DYNAMICS OF APPLIED NITROGEN IN ACIDIC SOILS OF KUTTANAD

I. KARAPPADOM SOIL

By

LIJI JOHN

THESIS

submitted in partial fulfilment of
the requirement for the degree of

Master of Science in Agriculture

Faculty of Agriculture
Kerala Agricultural University

Department of Agronomy
COLLEGE OF HORTICULTURE
Vellanikkara - Trichur

1987

DECLARATION

I hereby declare that this thesis entitled "Dynamics of applied nitrogen in acidic soils of Kuttanad. I. Karappadom soil" 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 any other similar title, of any other University or Society.

Vellanikkara,
July -1987.

(LIJI JOHN)

CERTIFICATE

Certified that the thesis entitled "Dynamics of applied nitrogen in acidic soils of Kuttanad. I. Karappadom soil" is a record of research work done by Ms. LIJI JOHN, under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to her.

Vellanikkara,
-1987.

Dr. J. THOMAS,
Chairman, Advisory Board,
Assistant Professor of Agronomy,
College of Horticulture,
Trichur.

CERTIFICATE

We, the undersigned, members of the Advisory Committee of Ms. LIJI JOHN, a candidate for the degree of Master of Science in Agriculture with major in Agronomy, agree that the thesis entitled 'Dynamics of applied nitrogen in acidic soils of Kuttanad. I. Karappadom Soil' may be submitted by Ms. LIJI JOHN, in partial fulfilment of the requirement for the degree.

CHAIRMAN : . . . .
Dr. J. THOMAS

MEMBERS : . . . .
Dr. R. VIKRAMAN NAIR

. . . .
Dr. (Mrs) P. PADMAJA

. . . .
Dr. P.A. WAHID

ACKNOWLEDGEMENTS

It gives me great pleasure to express my esteemed sense of gratitude to Dr. J. Thomas, Assistant Professor of Agronomy and Chairman of my Advisory Committee for his valuable guidance, critical suggestions and constant encouragement throughout the course of this investigation and preparation of the manuscript.

I extend my sincere thanks and express my indebtedness to Dr. C. Sreedharan, Professor and Head, Department of Agronomy for the sustained interest shown in the study. I am specially thankful to the members of my Advisory Committee, Dr. R. Vikraman Nair, Professor of Agronomy, Dr.(Mrs) P.Padmaja, Professor and Project Co-ordinator (Soils and Agronomy) and Dr. P.A. Wahid, Professor, Radio Tracer Laboratory, for the guidance and suggestions rendered during the various stages of work.

It is with pleasure that I express my heartfelt thanks to each and every staff member of the Department of Agronomy and Chemistry for the co-operation extended throughout the period of this investigation.

My thanks are due to all friends and colleagues for their help at various stages of this study.

I also place a record of thanks to Miss. Mariyamma, A.X., for the neat typing and prompt service.

The Junior Research Fellowship awarded by ICAR, during the period of my study is duly acknowledged.

It is with gratitude that I remember the warm blessings of my parents and constant encouragement of my sister, in-laws and husband, without which I would not have completed my M.Sc. degree programme.

Above all, I bow my head before The Lord Almighty who blessed me with sufficient health and gave me confidence to carry out the work successfully.

LIJI JOHN.

CONTENTS

LIST OF TABLES

.....

LIST OF FIGURES

.....

INTRODUCTION

INTRODUCTION

Kuttanad, the rice bowl of Kerala comprising an area of approximately 870 sq. km is a unique agricultural region in the world. Practically the whole of this area lies at a depth of 3 - 4 feet below sea level and for the major part of the year remains submerged under water.

Paddy is the most important crop in this region producing about 1.5 lakh tonnes of rice contributing one seventh of the States total. The agricultural operations commence at the close of the rainy season, with the strengthening of the mud embankments around the fields. The water within the embankment is then pumped out and sprouted paddy seeds are sown. During the growth period of the crop, water stands at a depth of 5 - 7 feet outside the embankments, the waves lashing out against the bunds. For this reason, paddy cultivation in this area is considered uncertain and risky. The harvest season, generally falls in February. After the harvest, sea water is allowed to get into the fields. Though this leads to a deterioration in soil structure, the practice has its own advantage, in that it prevents toxic salt accumulation on the surface soil.

With the construction of Thaneermukkom salt water barrier meant to halt salt water intrusion from the Arabian sea into Kuttanad's paddy fields in the summer and to regulate flow of flood water into the sea during the monsoons, it has been made possible to raise an additional crop in this area.

Origin of Kuttanad area as put forward by Velu Pillay (1940) in 'Travancore State Manual' is that the area was once a bay. The waters of Periyar and other rivers laden with sediments were discharged into this bay resulting in the formation of a sand bank linking up the nearest points of the land. The bay, thus eventually became a lagoon which gradually silted up and gave rise to the present wet paddy lands and coconut gardens.

The soils of Kuttanad tract come under clayey, mixed acidic isohyperthermic family of Tropic Fluvaquents. The factors which have been particularly dominant in the development of these soils are high rainfall, temperature, hydrological conditions and vegetation. The organic matter in these soils is resistant to decomposition and waxy in appearance, most of which is lignitic and ether soluble substances. The predominant clay is kaolinite.

Soils of Kuttanad are grouped into 3 categories 1) kari 2) Karappadom 3) kayal soils. Karappadom soils occur along the inland waterway and rivers, and are spread over a large part of the upper Kuttanad. Fertility problems of karappadom soils are connected with strong acidity, high lime requirements wide C:N ratio, low available nutrient status, high percentage saturation of hydrogen and aluminium ions. These characteristic properties are bound to have a profound influence on the nitrogen transformation in these soils (Kurup, 1967) and consequently the N uptake by rice crop.

Nitrogen efficiency in rice largely ranges between 25 to 30 per cent and seldom exceeds 50 per cent. The response and recovery of nitrogen in rice depends on the mechanism of transformation of added fertilizer material. Several nitrogen loss mechanisms operating in crop fields are largely responsible for low nitrogen recoveries. Hence it is highly essential that steps be taken to check these losses so that the Crops make efficient use of the fertilizer. High use efficiency of nitrogen by crops depends on good soil condition, adequate application of soil amendments, timely application of fertilisers, suitable method of application, use of nitrification inhibitors, coated or other modified forms of fertilisers.

