for plant analysis

(1) Nitrogen

Nitrogen in the plant samples was estimated by the semi-micro-kjeldahl method as described by Jackson (1973).

(2) Potassium

Triple acid digest of the different plant parts was diluted (Johnson and Ulrich, 1959) and potassium estimated in the extract using EEL Flame photometer.

(3) Starch content of tubers

Starch content of the edible portion was determined by the titration of the sugar solution with the ferricyanide ion in alkaline solution, using methylene blue as indicator (Aminoff et al., 1970).

(4) Crude Protein

Dried tubor flesh was analysed for total nitrogen by the micro-kjeldahl method (Jackson, 1973) and crude protein content was computed by multiplying with the factor 6.25.

(5) Hydrocyanic acid content

HCN content of the fresh tubers was determined immediately after harvest by the following method suggested by Indira and Sinha (1969).

The HCN released on acidulation of homogenised sample was absorbed in a picrate paper, which was later eluted with distilled water and the colour read at 540 nm.

The result was expressed as milligram of HCN per gram of fresh tuber flesh.

3.4 Analysis of oilcakes and fertilizers used

Nitrogen, phosphorus and potassium contents of the oilcakes were estimated as described by Jackson (1973). The oil content of the cakes was estimated using a soxhlet apparatus (Table 2). Standard analytical procedures were used for the estimation of N, P and K in the fertilizers.

3.5. Statistical analysis

The results obtained were statistically analysed as described by Snedecor and Cochran (1967).

In the mineralisation studies zero time analysis data formed a concommittant variable for the subsequent data and so covariance analysis was adopted for the adjustment of means and for testing the significance of the treatment mean differences.

Some of the relevant correlations were also worked out.

Results

RESULTS

This chapter presents the various results obtained in the investigation, which included an incubation study to assess the mineralisation pattern of different urea-oilcake blends and a field experiment with tapioca to test the feasibility of utilizing non-edible oilcake -urea blends for increased nitrogen utilization efficiency.

4.1 Physico-chemical characteristics of the soil (Table-1)

Data on the physico-chemical properties of soil used for the study indicated that it belonged to sandy loam textural class, had low cation-exchange capacity and was acidic in reaction. It was low in organic matter, avâilable nitrogen and potassium but medium in available phosphorus.

4.2 Laboratory incubation study

Soil samples from pots under different treatments were analysed for ammoniacal, nitrite and nitrate forms of nitrogen, at zero, two, seven, twelve, twenty two and twenty seven days after incubation at 60 per cent field moisture capacity.

4.2.1 NH_4^+-N content

Statistically adjusted mean concentrations of NH_4^+-N in the soil at different periods of sampling are given in Table-3 and the analysis of covariance of the data is presented in Appendix II(a) to II(f).

Statistically significant differences in the contents of NH_4^+-N of the soil under different treatments were observed upto twenty two days of incubation. With the advancement of days of incubation a general increase in NH_4^+-N upto second day by all the treatments and later a gradual decrease upto twenty seventh day in the case oilcake treated pots were noticed. However, untreated urea showed a faster rate of decline in NH_4^+-N content after the second day of incubation.

On the second day of incubation urea-karinja (5:2) blend and urea-rubber cake (5:1) blend recorded the lowest NH_4^+-N, and urea-mahua cake (5:3), the maximum.

On the seventh day, all the oilcake treatments in general recorded higher concentrations of NH_4^+-N, when compared to urea alone treatment. All the oilcake blends except that of maroti and karinja showed increased NH_4^+-N content with narrower ratios; the maximum being shown by urea mahua cake blend at 5:3 level and urea

Table 3. Mineralisation pattern of Urea-oil cake blend-NH_4^+-N content in soil (Adjusted Means in ppm)

Treatments		0 time	2nd day	7th day	12th day	17th day	22nd day	27th day
Urea alone		0.620	227.72	109.01	137.75	121.78	122.60	114.56
Urea + neem	5:1	0.610	175.34	138.17	167.84	144.81	130.96	128.04
	5:2	0.660	205.74	177.88	202.11	162.04	160.14	128.74
	5:3	0.600	247.96	179.59	241.52	157.64	167.73	139.61
	Mean		209.68	165.21	203.80	154.80	152.90	132.13
Urea + rubber	5:1	0.710	138.14	146.59	200.80	135.59	155.32	130.85
	5:2	0.610	263.34	133.17	174.52	133.91	143.63	127.04
	5:3	0.600	247.96	157.02	207.29	154.29	160.98	134.14
	Mean		216.49	145.59	194.20	141.20	153.30	130.70
Urea + karinja	5:1	0.600	254.96	125.31	211.49	160.95	141.19	126.44
	5:2	0.608	124.87	133.14	152.67	166.98	130.34	125.76
	5:3	0.610	219.30	127.41	164.52	153.51	153.63	125.55
	Mean		199.71	128.62	176.23	160.50	141.70	125.90
Urea + maroti	5:1	0.609	245.61	140.15	214.59	188.89	127.66	130.34
	5:2	1.040	168.68	201.28	204.08	163.46	144.05	190.59
	5:3	1.010	158.54	180.53	199.96	124.33	147.36	141.24
	Mean		190.94	173.99	206.20	158.90	139.70	154.10
Urea + mahua	5:1	0.590	231.58	194.38	172.06	175.12	151.96	120.49
	5:2	0.610	163.34	140.17	164.52	155.12	160.97	121.38
	5:3	0.610	261.34	201.02	233.52	186.18	166.97	136.06
	Mean		218.75	178.52	190.00	172.10	160.00	126.00
Regression F		-	NS	NS	NS	NS	NS	NS
Treatment		-	Sig.	Sig.	Sig.	Sig.	Sig.	NS
C.D. (0.05)		-	62.77	36.53	43.88	33.57	41.92	-
SEm ±		-	20.96	13.00	14.65	11.21	14.00	28.05

On the 12th day of sampling urea + neem at 5:2 and 5:3 ratios, urea + maroti at all ratios, urea + rubber at 5:1 and 5:3 ratios and urea + mahua at 5:3 ratio showed significantly higher NH_4^+-N content over control; the maximum being shown by urea+neem and urea+mahua at 5:3 ratios.

On the 17th day urea + mahua at 5:1 and 5:3 ratios, urea + maroti and urea + karinja at 5:1 and 5:2 ratios and urea + neem at 5:2 and 5:3 ratios showed statistically significant higher contents of NH_4^+-N.

On the 22nd day, statistically significant differences in NH_4^+-N content over untreated urea was shown by blends of mahua and neem at 5:3 ratios. Treatment differences were not statistically significant on 27th day sampling.

On all days of sampling except that on the twenty second day maroti cake blend at 5:3 recorded the lowest NH_4^+-N content when compared to other ratios.

Averaged over the ratios, the content of NH_4^+-N was more on the second day of incubation in untreated urea followed by urea + mahua, urea + rubber, and urea + neem, while urea + maroti and urea + karinja recorded very low contents.

On the seventh day of sampling urea + mahua recorded the highest value followed by urea + maroti and urea + neem.

On the 12th day sampling urea + maroti blend recorded the highest content followed by urea + neem and urea + rubber.

On the 17th and 22nd day of incubation urea-mahua cake blend gave the highest NH_4^+-N content of 172.1 and 160 ppm respectively. On the 27th day, though statistically not significant, urea-maroti blend gave the highest value (154.1 ppm).

4.2.2 Nitrite nitrogen

Table-4 presents the data on the adjusted mean NO_2^--N concentration in soil on second, seventh and twelfth day of sampling and the analysis of covariance tables are given in Appendix III (a) to III (c).

Analysis of NO_2^--N, in the subsequent periods of sampling was not attempted, since the contents were found to be trace and did not show any treatment difference.

In general, a slight increasing trend in the content of nitrite was noticed upto the second day sampling which later dropped to the initial status by the 12th day of incubation. Though treatments showed significant differences, the variation did not follow any consistent pattern to draw a conclusion.

Table 4. Mineralisation pattern of Urea-oil cake blend-NO_2^--N content in the soil (Adjusted Means in ppm)

Treatments		0 time	2nd day	7th day	12th day
Urea alone		0.00296	0.00309	0.00317	0.00198
Urea + neem	5:1	0.00274	0.00396	0.00310	0.00202
	5:2	0.00374	0.00344	0.00348	0.00223
	5:3	0.00328	0.00326	0.00254	0.00288
Urea + rubber	5:1	0.00304	0.00379	0.00255	0.00199
	5:2	0.00254	0.00367	0.00301	0.00302
	5:3	0.00206	0.00352	0.00303	0.00259
Urea + karinja	5:1	0.00292	0.00346	0.00321	0.00200
	5:2	0.00201	0.00296	0.00295	0.00210
	5:3	0.00329	0.00325	0.00294	0.00105
Urea + maroti	5:1	0.00329	0.00325	0.00298	0.00198
	5:2	0.00292	0.00304	0.00299	0.00255
	5:3	0.00201	0.00342	0.00304	0.00208
Urea + mahua	5:1	0.00274	0.00396	0.00321	0.00255
	5:2	0.00254	0.00289	0.00202	0.00259
	5:3	0.00201	0.00396	0.00324	0.00207
Regression F			NS	NS	NS
Treatment F			NS	Sig.	Sig.
C.D. (0.05)			-	0.00062	0.00057
$SE_m \pm$			0.00049	0.00020	0.00019

4.2.3 Nitrate nitrogen

Data on the nitrate nitrogen content of the soil monitored at different periods of incubation is presented in table No.5 and the analysis of covariance table in Appendices IV (a) to IV (f).

All the treatments showed an increasing trend with the period of incubation, the increase being more pronounced after the seventh and seventeenth day of incubation.

Decreasing the ratio of mixing of urea to oilcakes did not show any consistent trend to draw a conclusion. Upto 17 days of incubation, untreated urea maintained a higher nitrate nitrogen concentration when compared to other treatments. Treatments showed statistically significant differences on the second, seventh and seventeenth day of sampling.

Averaged over the ratios urea-neem blend showed a comparatively steady and slow rate of increase in nitrate nitrogen content throughout the period of incubation. Averaged over ratios, all the urea-oilcake blends showed a lower nitrate content upto twenty second day when compared to untreated urea.

Table 5. Mineralisation pattern of Urea-oil cake blend-NO_3^--N content in the soil (Adjusted means in ppm)

Treatments		0 time	2nd day	7th day	12th day	17th day	22nd day	27th day
Urea alone		0.035	1.109	2.100	5.720	7.764	15.570	14.936
Urea + neem	5:1	0.045	0.556	1.280	4.332	6.277	13.400	14.342
	5:2	0.045	0.505	1.450	4.802	5.527	12.700	15.542
	5:3	0.052	0.199	1.180	4.319	5.361	13.290	14.196
	Mean		0.420	1.703	4.484	5.722	13.130	14.693
Urea + rubber	5:1	0.045	0.655	1.560	5.272	6.027	15.400	15.442
	5:2	0.047	0.950	1.660	5.000	6.254	14.490	14.992
	5:3	0.052	0.524	1.470	5.589	5.712	15.990	14.796
	Mean		0.710	1.563	5.287	5.998	15.290	15.077
Urea + karinja	5:1	0.033	1.008	1.430	5.624	6.561	14.410	14.334
	5:2	0.077	0.698	1.100	5.007	5.436	13.350	17.238
	5:3	0.043	0.864	1.240	5.239	5.925	14.240	16.340
	Mean		0.857	1.257	5.290	5.974	14.000	15.971
Urea + maroti	5:1	0.053	0.799	1.560	5.289	4.838	16.070	16.346
	5:2	0.040	0.577	1.520	5.311	6.396	15.390	15.189
	5:3	0.030	0.901	1.750	5.389	5.383	12.160	14.183
	Mean		0.759	1.610	5.330	5.539	14.540	15.239
Urea + mahua	5:1	0.040	0.677	1.710	4.811	5.946	14.990	15.189
	5:2	0.052	0.624	1.800	5.789	4.362	14.990	16.546
	5:3	0.047	0.446	1.290	4.948	4.480	16.870	14.543
	Mean		0.582	1.600	5.183	4.930	15.617	15.426
Regression F			NS	Sig.	NS	NS	NS	NS
Treatment F			Sig.	Sig.	NS	Sig.	NS	NS
C.D. 0.05			2.173	0.310	-	1.010	-	-
$SE_m \pm$			0.726	0.104	0.341	0.337	2.890	2.940

4.2.4 Rate of nitrification and percentage - inhibition

Table No.6 presents the rate of nitrification (%) in the soil under different treatments and the percentage inhibition of nitrification imparted by the different oilcakes, at different ratios of mixing with urea, at different periods of incubation.

On perusal of the data, it could be seen that, in general nitrification percentage increased as the days of incubation advanced, at a rapid rate upto twenty second day, and thereafter gradually.

Except for the 27th day sampling, untreated urea maintained a higher nitrification rate compared to all other treatments.

Among the treatments at 5:1 ratios urea-mahua blend recorded the lowest nitrification rate on second, seventh and twenty second day of incubation, while at twelfth and seventeenth day sampling urea-maroti blend showed the minimum value.

Among the treatments at 5:2 ratios, urea-neem blend gave the lowest rate of nitrification on the second, twelfth and twenty second day of sampling while urea-maroti blend on seventh and twenty seventh day sampling. On seventeenth day of incubation, urea-mahua showed the lowest rate of nitrification at this ratio (5:2).

Table 6(a). Percentage Nitrification and Inhibition

		2nd day		7th day		12th day	
		Minera-lisation	Inhi-bition	Minera-lisation	Inhi-bition	Minera-lisation	Inhi-bition
Urea alone		0.49	-	1.89	-	3.99	-
Urea + neem	5:1	0.32	34.39	0.92	51.32	2.52	36.84
	5:2	0.25	48.98	0.81	57.14	2.32	41.85
	5:3	0.08	83.67	0.80	57.67	1.76	55.89
Urea + rubber	5:1	0.47	4.08	1.05	44.44	2.56	35.84
	5:2	0.36	26.53	1.23	34.92	2.79	30.08
	5:3	0.21	57.14	0.93	50.79	2.63	34.09
Urea + karinja	5:1	0.40	18.37	1.13	40.21	2.59	35.09
	5:2	0.56	-14.28	0.82	56.61	3.18	20.30
	5:3	0.39	20.41	0.97	48.68	3.09	22.56
Urea + maroti	5:1	0.33	32.65	1.10	41.80	2.41	39.60
	5:2	0.34	30.61	0.75	60.32	2.54	36.34
	5:3	0.63	-28.57	0.96	49.21	2.63	34.09
Urea + mahua	5:1	0.29	40.82	0.87	53.97	2.72	31.83
	5:2	0.38	22.45	1.27	32.80	3.40	14.79
	5:3	0.17	65.31	0.64	66.14	2.08	47.87

Table 6(b). Percentage Nitrification and Inhibition

		17th day		22nd day		27th day	
		Minera-lisation	Inhi-bition	Minera-lisation	Inhi-bition	Minera-lisation	Inhi-bition
Urea alone		6.00	-	11.30	-	11.50	-
Urea + neem	5:1	4.15	30.83	9.30	17.70	10.08	12.35
	5:2	3.30	45.00	7.30	35.40	10.80	6.09
	5:3	3.29	45.17	7.30	35.40	9.20	20.00
Urea + rubber	5:1	4.26	29.00	9.02	20.18	10.60	7.83
	5:2	4.46	25.67	9.20	18.58	10.60	7.83
	5:3	3.57	40.50	9.04	20.00	9.90	13.91
Urea + karinja	5:1	3.92	34.67	9.30	17.70	10.20	11.30
	5:2	3.15	47.50	9.30	17.70	12.10	-0.52
	5:3	3.72	38.00	8.48	24.96	11.50	-
Urea + maroti	5:1	2.50	58.33	11.20	0.89	11.10	3.48
	5:2	3.77	37.17	9.65	14.60	7.40	35.65
	5:3	4.15	30.83	7.60	32.74	9.20	20.00
Urea + mahua	5:1	3.28	45.33	8.98	20.53	11.20	2.61
	5:2	2.74	54.33	8.52	24.60	11.90	-3.48
	5:3	2.35	60.83	9.18	18.76	9.70	15.65

Among the treatments at 5:3 level, except on seventh day sampling, on all other days, urea-neem blend recorded the lowest rate of nitrification. On seventh day urea-mahua blend showed the minimum.

In general, increasing the concentration of oilcakes decreased nitrification rate in neem and mahua cake blends, but maroti cake blend showed minimum rate at 5:2 level. Karinja and rubber cake blends did not show any consistent pattern.

As the rate of nitrification increased the percentage inhibition was seen decreased.

In general, the percentage inhibition showed two peaks-one on the seventh day and the other on 17th day of incubation. It was seen that all the oilcakes possessed inhibitory properties, which varied in their capacity with, the period of incubation and ratio of mixing.

In general, increasing the concentration of oilcakes increased the rate of inhibition in neem, mahua and rubber seed cake blends, while maroti cake blend showed the maximum inhibition at the 5:2 level.

From the data it was revealed that by a period of one month in the soil, the oilcakes lose the inhibitory property, considerably.

4.3 Field experiment with tapioca

The results of analysis of soil and plant samples, biometric observations made on tapioca crop at the major growth stages, uptake of nutrients, tuber yield, and quality attributes of tubers, are presented hereunder.

4.3.1 Exchangeable NH_4^+-N

Results of the analysis of the soil for exchangeable NH_4^+-N at weekly intervals, in the field after the application of fertilizer treatments are presented here.

Table No.7 presents the NH_4^+-N content of the soil at zero time, and one, two, three and four weeks after the application of fertilizers. Analysis of covariance tables are presented in Appendices V (a) to V (d).

Regression analysis indicated that the content of NH_4^+-N in the first week soil samples was highly dependent on the pre-treatment data, while in the later periods, large treatment effects were found to nullify the pre-treatment differences.

Treatment effects were not significant at the first week, but untreated urea at n_3 (50 kg N) level plots showed the highest concentration (49.19 ppm), and urea-neem blend

Table 7. Exchangeable ammonium at weekly intervals (after basal application of urea) (Adjusted means in ppm)

Treatments		0 time	1 week	2 weeks	3 weeks	4 weeks
Urea	50 kg N (n_3)	24.54	49.19	73.62	50.33	20.02
	37.5 kg N (n_2)	17.43	35.56	54.26	14.81	19.97
	25 kg N (n_1)	14.73	41.07	61.41	19.98	18.69
	Mean		41.94	63.10	28.37	19.56
Urea + neem	50 kg N (n_3)	14.73	31.65	132.59	39.06	19.63
	37.5 kg N (n_2)	22.09	36.12	90.82	36.69	23.07
	25 kg N (n_1)	24.45	36.11	103.09	37.10	23.07
	Mean		34.63	108.83	37.58	21.92
Urea + rubber	50 kg N (n_3)	19.63	40.05	115.33	30.77	12.03
	37.5 kg N (n_2)	22.09	34.04	98.15	27.11	14.52
	25 kg N (n_1)	29.46	39.79	100.63	37.11	16.93
	Mean		37.96	104.70	31.66	14.49
Urea + maroti	50 kg N (n_3)	19.64	22.99	115.33	27.10	16.98
	37.5 kg N (n_2)	14.73	37.81	100.70	25.60	16.83
	25 kg N (n_1)	19.64	29.98	66.27	37.66	20.61
	Mean		93.78	94.10	30.12	18.14
Urea + mahua	50 kg N (n_3)	19.64	35.38	112.92	41.91	24.91
	37.5 kg N (n_2)	17.18	45.98	105.58	28.69	16.88
	25 kg N (n_1)	24.54	36.83	95.72	28.09	21.81
	Mean		39.40	104.74	32.90	21.20
Regression			Sig.	NS	NS	NS
Treatment			NS	Sig.	NS	NS
C.D.(0.05)			-	31.26	-	-
$SE_m \pm$			6.80	13.38	9.58	4.25

at n_3 level, the lowest (31.65 ppm). Different levels of nitrogen did not show any consistent pattern of variation.

Two weeks after the application, the treatment differences attained the level of significance. Ammoniacal nitrogen attained a peak value by that period, maximum being shown by neem-urea blend (132.59 ppm) at n_3 level while untreated urea at n_2 (37.5 kg N) level the minimum (54.26 ppm). All the oilcake treatments were on par, but superior to untreated urea treatment.

Averaged over the levels, two weeks, after the urea-neem cake blend recorded the highest ammoniacal nitrogen content (108.83 ppm).

Treatment effects were not found to significantly influence, the ammoniacal nitrogen content of the soil after three and four weeks of the basal application of fertilizers. Averaged over the periods and sources in general, increasing levels of nitrogen, had increased the NH_4^+-N content.

Table-8 presents the NH_4^+-N content of the soil at the time of application and one, two, three and four weeks after the top dressing of fertilizers. Analysis of covariance tables are presented in Appendices XIV to XVII.

Table 8. Exchangeable ammonium at weekly intervals (after top dressing of Urea) (Adjusted means in ppm)

Treatments		0 time	1 week	2 weeks	3 weeks	4 weeks
Urea	50 kg N (n_3)	40.68	56.60	83.07	22.64	15.91
	37.5 kg N (n_2)	4.84	42.52	43.62	5.52	3.77
	25 kg N (n_1)	5.96	47.29	27.31	1.53	2.71
	Mean		48.80	51.33	9.90	7.46
Urea + neem	50 kg N (n_3)	37.32	70.21	177.26	85.78	47.35
	37.5 kg N (n_2)	33.60	65.01	137.14	67.15	58.22
	25 kg N (n_1)	14.93	35.65	115.73	31.91	28.56
	Mean		56.96	143.38	61.35	44.71
Urea + rubber	50 kg N (n_3)	70.93	154.34	123.94	33.12	59.67
	37.5 kg N (n_2)	48.53	108.21	107.22	9.12	31.54
	25 kg N (n_1)	18.87	29.65	70.36	4.98	28.89
	Mean		97.40	100.51	15.74	40.03
Urea + maroti	50 kg N (n_3)	37.33	44.08	169.79	60.38	60.41
	37.5 kg N (n_2)	26.13	47.15	120.36	33.64	33.29
	25 kg N (n_1)	14.93	24.83	115.73	15.85	13.62
	Mean		38.69	135.29	36.62	35.77
Urea + mahua	50 kg N (n_3)	29.87	22.48	190.35	63.46	52.28
	37.5 kg N (n_2)	22.40	57.25	151.18	52.35	36.68
	25 kg N (n_1)	18.29	21.67	85.02	26.27	13.93
	Mean		33.80	142.18	47.36	34.30
Regression F			NS	Sig.	NS	NS
Treatment F			NS	Sig	Sig	Sig
C.D.(0 05)			-	64.45	38.77	31.75
$SE_m\pm$			31.85	29.71	16.58	13.59

At the first week, samples did not show significant treatment differences. Two weeks after tho application, treatment differences and regression analysis attained the level of significance.

Urea-mahua blend at n_3 level along with urea-neem and urea-maroti at the same level recorded higher concentrations of NH_4^+-N, in the order, and were found to be significantly superior to control.

Three weeks after application, urea-neem at n_3 and n_2 followed by urea-mahua at n_3 level, showed significantly higher contents of NH_4^+-N. Urea-maroti at n_3 level showed maximum concentration on the fourth week sampling, but was found on par with all other oilcake treatments at n_3 level.

At all the periods of sampling, plots receiving untreated urea, at all the three levels of nitrogen, showed a lower concentration, than plots receiving urea-oilcake-blend, at the corresponding levels.

Incremental doses of nitrogen produced an increase in exchangeable NH_4^+-N in both urea alone and urea-oilcake-blend treatments.

Averaged over the levels, urea-rubber cake-blend (97.4 ppm) along with urea-neem cake-blend (56.96 ppm) registered maximum concentrations of NH_4^+-N, at the first week sampling, while at the second and third week sampling, urea-neem cake blend (143.38 ppm and 61.35 ppm respectively) along with mahua-cake blend (142.18 ppm and 47.36 ppm, respectively) showed maximum concentrations. At the fourth week, neem cake blend (44.71 ppm) and rubber cake blend (40.03 ppm) recorded maximum contents.

4.3.2. Growth Characters

4.3.2.1 Height of plants

Data on the height of plants at three month, six month and harvest stages of the crop, as influenced by the treatments is presented in Table 9(a) to 9(c) and the Analysis of variance in Appendices VII to IX.

(a) Three month stage

The influence of different sources of nitrogen was significant at this stage, while that of levels and source-level interaction did not attain the level of significance.

All the oilcake blends were superior to urea alone treatment at all the three levels. Averaged over levels urea-maroti blend gave the maximum height but urea-neem and urea-mahua blends were on par with urea-maroti blend.

Averaged over the sources of nitrogen, among the levels of nitrogen, maximum height was recorded by n_3 level.

Table 9(a). Plant height at 3 month stage of the crop (metres)

Treatments	Levels of nitrogen			
	n_3	n_2	n_1	Mean
Urea	0.99	0.72	0.62	0.78
Urea + neem cake	1.26	1.38	1.30	1.31
Urea + rubber cake	1.34	1.16	0.78	1.09
Urea + maroti cake	1.16	1.34	1.47	1.32
Urea + mahua cake	1.40	1.19	1.24	1.28
Mean	1.23	1.16	1.08	-

n_3 = 50 kg N/ha (Full recommended dose)

n_2 = 37.5 kg N/ha (3/4th recommended dose).

n_1 = 25 kg N/ha (1/2 recommended dose).

	F	CD (5%)	SEm±
Between sources	Sig.	0.22	0.08
Between levels	NS	-	0.06
Interaction	NS	-	-
Combination	-	0.39	0.13

Among the combinations, urea-maroti blend at n_1 level showed the maximum height and untreated urea at n_1 level, the minimum.

(b) Six month stage

At this stage of growth different sources and levels of nitrogen significantly influenced the plant height, but interaction effect did not.

Urea-neem and urea-rubber cake blends were found statistically superior to urea alone treatment. All the oilcake treatments were on par with each other, in their effect on plant height of cassava.

As regards the levels of nitrogen, n_3 recorded the maximum height but on par with n_2, which was also on par with n_1. However, n_3 was significantly superior to n_1.