Studies at Rice Research Station, Moncompu strategically located for catering the research needs of the Kuttanad rice cultivation have shown varying response to N application, its time, method of application and sources. Application of lime is an absolute necessity for raising rice crop in Kuttanad. Liming ameliorated soil acidity and augmented Ca and Mg status of soil. It has a profound influence on the lime potential and

N transormation in soils.

The commissioning of the Thaneermukkom bund and introduction of an additional crop by avoiding a period of flooding, has resulted in considerable variations in soil acidity and allied soil problems. In the changed situation of rice eco-system this study was taken up with the following objectives.

1. To understand the basic mechanism of transformation of applied nitrogen in karappadom soil.

2. To evaluate the best source of nitrogen for rice production.

3. To find out the effect of interaction of lime and nitrogen on the nitrogen use efficiency and yield of rice.

REVIEW OF LITERATURE

REVIEW OF LITERATURE

Kuttanad is formed by the deltaic deposition of four rivers - Pamba, Manimala, Meenachil and Achankovil. Being below sea level, intrusion of sea water is a problem for rice cultivation. The soil contains large deposits of sulphur, on drying sulphur dioxide is formed which gets converted to sulphuric acid on further reaction with water. A flooded soil is a dynamic heterogenous soil - water system with oxidised and reduced soil layers. The nitrogen transformations functioning in these layers are unique. Precise information on these aspects are meagre. A brief review of research works pertaining to the above situation is presented below.

Nitrogen nutrition of rice plant

Nutritional studies of rice plant has been a subject of interest from very long. Kumura (1956) found positive correlation between tiller number and nitrogen content during tillering. Tanaka *et al*. (1959) reported maximum tillering and panicle initiation as the two peaks of nitrogen uptake. Early application of nitrogen was found to promote leaf area expansion (Murata, 1961). Wada and Matsushima (1962) confirmed that the differentiation of spikelets was strongly promoted by nitrogen supply.

Singlachar (1973) noticed that medium duration varieties responded upto 150 kg N ha^{-1}. A similar response of medium duration varieties to 145 kg N ha^{-1} was reported by Sadayappan et al. (1974). Rethinam et al. (1975) reported higher response of dwarf indica varieties to higher levels of nitrogen upto 150 kg N ha^{-1}. According to Roy et al. (1977) application of nitrogen in split doses at planting, tillering, panicle initiation and boot stage gave high grain yield of rice. Studies by Ando et al (1978) revealed that at tillering stage all ammoniacal nitrogen was used and that its supply controlled the attainment of greatest number of tillers.

Nitrogen fertilisers increased grain yield in rice (Saho et al. 1980; Kumar and Sharma, 1980; Snitwogse and Jirathana, 1981; Pandey and Dayanand, 1984; Kaushik et al., 1984). Gales (1983) found that leaf expansion was mainly dependent on temperature, plant water stress and nitrogen absorption. Reddy and Mittra (1985) confirmed from their studies that crop fertilised with nitrogen produced more tillers and grain yield.

This reveals that nitrogen fertilisers play an important role in the nutrition and growth of rice plants, leading to increased grain and straw yields when supplied timely.

Losses of nitrogen from soil.

Loss of nitrogen occurs through volatilization denitrification, leaching and run-off, and fixation. Gaseous loss of ammonia occured from nitrogen fertilisers applied to soils (Kresge and Satchell, 1960; Reddy and Patrick, 1980; Criag and Wollum, 1982; Ellington, 1986). High losses of nitrogen under conditions of alternate wetting and drying has been reported by many workers (Prasade and Rajale, 1972; Reddy and Patrick, 1975; Tisdale and Nelson, 1975). Drainage studies in heavily manured rice fields revealed that during monsoon crop season, the extent of nitrogen loss from a low land rice field through leaching was 42 kg N ha^{-1} (Chakravorthy _et al_., 1973). Large quantities of N was reported to be lost due to leaching (Yatazawa, 1977; Misra, 1980). Nitrogen was lost in run-off in Japan (Takamura _et al_., 1977). Singh (1978) observed that a mean loss of 3 kg N ha^{-1} occurred due to surface run-off in Philippines. Padmaja and Koshy (1978) reported that a maximum run-off of 70 per cent nitrogen occurred if the surface water was drained on the same day of fertiliser application. Fertilizer nitrogen entering the inorganic nitrogen pool was subjected to biological interchange with soil organic fraction (Saito and Watanabe, 1978). Ammonium fixation was yet another channel of nitrogen loss (Broadbent, 1979). Maximum nitrogen losses from nitrite decomposition occurred at about a pH of 5, at lower pH, below 4, nitrification predominated and nitrogen losses decreased (Ivanov, 1981). Denitrification losses were greater in undrained and irrigated land, after direct drilling, and following fertiliser application (Colbourn and Dowdell, 1984). About 10 per cent of the nitrogen applied as ammonium sulphate was lost as nitrogen, by denitrification in 60 days (Mian, 1985). Results of studies by Reddy and Patrick (1986) presented an indirect evidence that the process of rhizosphere nitrification-denitrification was active in rice, resulting in a significant amount of nitrogen loss.

Due to these losses of nitrogen occurring in different ways from paddy fields, nitrogen fertilizers are used less efficiently in this system than in any other food producing eco-system.

Nitrogen use efficiency in rice

Plant recovery of applied nitrogen is dependent on soil, climate and cultural practices. Studies in this field from year back, has revealed that the recovery of nitrogen was very low. Patrick and Wyatt (1964) found that 20 per cent of the total soil nitrogen was lost by drying and water-logging of soil alone. Under low land rice cultivation, the efficiency of applied nitrogen was only 10 to 50 per cent (Reddy and Patrick, 1977). Meelu (1980) observed that nitrogen recovered by rice under pot culture experiments varied from 25.9 per cent to 59.8 per cent. The nitrogen use efficiency in rice was less than 50 per cent (Mahendra and Singh, 1985). As nitrogenous fertilizers contribute to a substantial proportion of the cost of cultivation of rice and only a portion of the applied nitrogen is being utilised by rice plant, as evident from the low recovery, it is necessary to increase the efficiency of applied nitrogen.

Methods of increasing nitrogen use efficiency includes split application, placement, foliar application, use of nitrification inhibitors and slow release nitrogen fertilisers (Oertti 1980; Surendra and Prasad, 1984).