Urea-neem blend at n_2 level recorded the maximum height, among the treatment combinations, and untreated urea at n_2 level, the minimum.

(c) Harvest stage

Data showed that, the different sources and levels of nitrogen, differed significantly in their effect on plant height, but interaction effects were not statistically significant.

Table 9(b). Plant height at 6 month stage of tho crop (metres).

Treatments	Levels of nitrogen			
	n_3	n_2	n_1	Mean
Urea	1.90	1.29	1.30	1.50
Urea + neem cake	2.17	2.37	1.61	2.05
Urea + rubber cake	2.10	1.82	1.48	1.83
Urea + maroti cake	1.69	1.98	1.76	1.81
Urea + mahua cake	1.93	1.50	1.76	1.73
Mean	1.98	1.79	1.58	-

n_3 = 50 kg N/ha (full recommended dose)
n_2 = 37.5 kg N/ha ($3/4^{th}$ recommended dose)
n_1 = 25 kg N/ha (1/2 recommended dose).

	F	CD (5%)	SEm±
Between sources	Sig.	0.32	0.11
Between levels	Sig.	0.25	0.09
Interaction	NS	-	-
Combination	-	0.56	0.19

Table 9(c). Plant height at harvest stage (metres)

Treatments	Levels of nitrogen			
	n_3	n_2	n_1	Mean
Urea	1.95	1.68	1.28	1.64
Urea + neem cake	2.44	2.27	1.72	2.14
Urea + rubber cake	1.96	1.90	1.72	1.86
Urea + maroti cake	1.89	1.94	1.56	1.80
Urea + mahua cake	2.20	2.11	1.77	2.03
Mean	2.09	1.98	1.61	-

n_3 = 50 kg N/ha (full recommended dose)
n_2 = 37.5 kg N/ha (3/4th recommended dose)
n_1 = 25 kg N/ha (1/2 recommended dose)

	F	CD (5%)	SEm$\pm$
Between sources	Sig.	0.25	0.09
Between levels	Sig.	0.20	0.07
Interaction	NS	-	-
Combination	-	0.44	0.15

Among the sources, urea-neem blend recorded the maximum height, followed by urea-mahua blend. Both the treatments were found significantly superior to untreated urea. Urea-rubber and urea-maroti blends were found to be on par with urea alone treatment.

Maximum height was found, at n_3 level. But n_3 and n_2 levels were found to be on par, while both the treatments were significantly superior to n_1.

Urea-neem blend at n_3 level recorded the maximum height while untreated urea at n_1 level, the minimum.

4.3.2.2 Number of leaves

Data on the mean number of leaves per plant, at different growth stages of crop, are presented in Table 10(a) to 10(c) and analysis of variance in Appendices X to XII.

(a) Three month stage

The effects of different sources and levels on number of leaves were found significant, while their interaction effect was not.

Among the oilcakes, urea-mahua blend was most effective in augmenting leaf number, but was on par with urea-neem and urea-maroti blends. Untreated urea registered the minimum number.

Table 10 (a) Number of leaves/plant at 3 month stage of the crop.

Treatments	Levels of nitrogen			
	n_3	n_2	n_1	Mean
Urea	60.67	34.67	41.33	45.56
Urea + neem cake	113.33	110.00	80.67	101.33
Urea + rubber cake	63.00	106.67	31.33	67.00
Urea + maroti cake	118.33	100.67	76.00	98.33
Urea + mahua cake	111.00	122.00	82.33	105.11
Mean	93.27	94.80	62.33	-

n_3 = 50 kg N/ha (full recommended dose)
n_2 = 37.5 kg N/ha (3/4 recommended dose)
n_1 = 25 kg N/ha (1/2 recommended dose)

	F	CD (5%)	SEm$\pm$
Between sources	Sig.	27.02	9.33
Between levels	Sig.	20.94	7.23
Interaction	NS	-	-
Combination	-	46.81	16.16

Maximum number of leaves was recorded by n_2 level but was found to be on par with n_3 among the levels of nitrogen. However, both were significantly superior to n_1.

Among the treatment combinations, urea-mahua blend at n_2 level ranked first, followed by urea-maroti, urea-mahua and urea-neem at n_3 level, which were on par with each other.

(b) Six month stage

Effects of sources, levels and their interaction were found to be statistically significant.

All the oilcake treatments were found superior to untreated urea. However, the differences among the effects of the oilcake-urea-blends were not significant.

Among the levels n_3 recorded the maximum leaf number and was found to be on par with n_2. Both n_2 and n_3 levels were found superior to n_1.

Urea-rubber cake blend at n_3 level followed by urea-neem at n_2 level registered a higher number of leaves among treatment combinations.

(c) Harvest stage

Data showed that the different oilcake treatments

Table 10(b). Number of leaves/plant at 6 month stage of the crop.

Treatments	Levels of nitrogen			
	n_3	n_2	n_1	Mean
Urea	40.67	50.33	29.67	40.22
Urea + neem cake	70.33	108.67	44.33	74.44
Urea + rubber cake	111.67	72.67	55.00	79.78
Urea + maroti cake	73.00	68.00	41.67	60.89
Urea + mahua cake	53.67	88.00	83.33	75.00
Mean	69.87	77.53	50.80	-

n_3 = 50 kg N/ha (full recommended dose)
n_2 = 37.5 kg N/ha (3/4 recommended dose)
n_1 = 25 kg N/ha (1/2 recommended dose).

	F	CD (5%)	SE m±
Between sources	Sig.	20.42	7.05
Between levels	Sig.	15.82	5.46
Interaction	Sig.	-	-
Combination	-	35.37	12.20

Table 10(c). Number of leaves/plant at harvest stage of the crop.

Treatments	Levels of nitrogen			
	n_3	n_2	n_1	Mean
Urea	138.33	75.33	25.33	79.67
Urea + neem cake	120.67	55.33	40.67	72.22
Urea + rubber cake	88.67	67.67	49.33	68.56
Urea + maroti cake	92.67	96.67	72.67	87.33
Urea + mahua cake	64.67	57.67	66.00	62.78
Mean	101.00	70.53	50.80	-

n_3 = 50 kg N/ha (full recommended dose).
n_2 = 37.5 kg N/ha (3/4 recommended dose).
n_1 = 25 kg N/ha (1/2 recommended dose).

	F	CD (5%)	SE m±
Between sources	NS	-	9.33
Between levels	Sig.	20.93	7.22
Interaction	NS	-	-
Combination	-	46.80	0.15

did not influence the number of leaves at harvest stage, while the levels of nitrogen had shown significant differences, with the n_3 level recording the highest number of leaves. Interaction of sources and levels of nitrogen was not significant.

The n_3 level of nitrogen was found significantly superior to n_2 and n_1, which were on par with each other.

Among the treatment combinations, untreated urea at n_3 level gave the maximum number of leaves followed by urea-neem blend and urea-maroti blend at n_3 level.

4.3.2.3 <u>Dry weight of plant</u>

Table 11(a) to 11(c) presents the data on the dry matter production per plant at different growth stages of crop, as influenced by the treatments. Analysis of variance tables are given in Appendices XII to XV.

(a) <u>Three month stage</u>

The different sources and levels of nitrogen produced significant differences in dry matter yield at three month stage, while their interaction effect was not significant.

Among the sources of nitrogen, urea-neem blend

Table 11(a). Total plant dry weight of 3 month stage of the crop (g/plant).

Treatments	Levels of nitrogen			
	n_3	n_2	n_1	Mean
Urea	271.04	102.52	57.34	143.63
Urea + neem cake	614.70	430.60	305.48	450.26
Urea + rubber cake	381.04	149.19	68.31	199.51
Urea + maroti cake	474.86	343.59	174.03	330.82
Urea + mahua cake	431.24	325.56	130.94	295.91
Mean	434.57	270.29	147.22	-

n_3 = 50 kg N/ha (full recommended dose)
n_2 = 37.5 kg N/ha (3/4 recommended dose)
n_1 = 25 kg N/ha (1/2 recommended dose).

	F	CD (5%)	SEm±
Between sources	Sig.	107.84	46.15
Between levels	Sig.	83.54	35.75
Interaction	NS	-	-
Combination	-	186.79	79.94

was found to produce the maximum dry weight and was superior to all other sources of nitrogen. Urea-neem blend recorded the highest dry weight and was followed by urea-maroti and urea-mahua blends which were on par with each other. Untreated urea recorded the minimum, but was on par with urea-rubber blend.

Among the levels of nitrogen, n_3 was found superior to n_2 and n_1; n_1 presented the lowest among the three. All the different levels were statistically different in their effect on dry matter production.

Among the treatment combinations, urea-neem blend at n_3 and n_2 levels were on par and they recorded the highest values. Untreated urea at n_1 level recorded the lowest.

(b) Six month stage

Data revealed that the sources and levels of nitrogen tried had significant influence on the dry matter production. However the interaction was not statistically significant.

Averaged over the levels, neem cake was found to be superior to all other sources of nitrogen which were on par with one another. Urea-rubber cake blend gave the minimum dry weight.

Among the levels of nitrogen, n_3, the highest

Table 11(b). Total plant dry weight of 6 month stage of the crop (g/plant).

Treatments	Levels of nitrogen			
	n_3	n_2	n_1	Mean
Urea	1458.98	500.20	155.72	704.97
Urea + neem cake	1782.98	1350.95	734.47	1289.50
Urea + rubber cake	859.52	691.60	416.39	655.84
Urea + maroti cake	1149.65	966.90	490.16	868.90
Urea + mahua cake	1438.95	795.27	236.08	823.44
Mean	1338.02	860.98	406.58	

n_3 = 50 kg N/ha (full recommended dose)
n_2 = 37.5 kg N/ha (3/4 recommended dose)
n_1 = 25 kg N/ha (1/2 recommended dose).

	F	CD (5%)	SEm±
Between sources	Sig.	253.70	108.56
Between levels	Sig.	196.60	84.12
Interaction	NS	-	-
combination	-	439.54	188.09

dose, gave the maximum dry weight and was found significantly superior to n_2 and n_1, which were on par with each other.

Urea-neem blend at n_3 level produced the maximum dry weight and untreated urea at n_1 level the minimum. At n_2 and n_1 levels, untreated urea recorded the minimum dry weights.

(c) <u>Harvest stage</u>

Effects of different sources and levels were significant but the interaction was not. Urea-neem cake blend was found to be the best in increasing dry weight followed by urea-mahua blend. Rubber cake with urea recorded significantly lower dry weights than untreated urea.

Significant differences in dry weights between the different levels of nitrogen was observed; n_3 being the highest recorder.

Urea-neem blend at n_3 level recorded the highest dry matter yield followed by urea-mahua blend at the same level. Urea alone treatment at n_1 level recorded the minimum.

4.3.3 Nitrogen and Potassium concentration in plant parts

Nitrogen and potassium content of different

Table 11(c). Total plant dry weight at harvest stage of the crop (g/plant).

Treatments	Levels of nitrogen			
	n_3	n_2	n_1	Mean
Urea	1437.14	1158.26	789.17	1128.18
Urea + neem cake	1880.99	1459.26	956.38	1432.21
Urea + rubber cake	1379.75	881.19	473.95	911.63
Urea + maroti cake	1429.10	1118.82	582.60	1043.50
Urea + mahua cake	1728.56	1223.82	653.23	1201.87
Mean	1571.11	1168.27	691.07	-

n_3 = 50 kg N/ha (full recommended dose)
n_2 = 37.5 kg N/ha (3/4 recommended dose)
n_1 = 25 kg N/ha (1/2 recommended dose).

	F	CD(5%)	SEm±
Between sources	Sig.	204.69	87.59
Between levels	Sig.	158.55	67.85
Interaction	NS	-	-
Combination	-	354.54	151.71

plant parts, viz., leaf lamina, petiole, stem and tuber at different growth stages of plant, as influenced by the different sources and levels of nitrogen and their interaction are presented.

4.3.3.1 Three month stage

Table No.12 furnishes the mean percentage nitrogen and potassium in different plant parts. The analysis of variance table of the data are given in Appendices XVI(a) to XVII (d).

4.3.3.1.1 Leaf Lamina

(a) Nitrogen

The different sources of nitrogen did not significantly influence the lamina nitrogen content, however the incremental doses of nitrogen had significantly increased the nitrogen content. Source-level interaction was also not significant. Among the sources, urea-mahua blend recorded the highest value, and untreated urea, the lowest. Among the levels n_3 registered maximum nitrogen content and all the levels of nitrogen differed significantly in their effect on nitrogen concentration.

Among the treatment combinations urea-neem blend at n_3 level, followed by urea-mahua at the same level, recorded the maximum value.

Table 12. Nitrogen & Potassium concentration - 3 month stage

Treatments		Lamina		Petiole		Stem		Tuber	
		N%	K%	N%	K%	N%	K%	N%	K%
Ufea - alone	n_3	2.94	1.83	0.98	2.07	1.99	1.94	0.81	1.04
	n_2	2.44	2.27	0.98	2.26	1.92	2.52	0.80	1.08
	n_1	2.01	2.97	0.93	2.39	1.25	1.88	0.75	1.69
	Mean	2.46	2.36	0.97	2.24	1.72	2.11	0.79	1.27
Urea + neem	n_3	3.28	1.53	1.14	1.81	1.74	1.61	0.84	1.07
	n_2	2.63	2.17	0.95	3.23	1.89	2.06	0.82	1.22
	n_1	2.12	1.53	1.00	1.29	1.48	1.93	0.88	1.30
	Mean	2.68	1.75	1.03	2.11	1.70	1.87	0.82	1.19
Urea + rubber	n_3	2.94	1.27	0.83	0.91	1.79	1.62	0.82	1.12
	n_2	2.77	1.92	1.00	3.36	1.86	2.78	0.80	1.14
	n_1	2.07	2.05	1.01	2.85	1.50	1.88	0.79	2.91
	Mean	2.59	1.75	0.95	2.37	1.72	2.09	0.80	1.72
Urea + maroti	n_3	2.91	1.81	1.06	1.81	1.69	2.50	0.83	1.24
	n_2	2.84	1.67	1.05	1.62	1.56	1.47	0.82	1.07
	n_1	2.02	2.17	0.93	3.10	1.38	2.29	0.80	1.17
	Mean	2.58	1.88	1.01	2.18	1.54	2.09	0.82	1.15

Table 12 (contd...)

Treatments		N%	K%	N%	K%	N%	K%	N%	K%
Urea + mahua	n_3	3.00	1.53	0.98	1.36	1.53	1.92	0.84	0.91
	n_2	2.60	1.96	0.93	1.23	1.45	1.87	0.82	1.27
	n_1	2.53	2.92	0.94	2.52	1.58	1.99	0.78	1.28
	Mean	2.71	2.14	0.95	1.70	1.52	1.93	0.81	1.15
Mean for levels	n_3	3.01	1.60	0.99	1.59	1.75	1.92	0.83	1.08
	n_2	2.66	2.00	0.98	2.34	1.74	2.14	0.81	1.15
	n_1	2.15	2.33	0.96	2.43	1.44	1.99	0.79	1.67
Source	F	NS	NS	NS	NS	NS	NS	Sig.	NS
	C.D	-	-	0.11	0.79	0.24	0.84	2.02	0.68
	SEm	0.11	0.17	0.04	0.27	0.08	0.29	0.01	0.23
Levels	F	Sig.	Sig.	NS	Sig.	Sig.	NS	Sig.	NS
	C.D	0.24	0.39	0.08	0.62	0.18	0.65	0.02	0.53
	SE_m	0.08	0.13	0.03	0.21	0.06	0.22	0.01	0.18
Interaction	F	NS	NS	NS	Sig.	NS	NS	NS	NS
Combination	C.D	0.54	0.87	0.19	1.38	0.41	1.46	0.04	1.18
	SE_m	0.19	0.30	0.07	0.48	0.14	0.50	0.01	0.41

(b) Potassium

Effects of levels of nitrogen were found to significantly influence the potassium content, but sources and source-level interaction did not influence the same. The lowest level recorded the maximum content and was found significantly superior to n_3 and n_2. Untreated urea at n_1 level recorded the maximum value.

In general, incremental doses of nitrogen depressed the potassium content in lamina.

4.3.3.1.2 Petiole

(a) Nitrogen

Neither the sources nor the levels did influence the nitrogen content in petioles at this stage. Their interaction effect was also not significant.

(b) Potassium

The influence of levels of nitrogen and source-level interaction were found significant. The n_1 level registered the highest potassium content. The treatment combinations did not show consistent trend at different levels.

4.3.3.1.3. Stem

(a) nitrogen

Only the effects of different levels were found to attain the level of significance. Incremental doses of nitrogen favourably influenced the nitrogen content in stem.

(b) Potassium

Neither the sources, nor the levels of nitrogen and their interaction did influence the potassium concentration in stem.

4.3.3.1.4 Tuber

(a) Nitrogen

Both sources and levels of nitrogen significantly influenced the nitrogen content of tubers. However, the source-level interaction was not significant.

Urea-neem and urea-maroti blends ranked first among the sources, and n_3 level among the doses of nitrogen. Among the treatment combinations, urea-neem and urea-mahua blends at n_3 level showed maximum nitrogen concentrations in tubers.

(b) Potassium

Neither the sources, nor the levels and source-level interaction did influence the potassium content of tubers at three month stage.

In general, at this stage with increasing nitrogen concentration, a decrease in potassium concentration in all plant parts was observed.

4.3.3.2 Six month stage

Data on the mean percentage nitrogen and potassium in different plant parts (Leaf lamina, petiole, stem and tuber) are furnished in Table 13 and the analysis of variance of the data in the Appendices XVIII (a) to XIX(d)

4.3.3.2.1 Leaf Lamina

(a) Nitrogen

Neither the sources, nor the levels and source-level interaction did show any influence on the nitrogen content.

(b) Potassium

Levels of nitrogen significantly influenced the potassium concentration, while sources and source-level interaction did not. Maximum concentration of potassium was observed in plants receiving the lowest dose of nitrogen, which was found significantly superior to the other levels. Untreated urea along with urea-maroti blend at n_1 level showed maximum potassium contents.

4.3.3.2.2 Petiole

The influence of treatments on the nitrogen and

Table 13. Nitrogen and Potassium concentration - 6 month stage

Treatments		Lamina		Petiole		Stem		Tuber	
		N%	K%	N%	K%	N%	K%	N%	K%
Urea alone	n_3	2.07	1.00	1.30	1.00	0.51	1.07	0.47	0.51
	n_2	2.20	1.14	1.17	1.17	0.46	0.93	0.54	0.48
	n_1	1.93	1.33	1.12	1.47	0.41	1.13	0.50	0.93
	Mean	2.07	1.16	1.20	1.21	0.46	1.05	0.50	0.64
Urea + neem	n_3	2.17	0.90	1.13	1.17	0.65	0.90	0.22	0.50
	n_2	2.18	1.10	1.12	1.03	0.64	0.90	0.41	0.63
	n_1	2.13	1.27	1.00	1.25	0.51	1.00	0.28	0.47
	Mean	2.16	1.09	1.08	1.15	0.60	0.93	0.31	0.53
Urea + rubber	n_3	2.08	1.03	0.96	1.00	0.51	0.93	0.35	0.42
	n_2	2.17	1.00	1.10	1.10	0.53	1.03	0.35	0.56
	n_1	1.97	1.23	1.06	1.20	0.47	1.10	0.41	0.70
	Mean	2.07	1.09	1.04	1.10	0.50	1.02	0.37	0.56
Urea + maroti	n_3	2.04	1.10	1.14	1.23	0.62	0.93	0.41	0.52
	n_2	2.14	0.90	1.03	1.07	0.53	1.03	0.35	0.73
	n_1	2.15	1.27	0.86	1.53	0.49	1.10	0.47	0.70
	Mean	2.11	1.09	1.01	1.28	0.55	1.02	0.41	0.65

(contd..)

Table 13 (contd...)

Treatments		N%	K%	N%	K%	N%	K%	N%	K%
Urea + mahua	n_3	2.04	0.73	0.97	1.10	0.63	0.77	0.35	0.48
	n_2	2.27	1.07	1.03	1.03	0.63	1.00	0.41	0.73
	n_1	2.14	1.33	1.22	1.17	0.51	1.17	0.28	0.76
	Mean	2.15	1.04	1.07	1.10	0.60	0.98	0.35	0.66
Means for levels	n_3	2.08	0.95	1.10	1.10	0.58	0.92	0.36	0.49
	n_2	2.19	1.04	1.09	1.08	0.56	0.98	0.41	0.63
	n_1	2.06	1.29	1.05	1.32	0.48	1.10	0.39	0.71
Sources	F	NS	NS	NS	NS	Sig.	NS	NS	NS
	C.D	-	0.15	-	0.22	0.03	0.13	-	0.24
	SEm±	0.06	0.05	0.06	0.08	0.01	0.04	0.06	0.08
Levels	F	NS	Sig.	NS	Sig.	Sig.	Sig.	NS	NS
	C.D	-	0.12	-	0.17	0.02	0.10	-	0.19
	SEm±	0.04	0.04	0.05	0.06	0.01	0.03	0.04	0.07
Interaction	F	NS	NS	NS	NS	Sig.	NS	NS	NS
Combination	C.D	0.28	0.26	0.32	0.38	0.05	0.23	0.27	0.42
	SEm±	0.10	0.09	0.11	0.13	0.02	0.08	0.09	0.14

potassium concentrations in petiole, showed the same trend as that in lamina.

Maximum potassium concentration was shown by the lowest nitrogen level treatment, which was found significantly superior to the other levels. Among the treatment combinations urea-maroti at n_1 level showed the maximum content followed by untreated urea at the same level.

4.3.3.2.3 Stem

(a) Nitrogen

The sources and levels of nitrogen and the source-level interaction were found to influence significantly the nitrogen concentration in stem.

Neem cake and mahua cake blended urea treatments were found significantly superior to all other sources of nitrogen. Among the levels n_3 was found to be superior. Neem-urea-blend at n_3 level followed by mahua urea blend at n_3 and n_2 level, showed maximum concentration of nitrogen among treatment combinations.

(b) Potassium

The sources of nitrogen did not influence the potassium concentration, while, the incremental doses of nitrogen did show a depressing trend. Source-level interaction was not found significant.

4.3.3.2.4 Tuber

Neither the source nor the level of nitrogen did produce any significant effect on either nitrogen or potassium content of tubers at the six month stage.

In general, a decreasing trend for potassium concentration with increasing nitrogen concentration was observed at this stage also.

4.3.3.3 Harvest stage

Table 14. summerises the mean concentrations of nitrogen and potassium in different plant parts at the harvest stage of the crop. Analysis of variance tables of the data are presented in Appendices XXX (a) to XXI (d).

Perusal of the data shows that the different sources of nitrogen, have significant influence on the concentration of potassium only in the leaf lamina and stem.

In the lamina and stem urea-mahua blend recorded the highest potassium concentrations.

Different levels and source-level interaction did not influence either the nitrogen or the potassium

Table 14. Nitrogen and Potassium concentration - Harvest stage

Treatments		Lamina		Petiole		Stem		Tuber	
		N%	K%	N%	K%	N%	K%	N%	K%
Urea alone	n_3	2.17	1.41	0.91	1.23	0.41	0.26	0.34	0.35
	n_2	2.36	1.38	0.91	1.48	0.47	0.32	0.35	0.57
	n_1	2.24	1.28	0.98	1.48	0.41	0.28	0.22	0.37
	Mean	2.26	1.36	0.93	1.40	0.43	0.29	0.31	0.43
Urea + neem cake	n_3	2.24	1.18	0.79	1.33	0.60	0.24	0.41	0.78
	n_2	2.24	1.33	0.79	1.20	0.66	0.23	0.35	0.43
	n_1	2.11	1.14	0.85	1.32	0.41	0.32	0.35	0.50
	Mean	2.19	1.21	0.81	1.28	0.56	0.26	0.36	0.57
Urea + rubber cake	n_3	2.23	1.28	0.98	1.03	0.38	0.20	0.28	0.58
	n_2	1.42	1.49	0.91	1.23	0.73	0.23	0.41	0.57
	n_1	2.05	1.23	0.85	1.31	0.54	0.39	0.28	0.65
	Mean	1.90	1.33	0.91	1.19	0.55	0.28	0.33	0.60
Urea + maroti cake	n_3	2.17	1.36	0.85	1.47	0.38	0.23	0.47	0.58
	n_2	2.17	1.22	0.91	1.16	0.47	0.30	0.22	0.37
	n_1	3.06	1.33	0.85	1.48	0.35	0.38	0.41	0.68
	Mean	2.47	1.30	0.87	1.37	0.40	0.30	0.37	0.54

(contd...)

Table 14 (contd...)

Treatments		N%	K%	N%	K%	N%	K%	N%	K%
Urea + mahua cake	n_3	3.18	1.33	0.79	1.21	0.41	0.37	0.41	0.68
	n_2	2.30	1.36	0.91	1.50	0.28	0.49	0.35	0.65
	n_1	2.17	1.46	0.85	1.46	0.47	0.56	0.35	0.67
	Mean	2.55	1.38	0.85	1.39	0.39	0.47	0.37	0.67
Means for levels	n_3	2.40	1.33	0.86	1.25	0.44	0.26	0.38	0.60
	n_2	2.10	1.35	0.89	1.31	0.52	0.31	0.33	0.52
	n_1	2.32	1.28	0.88	1.41	0.44	0.39	0.32	0.57
Source	F	NS	Sig.	NS	NS	NS	Sig.	NS	NS
	C.D	-	0.11	-	-	-	0.13	-	-
	SEm±	0.22	0.04	0.51	0.12	0.09	0.04	0.04	0.07
Levels	F	NS	NS	NS	NS	NS	NS	NS	NS
	C.D	-	-	-	-	-	-	-	-
	SEm±	0.17	0.03	0.05	0.10	0.07	0.03	0.03	0.06
Interaction	F	NS	NS	NS	NS	NS	NS	NS	NS
Combination	C.D	1.11	0.19	2.54	0.63	0.43	0.23	0.20	0.37
	SEm±	0.38	0.07	0.88	0.22	0.15	0.08	0.07	0.13

concentration in any of the plant parts, at this stage.