Abraham et al. (1975) found that the application of 40 kg N ha^{-1} as neem coated urea was equivalent to 80 kg N ha^{-1} as urea. Urea treated with neem cake increased grain yield of paddy (Kulkarni et al., 1975; Shanker et al., 1976; Jadhav et al., 1983). Neem cake treated urea was superior to mahua cake extract treated urea (Manickan et al., 1976). Chakravorthi (1979) reported higher efficiency of ammonium sulphate, when blended with neem cake. Studies by Sharma and Prasad (1980) and Pandey and Dayanand (1980) revealed that neem coated urea increased paddy yields. According to Sinha et al. (1980) neem cake has nitrification inhibition properties and blending with urea helped in conserving ammoniacal nitrogen in soil.

Blending neem cake with urea gave significant yield advantage and savings in nitrogen, in experiments conducted in farmers' field at different locations in Kuttanad (Operational Research Project Report, 1980). Increasing the efficiency of nitrogen by blending urea with neem cake has been reported by Prasad (1980). In an AICRIP trial conducted during 1983-84 at Mancompu, highest yields were obtained when coal tar urea was used as source of nitrogen. Rao and Shinde (1985) showed that neem cake coated urea was effective in controlling leaching loss. Studies on the effect of split application of nitrogen for high yielding varieties conducted at Mancompu during 1968-'71, 1974-'78 and 1983-'86 showed no significant difference between times of application. (Koruth, Personal communication)

Rock phosphate increased grain yields in Kuttanad (Kurup and Ramankutty, 1969). Sharma (1973) has shown that application of sulphur coated urea is superior to urea applied in a single dressing or split doses. Mahajan and Kaistha (1974) concluded that urea and ammonium sulphate were better than calcium ammonium nitrate, Raghavalu and Sreeram Murthy (1975) experimenting with different sources of nitrogen for low land rice found ammonium sulphate superior to urea, and calcium ammonium nitrate. According to Saksena and Mehrotra (1978) applied nitrogen were heavily lost from urea than ammonium sulphate. Chahal et al. (1982) found that basal dose of neem coated urea and rock phosphate coated urea equally effective as urea applied as best split. Primed rock phosphate was found to be as efficient as superphosphate in Karappadom, Kayal and coastal sandy soil in increasing rice yields (Madhusoodhanan and Padmaja, 1982). Subbian (1983) comparing different forms of nitrogenous fertilizers showed that rock phosphate coated urea was the best among the sources tried and gypsum coated urea also showed promise. Puchades et al. (1984) found that nitrogen release from sulphur coated urea was slow and that after three months 29.5 per cent of the applied nitrogen remained in the granules. Singh and Yadav (1985) recommending ways of increasing nitrogen use efficiency in low land rice, high lighted the promise of rock phosphate and gypsum coated urea.

Thus it can be concluded that these products go a long way by releasing nitrogen from fertilisers slowly. In soil, they undergo slow mineralisation or inhibits nitrification and improves the use efficiency of nitrogen by plants.

Effect of submergence on soil properties and nitrogen transformation

The biological and physiochemical changes that accompany waterlogging are important in determining the suitability of the soil for crop production. The availability of several plant nutrients and the production of toxic substances are influenced by the restriction in soil aeration resulting from submergence.

The decomposition of organic matter leading to release of ammonium ions proceeds at a slow rate in a waterlogged soil (Tenny and Waksman, 1930). Nitrate in a water logged soil was found to be unstable and hence easily lost reports Patrick (1960). Due to flooding air movement through the flood water was restricted and the soil has no longer adequate supply of oxygen. Then facultative and true anaerobes became active. If reduction was intense, sulphate was reduced to sulfide. The pH values were higher and had narrower range than that of well drained soils (Reddy and Patrick, 1975). Soil submergence brought about considerable changes in electrochemical and chemical properties of soil which affected the plant nutrition considerably (Ponnamperuma, 1972). A less efficient group of organism with a low nitrogen requirement was involved in anaerobic organic matter decomposition in waterlogged soils (Alexander, 1977).

Patrick (1964) reports that pH changed from 4.6 at the most oxidised potential to 7.0 at the most reduced potential. The production of hydroxyl ions as a result of reduction of ferric and manganic compounds and production of ammonia could account for pH rises of 1.6 units in acid soils (Redman and Patrick, 1965). The pH values of flooded soil was sensitive to loss of carbondioxide and in most reduced soils it equilibrated with carbondioxide at one atmosphere and the value was 6.1 (Reddy and Patrick, 1975). Sunil et al. (1982) reported that during submergence of soils under lab conditions soil pH gradually increased to stabilised values in the neutral range. Kabeerthuma and Patnaik (1982) noted that in acid soils, the pH increased on flooding. At 37°C, the onset and complete reduction of nitrate was most rapidly effected at pH 7.5 while higher or lower pH values delayed the onset and decreased the rate of nitrate reduction (Usha and Alan, 1982). Campbell and Zenter (1984) and Wickramsinghe et al. (1985) reported that soil pH is inversely related to soil nitrate nitrogen. Studies by Martikainer (1985) showed that nitrification was inhibited by ammonium sulphate and Potassium sulphate added to soil from organic horizon of a pine forest at pH 4.7 but stimulated at pH 6.6 and that soil pH was decreased by salts but increased by urea. According to Goodroad, and Keeney (1984) and Roseberg and Christensen (1986) the rate of nitrification of added ammoniacal nitrogen increased with increasing soil pH and nitrification was much slower in strongly acidic soil than in near neutral soil.

Submergence for 30 days increased specific conductivity values and it was closely related to the organic matter content of soil. Organic matter influenced specific conductivity in 2 ways - by production of ionisable reduced organic materials and by serving as an energy source for reduction of inorganic compounds to more soluble forms (Redman and Patrick, 1965). The increase in conductance during the first few weeks after flooding was due to release of Fe^{+2} and Mn^{+2} following reduction of insoluble iron and managenese hydrous oxide, displacement of cations from soil colloids by Fe^{+2} and Mn^{+2} (Ponnamperuma, 1977). Sunil et al. (1982) reported that due to submergence the electrical conductivity of soils was almost doubled and reached peak values by 4th week and remained so upto 5 weeks and then decreased. Salts increased electrical conductivity of soil in acid conditions, and the salts had inhibitory effect on nitrification (Martikainer, 1985).