In general, a decreasing trend with an increase in nitrogen concentration in all the plant parts could be observed at this stage also.

4.3.4 Uptake of nitrogen by the plant

Tables 15(a) to 15(c) summerise the data on the mean uptake of nitrogen by the plant at three month, six month and harvest stages of the crop and analysis of variance tables are given in Appendices XXI to XXIII.

In general the uptake of nitrogen, was found to increase rapidly upto six month stage, and later gradually.

Data showed that the different sources and levels tried had significant influence on the nitrogen uptake by plants, at all the three stages of the crop. However source-level interaction was not found to significantly influence the uptake of nitrogen at any of the stages.

4.3.4.1 Three month stage

Neem-urea blend was found to be the best among the sources, and was found to be significantly superior to all other treatments. Untreated urea and rubber urea blend were on par and recorded the lowest value.

Table 15(a). Uptake of Nitrogen at 3 month stage of the crop (g/plant).

Treatments	Levels of nitrogen			
	n_3	n_2	n_1	Mean
Urea	3.67	1.29	1.04	2.00
Urea + neem cake	7.64	5.29	3.21	5.38
Urea + rubber cake	4.69	1.95	0.87	2.50
Urea + maroti cake	5.92	3.79	2.04	3.92
Urea + mahua cake	5.51	3.82	1.84	3.72
Mean	5.49	3.23	1.80	-

n_3 = 50 kg N/ha (full recommended dose)
n_2 = 37.5 kg N/ha (3/4 recommended dose)
n_1 = 25 kg N/ha (1/2 recommended dose).

	F	CD(5%)	SEm$\pm$
Between sources	Sig.	1.27	0.44
Between levels	Sig.	0.99	0.34
Interaction	NS	-	-
combination	-	2.21	0.76

The n_3 level of nitrogen recorded the maximum uptake and was found superior to n_2 and n_1. Significantly lower uptake was recorded by n_1 level than the other levels.

Neem-urea blend at all the levels recorded the maximum uptake, while untreated urea recorded the minimum nitrogen uptake at n_3 and n_2 levels. At n_1 level rubber urea blend recorded the minimum value.

4.3.4.2 <u>Six month stage</u>

Neem-urea blend kept superiority over all other sources at this stage also. All other sources were on par and rubber-urea blend recorded the lowest uptake. Nitrogen uptake was found significantly and favourably influenced by the incremental doses of nitrogen.

Among the treatment combinations untreated urea at n_3 level showed the highest uptake but on par with neem-urea blend at n_3 level. Plants supplied with untreated urea at n_1 level absorbed the minimum quantity of nitrogen.

4.3.4.3 <u>Harvest stage</u>

Neem-urea blend was found to be superior to all other sources at the harvest stage. Rubber-urea blend recorded the lowest uptake, but on par with untreated

Table 15(b). Uptake of Nitrogen at 6 month stage of the crop (g/plant).

Treatments	Levels of nitrogen			
	n_3	n_2	n_1	Mean
Urea	7.83	2.93	0.94	3.89
Urea + neem cake	7.55	7.40	2.97	5.97
Urea + rubber cake	4.02	2.98	2.14	3.05
Urea + maroti cake	6.55	4.61	2.06	4.40
Urea + mahua cake	6.91	4.25	1.25	4.14
Mean	6.57	4.43	1.87	-

n_3 = 50 kg N/ha (full recommended dose)
n_2 = 37.5 kg N/ha (3/4 recommended dose)
n_1 = 25 kg N/ha (1/2 recommended dose).

	F	CD (5%)	SEm±
Between sources	Sig.	1.53	0.53
Between levels	Sig.	1.19	0.41
Interaction	NS	-	-
Combination	-	2.65	0.91

Table 15(c). Uptake of Nitrogen at harvest stage of the crop (g/plant).

Treatments	Levels of nitrogen			
	n_3	n_2	n_1	Mean
Urea	7.15	5.41	2.40	4.98
Urea + neem cake	10.23	7.47	4.23	7.31
Urea + rubber cake	4.94	4.50	2.24	3.89
Urea + maroti cake	7.53	4.40	3.34	5.09
Urea + mahua cake	9.01	5.56	3.08	5.88
Mean	7.78	5.47	3.06	

n_3 = 50 kg N/ha (full recommended dose)
n_2 = 37.5 kg N/ha (3/4 recommended dose)
n_1 = 25 kg N/ha (1/2 recommended dose).

	F	CD (5%)	SEm$\pm$
Between sources	Sig.	1.79	0.62
Between levels	Sig.	1.32	0.46
Interaction	NS	-	-
Combination	-	2.95	1.02

urea and maroti-urea blend.

Among the levels tried n_3 was found significantly superior to the other two levels, which also were found to differ significantly.

Neem-urea blend at n_3 level was found to give the maximum nitrogen uptake, but on par with mahua-urea blend at the same level. Rubber-urea blend at n_1 level recorded the lowest uptake among all the treatment combinations.

In general, at all the stages of growth and at all levels of nitrogen neem cake urea blend recorded the maximum nitrogen uptake.

4.3.5. Uptake of potassium by the plant

Mean values of the total potassium uptake at different stages of the plant growth as influenced by the treatments are presented in table 16 and analysis of variance tables in Appendices XXV to XXVII.

At all the three stages of the crop, different sources and levels of nitrogen did influence the potassium uptake significantly. However source-level interaction was not found to affect the uptake.

4.3.5.1 Three month stage

Neem-urea , mahua-urea and maroti-urea blends

Table 16(a). Uptake of K at 3 month stage of the crop (g/plant)

Treatments	Levels of nitrogen			
	n_3	n_2	n_1	Mean
Urea	3.97	1.51	1.55	2.34
Urea + neem cake	7.63	6.67	4.05	6.12
Urea + rubber cake	4.61	2.09	1.22	2.64
Urea + maroti cake	7.32	4.07	2.82	4.74
Urea + mahua cake	5.05	4.77	4.51	4.78
Mean	5.72	3.82	2.83	

n_3 = 50 kg N/ha (full recommended dose)
n_2 = 37.5 kg N/ha (3/4 recommended dose)
n_1 = 25 kg N/ha (1/2 recommended dose)

	F	CD (5%)	SE m±
Between sources	Sig.	1.72	0.59
Between levels	Sig.	1.33	0.46
Interaction	NS	-	-
Combination	-	2.99	1.03

were found to influence the uptake of potassium favourably and were found significantly superior to rubber cake-urea blend and untreated urea in increasing potassium uptake.

Among the levels, n_3 was found significantly suporior to n_2 and n_1, which were on par.

Among the treatment combinations neem cake blended urea at n_3 level, has shown maximum potassium uptake followed by urea-maroti at the same level. Urea-rubber blend and untreated urea at n_1 level recorded the minimum potassium uptake.

4.3.5.2 Six month stage

Among the sources of nitrogen neem-urea blend recorded the maximum uptake but was found to be on par with maroti-urea blend.

With increasing levels of nitrogen, significant increases in potassium uptake were observed.

Among the treatment combinations, neem urea blend at n_3 level gave maximum potassium uptake and untreated urea at n_1 level, the minimum.

4.3.5.3 Harvest stage

At this stage, mahua-urea blend stood first

Table 16(b). Uptake of K at 6 month stage of the crop (g/plant)

Treatments	Levels of nitrogen			
	n_3	n_2	n_1	Mean
Urea	9.99	2.88	1.59	4.82
Urea + neem cake	10.79	9.92	4.72	8.48
Urea + rubber cake	4.90	4.82	3.17	4.30
Urea + maroti cake	8.28	8.00	4.39	6.89
Urea + mahua cake	8.25	7.68	2.23	6.05
Mean	8.44	6.67	3.22	

n_3 = 50 kg N/ha (full recommended dose)
n_2 = 37.5 kg N/ha (3/4 recommended dose)
n_1 = 25 kg N/ha (1/2 recommended dose)

	F	CD(5%)	SEm±
Between sources	Sig.	2.20	0.76
Between levels	Sig.	1.70	0.59
Interaction	NS	-	-
Combination	-	3.80	1.31

Table 16(c). Uptake of K at harvest stage of the crop (g/plant)

Treatments	Levels of nitrogen			
	n_3	n_2	n_1	Mean
Urea	6.11	6.61	3.19	5.30
Urea + neem cake	12.26	6.09	4.97	7.77
Urea + rubber cake	7.60	4.58	2.90	5.03
Urea + maroti cake	7.76	4.62	3.68	5.35
Urea + mahua cake	11.25	8.41	4.68	8.11
Mean	9.00	6.06	3.88	

n_3 = 50 kg N/ha (full recommended dose)
n_2 = 37.5 kg N/ha (3/4 recommended dose)
n_1 = 25 kg N/ha (1/2 recommended dose)

	F	CD (5%)	SEm±
Between sources	Sig.	2.15	0.74
Between levels	Sig.	1.66	0.57
Interaction	NS	-	-
Combination	-	3.72	1.28

among the sources, while untreated urea, the last. Neem cake blended urea was on par with the mahua blended urea and both were superior to the other sources.

Increasing levels of nitrogen had significantly enhanced potassium uptake at this stage also.

Among the treatment combinations, neem cake blended urea at n_3 level was significantly superior to all other treatments followed by mahua-urea blend at the same level. Untreated urea at n_1 level recorded the lowest uptake.

In general, at all stages of growth, and at all levels of nitrogen, neem cake blended urea recorded the maximum potassium uptake.

4.3.6 Available nitrogen and potassium in the soil at three month stage

Table 17 presents the mean values of available nitrogen and available potassium content of the soil at the three month stage of the crop, as influenced by the treatments. Analysis of variance table for the data are given in Appendices XXVIII and XXIX .

4.3.6.1 Available nitrogen

The different sources and levels of nitrogen have

Table 17(a). Available Nitrogen in the soil (ppm) at 3 month stage of the crop

Treatments	Levels of nitrogen			
	n_3	n_2	n_1	Mean
Urea	119.51	113.82	99.59	110.97
Urea + neem cake	204.87	165.55	113.82	161.42
Urea + rubber cake	153.65	128.05	119.51	133.74
Urea + maroti cake	116.67	119.51	99.59	111.92
Urea + mahua cake	190.65	116.67	102.44	136.58
Mean	157.07	128.72	106.99	

n_3 = 50 kg N/ha (full recommended dose)
n_2 = 37.5 kg N/ha (3/4 recommended dose)
n_1 = 25 kg N/ha (1/2 recommended dose)

	F	CD(5%)	$SE_m \pm$
Between sources	Sig.	34.50	11.90
Between levels	Sig.	26.73	9.22
Interaction	NS	-	-
Combination	-	59.76	20.61

been seen to significantly influence the available nitrogen content of soil significantly. However, source-level interaction did not affect its concentration.

Among the sources, neem-urea blend recorded the maximum concentration. However, neem-urea, mahua-urea and rubber-urea were statistically on par. Untreated urea recorded the minimum contents, but was found to be on par with maroti blended urea.

Plots receiving higher doses of nitrogen registered significantly higher available nitrogen contents also.

Among the treatment combinations, neem-cake blended urea at n_3 level was found to give maximum available nitrogen, but it was on par with mahua cake blend at n_3 and neem cake blend at n_2 level.

4.3.6.2 <u>Available potassium</u>

Different levels of nitrogen significantly influenced the available potassium content in the soil at three month stage. However, the sources of nitrogen and source-level interaction did not influence the content of this nutrient significantly.

Among the levels of nitrogen, n_1 level showed

Table 17(b). Available Potassium in the soil (ppm) at 3 month stage of the crop

Treatments	Levels of nitrogen			
	n_3	n_2	n_1	Mean
Urea	69.13	87.58	126.85	94.52
Urea + neem cake	51.51	57.12	75.75	61.46
Urea + rubber cake	61.74	70.83	111.88	81.48
Urea + maroti cake	69.87	71.06	98.75	79.89
Urea + mahua cake	53.50	58.83	97.81	70.04
Mean	61.15	69.08	102.21	

n_3 = 50 kg N/ha (full recommended dose)
n_2 = 37.5 kg N/ha (3/4 recommended dose)
n_1 = 25 kg N/ha (1/2 recommended dose)

	F	CD (5%)	SEm$\pm$
Between sources	NS	36.56	12.61
Between levels	Sig.	28.32	9.77
Interaction	NS	-	-
Combination	-	63.32	21.83

maximum concentration (102.21 ppm) which was found significantly superior to both n_2 and n_3. However, n_2 and n_3 were on par with each other.

Among treatment combinations, urea alone at n_1 level showed maximum concentration followed by rubber-urea blend at the same level. Neem-urea blend at n_3 level registered the lowest concentration of available potassium.

In general, the negative influence of available nitrogen content on available potassium could be made out from the table.

4.3.7 Yield and yield attributes

4.3.7.1 Tuber yield

Table 18 presents the data on the mean tuber yield per hectare, as influenced by the different treatments. Analysis of variance table is presented in Appendix XXIX.

Both sources and levels had shown significant influence on tuber yield, but the effect of source-level interaction did not attain the level of significance.

Neem cake blended urea recorded the maximum yield followed by mahua-urea and rubber-urea blends. But all these three blends were on par with untreated urea.

Table 18. Tuber yield (kg/hectare)

Treatments	Levels of nitrogen			
	n_3	n_2	n_1	Mean
Urea	21,235	17,161	12,716	17,037
Urea + neom cake	24,691	19,753	13,580	19,259
Urea + rubber cake	20,617	16,790	14,568	17,284
Urea + maroti cake	17,160	15,185	12,840	12,062
Urea + mahua cake	22,592	17,654	11,481	17,284
Mean	21,235	17,284	13,086	

n_3 = 50 kg N/ha (full recommended dose)
n_2 = 37.5 kg N/ha (3/4 recommended dose)
n_1 = 25 kg N/ha (1/2 recommended dose)

	F	CD(5%)	SEm$\pm$
Between treatments	Sig.	2,346	827.16
Between levels	Sig.	1,852	632.10
Interaction	NS	-	-
Combination	-	4,090	1,407.41

Maroti blended urea gave the lowest yield, but was on par with untreated urea and rubber cake blended urea.

The data showed that increasing levels of nitrogen supply, significantly increased the tuber yield. All the levels showed, statistically significant differences in yield.

Among the treatment combinations neem blended urea at n_3 level gave the highest yield, but was found to be on par with urea-mahua blend at the same level. At n_2 level also the same trend was observed. But at n_1 level rubber-urea blend along with neem-urea blend produced the maximum tuber yield.

4.3.7.2 <u>Number of tubers per plant</u>

Table 19 presents the data on the mean number of tubers per plant, as influenced by the different treatments and the analysis of variance table is given in Appendix XXXI.

Neither the sources, nor the levels of nitrogen and source-level interaction did influence the number of tubers significantly.

Though statistically not significant increasing

Table 19. Number of tubers/plant

Treatments	Levels of nitrogen			
	n_3	n_2	n_1	Mean
Urea	5.67	5.33	4.67	5.22
Urea + neem cake	6.89	5.67	4.67	5.74
Urea + rubber cake	6.00	5.67	5.33	5.67
Urea + maroti cake	5.67	5.67	5.56	5.63
Urea + mahua cake	5.67	5.45	5.45	5.52
Mean	5.98	5.56	5.13	

n_3 = 50 kg N/ha (full recommended dose)
n_2 = 37.5 kg N/ha (3/4 recommended dose)
n_1 = 25 kg N/ha (1/2 recommended dose)

	F	CD (5%)	SEm$\pm$
Between treatments	NS	-	0.404
Between levels	NS	-	0.310
Interaction	NS	-	-
Combination	-	-	0.701

trend with the increased nitrogen supply was observed with regard to this character.

4.3.7.3 Root to top dry weight ratio

The data on the mean ratio of the root dry weight to top dry weight of the plant, as influenced by the treatments are presented in the table 20 and the analysis of variance table in Appendix XXXII.

Data showed that, the treatment effects due to the differences in the sources of nitrogen was significant, but that due to the different levels and source level interaction was not.

The maximum value for the ratio was shown by untreated urea, followed by rubber cake blended urea, neem cake blended urea, and mahua cake blended urea treatments. The lowest ratio was observed for maroti cake blend, which was on par with mahua cake blended urea.

In general increasing levels of nitrogen showed a decreased root-shoot ratio.

Among the treatment combinations, untreated urea at n_1 level was found to give the highest ratio and the minimum by rubber cake blend at n_1 level, which was on par with urea-neem blend at n_3 and n_2 levels and urea-maroti at all the levels.

Table 20. Ratio of root dry weight to top dry weight - harvest stage

Treatments	Levels of nitrogen			
	n_3	n_2	n_1	Mean
Urea	3.83	3.49	6.39	4.57
Urea + neem cake	1.90	2.20	5.20	3.10
Urea + rubber cake	4.06	3.68	1.75	3.16
Urea + maroti cake	2.03	2.17	2.36	2.18
Urea + mahua cake	2.45	2.28	3.17	2.63
Mean	2.85	2.76	3.77	

n_3 = 50 kg N/ha (full recommended dose)
n_2 = 37.5 kg N/ha (3/4 recommended dose)
n_1 = 25 kg N/ha (1/2 recommended dose)

	F	CD(5%)	SEm±
Between sources	Sig.	1.48	0.515
Between levels	NS	-	0.397
Interaction	NS	-	-
Combination	-	-	0.884

4.3.8 Quality of tubers

4.3.8.1 Percentage dry matter of tubers

Table 21 presents the mean percentage dry matter of the tuber flesh as influenced by the levels and sources of nitrogen and their combinations. Analysis of variance table for the data is presented in Appendix XXXIII.

Neither the sources, nor the levels and source-level interaction did influence the dry matter content of tubers. Incremental doses of nitrogen had shown a decreasing trend. Untreated urea at n_1 level recorded the highest percentage among the treatment combinations and untreated urea at n_3 level, the lowest.

4.3.8.2 Starch content of tubers

Data on the mean percentage of starch as influenced by the different treatments are furnished in table 22. Appendix XXXIV presents the analysis of variance table for the data.

The different levels and sources of nitrogen did influence the starch content significantly, while the source-level interaction did not.

Table 21. Percentage dry matter of tuber

Treatments	Levels of nitrogen			
	n_3	n_2	n_1	Mean
Urea	39.02	40.10	40.97	40.03
Urea + neem cake	39.18	40.20	40.75	40.04
Urea + rubber cake	40.10	40.15	40.78	40.34
Urea + maroti cake	39.47	40.36	40.55	40.13
Urea + mahua cake	40.25	39.97	39.85	40.02
Mean	39.60	40.16	40.58	

n_3 = 50 kg N/ha (full recommended dose)
n_2 = 37.5 kg N/ha (3/4 recommended dose)
n_1 = 25 kg N/ha (1/2 recommended dose)

	F	CD (5%)	$SEm^{\pm}$
Between treatments	NS	-	0.388
Between levels	NS	-	0.301
Interaction	NS	-	-
Combination	-	-	0.673

Table 22. Percentage of starch of harvested tuber (oven dry basis)

Treatments	Levels of nitrogen			
	n_3	n_2	n_1	Mean
Urea	79.15	79.00	79.91	79.55
Urea + neem cake	78.59	79.38	79.66	79.21
Urea + rubber cake	79.33	79.80	79.85	79.67
Urea + maroti cake	79.30	79.69	79.80	79.61
Urea + mahua cake	79.45	79.50	79.50	79.48
Mean	79.16	79.60	79.75	

n_3 = 50 kg N/ha (full recommended dose)
n_2 = 37.5 kg N/ha (3/4 recommended dose)
n_1 = 25 kg N/ha (1/2 recommended dose)

	F	CD(5%)	SEm$\pm$
Between treatments	Sig.	0.287	0.999
Between levels	Sig.	0.224	0.077
Interaction	NS	-	-
Combination	-	-	0.152

Rubber cake blended urea recorded the maximum starch content but it was statistically on par with all other sources, except neem cake blended urea which gave the lowest starch percentage. However, neem-urea blend was on par with mahua cake blended urea.

Incremental doses of nitrogen have shown a significant depression on the starch content.

Among the treatment combinations untreated urea at n_1 level ranked the first, and neem cake blended urea at n_3 level the last, but it was on par with untreated urea at n_2 level. At the n_1 and n_2 levels all the treatment combinations were on par.

4.3.8.3 <u>Crude protein content</u>

Data on the mean crude protein content of the tuber flesh as influenced by the treatments, is presented in Table 23 and analysis of variance for the data is given in the Appendix XXXIV.

The levels of nitrogen significantly influenced the crude protein content, while the effects of sources and source-level interaction were not found to be significant.

Among the levels n_3 and n_2 were on par with

Table 23. Percentage of Crude Protein (oven dry basis)

Treatments	Levels of nitrogen			
	n_3	n_2	n_1	Mean
Urea	2.43	2.27	1.73	2.14
Urea + neem cake	2.50	2.40	2.18	2.36
Urea + rubber cake	2.30	2.20	2.12	2.21
Urea + maroti cake	2.37	2.33	2.07	2.26
Urea + mahua cake	2.47	2.40	2.08	2.32
Mean	2.41	2.32	2.04	

n_3 = 50 kg N/ha (full recommended dose)
n_2 = 37.5 kg N/ha (3/4 recommended dose)
n_1 = 25 kg N/ha (1/2 recommended dose)

	F	CD (5%)	SEm±
Between treatments	NS	-	0.061
Between levels	Sig.	0.14	0.047
Interaction	NS	-	-
Combination	-	0.31	0.105

each other but both were significantly superior to n_1. Among the treatment combinations neem-urea blend at n_3 level (2.5%) showed the maximum protein content followed by urea-mahua blend (2.47%) at the same level. Untreated urea at n_1 level (1.73%) recorded the minimum content of protein which was significantly inferior to all other treatment combinations.

Though neem cake blended urea at n_3 level, gave the highest protein content, it was on par with all the sources at n_3 and n_2 levels. Untreated urea at n_1 level was found to be significantly inferior to all other treatment combinations, in augmenting the protein content of tubers.

4.3.8.4 Hydrocyanic acid content

Mean hydrocyanic acid content of tubers is furnished in the Table 24 and the analysis of variance Table in Appendix XXXV.

Data showed that both the sources and levels of nitrogen significantly influenced the prussic acid content, but the source-level interaction was not significant.

Mahua-cake blended urea recorded the maximum

Table 24. HCN content of tubers (fresh weight basis)

Treatments	Levels of nitrogen			
	n_3	n_2	n_1	Mean
Urea	30.50	30.00	26.17	28.89
Urea + neem cake	32.50	29.50	27.33	29.78
Urea + rubber cake	29.50	29.50	25.17	28.06
Urea + maroti cake	28.50	27.50	27.50	27.83
Urea + mahua cake	32.50	29.50	27.83	29.94
Mean	30.70	29.20	26.80	

n_3 = 50 kg N/ha (full recommended dose)
n_2 = 37.5 kg N/ha (3/4 recommended dose)
n_1 = 25 kg N/ha (1/2 recommended dose)

	F	CD(5%)	SEm±
Between treatments	Sig.	1.54	0.524
Between levels	Sig.	1.18	0.406
Interaction	NS	-	-
Combination	-	-	0.907

content followed by neem-urea blend. Urea-maroti blend recorded the minimum concentration.

Reference to the table indicates that increased nitrogen supply exerted a significant positive influence on this character, at all the levels tried.

Among the treatment combinations mahua cake and neem cake blends at n_3 level recorded the highest consents while rubber cake blend at n_1 level, the lowest with regard to this quality.

Discussion

DISCUSSION

The present investigation elucidates, the performance of some of the non-edible oilcake urea blends in increasing nitrogen use efficiency in upland soils. The study also brings out the influence of different nonedible oilcake-urea blends, at different graded doses of nitrogen, on plant growth, uptake of nitrogen and potassium and the yield and quality of tubers of cassava.

5.1 Study of mineralisation pattern of urea-oilcake blends

On perusal of tables 3, 4 and 5 it could be seen that the contents of ammoniacal, nitrite and nitrate nitrogen at different periods of incubation, throw light on the extent of the different processes involved in the transformation of applied urea in soil.

In the present study it was observed that in general, urea hydrolysis or ammonification proceeded upto twelve days of incubation. The longer period for the completion of urea hydrolysis might be due to the low organic matter status (0.90 per cent) of the soil (Singh and Yadav, 1981).

But during the first two days of incubation a relatively faster rate of ammonification was observed. Similar observation was made by Bhuiya et al. (1974) and Thomas and Prasad (1982).

In the initial periods of incubation both ammonification (a process, which leads to an increase in NH_4^+-N content) and nitrification (a process which leads to the decrease in NH_4^+-N, due to its conversion to NO_3^--N) are operative side by side. Hence, ammoniacal nitrogen content of soil, at a particular time, would be decided by the relative rates of these two microbial processes.

Comparatively faster rate of decline in NH_4^+-N content and an accompanied faster increase in NO_3^--N content presented by untreated urea treatment, as against that shown by oilcake-urea treatments, indicated the differential inhibition on nitrification with respect to ammonification brought out by the oilcakes at varying degrees.