Redman and Patrick (1965) found that the redox potential decreased from high values immediately after flooding to very low values after 30 days. Iron compounds were active in retarding decline of redox potential after submergence. Redox potential of highly reduced soils was increased by addition of nitrate. According to Van Cleemput and Patrick (1974) nitrate reduction rate increased with increasing pH and decreasing redox potential. Reddy and Patrick (1975) reported that, for continuously anaerobic condition, the potential decreased rapidly to -300 mv and remained constant thereafter. Studies by Reddy and Patrick (1976) revealed that redox potential values below +340 mv was favourable for denitrification. Ponnamperuma (1977) found that redox potential affects nitrogen status of the soil, availability of phosphorus and silicon and generation of organic acids and hydrogen sulphite. Buresh and Patrick (1981) concluded that denitification is dominant in soils with Eh less than -100 mv. Reddy and Patrick (1926) confirmed from their works that an Eh value of 300 mv at pH 7 was the break point between oxidised and reduced zones.

Thus it can be summarised that submergence has profound influence on the physico-chemical properties of rice soil which in turn affect nitrogen transformations in the soil.

Effect of liming on soil properties and nitrogen transformation

Soil acidity is common in all regions were precipitation is high enough to leach appreciable amounts of exchangeable bases from the surface layers of soils. It has been proved that liming has a direct influence on the nitrogen transformations in acidic soils (Tisdale and Nelson, 1975). Studies by Murali and Nielsen (1978) revealed that nitrogen content in aerial parts of soybean increased with liming acid sulphate soil. Murphy and Follet (1979) found that liming of soil reduces acidity and stimulated nitrogen fixation. According to Thiagalingam et al. (1979) growth of rice and soil pH were increased by application of lime to flooded acid sulphate soil. Rice yields increased on liming acidic soils (Gajbhiye, 1980). Merzlyakov et al. (1981) noticed that application of lime or open-hearth slag increased the uptake of soil and fertilizer nitrogen. Studies by Attanandana and Vacharotayan (1984) revealed that liming was very necessary for soils with pH less than 4.5 for good yields. Subba Rao and Ahmed (1984) concluded that raising the pH of extremely acidic soils from 4 to 5 with $Ca(OH)_2$ and NaOH solutions resulted in sharp increase in urea adsorption. Liming acidic soils increased the pH (Chanchareonsook and Panichsakpatna, 1984; Datta, 1984; and Maria et al. (1985). The favourable results produced due to liming of acid soils could be attributed to a four fold change as described by Baligar and Bennett (1986).

1. Eliminates acidity and reduces toxicity of aluminium and manganese.
2. Improves structure and calcium, phosphorus and molybdenum availability.
3. Creates favourable conditions for symbiotic nitrogen fixation.
4. Reduces availability of zinc, manganese and copper.

Experiments conducted at Kuttanad revealed that liming was essential for better nutrient availability and yield increase. Due to the high acidity in these soils depletion of exchangeable bases, nutrient status and plant available nutrients show extreme variations depending on the vagaries of tropical conditions.

Liming experiments conducted by Subramoney and Sankaranarayanan (1963) concluded that fully burnt lime, when applied at sowing gives maximum benefit. Anandavalli *et al.* (1966) reported that the application of lime to Kuttanad soils increased the available nitrogen in soil Kurup (1967) in his studies revealed that liming favoured mineralisation of soil nitrogen. Kabeerthuma (1969) reported that liming increased the availability of nitrogen by enhancing the mineralisation of organic matter. Sukumaran *et. al* (1971) and Kabeerthuma and Chithranjan (1973) found that lime application to kari and karappadom soils had beneficial effects on growing rice and that the optimum dose of lime for maximum efficiency was half the lime requirement for karappadom soils. Kuruvilla (1973) suggested that acid sulphate soils of Kerala could be ameliorated for growing good rice crop by leaching of salts followed by application of lime and continuous flooding. Kabeerthuma and Patnaik (1982) noted, in acid soils that the pH increased on flooding. Liming ameliorated soil acidity and augumented the calcium and magnesium status and lime potential in soil (Datta and Gupta, 1983).

From the above review it can be concluded that liming plays a definite role in acidic soils in modifying the soil properties and making conditions suitable for availability of other nutrients. It also plays a major role in the nitrogen transformation. Hence it is necessary that such soils be limed for better yields.

MATERIALS AND METHODS

MATERIALS AND METHODS

The present study was aimed at studying the mineralisation pattern of different sources of nitrogen in karappadom soils and their interaction with lime.

The study comprised of two parts.

A. Laboratory experiments

B. Pot - culture experiment

The experiments were conducted during the period from January 1986 to December 1986, at the College of Horticulture, Vellanikkara, Trichur.

The soil for both the experiments was collected during the month of December 1985 from the Rice Research Station, Mancompu, from a site where bulk crop of rice was grown. The soil taken from the top 15 cm depth was air dried under shade, sieved through 2 mm sieve and utilised for the study. Mechanical composition and important characteristics of the soil are given in Table 1.

Table 1. Physico-chemical properties of the soil.

A. <u>Physical characteristics</u>

Mechanical composition (International pipe te method, piper 1950)	
Coarse sand	10.4%
Fine sand	19.53%

Table 1 (contd.)

Silt	25.55%
Clay	40.82%
Textural class	Clayey
Moisture at 1/3 atmospheric tension (Pressure plate apparatus, Richards, 1948)	14.98%
Moisture at 15 atmospheric tension (Pressure membrane apparatus, Richards, 1947)	9.68%
Water holding capacity (maximum)	35.4%
B. Chemical characteristics	
pH (1:2.5 soil water suspension) (Elico pH meter, Jackson, 1958)	4.5
Electrical conductivity (1:2.5 soil water, suspension) (Direct reading conductivity bridge, Jackson, 1958)	0.3 mmhos/cm
Cation exchange capacity	27.23 me/100g
Organic carbon (Walkley and Black Method, Piper, 1950)	1.36%
Total nitrogen (Macro-Kjeldhal, Jackson, 1958)	0.37%
Available phosphorus (Bray I extract) (Chlorostannous reduced molybdophosphoric blue colour method, Jackson, 1958)	11.66 kg ha^{-1}
Available potassium (Neutral normal ammonium acetate) (Flame photometric Method, Jackson, 1958)	125 kg ha^{-1}

A. LABORATORY EXPERIMENTS

Laboratory incubation study was undertaken to study the pattern of transformation of nitrogen applied through different fertiliser sources under limed and no-lime conditions and also under two different moisture regimes.

The treatments were:

1. No nitrogen - control (L_oC)
2. Lime + no nitrogen-control (LC)
3. Urea (L_oU)
4. Lime + Urea (LU)
5. Ammonium sulphate (L_oAS)
6. Lime + ammonium sulphate (LAS)
7. Neem coated urea (L_oNCU)
8. Lime + Neem coated Urea (LNCU)
9. Neem coated ammonium sulphate (L_oNCA)
10. Lime + Neem coated ammonium sulphate (LNCA)
11. Gypsum coated urea (L_oGCU)
12. Lime + Gypsum coated urea (LGCU)
13. Rock phosphate coated urea (L_oRPU)
14. Lime + Rock phosphate coated urea (LRPU)

One set of treatments were kept at complete submergence and the other at 70 per cent of field moisture capacity.

<u>Experiment (1)</u> Studies on soil reaction of karappadom soil

This experiment was aimed at studying the change in pH due to submergence and liming of soil and its consequent effect on the transformation of different N fertiliser materials. Soil water suspension (1:1) was used to determine the pH of soil in all treatments. The pH reading was taken at periodic intervals using Elico pH meter.

Experiment (2) Studies on the redox-potential (Eh) of karappadom soil

This experiment was to study the change in Eh due to submergence of soil and its effect on the transformation of different N fertilizer materials over a period of time. (30 days) Soil-Water suspension (1:1) was used. The Eh readings were taken using platinum-reference combination electrode in an exidation Reduction Potential meter. Model RM-1K of TOA Electronics Ltd. (The reference electrode is silver - silver chloride electrode). The values were corrected with respect to the potential of standard H^+ ion electrode.

Experiment (3) Studies on the electrical conductivity (EC) of Karappadom soil

This experiment was intended to study the change in electrical conductivity due to submergence and the effect of N fertilizer materials and lime on the change in EC. Soil water suspension (1:2.5) was used. The EC of the suspension was measured using direct reading conductivity meter.

Experiment (4) Studies on the nitrifying organism of karappadom soil

Nitrifying bacteria, being difficult to isolate they are usually detected in soil by suitable tests and determining their most probable numbers (MPN). In this experiment serial dilutions of 10 g soil sample were made and 1 ml aliquots of each dilution were transfered into test tubes containing 3 ml sterilised NH_4 - $CaCO_3$ medium. The tubes were plugged and incubated for 3 weeks, at 28°C for determining MPN of Nitrosomonas. In the case of MPN for Nitrobacter, NO_2 - $CaCO_3$ medium was used to enumerate the organism. At the end of the incubation, they were tested with Griess-Illosvay reagent and the negative and positive tubes were marked. Based on the data the MPN was calculated from table provided by Alexander (1965).

Experiment (5) Nitrogen transformations in karappadom soils at submerged moisture regime.

Soil samples (20 g) were mixed with required quantities of different sources as per treatments to give a final concentration of 100 ppm N with respect to soil, and kept in plastic containers. Lime was added at the rate of 1000 kg ha^{-1}. In the case of neem coated urea and neem coated ammonium sulphate, neem was coated at the rate of 20 per cent by weight of urea and ammonium sulphate. After the addition of lime, the soils were kept submerged for 7 days, prior to the addition of the fertiliser material. Absolute care was taken to maintain equal quantity of water in all containers by adding distilled water. Sufficient number of replications were kept, so as to remove duplicate samples at different intervals for 3 months. Samples were analysed for ammoniacal, nitrite and nitrate nitrogen.

Experiment (6) Nitrogen transformation in karappadom soils at non-submerged moisture regime.

Soil samples were incubated in the similar way, as in experiment 5, but, here appropriate quantity of distilled water was added to maintain the soil at 70 per cent of field capacity. Samples were drawn in duplicate and estimations were carried out as in experiment 5.

Soil analysis

To 20 g soil, 2 M neutral KCl solution was added and extracted for one hour. It was fittered through Whatman No.42 filter paper and the extract was used for analysis (Bremner, 1965). Ammoniacal nitrogen was estimated by steam distillation (Bremner, 1965), nitrate nitrogen by chromotropic acid method (Sims and Jackson, 1971) and nitrite nitrogen by Griess Illosvay method (Bremner, 1965).

B. POT-CULTURE EXPERIMENT

A pot culture study was conducted to find out crop response to the application of different sources of nitrogen along with the effect of lime.

Soil

The soil for the experiment was collected from the Rice Research Station, Moncompu. The details of the characteristics of the soil is given Table 1.

Season and climate

The pot-culture study was conducted during the period from June 1986 to October 1986. Meteorological data for the crop period are presented in Appendix.I.

Lay out

The experiment was laid out in completely randomised design, so as to sample two replications each at four intervals viz. maximum tillering, panicle initiation, flowering and harvest. Separate replications were set to sample soil at these four intervals.

Treatments

All the fourteen treatments of the laboratory experiment were used in the pot-culture studies also.

Important characteristics of nitrogen carriers used

Urea

This is a high analysis fertilizer containing 46 per cent N. It contains N in the amide form. It is readily soluble in water and easily decomposed by micro-organisms in soil.

Neem coated urea

Neem (*Azadirachta indica*) cake is one of the easily available non-edible indigenous cake reported to posses nitrification inhibiting properties. Known amount of urea was taken in a polythene bag and coal tar solution added (2 ml/100 g fertiliser) and contents were mixed thoroughly. Then fresh finely powdered neem cake was added at the rate of 20 g/100 g urea and contents were again thoroughly mixed so that an uniform coating was obtained.

Ammonium sulphate

This is the well-known nitrogenous fertiliser to the cultivators of India. It contains 20-21% N. It is crystalline, stable, soluble in water and stores well.

Neem coated ammonium sulphate

A known quantity of ammonium sulphate was taken in a polythene bag and coal tar solution (2 ml/100 g) was added. It was mixed well, then neem cake was added (20 g/100 g) and contents were thoroughly mixed.

Gypsum coated urea

The material used was supplied by Madras Fertilizers Ltd. It contained 32 per cent urea N, 8.5 per cent calcium and 6.5 per cent sulphur.

Rock phosphate coated urea

This fertiliser material was also supplied by Madras Fertilisers Ltd. It contained 31 per cent Urea N and 4.6 per cent P_2O_5.