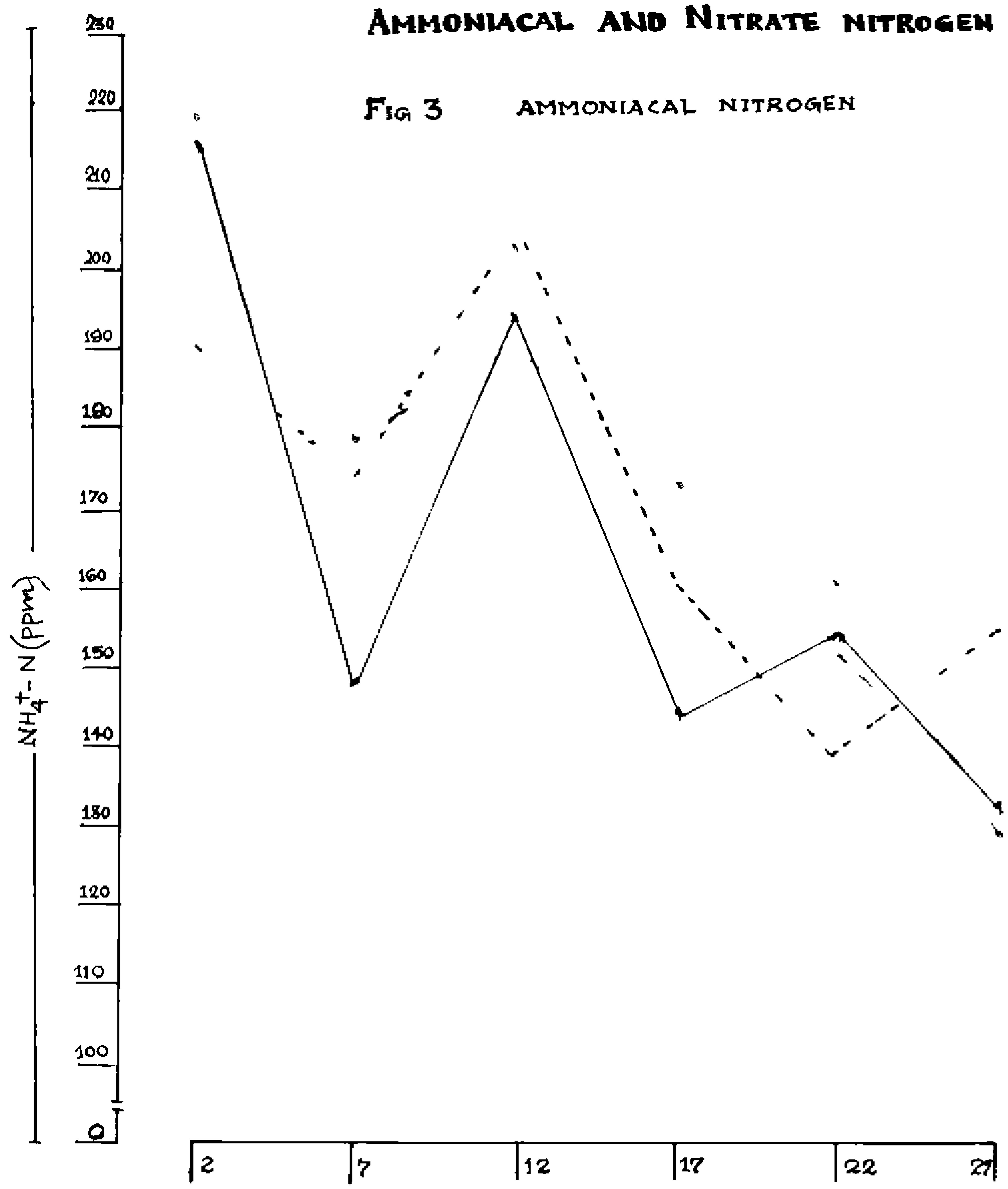
5.1.1 Influence of oilcakes on the mineralisation pattern of urea

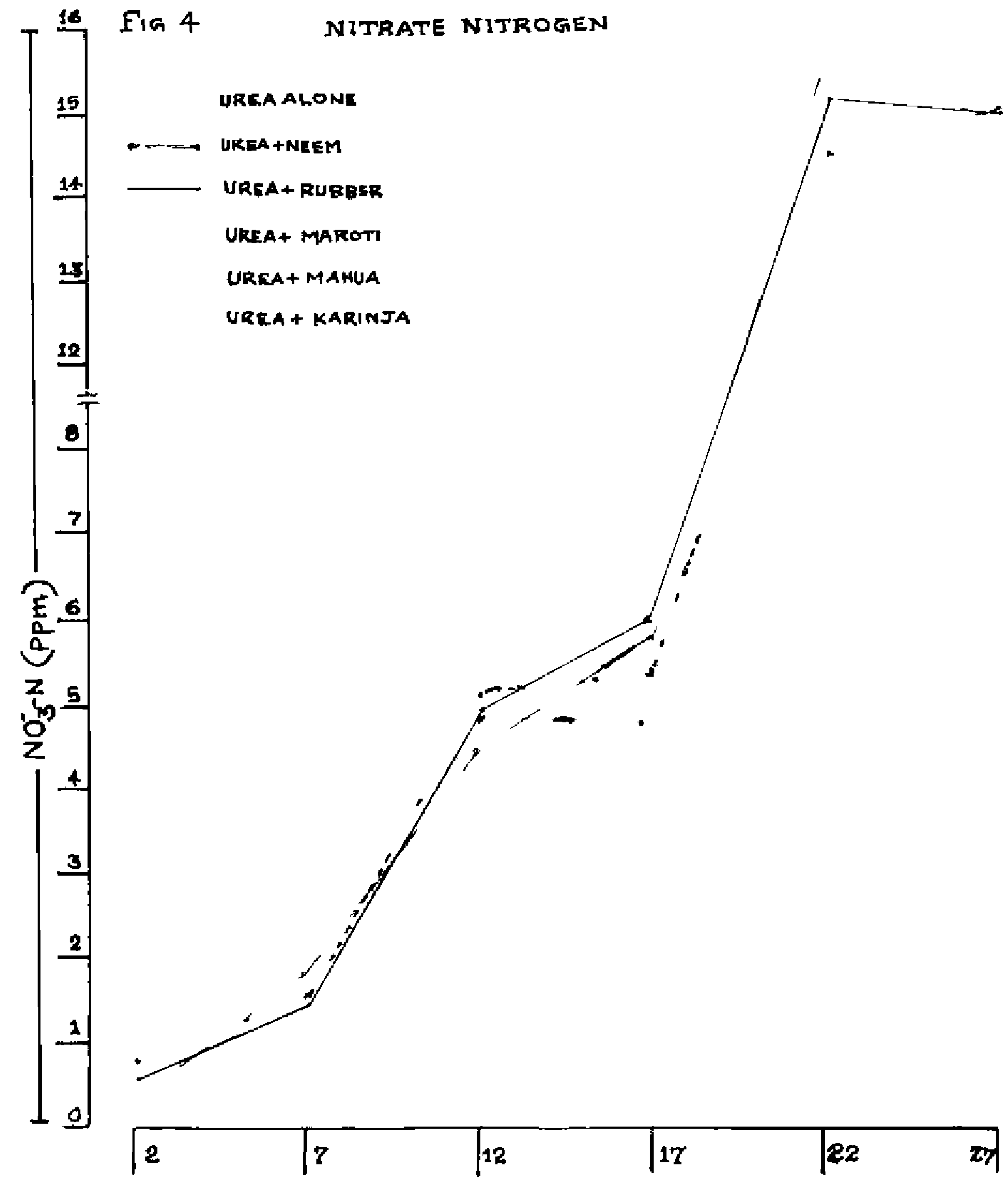
The influence of treatments on NH_4^+-N content was found significant at all periods of incubation except on the 27th day sampling. (Table 3). But nitrate content was significantly influenced by the different treatments only on the second, seventh and seventeenth day of incubation (Table-5).

In the moist aerobic condition provided in the incubation study, an increase in NH_4^+-N content was observed in the initial stages. Later NH_4^+-N concentration dropped down in twenty seven days indicating a comparatively faster nitrification rate in this treatment. Some compounds present in the oilcakes might have been toxic to nitrifiers and thus nitrification process might have been slowed down. Moreover the rate of ammonification itself might play an important role in deciding the size of nitrifier population (Belser, 1982). In the initial stages, the rate of ammonification also has been seen slow in oilcake treated urea pots.

From the seventh day of incubation onwards all the oilcake-urea-blends showed higher NH_4^+-N (Fig.3) and a correspondingly lower NO_3^--N (Fig.4), when compared to untreated urea. This might be due to the faster rate of nitrification (Fig.5) in untreated urea treatment when compared to other treatments where nitrification might have been retarded by some compounds in the oilcakes.

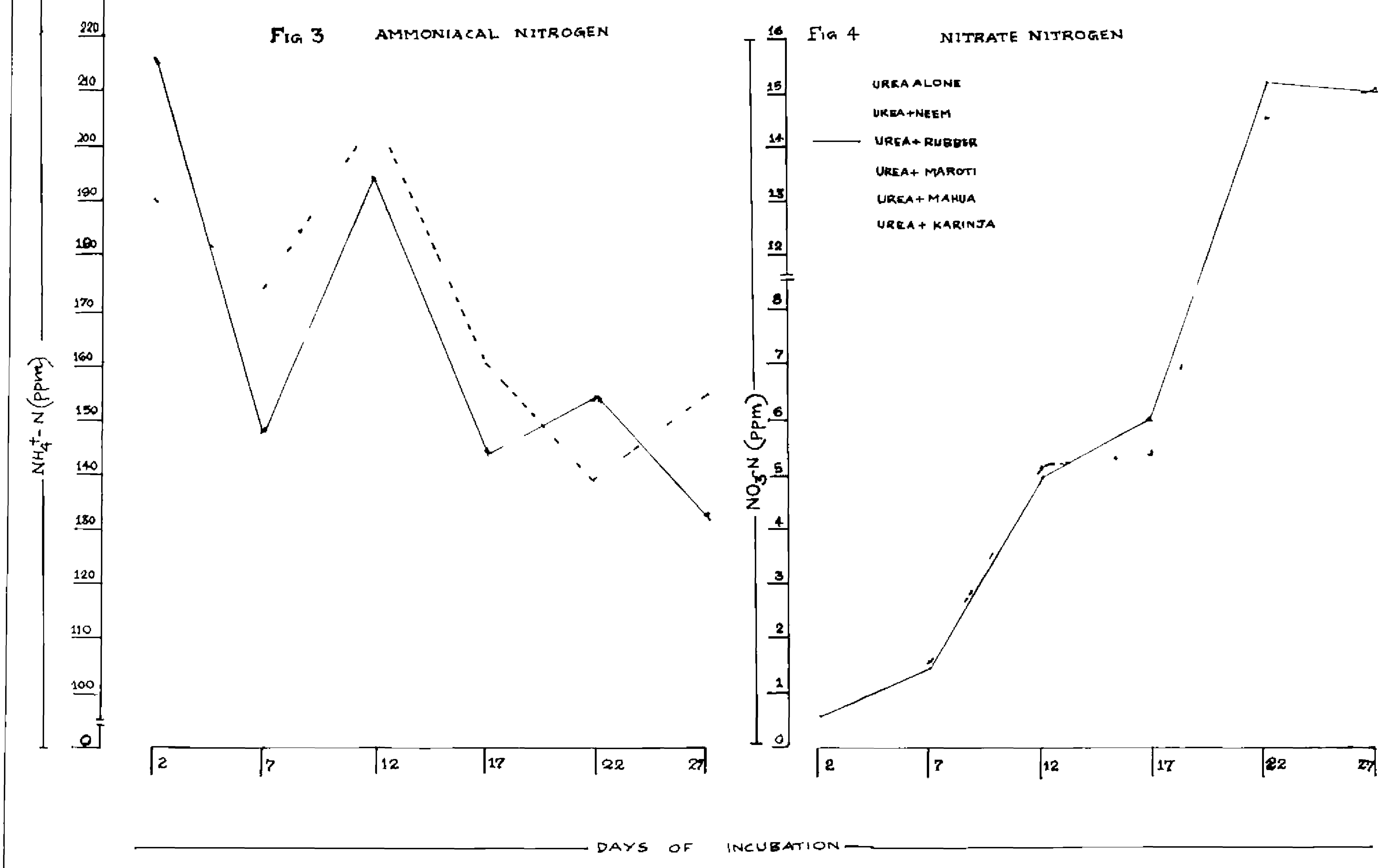
AMMONIACAL AND NITRATE NITROGEN (AVERAGED OVER RATIOS)





DAYS OF INCUBATION

AMMONIACAL AND NITRATE NITROGEN (AVERAGED OVER RATIOS)



Among the oilcakes, karinja and maroti inhibited ammonification to the maximum extent in the initial periods of incubation.

Mahua and neem blends retained more NH_4^+-N and a low NO_3^--N, upto 7th day of incubation compared to other treatments, indicating their differential inhibition of nitrification with respect to ammonification, to the maximum extent.

The fact that karinja and maroti cakes registered a lower NH_4^+-N and NO_3^--N at this stage, is suggestive of its capacity for inhibition on ammonification also.

On the 12th day of sampling, all the treatments showed an increasing trend with regard to NH_4^+-N and NO_3^--N contents. This indicated the relatively faster rate of ammonification when compared to nitrification, in all the pots. Similar increasing trend for NH_4^+-N was observed by Bhuiya et al.(1974).

On 12th day maroti and neem blends showed the highest NH_4^+-N, but the latter showed the lowest NO_3^--N also. This appeared to be due to the comparatively higher capacity of nitrification inhibition imparted by neem cake.

Biddapah and Sarkunam (1979) also obtained higher NH_4^+-N and lower NO_3^--N, by the treatment of urea with neem cake, in an incubation study using laterite soil in moist aerobic condition.

On 17th and 22nd day mahua cake maintained its superiority in conserving NH_4^+-N. However, on 27th day of incubation, treatments did not significantly influence NH_4^+-N and NO_3^--N content. By this time, oilcakes would have been subjected to degradation and might have lost the capacity to inhibit nitrification so much so, the nitrate content was more in oilcake treated urea pots than in untreated urea pots.

With regard to NO_2^--N, an initial increasing trend upto the second day, followed by a decline later (Table 4) could be seen. This appeared to be due to the oxidation of NH_4^+-N during the nitrification process, in which nitrite formation is an intermediate stage. Since NO_2^--N is converted to NO_3^--N soon after its formation, its accumulation in soil was negligible. Differences in NO_2^--N content of the soil as influenced by the treatments did not present any consistent pattern to draw a conclusion and hence monitoring of NO_2^--N was discontinued after 12 days of incubation. Biddappah and Sarkunam (1979), in an incubation in moist aerobic soil with coaltar and neem coated urea, also did not find any treatment influence on NO_2^--N content. A general decreasing trend for NO_2^--N in the initial periods upto 12 days of incubation, observed in the present study, finds support in the results of Biddappah and Sarkunam (1979).

Since NO_2^--N accumulation has been found negligible, it was inferred that, inhibition of nitrification took place at the NH_4^+-N oxidation step mediated by mainly Nitrosomonas sp. and Nitrosococcus sp. and not at the nitrite oxidation step. Nitrobacter sp. which oxidises NO_2^--N to NO_3^--N might not have been affected by the treatments.

Hooper and Terry (1973) have shown that ammonia oxidase enzyme, which is associated with the initial step of NH_4^+ to hydroxyl amine conversion, is selectively inhibited by over 40 of the nitrification inhibitors which they tried. Selective inhibition of neem cake on Nitrosomonas sp. has been earlier observed by Mishra et al. (1975).

Narrower ratios of urea to oilcakes increased NH_4^+-N content of soil in general. Neem, mahua and rubber blended urea have shown consistent increase in NH_4^+-N, when the ratio was narrowed to 5:3. Karinja cake blend did not show any consistent trend, whereas maroti cake blend showed a decrease in NH_4^+-N concentration with narrower ratios than 5:2. The above facts indicated that among the different ratios tried, 5:3 was the most suitable for blends with neem, mahua and rubber cakes and 5:2 for maroti blend. Oil cakes at these concentrations in the blend were expected to inhibit nitrification more efficiently and thereby retain more NH_4^+-N.

An accompanied decreasing trend for NO_3^--N, at narrower ratios along with the increase in NH_4^+-N could be observed. This also indicated that when concentration of oilcakes in the blend was increased nitrification process would have been more efficiently inhibited. Thus oilcakes at the aforesaid ratios might inhibit nitrification to the maximum extent and thereby reduce losses of nitrates and prolong the period of availability of nitrogen from the applied fertilizers.

5.1.3 The influence of oilcake treatments on the rate of nitrification and percentage inhibition

maintained a higher nitrification rate on all days upto 27 days of incubation. The nitrification process would have been slowed down by some compounds present in the oilcakes. After three weeks the rate of nitrification slowed down in untreated urea pots also, possibly due to meagre NH_4^+-N availability.

It was also seen that at different ratios of mixing and at different periods of incubation, the urea oilcake blends showed different rates of nitrification. This might be due to the differences in the nature of active compounds involved in the regulation of nitrification of urea oilcake blends.

In general, a rapid increase in the rate of nitrification was observed for all treatments upto the twenty second day (Fig.5). This rise was more pronounced on the seventeenth day.

Averaged over ratios and periods (Table 25) the rate of nitrification in the decreasing order was found as untreated urea > urea + karinja > urea + rubber > urea + mahua > urea + maroti > urea + neem, blends.

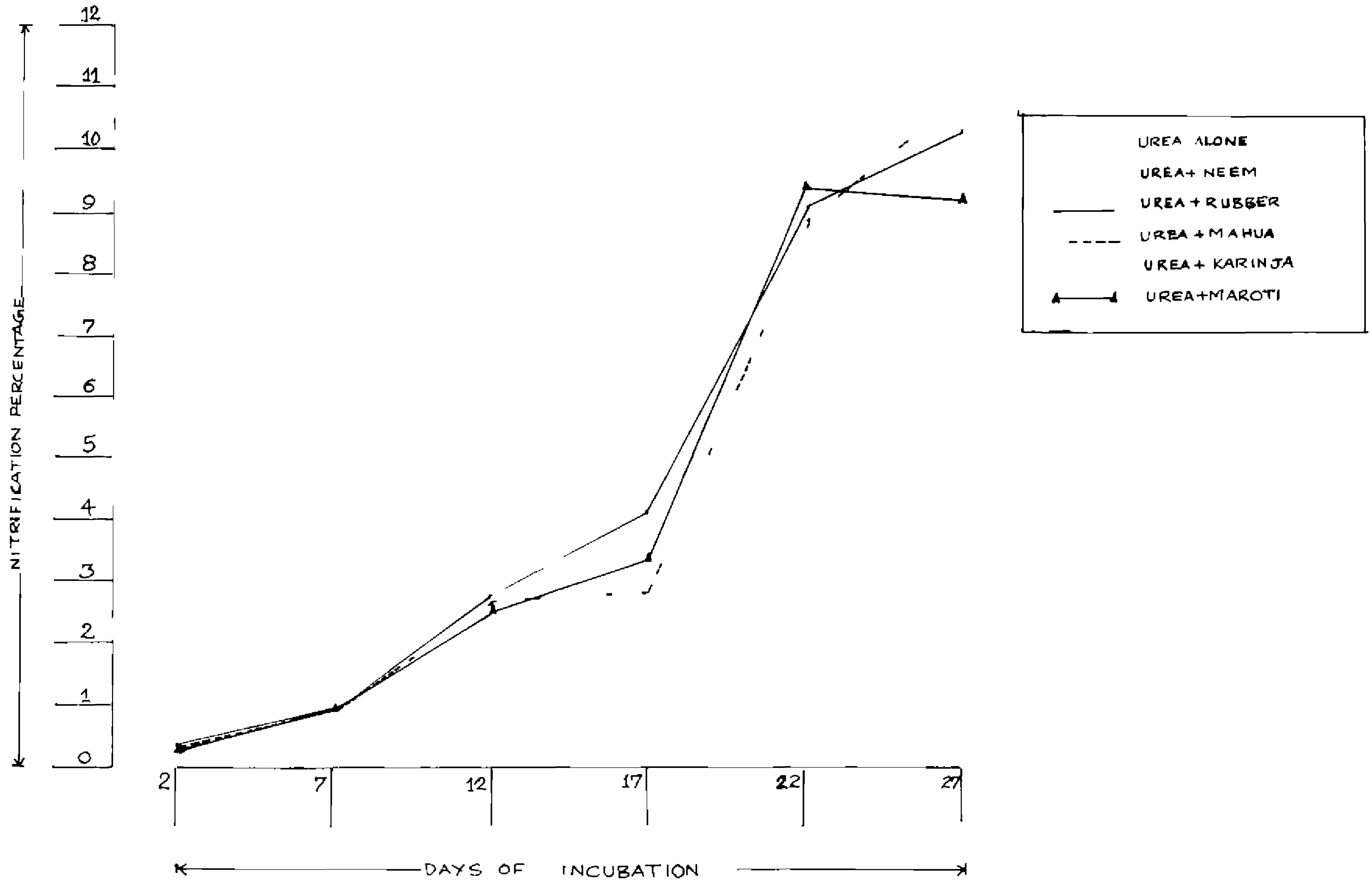
Averaged over ratios (Table 25 and Fig.5), it is seen that on all days of incubation oilcake-urea blends

Table 25. Nitrification percentage (Average over ratios)

Treatments	2nd day	7th day	12th day	17th day	22nd day	27th day	Mean
Urea alone	0.49	1.89	3.99	6.00	11.30	11.50	5.86
Urea + neem	0.22	0.84	2.20	3.58	7.97	10.03	4.11
Urea + rubber	0.35	1.07	2.66	4.10	9.09	10.37	4.61
Urea + karinja	0.45	0.97	2.95	3.60	9.03	11.27	4.72
Urea + maroti	0.43	0.94	2.53	3.47	9.48	9.23	4.35
Urea + mahua	0.28	0.93	2.73	2.79	8.89	10.93	4.43
Mean	0.37	1.11	2.84	3.93	9.29	10.56	

FIG 5

NITRIFICATION PERCENTAGE (AVERAGED OVER RATIOS)



recorded a lower rate of nitrification over untreated urea. Among the oilcake-urea blends, that of neem maintained a lower rate on all days except on the seventeenth and twenty seventh day of sampling. On the seventeenth day mahua cake and on the twenty seventh day maroti cake blend showed minimum rates of nitrification. This showed the superiority of neem cake in retarding the rate of the process. Urea-neem blend presented a steady but gradual increase in nitrification rate compared to other blends with the advancement of days of incubation.

Mahua, karinja and maroti blends showed a more or less steady rates between twelfth and seventeenth day of incubation. Untreated urea maintained the same level after the twenty second day. But maroti cake showed a drop in the rate of nitrification after the twenty second day of incubation.

Averaged over periods (Table 26) at 5:1 and 5:3 ratios, urea-neem blend showed minimum rates of nitrification (27.39 per cent and 22.43 per cent respectively), and at 5:2 ratio, urea-maroti blend presented the minimum (24.45 per cent). At 5:3 ratio urea-mahua blend showed the same trend as urea-neem blend.

Table 26. Nitrification percentage (Averaged over periods)

Ratios/ Blends	5:1	5:2	5:3
Urea - neem	27.29	24.78	22.43
Urea - rubber	27.96	28.64	26.28
Urea - karinja	27.54	29.11	28.15
Urea - maroti	28.64	24.45	25.17
Urea - mahua	27.34	28.21	24.12

(b) <u>Percentage inhibition of nitrification</u>

Reference to table 6, shows that in most of the cases, as the rate of nitrification increased the percentage inhibition decreased.

All the oilcakes have shown inhibitory capacity, but at varying degrees, with the changes in the nature of oilcakes, ratio of mixing and the [redacted] period of incubation (Table 6).

Averaged over the ratios (Table 27 and Fig.6) on all days except on the seventeenth and twenty seventh day neem cake maintained its superiority over other oilcakes in nitrification inhibition. On seventeenth and twenty seventh day mahua cake inhibited nitrification to the maximum extent.

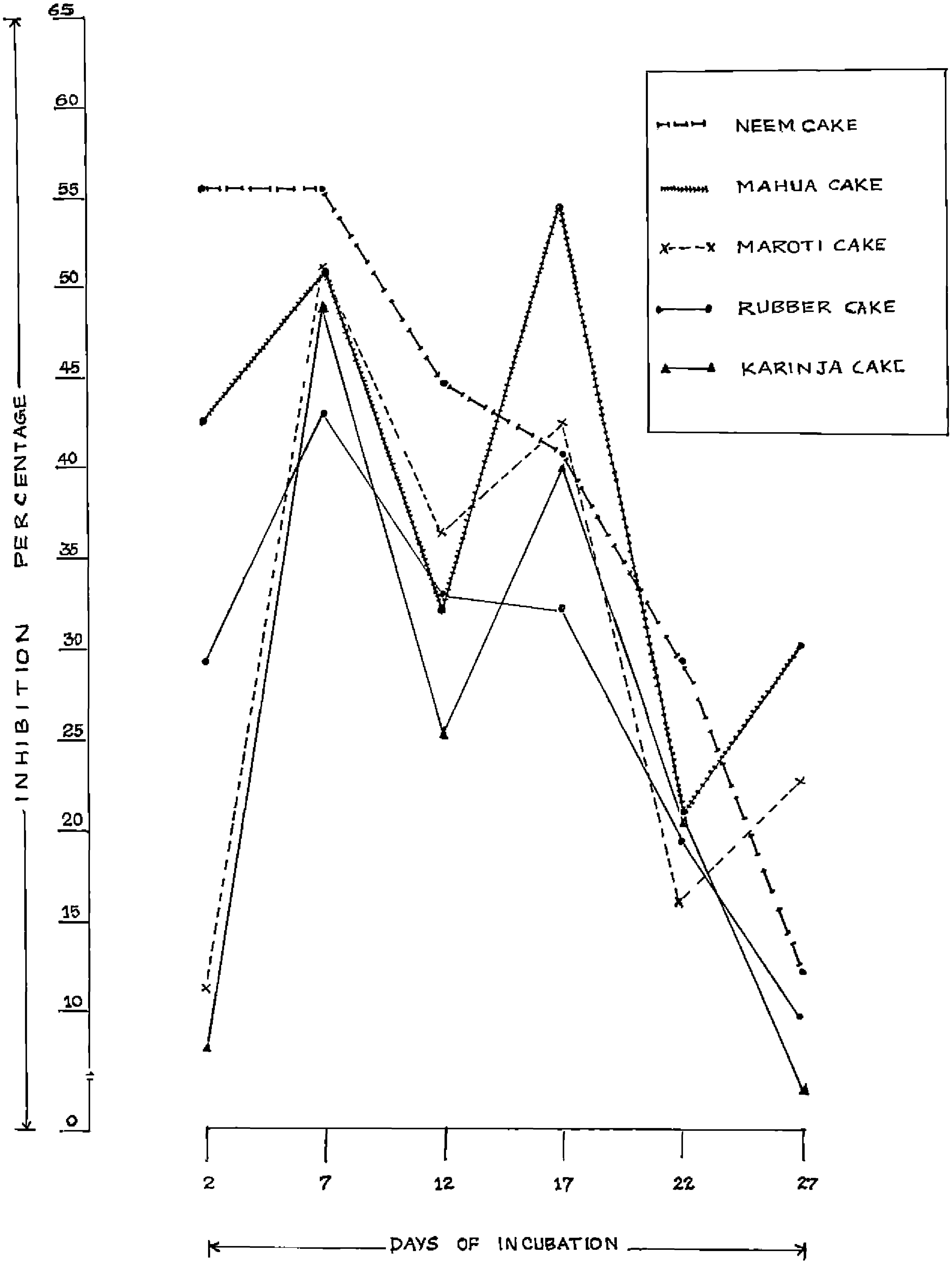
Neem cake showed maximum inhibition on the second day. Later, the inhibition capacity was seen to decline gradually (Fig.6). This decrease in the inhibition capacity with time may be due to the degradation of oilcakes in the soil. Sahrawat (1980) also observed a decline in inhibition percentage, after three weeks of incubation when 'karinjin' was used as an inhibitor.

Table 27. Inhibition Percentage (Averagedover ratios)

Treatments	2nd day	7th day	12th day	17th day	22nd day	27th day	Mean
Neem	55.68	55.38	44.86	40.33	29.50	12.81	39.76
Rubber	29.25	43.38	33.34	31.72	19.59	9.86	27.86
Karinja	8.17	48.50	25.98	40.06	20.12	3.59	24.40
Maroti	11.56	50.44	36.68	42.11	16.08	19.71	29.43
Mahua	42.86	50.97	31.50	53.50	21.30	4.93	34.18
Mean	29.50	49.73	34.47	41.54	21.32	10.18	

FIG 6

NITRIFICATION INHIBITION (AVERAGED OVER RATIOS)



Karinja cake showed peaks of inhibition on second and seventeenth day of incubation. Later it showed a relatively faster rate of decline and presented the lowest value at the twenty seventh day.

Mahua cake showed three peaks (on seventh, seventeenth and twenty seventh day) and the maximum inhibition was observed on the seventeenth day of incubation. Maroti cake also presented three peaks like mahua cake.

Rubber cake showed an increasing trend for the inhibition percentage only at the first week. Later it imparted inhibition of nitrification only to a lesser extent.

Averaged over the periods (Table 28), mahua cake recorded the highest inhibition (32.51 per cent) among 5:1 levels and rubber cake blend the minimum (23.55 per cent). Neem cake recorded the maximum inhibition of nitrification, among 5:2 (39.09 per cent) and 5:3 (49.63 per cent) levels and karinja cake registered the minimum among 5:2 levels (21.22 per cent), and maroti cake among 5:3 levels (23.06 per cent).

Averaged over periods and ratios (Table 27) the order of inhibition capacity was found as neem > mahua > maroti > rubber > and karinja.

Table 28. Inhibition of nitrification percentage (Averaged over periods)

Ratios/ oilcakes	5:1	5:2	5:3
Urea - neem cake	30.57	39.08	49.63
Urea - rubber cake	23.55	23.94	36.07
Urea - karinja cake	26.22	21.22	25.76
Urea - maroti cake	29.45	35.78	23.06
Urea - mahua cake	32.51	24.25	45.76

A number of earlier studies had revealed the nitrification inhibitory property of neem cake (Mishra et al.,1972; 1975; Muthuswamy et al.,1977; 1978; Prasad et al., 1980).

In general, all the treatments including untreated urea treatment showed a lower nitrification rate within a period of study of one month (Table 6). This might be due to the greater hydrogen ion concentration in the soil (Table 1) used for the present study (Siddarappa and Rao, 1971 and Sarigumba et al. 1978). The inhibition capacity of the oilcakes were seen to reduce considerably within a period of one month, possibly due to the faster degradation of the oilcakes.

In general, the inhibition capacity was seen to be enhanced with narrowing urea to oilcake ratio. However, maroti cake showed maximum inhibition at 5:2 ratio and karinja at 5:1 ratio. This lower nitrification inhibition at higher oil cake concentrations might be either due to an accompanied higher inhibition of ammonification and/or higher nitrogen losses due to volatalisation and immobilization at higher inhibitor concentration. Supporting to this view, Jain et al.(1981) has observed increased volatilization losses, when oilcake of Citrullus colosynthis was used as a nitrification inhibitor.

The irregular trend in the percentage inhibition presented by the different oilcakes, at different ratios of mixing with urea and on the different periods of incubation, might be due to the differences in the nature of the active compounds responsible for imparting nitrification inhibition. These compounds would have responded differently to the periods of incubation and the changes in soil environments during the course of study. As Belser (1982) suggested, the differences in the effect of oilcakes on the ammonification process, which preceded the process of nitrification in the mineralisation of urea, would have also in turn, affected the extent of inhibition of nitrification.

5.2 Field Experiment

5.2.1 Exchangeable NH_4^+-N

From the regression analysis it was inferred that, during the initial periods, the influence of treatments was less pronounced due to the differences in the pre-treatment concentration of NH_4^+-N. But in the later periods, greater influence of the treatments on the concentration of NH_4^+-N, nullified, the pre-treatment differences in concentration.

Tables 7 and 8 indicated that, in general, all the oilcake treatments retained more NH_4^+-N in the soil. In general urea-neem blend followed by urea-mahua blend retained more nitrogen in ammonical form upto a period of one month after application of both basal as well as top dressing of urea.

The oilcake would have inhibited nitrification process, and reduced the chance of loss of nitrate nitrogen in percolating water under heavy rainfall condition (Appendix I) noticed in the earlier period of crop growth.

Irregularities in the content of NH_4^+-N observed at different periods of sampling might be due to the differences in the crop removal and losses of nitrogen in the field. Subbiah et al.(1982) also observed higher NH_4^+-N content in fields planted to ragi, fertilized with neem cake blended urea and ammonium sulphate, compared to untreated fertilizer applied fields. The results of Biddappah and Sarkuna (1979) also lends support to this finding.

It is but natural that the incremental doses of nitrogen registered an increasing trend with regard to the NH_4^+-N content. Alexander (1977) opined that higher concentration of NH_4^+-N, itself was toxic to nitrifiers. But this warrants further study for conclusive proof.

The influence of treatments was found more pronounced in the top dressing than the basal application of nitrogen. In general urea-maroti blend recorded the minimum NH_4^+-N among the blends but it was found superior to untreated urea.

5.2.2 The influence of non-edible oilcakes at different nitrogen levels on the growth characters of tapioca

The growth characters such as height of plants number of leaves/plant and dry matter production were recorded at three month, six month (which approximately coincide with the tuber formation and starch synthesis respectively) and harvest stages of the crop.

5.2.2.1 Height of plants

At all the three stages of crop growth, the height of plants was favourably and significantly influenced by the oilcake treatments. The levels of nitrogen did not influence the height of plants significantly in the initial stages, but a favourable trend could be observed for the incremental doses (Table 9).

At the six month and harvest stages of the crop, 50 kg nitrogen dose produced significantly greater height of plants, when compared to 25 kg of nitrogen dose.

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the height of plants was restricted. Similar results were obtained by Krochmal and Samuels (1970) and Ngongi (1976). Pillai (1967) did not observe significant influence of nitrogen on plant height, though a favourable trend was noticed.

The oilcakes would have inhibited nitrification process, and thereby provented the subsequent leaching and run off losses and made nitrate nitrogen available for a longer period. This hypothesis was confirmed by the fact that the urea oilcake blends gave more exchangeable NH_4^+-N compared to untreated urea (Tables 7 and 8). The nitrification inhibitory property imparted by the oilcakes was earlier brought out in the laboratory incubation study (Tables 25 and 26, Fig.6).

Seshadri (1976) in cotton and Oommen et al.(1977) in rice also obtained increased plant height, with the use of nitrification inhibitors. Much of the applied nitrogen in the untreated urea plots, which recordod the minimum plant height at all the stages of crop growth, would have been lost in the percolating water, so much so, plants height was restricted.

In general, among the oilcakes, neem cake treatment was found to be superior, in augmenting plant height; the influence being more pronounced in the later periods of crop growth. Neem cake would have conserved nitrogen to the maximum extent and thus favourably influenced the plant growth to record the maximum plant height (Tables 7 and 8, Fig.6). Result obtained by Oommen et al.(1977) lends support to this finding.

Mahua cake closely followed neem cake at the harvest stage. Upto the six month stage maroti cake was found on par with neem, but it could not retain the capacity till harvest stage. This might be due to the loss of nitrification inhibitory capacity with the elapse of time, owing to the degradation of the oilcake in the soil. Rubber cake also did not maintain significant superiority over untreated urea towards the harvest stage.

In general, after the six month stage, plant height did not increase much. At the harvest stage urea-neem blend at 50 kg nitrogen dose was found equivalent to the application of the same blend at 37.5 kg dose and urea-mahua blend at 50 kg and 37.5 kg dose. Neem cake is known to contain, an alkaloid nimbidin, and mahua cake, saponin, which would have suppressed the nitrifer population and enhanced the period of suppression of nitrification (Table 27 and Fig.6). This would have resulted in a longer period of availability of nitrogen. Results of the laboratory incubation study also revealed that mahua cake could maintain the inhibitory capacity for a longer period in the soil.

5.2.2.2 <u>Number of leaves per plant</u>

Both sources and levels of nitrogen, favourably and significantly influenced the number of leaves of cassava upto the six month stage of the crop. At the harvest stage the oilcake treatments did not significantly influence the number of leaves. This might be due to the defoliation and lesser leaf production, observed after the six month stage of the crop (Tables 10 b and c).

Ngongi (1976), Pillai and George (1978 b) and Prabhakar et al. (1979) also have reported positive influence of nitrogen on leaf number. Rate of leaf production is greatly enhanced by increased nitrogen supply (Ramanujam and Indira, 1979).

Significant positive influence on leaf number was noticed only upto the 37.5 kg level and till the six month stage of the crop. The level of nitrogen supplied might have been sufficient for the maximum production of leaves, so much so, the additional dose did not influence the leaf number at this stage. However, increased supply of nitrogen above 37.5 kg level, would have lowered the defoliation later, and thus at the harvest stage, 50 kg N dose retained significantly higher number of leaves.

Some compounds present in the oilcakes might have inhibited nitrification process; and hence the nitrogen supplied through the basal and top dressing of fertiliser, would have been more efficiently utilised by the crop when urea was blended with oilcakes. The influence of treatments on the leaf number was not found to follow a definite pattern at the different stages of crop growth possibly due to the abscission of leaves.

5.2.2.3 <u>Dry weight of plants</u>

The different sources and levels of nitrogen significantly and positively influenced dry matter production at all the stages of plant growth (Tables 11 a to 11 c).

The spectacular role played by nitrogen in increasing vegetative growth in plants and dry matter production has been revealed since long (Black, 1968; Russel, 1973). Growth of cassava also responds well to nitrogen application (Malavotta et al.1955; Cheo-samut, 1974). Nitrogen at 50 kg level has produced significantly higher dry matter at all the stages of crop growth.

Upto the six month stage, all the oilcake treatments, produced higher dry matter than untreated urea treatment. Comparatively heavy rains received during the cropping period (Appendix-I) and alternate wetting and drying conditions might have increased nitrification rate and leaching losses of nitrates in untreated urea plots (Bains et al.1971). This might explain the lowered availability of nitrogen, and consequent reduction in dry matter production.

Urea-neem blend was found to be superior to other sources at all the stages of growth. Maroti and mahua blend closely followed neem blend (Fig.8 and Tables 11 a to 11 c). Hilgur and Shinde (1981) and Krishnaiah and Shinde (1981) also observed increased dry matter production in rice by the treatment of urea with neem and other oilcakes. At all the stages and levels of nitrogen neem cake treatment showed superiority. This brings out that, by providing a steady supply of nitrogen throughout the growing season, urea-neem blend might have supported the plant growth, which resulted in increased height, number of leaves (Tables 9 and 10) and tubers. Result of the laboratory incubation study also lends support to this conclusion.

Rubber cake could not maintain the favourable influence on dry matter production towards the later periods of growth.

5.2.3 Influence of oilcake treatments at different levels of nitrogen on the available nitrogen and potassium in soil at the three month stage of the crop

5.2.3.1 Available nitrogen

Both sources and levels of nitrogen influenced favourably and significantly the available nitrogen status of the soil.

It is but natural that incremental dose of nitrogen had significantly enhanced the available nitrogen content in the soil.

Lowest available nitrogen was recorded by the untreated urea plots. Alternate wetting and drying would have enhanced nitrification rates and heavy rains would have washed the nitrates off the rootzone, resulting in a lower available nitrogen in untreated urea plots.(Fig 7).

Oilcakes would have efficiently inhibited the growth of nitrifier population and prevented the formation

Fig 7 AVAILABLE NITROGEN AND POTASSIUM (3 MONTH STAGE)

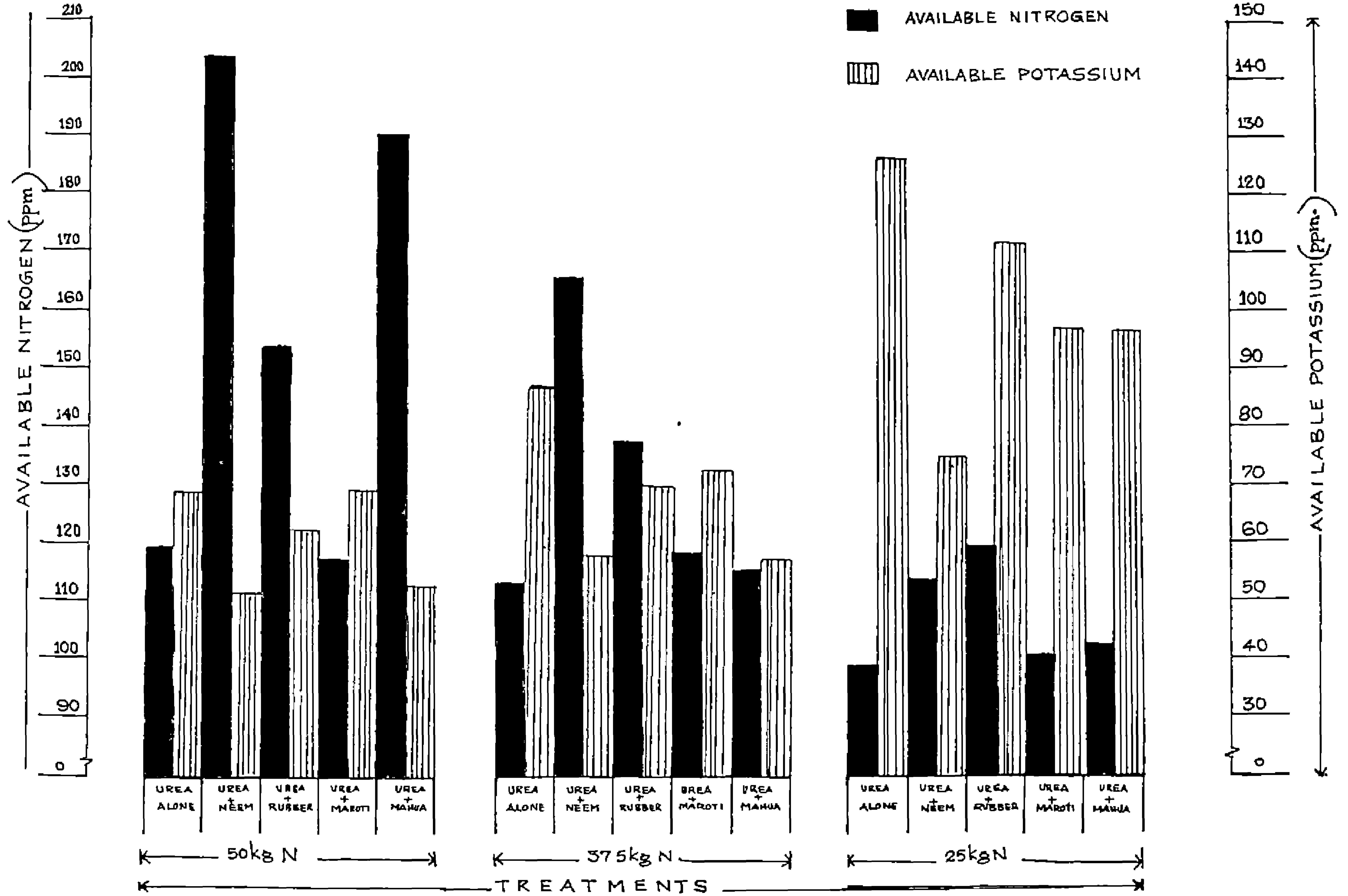
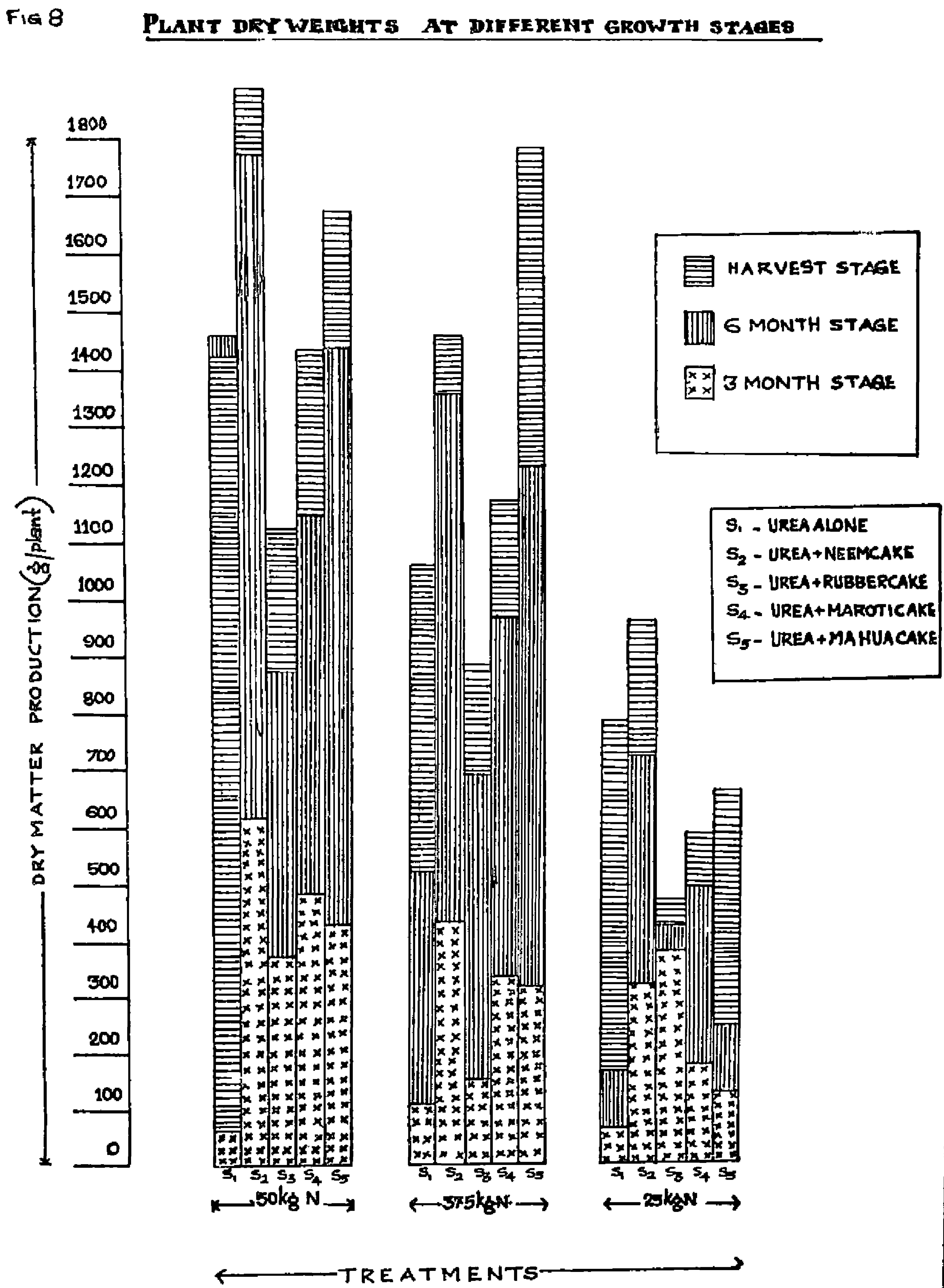


Fig 8


PLANT DRY WEIGHTS AT DIFFERENT GROWTH STAGES
DRY MATTER PRODUCTION (g/plant)
1800
1700
1600
1500
1400
1300
1200
1100
1000
900
800
700
600
500
400
300
200
100
0
HARVEST STAGE
6 MONTH STAGE
3 MONTH STAGE
S1 - UREA ALONE
S2 - UREA+NEEMCAKE
S3 - UREA+RUBBERCAKE
S4 - UREA+MAROTICAKE
S5 - UREA+MAHUACAKE
S1 S2 S3 S4 S5
50kg N
S1 S2 S3 S4 S5
37.5kg N
S1 S2 S3 S4 S5
25kg N
TREATMENTS

of nitrates (Fig.4). The capacity of the oilcake-urea blends to retain more nitrogen in NH_4^+-N form - the form in which mineral nitrogen can be best adsorbed on soil colloids - have already been revealed from the data on exchangeable NH_4^+-N (Tables 7 and 8). Neem urea blend recorded the maximum available nitrogen. Biddappah and Sarkunam (1979) also obtained higher NH_4^+-N with neem cake treatment. From Fig.9, it could be seen that benefits out of neem and mahua treatments were higher at higher levels of nitrogen. However, a reverse trend was observed for rubber cake treatment.

Available nitrogen at this stage is well related to the growth and uptake of nutrients by plants.

5.2.3.2 Available potassium

Higher doses of nitrogen have significantly depressed the available potassium in soil. Though not statistically significant, oilcake treatments have shown a depressing trend on the available potassium content (Fig 7).

This effect appears to be due to three reasons (1) After the absorption of K^+ inside the clay lattice the NH_4^+ getting adsorbed on the edges under high levels of NH_4^+-N concentration might have blocked the release of

K^+, causing a reduced availability (Tisdale and Nelson, 1975). Subbiah et al.(1982) also made similar observations. Nitrification inhibitory capacity of the oilcakes would have accentuated the situation by reducing the release of non-exchangeable K^+ due to entrapment by the increased amounts of NH_4^+-N. Even though this situation is more pronounced in soils, constituted predominantly of 2:1 type clay minerals, the chance of this type of K^+ fixation in this soil cannot be completely ruled out.

(2) Higher levels of NH_4^+ in the soil may have caused the replacement of K^+ from the exchange sites, enhancing K^+ concentration in soil solution which would have resulted in higher leaching losses of this nutrient. Inhibition of nitrification aggravates the situation. Singh and Sinha (1975) studied the interaction of NH_4^+ and K^+ and found that simultaneous application of NH_4^+ and K^+ reduced the yield of rice. Asokan and Sreedharan (1978) had observed severe losses of applied potassium through leaching and recommended three split application for cassava.

(3) The influence of the increased supply of nitrogen on the growth of plants, would have increased the demand for K resulting in greater crop removal and

a lower potassium content in soil (Table 17). Available K status of the soil has been seen to be reflected in the potassium concentration in different plant parts (Table 12 to 14).

A negative influence of available nitrogen on available potassium brought out in the present study finds support in the results obtained by Muthuvel and Krishnamoorthy (1981).

Though supply of potassium was uniform in all the plots, relatively higher proportion of potassium with respect to nitrogen supplied would have resulted in a higher accumulation of potassium in plots receiving 25 kg nitrogen dose. Untreated urea at 25 kg level showed maximum potassium concentration and neem-urea blend at 50 kg level, the minimum. Shankar et al.(1976) also observed an adverse effect exerted by neem cake on the uptake of potassium by rice.

The effect of insufficient supply of potassium, corresponding to a higher nitrogen supply, has been reflected in the quality of tubers (Fig.11).

5.2.4 Influence of levels of nitrogen and oilcake treatment on nitrogen and potassium concentration in different plant parts

5.2.4.1 Leaf lamina

Incremental doses of nitrogen had significantly influenced the nitrogen content of leaf lamina only upto the three month stage of the crop, but depressed potassium content upto the six month stage.

Okeke et al.(1979) also observed increased percentage nitrogen in various plant parts of cassava with higher doses of nitrogen both in green house and field conditions. In conformity with the observation made in the present study, a depressing effect of nitrogen on the potassium content of leaf lamina was observed by Okeke et al.(1979) also.

Though statistically not significant, oilcake treatments have favourably influenced nitrogen concentration, evidently due to the increased nitrogen supply to the plant. Absorbed nutrients are utilised in different plant parts of cassava in different proportions, and nitrogen is mostly concentrated in leaf lamina (Krochmala and Samuels, 1968; Kanapathy, 1974).

Urea-neem-blend which gave maximum nitrogen concentration in leaf lamina, depressed K concentration to record the minimum value at all the growth stages. Leaf potassium concentration is dependent on the available potassium in soil (Thampan, 1979). Available potassium, as estimated at the three month stage of the crop (Table 17 and Fig.7) also indicated that, with an increase in available nitrogen status, consequent to the application of higher doses of nitrogen and/or conservation of nitrogen against losses through the oilcake treatment, there was a decrease in the availability of potassium.

Potassium absorption may also be affected due to the ionic competition between NH_4^+ and K^+ at the root adsorption site. Increased nitrogen supply might have enhanced the vegetative growth and dry matter production (Table 10) resulting in the dilution of the content of potassium in tissues.

5.2.4.2 Petiole

Neither the levels nor the sources did influence the nitrogen content of petiole in any of the growth stages. However, incremental doses of nitrogen had significantly depressed petiole potassium concentration upto the six month stage of the crop. Okeke et al.(1979) observed a linear response of petiole potassium concentration to potassium application. The meagre supply of potassium at higher nitrogen levels has been discussed earlier.

Neem-urea blend recorded minimum potassium concentration, evidently due to the higher amount of nitrogen conserved by neem-urea blend.