Crop

The rice variety selected for the study was Jyothi, a cross between PTB-10 and IR-8. This variety has a duration of 110 to 125 days with moderate to profuse tillering habit, good fertiliser response and an yield potential of 5.5 tons ha^{-1}. The colour of bran is red and the grain is long. It is moderately tolerant to BPH and blast. It is susceptible to sheath blight and sheds grains at maturity.

Pot-culture

The paddy seeds were obtained from the Agricultural Research Station, Mannuthy. The seeds were soaked in water and incubated in a warm, moist place for sprouting. The germinated seeds were sown on the third day, in pots previously prepared for the purpose. The seedlings were pulled out on the 21st day after sowing and transplanted into the prepared pots containing 5 kg soil each. The soil in the pots were submerged for two weeks. Lime was added and a week later the seedlings were transplanted.

Irrigation

The pots were watered and the level of water maintained uniformly upto harvest.

Nitrogen application

Fertilisers were applied at the rate 90: 45: 45 N: P_2O_5:K_2O. kg ha^{-1}. Nitrogen was applied in two splits; half at tillering and the remaining a week before panicle initiation stage.

After cultivation

Weeding and plant protection operations were carried out as and when required.

Observations

Periodic soil analysis

Soil samples were drawn from two replications at periodic intervals and analysed for NH_4^+ - N, NO_3^- - N and NO_2^- - N. The pH and EC of the soil was also recorded. NH_4^+ - N was estimated by steam distillation (Bremner, 1965), NO_3^- - N by chromotropic acid method (Sims and Jackson, 1971) and NO_2^- - N by Griess - Illosvay Method. (Bremner, 1965)

Growth parameters

The plants were selected from each treatment and the observations were made on these plants.

Plant height

Height was recorded from the base of the plant to the tip of the longest leaf.

Number of tillers

The number of tillers in a hill was counted at periodic intervals, till harvest.

Leaf area index (LAI)

The plants sampled at different periods were used to determine the LAI. The total leaf area of the plant was found out by measuring the length and width of leaves and multiplying it with the factor 0.8. The leaf area index was computed as follows.

$$\text{LAI} = \frac{\text{Total leaf area}}{\text{Total land area}}$$

Dry matter production

The samples drawn for measuring LAI were used for determining the dry matter production. The plants were oven dried at 70° ± 2°C and total dry weight expressed as g plant $^{-1}$.

Yield parameters

Number of panicles per plant

The number of panicles in each hill of each replication was counted and the mean number of panicles per plant was noted separately.

Number of spikelets per panicle

The number of spikelets in each panicle of a replication was counted and the average number of spikelets per panicle was recorded.

Grain yield

The weight of grains in each replication was recorded and expressed as g pot^{-1}.

Chemical analysis

Total nitrogen

The total nitrogen in the plant sample was estimated by micro-kjeldahl method (Bremner, 1965).

Total phosphorus

The plant samples were ground and P content determined colorimetrically by vanadomolybdate method.

Total potassium

The potassium content in plant samples were determined using flame photometric method. Chemical analysis of grain and straw was done separately.

Uptake of N, P and K

The N, P and K contents of the plant were multiplied with their respective dry matter yields to get the uptake values. It was expressed in mg plant^{-1}.

Statistical analysis

The data obtained from the incubation studies and the pot-culture studies were subjected to statistical analysis using analysis of variance technique (Panse and Sukhatme, 1967).

RESULTS AND DISCUSSION

RESULTS AND DISCUSSION

The data from the laboratory experiments are presented first and these are followed by the results from pot-culture study.

Laboratory experiments

Experiment 1. Studies on soil reaction of karappadom soil

This experiment was undertaken to study the changes in pH due to submergence and liming of soil and its effect on the transformation of different N fertiliser materials.

The data on pH of the soil are given in Table 2 and representative N sources illustrated in Fig. 1 and 2. The change in pH due to submergence, application of lime, and N fertilisers showed that liming increased soil pH compared to its corresponding unlimed treatments, during the initial days of submergence. Thereafter, though the limed treatments recorded higher values, the difference was not considerable. In the case of unlimed urea, the pH increased upto 5.3 on the 30th day and was maintained almost the same till the 90th day. When limed, the pH was 6.2 on the 2nd day and it remained more or less the same till the 5th day. It gradually decreased to 5.5 on the 45th day and was maintained at 5.6 till the 90th day. With unlimed ammonium sulphate, there was

Table 2. Changes in pH of the soil on submergence as influenced by N-sources and liming

Treatments	Days after incubation 1	2	5	10	15	20	30	45	60	75	90
L_oC	4.5	4.4	4.5	5.5	5.5	5.5	5.4	5.3	5.4	5.6	5.5
LC	5.1	5.5	5.4	5.5	5.5	5.6	5.8	5.8	5.8	5.8	5.7
L_oU	4.8	4.9	5.1	4.9	5.0	5.1	5.3	5.2	5.3	5.3	5.3
LU	5.6	6.2	6.1	5.7	5.8	5.9	5.9	5.5	5.6	5.6	5.6
L_oAS	4.6	4.4	4.4	4.4	5.0	5.2	5.3	5.1	5.2	5.5	5.0
LAS	4.7	5.2	5.0	5.3	5.3	5.2	5.4	5.2	5.8	5.8	5.3
L_oNCU	4.5	4.6	5.1	5.2	5.0	5.5	5.6	5.4	5.5	5.9	6.0
LNCU	6.6	6.6	6.4	5.5	5.5	5.7	5.7	5.4	5.5	6.0	5.8
L_oNCA	4.3	4.3	4.3	4.5	5.2	5.4	5.0	5.5	5.5	5.5	5.5
LNCA	6.1	5.8	5.2	5.1	5.3	5.5	5.6	5.6	5.5	5.5	5.6
L_oGCU	4.7	4.8	4.9	5.4	5.5	5.8	5.8	5.5	5.6	5.7	5.5
LGCU	5.6	6.5	6.1	5.5	5.6	5.8	6.3	6.0	6.0	6.1	5.8
L_oRPU	4.9	4.8	5.1	5.4	5.5	5.6	5.6	5.5	5.6	5.6	5.9
LRPU	6.4	6.5	6.2	5.5	5.7	5.8	6.3	6.1	6.1	6.1	5.8

FIG. 1. CHANGES IN pH OF THE SOIL AS INFLUENCED BY UNCOATED N-SOURCES AND LIME.

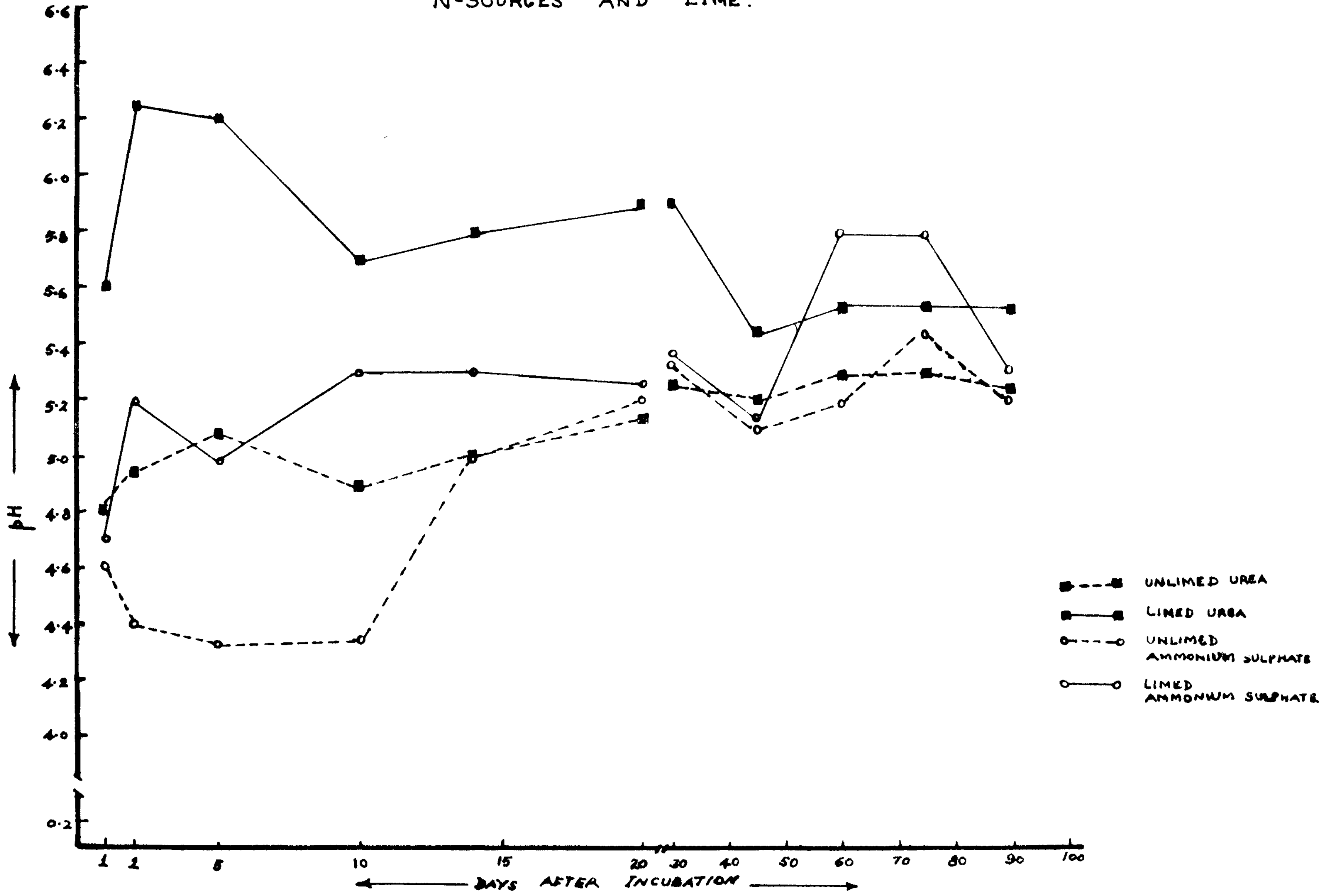
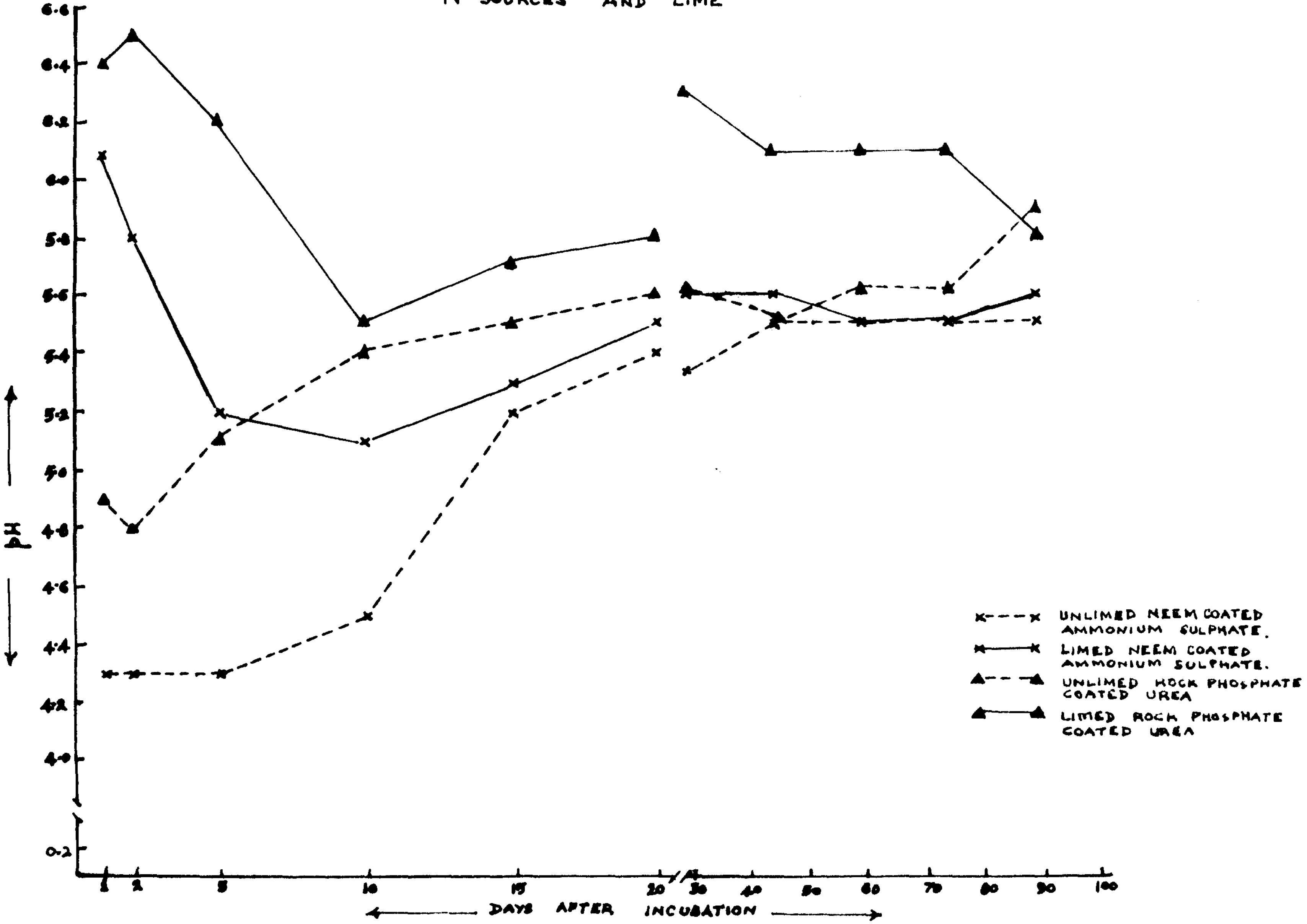