5.2.4.3 Stem

Nitrogen concentration in stem was significantly influenced by the levels of nitrogen upto the six month stage while the oilcake treatments enhanced the concentration significantly only at the six month stage of the crop. Favourable influence of nitrogen on the tissue concentration of nitrogen has been observed also by Okeke et al.(1979).

At the six month stage, levels of nitrogen significantly depressed the stem potassium concentration.

Urea-neem and urea-mahua blend depressed stem potassium concentration, possibly due to the higher amount of nitrogen conserved by the treatment.

5.2.4.4 Tuber

Only at the initial stages, levels and sources of nitrogen influenced nitrogen concentration in tuber. But potassium concentration was not influenced by either the levels or the sources of nitrogen.

A negative relationship between nitrogen and potassium concentration could be noticed in all the plant parts. The influences of treatments on the concentrations of nitrogen and potassium in different plant parts are different. The effect of treatments on nitrogen concentration was found more pronounced in the leaf lamina (Kanapathy, 1974) and the leaf petioles best reflected the treatments' influence on potassium concentration (Puspadas and Aiyer, 1976).

In general as the plants become older, the nitrogen and potassium concentrations in different plant parts are seen to be reduced considerably. Oelsligle and Mccollum (1975) have also observed this trend, which may be either due to the increase in structural material (Ulrich, 1952) or due to the less vigorous nutrient absorption with respect to dry matter production. Thus at the harvest stage, the treatment influence on the nitrogen content in any of the plant parts, did not assume the level of significance.

5.2.5 Effect of levels of nitrogen and oilcake treatments on the uptake of nitrogen and potassium

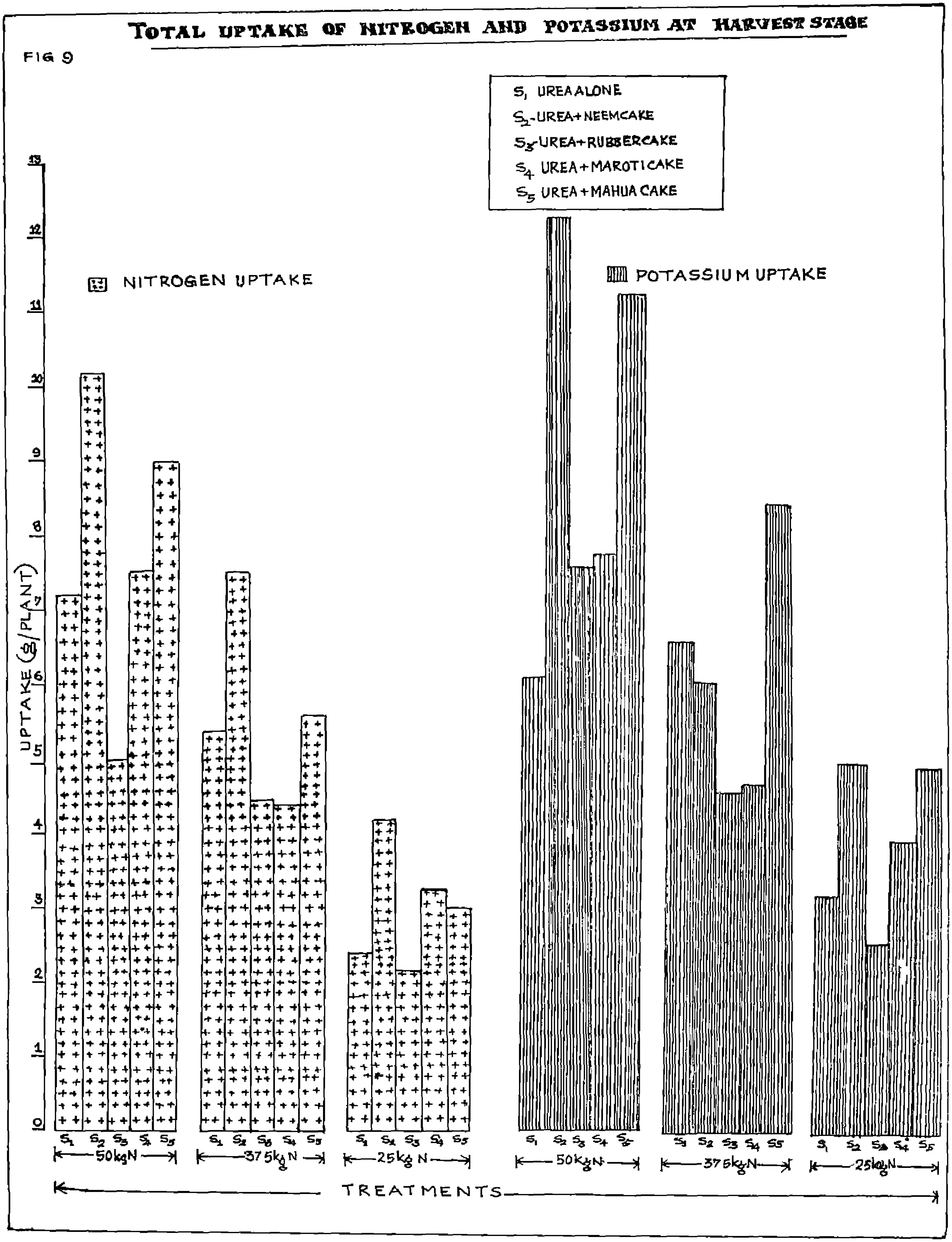
5.2.5.1 Nitrogen uptake

Uptake of nitrogen was found to increase rapidly upto the six month stage and then gradually. This may be due to the lower rate of nutrient absorption and growth after the six month stage of the crop (Table 11) or due to the increased defoliation after the six month stage. Thampan (1979) reported that 50-60 per cent of nitrogen taken up by cassava may get back to soil by leaffall.

It could be seen that different sources and levels of nitrogen have significantly influenced nitrogen uptake at all stages of growth (Table 15). Irregular pattern of nitrogen uptake in different periods observed in different treatments might be due to the losses of nitrogen through the abscissed leaves (Nigholt, 1935).

Incremental doses of nitrogen favourably influenced nitrogen uptake at all the stages of growth. Increased nitrogen uptake at higher nitrogen levels has been reported by many in different crops (Rajendran et al., 1976; Sankaram, 1978; Mani and Ramanathan, 1981; Subbiah et al. 1982).

Soil mineral nitrogen can be well correlated with nitrogen uptake (Morachan, 1978). Urea-oilcake blends, in general, increased nitrogen uptake over



TOTAL UPTAKE OF NITROGEN AND POTASSIUM AT HARVEST STAGE
FIG 9
S1 UREA ALONE
S2-UREA+NEEMCAKE
S3-UREA+RUBBERCAKE
S4 UREA+MAROTICAKE
S5 UREA+MAHUA CAKE
NITROGEN UPTAKE
POTASSIUM UPTAKE
UPTAKE (g/PLANT)
0
1
2
3
4
5
6
7
8
9
10
11
12
13
S1 S2 S3 S4 S5
50kgN
37.5kgN
25kgN
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untreated urea at all the three stages of growth. Oilcakes would have inhibited nitrification and conserved nitrogen against leaching and run off losses under heavy rainfall conditions. This would have resulted in higher uptake of nitrogen.

Urea-neem blend maintained superiority over other sources, throughout the growth period. The slow release of nitrate nitrogen would have prolonged the period of availability of nitrogen for the plants resulting in maximum recovery of applied nitrogen. Result of the laboratory incubation study also confirms this finding. Shankar et al.(1976) and Chakravarthi (1979) also have observed increased nitrogen uptake in rice, by the treatment of urea with neem.

Hilgur and Shinde (1981) used either extracts of different oilcakes and obtained higher nitrogen uptake. Krishaiah and Shinde (1979 b) compared the effect of different non-edible oilcakes at different ratios of mixing and obtained higher nitrogen uptake in rice when neem cake was mixed with urea (at 50 per cent by weight of fertilizer). In the present study also urea-neem blend at 5:3 ratio recorded maximum nitrogen uptake compared to other oilcake treatments. In ragi also, higher nitrogen uptake with neem cake blended urea was observed (Subbiah et al., 1982). At lower doses of nitrogen, urea-neem cake blend has enhanced the nitrogen uptake nearly three times when compared to untreated urea. But at higher doses, except at the three month stage, the magnitude of the benefit obtained out of the neem cake treatment, was less.

Mahua and maroti cake treatments have shown significant superiority over control, only at the initial stages. With the advancement of months, these oilcakes would have lost their inhibitory capacity when compared to neem cake, possibly due to the faster rate of degradation in soil. It may be recalled that mahua and maroti closely followed neem cake in inhibitory capacity (Table 28), though the pattern of inhibition was different. Rubber cake, though found better in the initial stages compared to untreated urea, was found inferior in nitrogen uptake at later stages. Maroti cake treatment faired better at 25 kg nitrogen level and came next to neem cake.

5.2.5.2 (b) Potassium uptake

Similar to nitrogen uptake, the total potassium uptake was also significantly influenced by the different sources and levels of nitrogen at all the growth stages (Table 16).

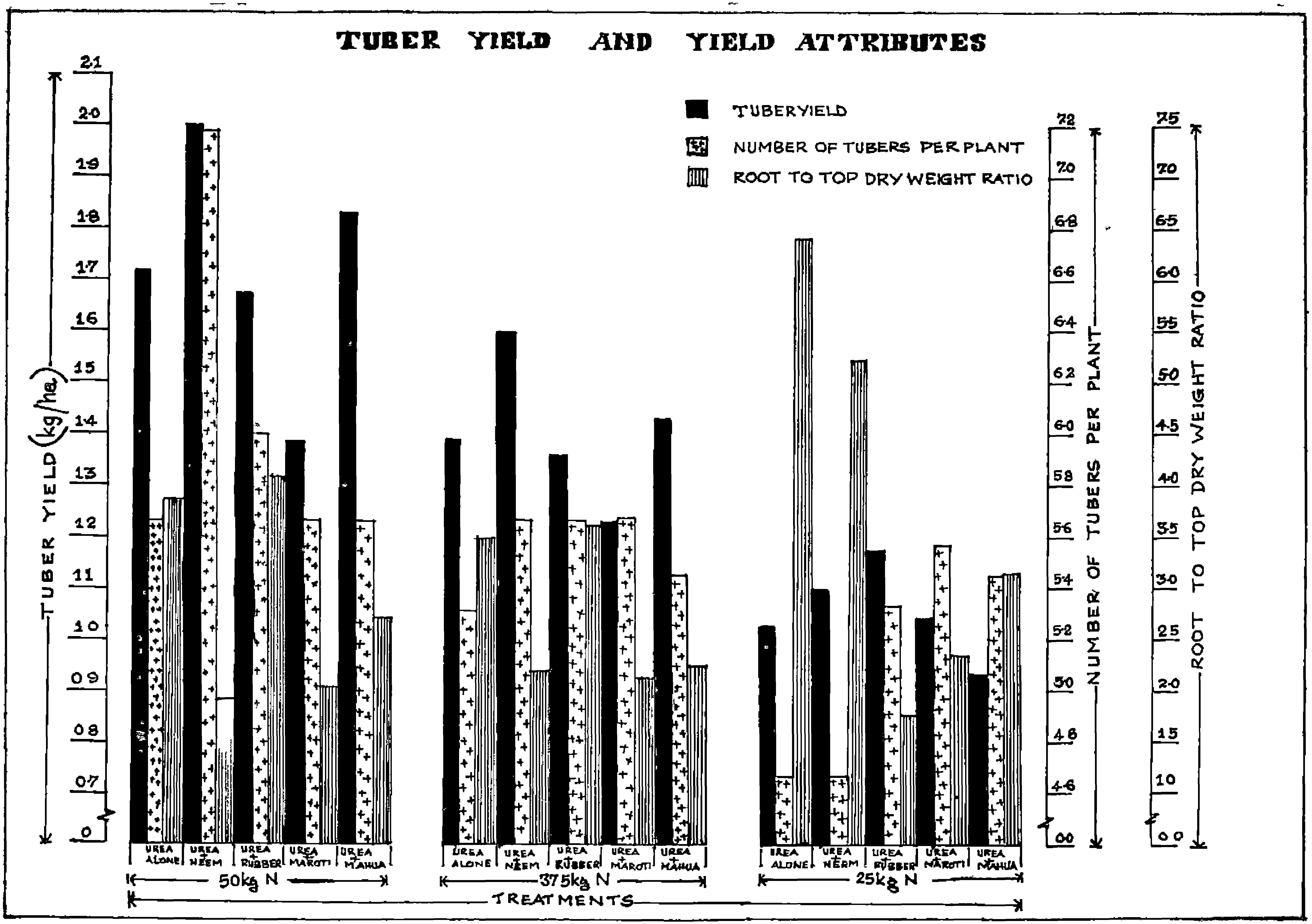
Increased nitrogen supply to the plant would have enhanced shoot and root growth which would have resulted in a higher requirement of other nutrients also, especially potassium. Though supply of potassium was uniform the higher demand for the nutrient and extended root growth induced by nitrogen, would have resulted in a higher potassium uptake. Rajendra et al.(1976) and Chattopadhayay et al.(1975) also observed increased potassium uptake at higher nitrogen levels in rice and wheat respectively. Oilcakes would have increased the efficiency of applied nitrogen and prolonged the availability for a longer period. Higher dry matter production induced by the greater supply of nitrogen would have been able to compensate for the lesser concentration of potassium in the tissues (Tables 12, 13 and 14) so that the total potassium uptake was high in plots receiving higher doses of nitrogen or in plots fertilized with urea-oilcake blends. At the three month and six month stages, urea-neem blend showed maximum uptake while at the harvest stage, urea-mahua blend stood first. But at all the three stages, urea-neem and urea-mahua blends were on par. Untreated urea and rubber cake blended urea though recorded higher potassium concentration in tissues, registered a lower total potassium uptake, evidently due to the lower dry matter production (Table 11).

5.2.6 The influence of urea-oilcake blend at different levels of nitrogen on tuber yield and yield attributes of cassava.

5.2.6.1 Number of tubers per plant

Treatment effects on the number of tubers per plant did not assume the level of significance, but an increasing trend with increasing supply of nitrogen could be noticed. (Table 19 and Fig.10). Blending oilcake with urea, would have conserved nitrogen and provided a steady supply to plants, and thus favourably influenced the number of tubers.

Many workers have observed a favourable influence of nitrogen in augmenting the number of tubers (Degeus, 1967; Vijayan and Aiyer, 1969; Pillai and George, 1978; Pillai et al., 1978; Ramanujam and Indira, 1979). Neem-urea blend at 50 kg nitrogen level gave the maximum number of tubers, evidently due to the greater nitrogen uptake compared to other treatments (Fig.9)



TUBER YIELD AND YIELD ATTRIBUTES
TUBERYIELD
NUMBER OF TUBERS PER PLANT
ROOT TO TOP DRY WEIGHT RATIO
TUBER YIELD (kg/ha)
0
0.7
0.8
0.9
1.0
11
12
13
14
15
16
17
18
19
2.0
21
NUMBER OF TUBERS PER PLANT
0.0
4.6
4.8
5.0
5.2
5.4
5.6
5.8
6.0
6.2
6.4
6.6
6.8
7.0
7.2
ROOT TO TOP DRY WEIGHT RATIO
0.0
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
5.5
6.0
6.5
7.0
7.5
UREA ALONE
UREA + NEEM
UREA + RUBBER
UREA + MAROTI
UREA + MAHUA
50kg N
37.5kg N
25kg N
TREATMENTS

5.2.6.2 Root to top dry weight ratio

The different sources of nitrogen have significantly influenced the ratio, but incremental doses of nitrogen have not influenced the same.

All the urea-oilcake blends were found to record a lower ratio compared to untreated urea. Increased nitrogen supply, by the oilcake treatments would have tended to decrease the ratio. Cheo-samut (1974) also observed similar trend.

Fox et al.(1975) reported that top growth responded more strongly to nitrogen application than tuber growth. Krochmala and Samuels (1970) have revealed that in cassava, excess availability of nitrogen may stimulate top growth at the expense of tuber development.

Potassium is essential for efficient translocation and is involved in carbohydrate metabolism. When K was omitted from nutrient solution, shoot growth was increased and root growth was suppressed (Malavolta, 1955).

A spurt in the vegetative growth of plants, when nitrogen was supplied abundantly, causes the utilization of the available potassium for top growth (Anderson,1967) and Wilson, 1969) and hence tuber development would have been suppressed.

Moreover, the supply of potassium was also meagre, when oilcake treated urea was supplied (Table 17). As explained earlier, this may be due to the retention of nitrogen in NH_4^+-N, through nitrification inhibition (Fig.7).

Urea-neem blend recorded the minimum ratio at 50 kg nitrogen dose, while urea-maroti blend and urea rubber-blend registered minimum ratios at 37.5 kg and 25 kg levels respectively. At all the levels of nitrogen, untreated urea recorded the maximum ratios. It may be recalled that the untreated urea plots showed maximum available potassium in the soil (Table 17).

From Fig.10, it could be seen that a negative relationship exists between ratio of root to top dry weight on one hand and the tuber yield and number of tubers per plant on the other.

5.2.6.3 Tuber yield

Incremental doses of nitrogen have significantly influenced the tuber yield in cassava. Enhanced tuber yield at higher nitrogen dose has been reported by many workers in different soil conditions (Chadha, 1958; Pillai et al.1967; Saraswat and Chattiar, 1976; Mohankumar and Mandal, 1977; Prabhakar et al, 1979).

Among the sources, urea-neem and urea-mahua blends showed a non-significant increased yield compared to untreated urea. But maroti-urea blend was found significantly inferior to neem-urea blend but was on par with untreated urea (Table 18 and Fig.10).

At 50 kg and 37.5 kg nitrogen doses, urea-neem blends (24691 kg and 19753 kg tuber) and urea mahua-blends (22592 kg and 17654 kg tuber) gave spectacular increased yields compared to other sources. Urea-rubber and urea-maroti blends were found to be even inferior to untreated urea at these levels. Only at 25 kg nitrogen level urea-rubber and urea-maroti blends gave higher tuber yields than untreated urea. The study thus brings out that at lower nitrogen levels, the efficiency of neem and mahua cakes in increasing the tuber yield is low.

In a long duration crop like cassava, the fertilizer application is needed to be adjusted to ensure fair and steady supply of nutrients according to the crop requirements. NH_4^+-N released on urea hydrolysis, undergoes faster nitrification and the nitrates thus formed do not remain in the soil for any length of time under the heavy rainfall conditions of Kerala. It is evident from the incubation study that neem and mahua cakes could inhibit nitrification process to the maximum extent (Tables 27 and 28). The same treatments have shown a higher exchangeable NH_4^+-N content in the soil after the application of urea for longer periods (Tables 7 and 8). Available nitrogen as estimated at the three month stage of the crop was found significantly correlated with tuber yield ($r = + 0.542^{**}$). Pillai and George (1978 b) also obtained positive correlation of tuber yield with available nitrogen content of soil. Fox et al.(1975) have observed a positive correlation of leaf nitrogen content at the three month stage of the crop with tuber yield. In the present study also (Table 12) this relationship was noticed.

Tuber yield was also significantly correlated with nitrogen uptake at the three month ($r = 0.609^{**}$) the six month (0.689^{**}) and the harvest ($r = 0.618^{**}$) stages of the crop. Neem and mahua cakes, by providing a slow and steady nitrification, favoured the supply of nitrogen for a longer period, which resulted in a greater uptake of nitrogen (Table 15) and a higher yield. Rajendran et al.(1976) also obtained positive correlation of the nitrogen uptake with tuber yield.

Total potassium uptake at all the three stages were also highly correlated with the tuber yield (Three month stage, $r = 0.420^{**}$; Six month stage, $r = 0.630^{**}$; and harvest stage, $r = 0.632^{**}$).

Increased availability of nitrogen increased plant height, number of leaves and dry matter production (Tables 9, 10 and 11) which would have resulted in a higher photosynthate production and a higher tuber yield. Dry matter production at the different growth stages showed a significant positive correlation with the tuber yield (Three month stage, $r = 0.549^{**}$; Six month stage, $r = 0.766^{**}$ and harvest stage, $r = 0.796^{**}$).

Increased yield through the use of neem was reported by many in many other crops (Subbiah et al.,1979; Krishnaiah and Shinde 1979; Biddappah and Sarkunam, 1979).

In spite of the spectacular superiority with regard to the growth characters and uptake of nutrients and dry matter production, shown by neem and mahua blend treatment, the increase in yield did not assume the level of significance compared to untreated urea.

This might be due to the inadequate supply of potassium, which would have limited the full manifestation of the influence of treatments on tuber yield.

It could be noticed that the uptake of potassium at the harvest stage was better correlated with tuber yield ($r = 0.632^{**}$) than nitrogen uptake at the same stage ($r = 0.618^{**}$). This indicated that supply of potassium would enhance tuber yield, to a greater extent than that of nitrogen.

Cassava prefers a certain ratio between nitrogen and potassium for manifesting its maximum yield potential (Thampan 1979). Experiments in CIAT also revealed that cassava responded to nitrogen, only in presence of adequate supply of potassium (Anon, 1975).

Increased nitrogen supply would have enhanced the top growth, but a corresponding increase in tuber growth did not occur; hence the lower root to shoot ratio (Table 20). This was due to the inadequate supply of potassium which was evident from the data on the available potassium status of the soil (Table 17). Thus the increase in tuber yield by the use of oilcake treatment was too, low that it did not attain the level of significance.

5.2.7 The influence of the application of oilcake blended urea to cassava on the quality attributes of tubers

5.2.7.1 Percentage dry matter of tubers

Dry matter content of tubers was not significantly influenced by either the levels or the sources of nitrogen

(Table 21). In confórmity with the present finding, Hukkeri (1968); Vijayan and Aiyer, (1969); Ramanujam and Indira, (1979); and Prabhakar et al.(1979) also did not obtain significant influence of nitrogen application on dry matter content.

But a decreasing trend for dry matter content with a higher nitrogen supply could be noticed (Fig.11). This may be due to the insufficient supply of potassium (Table 17 and Fig.7) in relation to the higher nitrogen supply. A reduction in dry matter content, at lower levels of potassium have been reported by Pushpadas and Aiyer (1976) and Asokan and Sreedharan (1977).

Untreated urea at n_1 level, received a relatively higher proportion of potassium with respect to nitrogen, and hence recorded a comparatively higher dry matter content in tuber. Correlation studies showed that this character has got direct significant relationship with starch content ($r = 0.640^{**}$) and an inverse relationship with crude protein and hydrocyanic acid ($r = 0.530^{**}$) content (Fig.11 and Table 29 b).

5.2.7.2 Percentage starch

Table 22 indicates that the influence of sources and levels of nitrogen on the starch concentration of

FIG 11

QUALITY OF TUBERS

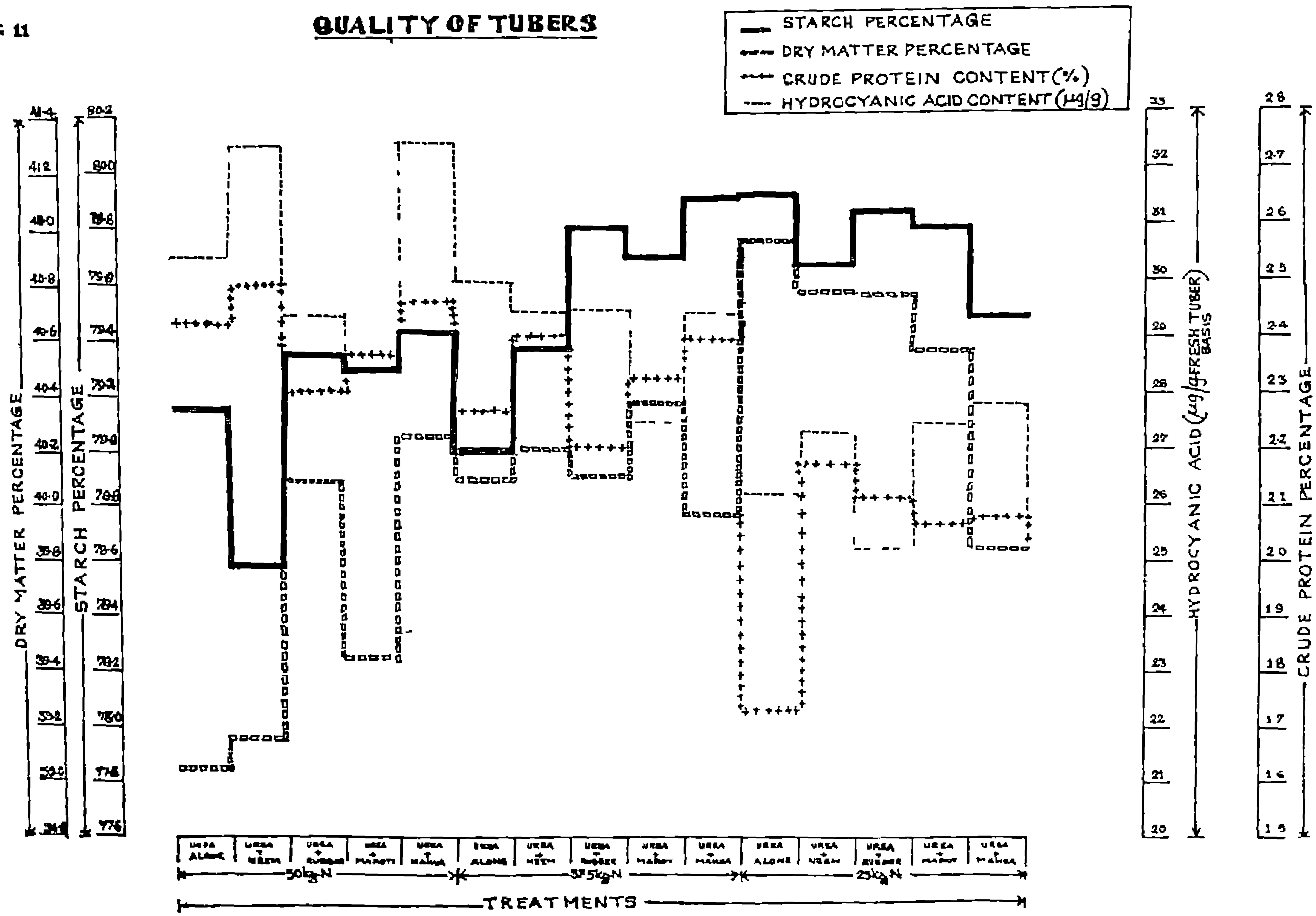


Table 29. Simple correlation coefficients

29 a) Yield Vs

		r values
(a)	3 month stage Dry weight	0.549 **
(b)	3 month stage N uptake	0.609 **
(c)	3 month stage K uptake	0.420 **
(d)	6 month stage dry weight	0.766 **
(e)	6 month stage N uptake	0.689 **
(f)	6 month stage K uptake	0.630 **
(g)	Harvest stage dry weight	0.796 **
(h)	Harvest stage N uptake	0.618 **
(i)	Harvest stage K uptake	0.632 **
(j)	Available N at 3 month stage	0.542 **

29 b) Quality attributes

	Crude protein	Starch	Dry matter %
HCN	+ 0.630 **	- 0.640 **	- 0.530 **
Starch	- 0.510 **	-	+ 0.640 **

* Significant at 0.05 level

** Significant at 0.01 level

tubers are significant.

Incremental doses of nitrogen has got a depressing effect on starch content. This observation finds support from the results of Malavolta et al (1955); and Vijayan and Aiyer (1969).

Malavolta et al (1955) found that an increased tuber yield at higher nitrogen levels did not compensate for a drop in starch content induced by the higher nitrogen supply, when higher starch yield per unit area was aimed at.

When the supply of nitrogen is high, more and more photosynthates are utilised for protein synthesis resulting in a lower starch synthesis (Russel, 1973). Data on the crude protein content lends support to this observation (Table 23 and Fig.11).

Thampam (1979) revealed the necessity for balanced nitrogen, phosphorus and potassium supply for maximum starch concentration.

Potassium is essential for translocation in plants and is involved in carbohydrate metabolism. It is highly required for starch synthesis (Dageus, 1967). This view has been supported by Kumar et al.(1971), Obigbesan, (1973) and Pushpadas and Aiyer (1975).

Though nitrogen favourably influences photosynthesis, the conversion of glucose to starch requires sufficient supply of potassium.

A uniformly lower dose of potassium supplied, the depressing effect of higher nitrogen supply on available potassium content in the soil (Table 17), and the utilisation of the absorbed potassium for the higher top growth induced by nitrogen, might be the probable reasons for the inadequate supply of potassium for starch synthesis.

Among the sources of nitrogen, urea-neem blend recorded the minimum starch content. The oilcakes would have conserved nitrogen to the maximum extent, but the lack of an accompanied sufficient supply of potassium, would have depressed starch content. The depressing effect was more pronounced at the 50 kg level by neem-urea blend.

Starch content has shown a significant positive correlation with dry matter content ($r = p.640^{**}$) and a significant negative correlation with crude protein ($r = 0.510^{**}$) and HCN ($r = 0.640^{**}$) contents. (Fig.11 and Table 20 b).

5.2.7.3 Crude protein

From table 23 it is seen that crude protein content increased progressively and significantly with increasing levels of nitrogen.

Though statistically not significant oilcake treatments have shown a favourable trend for protein content, compared to untreated urea.

Higher nitrogen supply would have enhanced the synthesis of aminoacids and polymerisation of it into proteins (Hukkeri, 1968; Pillai, 1967; Thampan, 1979; Gomes and Howler, 1980; Muthuswamy and Rao, 1981). Malavolta (1955) also observed an increase upto 50% in protein content in cassava at higher nitrogen doses. Degeus (1967) observed a lower starch to protein ratio at higher nitrogen levels.

As explained earlier the non-utilisation of carbohydrates for starch synthesis, due to inadequate supply of potassium at higher nitrogen levels, would have resulted in a higher protein content. In support of this Pillai (1967); Natarajan (1975) and Asokan and Sreedharan (1977) have also observed higher protein content at lower potassium supply.

The tubers from plots receiving urea-neem blend and urea-mahua blend showed higher protein contents. This evidently indicates that neem and mahua cakes have enhanced the efficiency of applied nitrogen and made more nitrogen available to plants increase the protein content. Arunachalam and Morachan (1974) also obtained higher protein content in rice with neem cake extract treated urea. Crude protein content in tubers showed a significant positive relationship with HCN content ($r = 0.630^{**}$) and a negative relationship with starch ($r = 0.510^{**}$) content. (Table 29 and Fig.11).

5.2.7.4 Hydrocyanic acid content

Table 24 shows that both the sources and levels of nitrogen have significantly influenced the HCN content of tubers.

Increasing the levels of nitrogen is found to significantly enhance HCN content. Results obtained by Vijayan and Aiyer (1969) and Muthuswamy and Rao (1981) lend support to this observation. When potassium supply in relation to that of nitrogen is low (Tables 17 a and b and Fig.7), nitrogen, instead of being utilised for protein synthesis, combines with free glucose and undergoes a special pathway in cyanophoric plants forming cyanogenic glucosides. Increased nitrogen supply would have increased the total photosynthate production. But elaboration of glucose to starch, requires potassium. This results in an accumulation of free glucose.

Increased potassium supply divert glucose to starch synthesis and prevent the accumulation of free glucose; and thus reduce HCN content (Jacob et al.1966; Thampan, 1979)..

Warcholowa et al.(1965) observed that, in sugar beet plants, potassium fertilisation decreased the content of reducing sugars in leaves and increased the percentage of sucrose in roots.

Urea-mahua blend followed by urea-neem blend recorded maximum HCN contents. But they were on par with untreated urea. Urea-neem blend at 50 kg level would have conserved nitrogen against leaching and run off losses and made the nutrient available to plants for a longer period, resulting in a higher uptake of nitrogen (Table 15). But an inadequate supply of potassium (Table 17 b) would have caused the accumulation of cyanogenic glucosides in tubers. It may be recalled that neem and mahua cake inhibited nitrification to the maximum extent (Table 28) and conserved more nitrogen against leaching losses. Urea-rubber and urea-maroti blends would not have enhanced nitrogen supply to the plants at later periods of crop growth and hence HCN content is low in plants receiving these blends.

At lower levels of nitrogen, supply of comparatively higher proportion of potassium, would have alleviated the accumulation of HCN.

HCN content has shown a significant positive correlation with crude protein ($r = + 0.630^{**}$) and a negative correlation with starch percentage ($r = 0.640^{**}$) and dry matter ($r = 0.530^{**}$) content. (Table 29 b and Fig.11).

Summary and Conclusions

SUMMARY AND CONCLUSIONS

An investigation was carried out at the College of Agriculture, Vellayani, during the year 1980-81 to select some of the most popular non-edible oilcakes of crushing industry for blending with urea to increase nitrogen use efficiency in the rainfed upland soils of Kerala. Tapioca, a popular upland crop of Kerala was used as the test crop.

Mineralisation pattern of urea-oilcake-blends were studied in an incubation experiment using a typical upland red loam soil. Urea was mixed with neem, mahua, maroti, rubber or karinja cake at 5:3, 5:2 and 5:1 ratios (Urea:oilcake) incorporated in soil kept at 60 per cent of the field moisture capacity. Different forms of mineral nitrogen were monitored periodically to select the most efficient oilcakes in their best ratios, which will retain more NH_4^+-N for an extended period, by inhibiting nitrification effectively.

A field experiment with cassava was conducted to test the efficiency of the selected urea-oilcake blends of the incubation study under the typical rainfed upland conditions of Kerala.

The results obtained and conclusions drawn are summarised below.

(1) A faster rate of decline in NH_4^+ - N content accompanied

by a faster increase in NO_3^--N observed in untreated urea treatment indicated the inhibition on nitrification brought about by the oilcakes in urea-oilcake blends.

(2) Among the urea-oilcake blends, that of mahua, rubber and neem retained more NH_4^+ - N in the initial stages than other oilcake blends, indicating the lesser influence of those oilcakes on urea hydrolysis.

(3) Narrowing the ratio of urea to oilcakes has enhanced the efficiency of inhibition of all the oilcake treatments except that of urea-maroti blend, which showed maximum inhibition at 5:2 level. Urea-maroti-blend at 5:3 level showed a reduction in ammoniacal nitrogen in the initial stages, indicating the inhibition on urease activity brought about by this oilcake.

(4) Averaged over the periods of incubation and the rates of mixing the nitrification inhibitory capacity was found in the decreasing order as neem > mahua > maroti > rubber > karinja.

(5) The inhibition of the process was found to take place at the NH_4^+ oxidation stage and hence the chance of accumulation of NO_2^-- N to a toxic level can be ruled out, when these oilcakes were used as nitrification inhibitors.

(6) Soil analysis after the field application of treatments indicated that neem and mahua cakes were efficient in

retaining more nitrogen in ammoniacal form under field condition also. Thus the oilcakes reduced the leaching losses and extended the period of availability of nitrogen to the crop from the applied fertilizers. This is evident from the estimated plant uptake of nitrogen at different growth stages.

(7) The study of the growth characters like height of plants, number of leaves and dry matter production indicated the favourable influence of the urea-oilcake blends on them in general and with urea-neem and urea-mahua blend in particular.

(8) Available soil nitrogen as estimated at the three month stage of the crop brought out that urea-oilcake blends reduced losses of nitrogen and thus retained more available nitrogen in soil. Neem-urea blend followed by mahua-urea blend recorded the maximum plant available nitrogen in soil at all the levels of nitrogen supplied.

(9) In general, oilcake treatments depressed the available potassium status of the soil. A negative relationship between available nitrogen and available potassium could be noticed.

(10) Nitrogen concentration in different plant parts showed a favourable trend with incremental doses of nitrogen supply. In general, among the sources tried, urea-neem blend enhanced nitrogen content to the maximum extent.

(11) In general potassium concentration in different plant

parts presented an inverse relationship with nitrogen concentration, which in turn was favourably influenced by the oilcake treatments.

(12) The uptake of nitrogen at all the three stages of growth was found favourably influenced by the incremental doses of nitrogen supply and by the treatment of urea with oilcakes. Urea-neem blend significantly increased nitrogen uptake of cassava at all the major growth stages.

(13) Higher uptake of potassium registered by urea-oilcake blends, inspite of the lower concentration of potassium in different plant parts, might be probably due to the increased dry matter production in those treatments consequent to the higher nitrogen uptake. Neem-urea blend which showed maximum nitrogen uptake recorded maximum potassium uptake also.

(14) Though not statistically significant, the treatment of urea with neem or mahua cake has shown a favourable trend in increasing tuber yield of cassava.

(15) Tuber yield showed a better correlation with the uptake of potassium ($r = 0.632^{**}$) than that of nitrogen ($r = 0.618^{**}$)

(16) Study of the root-shoot ratio indicated that top growth responded more strongly to incremental doses of nitrogen supply and the treatment of urea with the oilcakes, than

root growth. This is also suggestive of the insufficient supply of the nutrient, potassium, which is known to be essential for the proper root and tuber development in cassava.

(17) Starch and dry matter content of tubers were found to be depressed by the incremental doses of nitrogen and by the treatment of urea with oilcakes, especially that with neem cake.

(18) Crude protein and HCN contents of tubers were found to be enhanced by the supply of incremental doses of nitrogen and by the oilcake-blended urea treatment.

(19) Correlation studies indicated a significant positive relationship between HCN and protein contents, both of which showed a significant negative relationship with starch and dry matter contents.

From the results of the investigation it may be concluded that all the oilcakes possessed nitrification inhibitory capacity at varying levels. Neem and mahua cakes showed the maximum inhibition. Retardation of nitrification resulted in increased nitrogen availability for the crop, as evidenced by the increased nitrogen uptake at various growth stages. But the expected yield increase could not be obtained possibly due to the decreased availability and uptake of potassium, resulting in an unfavourable N:K ratio in the plant, which might have upset the physiological processes connected with tuber development.

The results of the investigation suggests that when these oilcakes are used as nitrification inhibitors either an additional dose of potassium may be supplied or the time of application of potassium may be suitably changed for the effective uptake of both the nutrients.

Some of the future lines of investigation which the present study has opened up are:-

(1) Study of the effect of application of urea-oilcake blends on the uptake of other nutrients.

(2) Study of the requirements of other nutrients, especially that of potassium when the oilcakes are used as nitrification inhibitors.

(3) Effect of changing the time of application of potassium on the availability and uptake of that nutrient when urea-oilcake blends are used for increasing nitrogen use efficiency.

(4) Search for indigenous materials having nitrification inhibitory property is to be continued. Isolation, characterisation and cheap method of extraction of the active principles responsible for effecting nitrification inhibition may be attempted so that the treatment of nitrogenous fertilizers with them can be tried.

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* Originals not seen.

Appendices

APPENDIX I

Weather conditions during the cropping period

Month	Rainfall (mm)	Temperature °C Maximum	Temperature °C Minimum	Relative humidity (%)
July	125.5	30.0	22.9	93.5
August	268.5	29.73	22.9	93.0
September	312.0	29.35	21.6	94.5
October	335.0	29.6	21.9	94.1
November	253.5	30.9	22.8	93.7
December	11.5	29.6	21.6	84.38
January	0	32.01	20.33	79.31
February	0	29.65	19.26	81.12
March	16.5	33.88	22.82	79.93
April	73.0	32.99	24.42	76.15

APPENDIX - II(a)

Incubation Experiment - NH_4^+-N on second day

Ancova Table

Source	SSx	SSy	SSxy	Adjusted SS	df	MS	F
Treatment	0.607	59157.29	67.78				
Error	0.0144	4420.5	3.786				
(T+E)	0.6211	63577.7	71.57				
Regression				991.96	1	991.96	4.34 NS
Treatment				51903.04	15	3460.20	15.14 **
Error				3428.54	15	228.57	

APPENDIX - II(b)

Incubation Experiment - NH_4^+-N on seventh day

Ancova Table

Source	SSx	SSy	SSxy	Adjusted SS	df	MS	F
Treatment	0.607	24645	49.62				
Error	0.0144	1164.6	-0.205				
(T+E)	0.6211	25810	49.42				
Regression				2.919	1	2.919	0.0377 NS
Treatment				20716	15	1381.10	17.83 **
Error				1161.76	15	77.45	

** Significant at 0.01 level

APPENDIX II (c)

Incubation Experiment - NH_4^+-N on twelfth day

Ancova Table

Source	SSx	SSy	SSxy	Adjusted SS	df	M.S.	F
Treatment	0.6070	32637	67.131				
Error	0.0144	1755	1.115				
(T+E)	0.6211	34393	68.250				
Regression				85.99	1	85.99	0.773 NS
Treatment				25225.00	15	1681.67	15.110 **
Error				1669.88	15	111.33	

APPENDIX II (d)

Incubation Experiment - NH_4^+-N on seventeenth day

Anvoca Table

Source	SSx	SSy	SSxy	Adjusted SS	df	M.S.	F
Treatment	0.5070	11961	27.05				
Error	0.0144	1079	1.19				
(T+E)	0.6211	13040	28.34				
Regression				97.67	1	97.670	1.492 NS
Treatment				10775.00	15	718.340	10.97 **
Error				981.90	15	65.460	

** Significant at 0.01 level

APPENDIX II (e)

Incubation Experiment - NH_4^+-N on twenty second day
Anvoca Table

Source	SSx	SSy	SSxy	Adjusted ss	df	M.S.	F	
Treatment	0.6070	6250.53	8.0050					
Error	0.0140	1533.07	0.2380					
(T+E)	0.6211	7783.61	8.2439					
Regression				3.940	1	3.94	0.0386	NS
Treatment				6145.050	15	409.67	4.0200	**
Error				1529.13	15	101.94		

APPENDIX II (f)

Incubation Experiment - NH_4^+-N on twenty seventh day
Ancova Table

Source	SSx	SSy	SSxy	Adjusted ss	df	M.S.	F	
Treatment	0.6070	4801.511	29.150					
Error	0.0140	6172.190	-0.605					
(T+E)	0.6211	10973.700	28.540					
Regression				28.820	1	28.82	0.0703	NS
Treatment				3522.215	15	234.81	0.5720	NS
Error				6143.110	15	409.54		

** Significant at 0.01 level

APPENDIX III (a)

Incubation Experiment - NO_2^--N on second day
Ancova Table

Source	SSx	SSy	SPxy	Adjusted ss	df	M.S.	F
Treatment	1.2×10^{-5}	6.0×10^{-6}	6.1×10^{-6}				
Error	5.2×10^{-6}	7.9×10^{-6}	2.9×10^{-6}				
(T+E)	1.7×10^{-5}	1.5×10^{-5}	8.9×10^{-6}				
Regression				1.6×10^{-6}	1	1.6×10^{-6}	3.797 NS
Treatment				2.4×10^{-7}	15	2.4×10^{-7}	0.559 NS
Error				6.4×10^{-6}	15	4.3×10^{-7}	

APPENDIX III (b)

Incubation Experiment - NO_2^--N on seventh day
Ancova Table

Source	SSx	SSy	SPxy	Adjusted ss	df	M.S.	F
Treatment	1.2×10^{-5}	3.6×10^{-6}	1.1×10^{-6}				
Error	5.2×10^{-6}	1.1×10^{-6}	2.0×10^{-7}				
(T+E)	1.7×10^{-5}	4.7×10^{-6}	1.3×10^{-6}				
Regression				7.8×10^{-9}	1	7.8×10^{-9}	0.104 NS
Treatment				3.5×10^{-6}	15	2.3×10^{-7}	3.102 *
Error				1.1×10^{-6}	15	7.5×10^{-8}	

* Significant at 0.05 level

APPENDIX III (c)

Incubation Experiment - NO_2^--N on twelfth day

Ancova Table

Source	SSx	SSy	SPxy	Adjusted SS	df	M.S.	F
Treatment	1.2×10^{-5}	6.2×10^{-6}	-1.1×10^{-6}				
Error	5.2×10^{-6}	9.7×10^{-7}	3.8×10^{-7}				
(T+E)	1.7×10^{-5}	7.2×10^{-6}	-6.8×10^{-7}				
Regression				2.7×10^{-8}	1	2.7×10^{-8}	0.437 NS
Treatment				6.2×10^{-6}	15	4.2×10^{-7}	6.590 **
Error				9.4×10^{-7}	15	6.3×10^{-8}	

APPENDIX IV (a)

Incubation Experiment - NO_3^--N on second day

Ancova Table

Source	SSx	SSy	SPxy	Adjusted SS	df	M.S.	F
Treatment	0.00395	1.530	-0.01360				
Error	0.00080	0.133	0.00354				
(T+E)	0.00475	1.667	-0.01020				
Regression				0.0156	1	0.01560	1.994 NS
Treatment				1.5280	15	0.10100	13.009 **
Error				0.1740	15	0.00782	

** Significant at 0.01 level

APPENDIX IV (b)

Incubation Experiment - NO_3^--N on seventh day
Ancova Table

Source	SSx	SSy	SPxy	Adjusted ss	df	M.S.	F
Treatment	0.00396	1.470	0.0057				
Error	0.00080	0.380	0.0110				
(T+E)	0.00475	1.850	0.0170				
Regression				1.450	1	1.4500	9.180 *
Treatment				5.663	15	0.3784	6.550 **
Error				0.237	15	0.0158	

APPENDIX IV (c)

Incubation Experiment - NO_3^--N on twelfth day
Ancova Table

Source	SSx	SSy	SPxy	Adjusted ss	df	M.S.	F
Treatment	0.00396	5.798	-0.0270				
Error	0.00080	2.567	0.0010				
(T+E)	0.00477	8.365	0.0256				
Regression				0.0026	1	0.0026	0.0157 NS
Treatment				5.6630	15	0.3780	2.2100 NS
Error				2.5600	15	0.1710	

* Significant at 0.05 level

** Significant at 0.01 level

APPENDIX IV (d)

Incubation Experiment - NO_3^--N on seventeenth day

Ancova Table

Source	SSx	SSy	SPxy	Adjusted SS	df	M.S.	F
Treatment	0.00396	17.540	-0.0311				
Error	0.00080	3.004	0.0190				
(T+E)	0.00476	20.5[illegible]	-0.0121				
Regression				0.450	1	0.450	2.64 NS
Treatment				17.960	15	1.197	7.031**
Error				2.550	15	0.170	

APPENDIX IV (e)

Incubation Experiment - NO_3^--N on twenty second day

Ancova Table

Source	SSx	SSy	SPxy	Adjusted SS	df	M.S.	F
Treatment	0.00396	79.850	-0.320				
Error	0.00080	192.160	-0.060				
(T+E)	0.00475	272.008	-0.396				
Regression				5.54	1	5.54	0.446 NS
Treatment				52.38	15	3.49	0.281 NS
Error				186.61	15	12.44	

** Significant at 0.01 level

APPENDIX IV (f)

Incubation Experiment - NO_3^--N on twenty seventh day

Ancova Table

Source	SSx	SSy	SPxy	Adjusted ss	df	M.S.	F
Treatment	0.00396	14.830	0.00900				
Error	0.00080	195.470	-0.04060				
(T+E)	0.00475	210.302	-0.00315				
Regression				2.05	1	2.05	0.159 NS
Treatment				16.67	15	1.11	0.086 NS
Error				193.41	15	12.89	

APPENDIX V (a)

Field Experiment - Exchangeable NH_4^+-N after basal application of fertilizer (one week after)

Ancova Table

Source	SSy	SSx	SPxy	Adjusted ss	df	M.S.	F
Replication	2.193	4.06	1.905				
Treat-ment	1677.630	865.61	343.530				
Error	3260.920	2105.58	1342.950				
Regression				0.0901	1	0.09012	0.000266 NS
Treatment				20650.8400	14	1475.0600	4.348 **
Error				9160.0000	27	339.2600	

** Significant at 0.01 level

APPENDIX V (b)

Field Experiment - Exchangeable NH_4^+-N after basal application of fertilizer (two weeks after)

Ancova Table

Source	SSy	SSx	SPxy	Adjusted ss	df	M.S.	F
Replication	818.27	4.060	6.530				
Treatment	20707.93	865.610	398.600				
Error	9160.13	2105.58	13.780				
Regression				0.0901	1	0.09012	0.000266 NS
Treatment				20650.8400	14	1475.06	4.348**
Error				9160.0000	27	339.26	

APPENDIX V (c)

Field Experiment - Exchangeable NH_4^+-N after basal application of fertilizer (three weeks after)

Ancova Table

Source	SSy	SSx	SPxy	Adjusted ss	df	M.S.	F
Replication	8.19	4.06	-1.59				
Treatment	3563.90	865.61	505.31				
Error	4719.07	2105.58	251.23				
Regression				29.97	1	29.97	0.173 NS
Treatment				3401.26	14	242.94	1.398 NS
Error				4689.09	27	173.67	

** Significant at 0.01 level

APPENDIX V (d)

Field Experiment - Exchangeable NH_4^+-N after basal application of fertilizer (four week after)

Ancova Table

Source	SSy	SSx	SPxy	Adjusted ss	df	M.S.	F
Replication	80.15	4.06	-2.64				
Treatment	477.92	865.61	54.73				
Error	1049.80	2105.58	2105.73				
Regression				121.11	1	121.1	3.52 NS
Treatment				493.58	14	35.26	1.02 NS
Error				928.69	27	34.39	

APPENDIX VI (a)

Field Experiment - Exchangeable NH_4^+-N after top dressing of fertilizers (one week after)

Ancova Table

Source	SSx	SPxy	SSy	Adjusted ss	df	M.S.	F
Replication	2390	4719.00	12279				
Treatment	11067	16412.00	37993				
Error	14399	-5656.14	52935				
Regression				2221.7	1	2221.70	1.18 NS
Treatment				35672.5	14	2548.04	1.36 NS
Error				50713.9	27	1878.29	

APPENDIX VI (b)

Field Experiment - Exchangeable NH_4^+-N after top dressing of fertilizers (two weeks after)

Ancova Table

Source	SSx	SPxy	SSy	Adjusted SS	df	M.S.	F
Replication	2390	-5481.39	32016				
Treatment	11067	13144.00	99602				
Error	14399	3649.00	45013				
Regression				924.97	1	924.97	5.66 *
Treatment				89453.00	14	6389.50	3.91 *
Error				44088.00	27	1632.89	

APPENDIX VI (c)

Field Experiment - Exchangeable NH_4^+-N after top dressing of fertilizers (three weeks after)

Ancova Table

Source	SSx	SPxy	SSy	Adjusted SS	df	M.S.	F
Replication	2390	86.33	4151.95				
Treatment	11067	4590.00	28698.00				
Error	14399	169.15	13741.00				
Regression				1.98	1	1.98	0.003 NS
Treatment				27810.00	14	1986.49	3.90*
Error				13733.00	27	508.87	

* Significant at 0.05 level

APPENDIX VI (d)

Field Experiment - Exchangeable NH_4^+-N after top dressing of fertilizers (four weeks after)

Ancova Table

Source	SSx	SPxy	SSy	Adjusted SS	df	M.S.	F
Replication	2390.1	-769.83	1186.8				
Treatment	11067.0	7159.10	15223.0				
Error	14399.0	-1279.43	9328.0				
Regression				113.68	1	113.68	0.33 NS
Treatment				13980.00	14	998.57	2.93*
Error				9214.6	27	341.28	

APPENDIX VII

Analysis of variance table - Height of plants at 3 month stage

Source	SS	df	M.S.	F
Block	0.026	2	0.013	0.242 NS
Treatments	2.868	14	0.200	3.72*
Source	1.920	4	0.480	8.95**
Levels	0.164	2	0.082	1.03 NS
Interaction	0.784	8	0.079	1.82 NS
Error	1.501	28	0.0537	

* Significant at 0.05 level

** Significant at 0.01 level

APPENDIX VIII

Analysis of variance table - Height of plants at 6 month stage

Source	SS	df	N.S.	F
Block	0.650	2	0.325	2.890 NS
Treatments				
Source	1.427	4	0.357	3.173*
Levels	1.174	2	0.587	5.220**
Interaction	1.687	8	0.211	1.876 NS
Error	3.147	28	0.112	

APPENDIX IX

Analysis of variance table - Height of plants at harvest stage

Source	SS	df	N.S.	F
Block	0.168	2	0.0841	1.2145 NS
Treatments	-	-	-	-
Source	1.392	4	0.348	5.023 **
Levels	1.893	2	0.946	13.659 **
Interaction	0.306	8	0.038	0.551 NS
Error	1.939	28	0.069	-

* - Significant at 0.05 level

** - Significant at 0.01 level

APPENDIX X

Analysis of variance table - No.of leaves/plant at 3 month stage

Source	SS	df	N.S.	F
Block	452.93	2	226.47	0.289 NS
Treatments	-	-	-	-
Source	24454.08	4	6113.52	7.8007 **
Levels	10066.53	2	5033.27	6.422 **
Interaction	6779.91	8	847.49	1.081 NS
Error	21943.73	28	783.70	-

APPENDIX XI

Analysis of variance table - No.of leaves/plant at 6 month stage

Source	SS	df	N.S	F
Block	2654.80	2	1327.40	2.9670 NS
Treatments	-	-	-	-
Source	9294.58	4	2323.64	5.1939 **
Levels	5684.93	2	2842.47	6.3536 **
Interaction	10065.96	8	1258.24	2.8124 *
Error	-	-	-	-

* Significant at 0.05 level

** Significant at 0.01 level

APPENDIX XII

Analysis of variance table - No.of leaves/plant at harvest stage

Source	SS	df	N.S.	F
Block	10748.84	2	5374.42	6.8593**
Treatments	36875.11	14	2633.94	3.3600*
Source	3317.11	4	829.28	1.0584 NS
Levels	19188.31	2	9594.16	12.2450**
Interaction	14369.69	8	1796.21	2.2925 NS
Error	21938.49	28	783.52	-

APPENDIX XIII

Analysis of variance table - Total plant dry weight at 3 month stage

Source	SS	df	N.S.	F
Block	416989.53	2	208494.77	16.708**
Treatments	-	-	-	-
Source	511353.25	4	127838.31	10.240**
Levels	623508.24	2	311754.12	24.984**
Interaction	31527.478	8	3940.934	0.315 NS
Error	349390.11	28	12478.22	-

* Significant at 0.05 level

** Significant at 0.01 level

APPENDIX XIV

Analysis of variance table - Total plant dry weight at 6 month stage

Source	SS	df	N.S	F
Block	1344031	2	672015	9.73**
Treatments	-	-	-	-
Source	2261142	4	565285	8.18**
Levels	6508070	2	3254035	47.09**
Interaction	1063931	8	132991	1.92 NS
Error	1934606	28	69093	-

APPENDIX XV

Analysis of variance table - Total plant dry weight at harvest stage

Source	SS	df	N.S	F
Block	10863.60	2	5431.80	0.12 NS
Treatments	-	-	-	-
Source	1356820.59	4	39205.14	7.54**
Levels	5822389	2	2911194.00	64.76**
Interaction	169050	8	21131.28	0.47 NS
Error	1258684	28	44953.02	-

* Significant at 0.05 level

** Significant at 0.01 level

APPENDIX XVI (a)

Analysis of variance table - 3 month stage - percentage nitrogen in leaf lamina

Source	SS	df	M.S	F	
Replication	1.04	2	0.5117	4.905	NS
Treatment	-	-	-	-	
Source	3.32	4	0.083	0.789	NS
Levels	5.69	2	2.840	27.004	**
Interaction	7.93	8	0.099	0.941	NS
Error	2.948	28	0.105	-	

APPENDIX XVI (b)

Analysis of variance table - 3 month stage - percentage nitrogen in leaf petiole

Source	SS	df	M.S	F	
Replication	0.283	2	0.141	11.095	**
Treatment	-	-	-	-	
Source	0.049	4	0.0120	0.934	NS
Levels	0.0104	2	0.0052	0.410	NS
Interaction	0.150	8	0.0018	1.480	NS
Error	0.358	28	0.0130		

** Significant at 0.01 level

APPENDIX XVI (c)

Analysis of variance table - 3 month stage - percentage nitrogen in stem

Source	SS	df	M.S	F
Replication	9.069	2	0.045	0.762 NS
Treatment	-	-	-	-
Source	0.362	4	0.0905	1.520 NS
Levels	0.930	2	0.467	7.850 **
Interaction	0.716	8	0.089	1.504 NS
Error	1.670	28	0.059	

APPENDIX XVI (d)

Analysis of variance table - 3 month stage - percentage nitrogen in tuber

Source	SS	df	M.S	F
Replication	0.00063	2	0.00031	0.640 NS
Treatment	-	-	-	-
Source	0.00550	4	0.00140	2.780 NS
Levels	0.01200	2	0.00590	11.900 **
Interaction	0.00220	8	0.00027	0.554 NS
Error	0.01380	28	0.00049	

** Significant at 0.01 level

APPENDIX XVII (a)

Analysis of variance table - 3 month stage - percentage potassium in leaf lamina

Source	SS	df	M.S	F
Replication	7.060	2	3.530	1.31 NS
Treatment	-	-	-	-
Source	2.550	4	6.370	2.36 NS
Levels	4.020	2	2.010	7.47**
Interaction	3.206	8	0.408	1.49 NS
Error	7.530	28	0.269	

APPENDIX XVII (b)

Analysis of variance table - 3 month stage - percentage potassium in leaf petiole

Source	SS	df	M.S	F
Replication	0.406	2	0.203	0.300 NS
Treatment	-	-	-	-
Source	2.290	4	0.574	0.849 NS
Levels	6.390	2	3.190	4.720
Interaction	16.860	8	2.110	3.110 NS
Error	18.940	28	0.676	

** Significant at 0.01 level

APPENDIX XVII (c)

Analysis of variance table - 3 month stage - percentage potassium in stem

Source	SS	df	M.S	F
Replication	1.310	2	0.660	0.870 NS
Treatment	-	-	-	-
Source	0.452	4	0.113	0.148 NS
Levels	0.388	2	0.194	0.255 NS
Interaction	4.740	8	0.591	0.786 NS
Error	21.230	28	0.758	0.786 NS

APPENDIX XVII (d)

Analysis of variance table - 3 month stage - percentage potassium in tuber

Source	SS	df	M.S	F
Replication	1.024	2	0.512	1.002 NS
Treatment	-	-	-	-
Source	2.110	4	0.527	1.050 NS
Levels	3.120	2	1.560	3.110 NS
Interaction	4.440	8	0.550	1.100 NS
Error	14.030	28	0.501	

APPENDIX XVIII (a)

Analysis of variance table - 6 month stage - percentage nitrogen in leaf lamina

Source	SS	df	M.S	F
Replication	0.250	2	0.1240	4.32 NS
Treatment	-	-	-	-
Source	0.064	4	0.0160	0.56 NS
Levels	0.140	2	0.0710	2.49 NS
Interaction	0.130	8	0.0162	0.57 NS
Error	0.803	28	0.0286	0.57 NS

APPENDIX XVIII (b)

Analysis of variance table - 6 month stage - percentage nitrogen in leaf petiole

Source	SS	df	M.S	F
Replication	0.026	2	0.013	0.363 NS
Treatment	-	-	-	-
Source	0.187	4	0.047	1.290 NS
Levels	0.019	2	0.010	0.272 NS
Interaction	0.323	8	0.040	1.110 NS
Error	1.010	28	0.036	

APPENDIX XVIII (c)

Analysis of variance table - 6 month stage - percentage nitrogen in stem

Source	SS	df	M.S	F
Replication	0.0060	2	0.00300	5.610**
Treatment	-	-	-	-
Source	0.2260	4	0.01600	30.160**
Levels	0.1260	2	0.01150	61.300 **
Interaction	0.0950	8	0.05700	3.114 NS
Error	0.0219	28	0.00078	

APPENDIX XVIII (d)

Analysis of variance table - 6 month stage - percentage nitrogen in tuber

Source	SS	df	M.S	F
Replication	0.312	2	0.1560	5.940**
Treatment	-	-	-	-
Source	0.210	4	0.0520	1.980 NS
Levels	0.019	2	0.0096	0.369 NS
Interaction	0.097	8	0.0120	0.464 NS
Error	0.735	28	0.0262	

** Significant at 0.01 level

APPENDIX XIX (a)

Analysis of variance table - 6 month stage - percentage potassium in leaf lamina

Source	SS	df	M.S	F
Replication	0.017	2	0.0087	0.370 NS
Treatment	-	-	-	-
Source	0.058	4	0.0150	0.617 NS
Levels	0.896	2	0.4480	19.010 **
Interaction	0.314	8	0.0393	1.668 NS
Error	0.659	28	0.0240	

APPENDIX XIX (b)

Analysis of variance table - 6 month stage - percentage potassium in leaf petiole

Source	SS	df	M.S	F
Replication	0.489	2	0.2440	4.730 NS
Treatment	-	-	-	-
Source	0.206	4	0.0517	1.001 NS
Levels	0.550	2	0.2750	5.320 **
Interaction	0.281	8	0.0351	0.680 NS
Error	1.450	28	0.0520	

** Significant at 0.01 level

APPENDIX XIX (c)

Analysis of variance table - 6 month stage - percentage potassium in stem

Source	SS	df	M.S	F
Replication	3.9200	2	0.0196	1.055 NS
Treatment	-	-	-	-
Source	0.0742	4	0.0185	0.999 NS
Levels	0.2500	2	0.1250	6.736 **
Interaction	0.1600	8	0.0200	1.007 NS
Error	0.5200	28	0.0186	

APPENDIX XIX (d)

Analysis of variance table - 6 month stage - percentage potassium in tuber

Replication	0.0916	2	0.0458	0.720 NS
Treatments	-	-	-	-
Source	0.1180	4	0.0297	0.467 NS
Levels	0.3930	2	0.1960	3.089 NS
Interaction	0.3740	8	0.0470	0.734 NS
Error	1.7820	28	0.0637	

** Significant at 0.01 level

APPENDIX XX (a)

Analysis of variance table - harvest stage - percentage nitrogen in leaf lamina

Source	SS	df	M.S	F
Replication	0.10009	2	0.050	0.113 NS
Treatment	-	-	-	-
Source	2.35000	4	0.587	1.325 NS
Levels	0.74300	2	0.371	0.838 NS
Interaction	3.81300	8	0.477	1.076 NS
Error	12.40300	28	0.443	

APPENDIX XX (b)

Analysis of variance table - harvest stage - percentage nitrogen in leaf petiole

Source	SS	df	M.S	F
Replication	0.2330	2	0.1170	5.042 NS
Treatment	-	-	-	-
Source	0.0903	4	0.0225	0.978 NS
Levels	0.0047	2	0.0024	0.102 NS
Interaction	0.0670	8	0.0860	0.360 NS
Error	0.6470	28	0.0230	

APPENDIX XX (c)

Analysis of variance table – harvest stage – percentage nitrogen in stem

Source	SS	df	M.S	F
Replication	0.4240	2	0.2120	3.185 NS
Treatment	-	-	-	-
Source	0.2350	4	0.0589	0.885 NS
Level	0.0772	2	0.0386	0.579 NS
Interaction	0.2950	8	0.0365	0.554 NS
Error	1.8600	28	0.0665	

APPENDIX XX (d)

Analysis of variance table – harvest stage – percentage nitrogen in tuber

Source	SS	df	M.S	F
Replication	0.0905	2	0.0452	3.097 NS
Treatment	-	-	-	-
Source	0.0318	4	0.0079	0.544 NS
Levels	0.0330	2	0.0167	1.139 NS
Interaction	0.1480	8	0.0186	1.270 NS
Error	0.4090	28	0.0146	

APPENDIX XXI (a)

Analysis of variance table - harvest stage - percentage potassium in leaf lamina

Source	SS	df	M.S	F
Block	0.2150	2	0.1073	8.130**
Treatment	-	-	-	-
Source	0.2010	4	0.0503	3.812 *
Levels	0.0325	2	0.0160	1.231 NS
Interaction	0.2140	8	0.0268	2.030 NS
Error	0.3690	28	0.0132	

APPENDIX XXI (b)

Analysis of variance table - harvest stage - percentage potassium in leaf petiole

Source	SS	df	M.S	F
Block	1.470	2	0.733	5.168 NS
Treatment	-	-	-	-
Source	0.289	4	0.072	0.508 NS
Levels	0.187	2	0.093	0.658 NS
Interaction	0.450	8	0.056	0.396 NS
Error	3.970	28	0.142	

* Significant at 0.05 level

** Significant at 0.01 level

APPENDIX XXI (c)

Analysis of variance table - harvest stage - percentage potassium in stem

Source	SS	df	M.S	F
Block	0.1938	2	0.0969	5.220 NS
Treatment	-	-	-	-
Source	0.2720	4	0.0679	3.660 *
Levels	0.1216	2	0.0608	3.280 NS
Ineraction	0.0519	8	0.0064	0.350 NS
Error	0.5190	28	0.0185	

APPENDIX XXI (d)

Analysis of variance table - harvest stage - percentage potassium in tuber

Source	SS	df	M.S	F
Block	0.0307	2	0.0154	0.32200NS
Treatment	-	-	-	-
Source	0.2770	4	0.0690	1.4520 NS
Levels	0.0507	2	0.0250	0.5314 NS
Interaction	0.4140	8	0.0518	1.0840 NS
Error	1.3400	28	0.0478	

* Significant at 0.05 level

APPENDIX XXII

Analysis of variance table - uptake of Nitrogen at 3 month stage

Source	SS	df	M.S	F
Block	36.24	2	18.120	10.3925**
Treatments	-	-	-	-
Source	63.17	4	15.790	99.0561**
Levels	103.78	2	51.890	29.7585**
Interaction	4.64	8	0.5790	0.3326 NS
Error	48.82	28	1.740	

APPENDIX XXIII

Analysis of variance table - uptake of Nitrogen at 6 month stage

Source	SS	df	M.S	F
Block	60.17	2	30.09	11.9388**
Treatment	-	-	-	-
Source	41.09	4	10.27	4.0768*
Levels	166.22	2	83.11	32.9800**
Interaction	33.77	8	4.22	1.6750 NS
Error	70.56	28	2.52	

* Significant at 0.05 level

** Significant at 0.01 level

APPENDIX XXIV

Analysis of variance table - uptake of Nitrogen at harvest stage

Source	SS	df	M.S	F
Block	3.44	2	1.72	0.551 NS
Treatment	-	-	-	-
Source	57.75	4	14.44	4.6287 **
Levels	166.74	2	83.37	26.7262 **
Interaction	16.44	8	2.05	0.6588 NS
Error	87.34	28	3.12	

APPENDIX XXV

Analysis of variance table - uptake of potassium at 3 month stage

Source	SS	df	M.S	F
Block	72.46	2	36.23	11.4460 **
Treatment	-	-	-	-
Source	91.32	4	22.83	7.2128 **
Levels	64.50	2	32.25	10.1900 **
Interaction	19.40	8	2.43	0.7660 NS
Error	88.63	28	3.17	

* Significant at 0.05 level

** Significant at 0.01 level

APPENDIX XXVI

Analysis of variance table - uptake of potassium at 6 month stage

Source	SS	df	M.S	F
Block	56.59	2	28.29	5.47*
Treatment	-	-	-	-
Source	100.49	4	25.12	4.86**
Levels	211.43	2	105.71	20.45**
Interaction	76.14	8	9.52	1.84 NS
Error	144.75	28	5.17	

APPENDIX XXVII

Analysis of variance table - uptake of potassium - at harvest stage

Source	SS	df	M.S	F
Block	8.34	2	4.1709	0.8426 NS
Treatment	-	-	-	-
Source	80.81	4	20.2000	4.0810**
Levels	197.59	2	98.7900	19.9579**
Interaction	42.07	8	5.2600	1.0624 NS
Error	138.61	28	4.9500	

* Significant at 0.05 level

** Significant at 0.01 level

APPENDIX XXVIII

Analysis of variance table - Available nitrogen in soil at 3 months stage

Source	SS	df	M.S.	F
Replication	5585.06	2	2792.53	2.186 NS
Treatment	44751.44	14	3196.53	2.500
Source	15559.50	4	3889.89	3.645*
Levels	18918.58	2	9459.29	7.406**
Interaction	10273.36	8	1284.17	1.005 NS
Error	3576.51	28	1277.33	

APPENDIX XXIX

Analysis of variance table - Available potassium in soil at 3 month stage

Source	SS	df	M.S.	F
Replication	4688.60	2	2344.30	1.67 NS
Treatment	21189.63	14	1513.55	1.06 NS
Source	5617.32	4	1414.33	1.00 NS
Levels	14226.58	2	7113.29	4.96*
Interaction	1345.73	8	168.22	1.00 NS
Error	40162.07	28	1434.36	

* Significant at 0.05 level

** Significant at 0.01 level

APPENDIX XXX

Analysis of variance table - Tuber yield (kg/plant)

Source	SS	df	M.S.	F
Block	0.083	2	0.0417	1.0619 NS
Treatment	-	-	-	-
Source	0.579	4	0.1450	3.6846*
Levels	3.290	2	1.6470	41.9614**
Interaction	0.3457	8	0.0432	1.1009 NS
Error	1.090	28	0.0393	

APPENDIX XXXI

Analysis of variance table - Number of tubers/plant

Source	SS	df	M.S.	F
Replication	4.030	2	2.020	1.37 NS
Treatment	-	-	-	-
Source	1.490	4	0.372	0.252 NS
Levels	5.334	2	2.668	1.806 NS
Interaction	4.410	8	0.551	0.373 NS
Error	41.350	28	1.480	

* Significant at 0.05 level

** Significant at 0.01 level

APPENDIX XXXII

Analysis of variance table - Ratio of root dry weight to top dry weight

Source	SS	df	M.S.	F
Replication	3.980	2	1.99	0.85 NS
Treatment	-	-	-	-
Source	29.024	4	7.26	3.09*
Levels	9.350	2	4.67	1.99 NS
Interaction	36.35	8	4.54	1.94 NS
Error	65.65	28	2.34	

APPENDIX XXXIII

Analysis of variance table - Percentage drymatter of tuber

Source	SS	df	M.S.	F
Block	1.840	2	0.92	0.6772 NS
Treatment	-	-	-	-
Source	0.661	4	0.17	0.1216 NS
Levels	7.180	2	3.60	2.6431 NS
Interaction	5.420	8	0.68	0.4982 NS
Error	38.040	28	1.36	

* Significant at 0.05 level

APPENDIX XXXIV

Analysis of variance table - Percentage of starch in tuber (dry weight basis)

Source	SS	df	M.S.	F
Block	0.088	2	0.020	0.2761 NS
Treatment	-	-	-	-
Source	1.150	4	0.290	3.2562*
Levels	2.810	2	1.400	15.8700**
Interaction	0.910	8	0.114	1.2919 NS
Error	2.480	28	0.088	

APPENDIX XXXV

Analysis of variance table - Crude protein percentage in tuber

Source	SS	df	M.S.	F
Block	0.310	2	0.160	4.6680*
Treatment	-	-	-	-
Source	0.269	4	0.067	2.0200 NS
Levels	1.150	2	0.580	17.3310**
Interaction	0.270	8	0.034	1.0089 NS
Error	0.933	28	0.033	

* Significant at 0.05 level

** Significant at 0.01 level

APPENDIX XXXVI

Analysis of variance table - HCN content of tuber

Source	SS	df	M.S.	F
Block	0.1	2	0.05	0.0202 NS
Treatment	-	-	-	-
Source	33.41	4	8.35	3.3863*
Levels	116.10	2	58.05	23.5338**
Interaction	31.12	8	3.89	1.5771 NS
Error	69.07	28	2.467	

* Significant at 0.05 level

** Significant at 0.01 level

Plate - I

n_3 - Full dose of Nitrogen - 50 kg/ha.

1. Urea alone. 2. Urea+Mahua cake

3. Urea+Neem cake. 4. Urea+Maroti cake.

Plate - II

n_2 - 3/4 dose of Nitrogen - 37.5 kg/ha.

1. Urea alone. 2. Urea+Mahua cake.

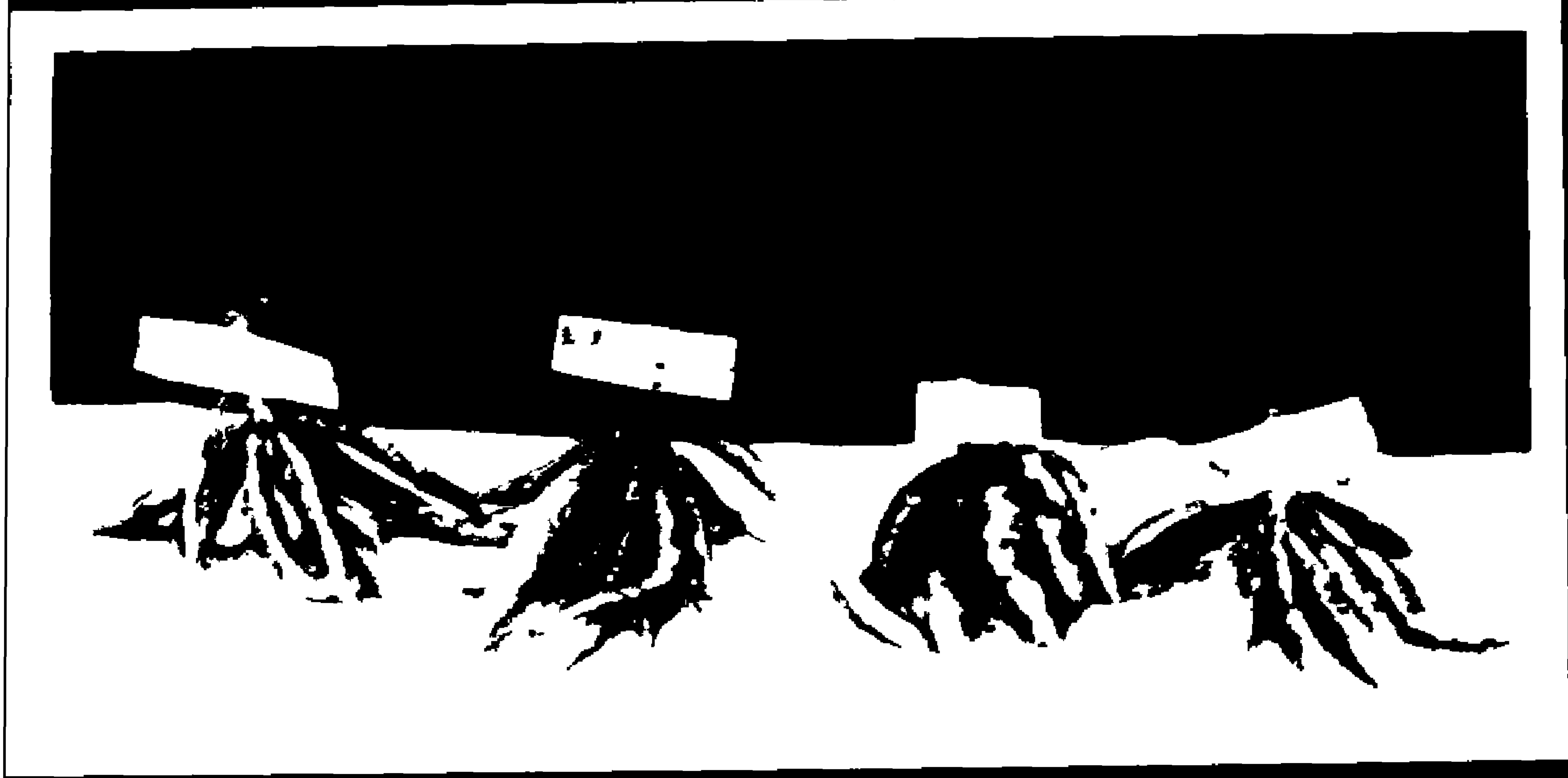
3. Urea+Neem cake. 4. Urea+Maroti cake.

Plate - III

n_1 - 1/2 dose of Nitrogen - 25 kg/ha.

1. Urea alone. 2. Urea+Mahua cake.

3. Urea+Neem cake. 4. Urea + Maroti cake.



INCREASING NITROGEN USE EFFICIENCY IN UPLAND SOILS

By

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ABSTRACT OF A THESIS

Submitted in partial fulfilment of the requirement for the degree

Master of Science in Agriculture

Faculty of Agriculture
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1982

ABSTRACT

Increasing nitrogen use efficiency in upland soils

An investigation was carried out at the College of Agriculture, Vellayani, during the year 1980-81 to study the efficacy of the use of some of the commonly available non-edible oilcakes as nitrification inhibitors to increase the nitrogen use efficiency in rainfed upland soils of Kerala.

Urea was mixed with neem, mahua, maroti, rubber or karinja cakes at 5:1, 5:2 and 5:3 ratios (urea : oil-cake) to obtain a blend. The mineralisation pattern of those blends were studied along with untreated urea in an incubation study in a typical red loam upland soil kept at 60 per cent field moisture capacity to screen them for nitrification inhibitory properties. Selected blends at the most efficient ratio of mixing were tried in the field at 3 levels of nitrogen supply with cassava as the test crop. The experiment was laid out in randomised block design in factorial structure.

All the oilcakes tried showed nitrification inhibitory property at varying degrees. The descending

order of inhibition capacity was found as neem mahua maroti rubber and karinja. Narrowing the ratio of mixing urea with oilcakes, increased the inhibition capacity of all the oilcakes except that of maroti cake which showed maximum inhibition at 5:2 ratio.

Urea-neem blend followed by unrea-mahua blend retained more nitrogen in ammoniacal form than other oilcake blends and untreated urea, upto a period of one month after the application of both basal as well as top dressing of fertilizers.

Favourable influences of the incremental supply of nitrogen and the treatment of urea with oilcakes, especially with neem or mahua cakes on growth characters like hight of plants, number of leaves and total dry matter production were observed.

Available nitrogen in soil at the three month stage of the crop was favourably influenced by oilcake treatments, but a depressing trend for available potassium content was noticed. Neem-urea blend recorded the maximum tuber yield, but it was found statistically on par with untreated urea, which showed the maximum root to top dry weight ratio.

Urea-oilcake blends in general recorded a higher crude protein and HCN contents in tubers, but registered a lower starch content and dry matter percentage.