FIG. 2. CHANGES IN pH OF THE SOIL AS INFLUENCED BY COATED N-SOURCES AND LIME



a decrease in pH from 4.6 to 4.4 on the 10th day, followed by an increase by one unit, whereas, for the limed treatment, there was an increase from 4.7 to 5.2 on the 2nd day. After the 10th day the value remained almost constant till the 45th day. There after there was a slight increase to 5.8 and then a decrease to 5.3 on the 90th day.

For coated fertilisers (NCU, NCA, GCU, RPU) the increase in pH due to liming was higher. When compared with the uncoated fertilisers (Urea and AS) the difference between limed and unlimed treatments were highly conspicuous upto 5 days. From the 30th day onwards, limed GCU and RPU showed and increase in pH. On the 90th day the limed and unlimed treatments had almost similar values.

Discussion: It could be seen that the pH increased on submergence. This observation is in confirmity with the general observation that pH increases in acidic soils on submergence. (De Datta, 1981). The restricted diffusion of oxygen in flood water followed by soil reduction which involve the consumption of H^+ ion would have resulted in the increase in soil pH. The Karappadom soils have a high content of ferric and manganic compounds (Pisharody, 1965) and an increase in pH would be mainly due to the reduction of iron, represented as

$$Fe(OH)_3 + 3\ H^+ + e \longrightarrow Fe^{+2} + 3\ H_2O$$

A nearly stable pH attained after a few weeks of submergence could be due to the stabilisation of partial pressure of carbon dioxide. There was an increase in pH for all treatments because, the liming material reacted with acid soil replacing the hydrogen ions on the colloidal complex. Calcium adsorbed on the colloidal complex might have raised the percentage base saturation and the pH pushed up.

However, it should be noted that after 2-3 weeks of submergence the pH difference between limed and unlimed treatments narrowed down. This was due to the effect of submergence. It may be probable that beneficial effect of liming was more as a source of calcium in the soil than ameliorating the soil pH. The temporary neutralising effect of liming on active acidity might have been masked by the potential acidity of the soil.

For limed urea, the pH increased sharply on the 2nd day of submergence compared to unlimed urea and it gradually reduced almost to the initial value after the 10th day (Fig.1). This temporary increase was probably due to the beneficial effect of lime in enhancing urea hydrolysis. It is established that urea hydrolysis increases soil pH, as evident from the following reaction.

$$(NH_2)_2\,CO + 2\,H_2O \longrightarrow (NH_4)_2\,CO_3$$

By the 5th day, the hydrolysis might have been completed and hence the pH declined.

The increase in pH that was noted for limed ammonium sulphate (LAS) could be due to the effect of submergence and application of lime. Compared to urea, the increase in pH for ammonium sulphate soon after submergence was not very drastic. Hence, the higher pH maintained by urea was due to hydrolysis.

There was an increase in pH for coated urea fertilisers (GCU, RPU and NCU) in the presence of lime, just as in the case of urea. Therefore, it could be that irrespective of whether the material is coated or not, the process of urea hydrolysis was enhanced by liming.

<u>Experiment - 2</u>. Studies on the redox potential of Karappadom soil.

This experiment was aimed to study the effect of submergence and liming on the Eh of the soil and its influence on the transformation of N fertiliser materials. The data pertaining to this is presented in Table. 3. and representative N sources depicted in Fig. 3 and 4.

On the first day of incubation the Eh value ranged from +265 mv for limed urea to +170 mv for limed rock phosphate coated urea (LRPU). On the 5th day, the value drastically decreased in all the treatments. It ranged from +25 mv to +90 mv. From the 5th day, the values increased, to a maximum around the 10th day. The Eh values decreased thereafter till the 20th day and was maintained till the 30th day.

The limed treatments recorded lower values compared to the unlimed treatments. However, the difference was not

Table 3. Changes in redox potential of the soil as influenced by N-sources and liming (in mv)

Treatments	Days after incubation						
	1	2	5	10	15	20	30
L_oC	+225	+205	+55	+166	+154	+30	+30
LC	+200	+220	+75	+176	+164	+50	+50
L_oU	+250	+135	+75	+206	+234	+105	+105
LU	+265	+180	+55	+176	+104	+25	+20
L_oAS	+245	+225	+60	+246	+274	+90	+90
LAS	+195	+200	+70	+196	+139	+35	+35
L_oNCU	+225	+130	+35	+196	+169	+50	+55
LNCU	+175	+165	+25	+206	+149	+25	+25
L_oNCA	+215	+195	+90	+186	+294	+120	+120
LNCA	+200	+165	+55	+196	+189	+80	+85
L_oGCU	+180	+135	+90	+186	+194	+80	+85
LGCU	+180	+105	+35	+211	+169	+35	+35
L_oRPU	+205	+185	+60	+201	+179	+70	+75
LRPU	+170	+175	+45	+176	+144	+70	+75

FIG. 3. CHANGES IN REDOX-POTENTIAL OF THE SOIL AS INFLUENCED BY UNCOATED N-SOURCES AND LIME.

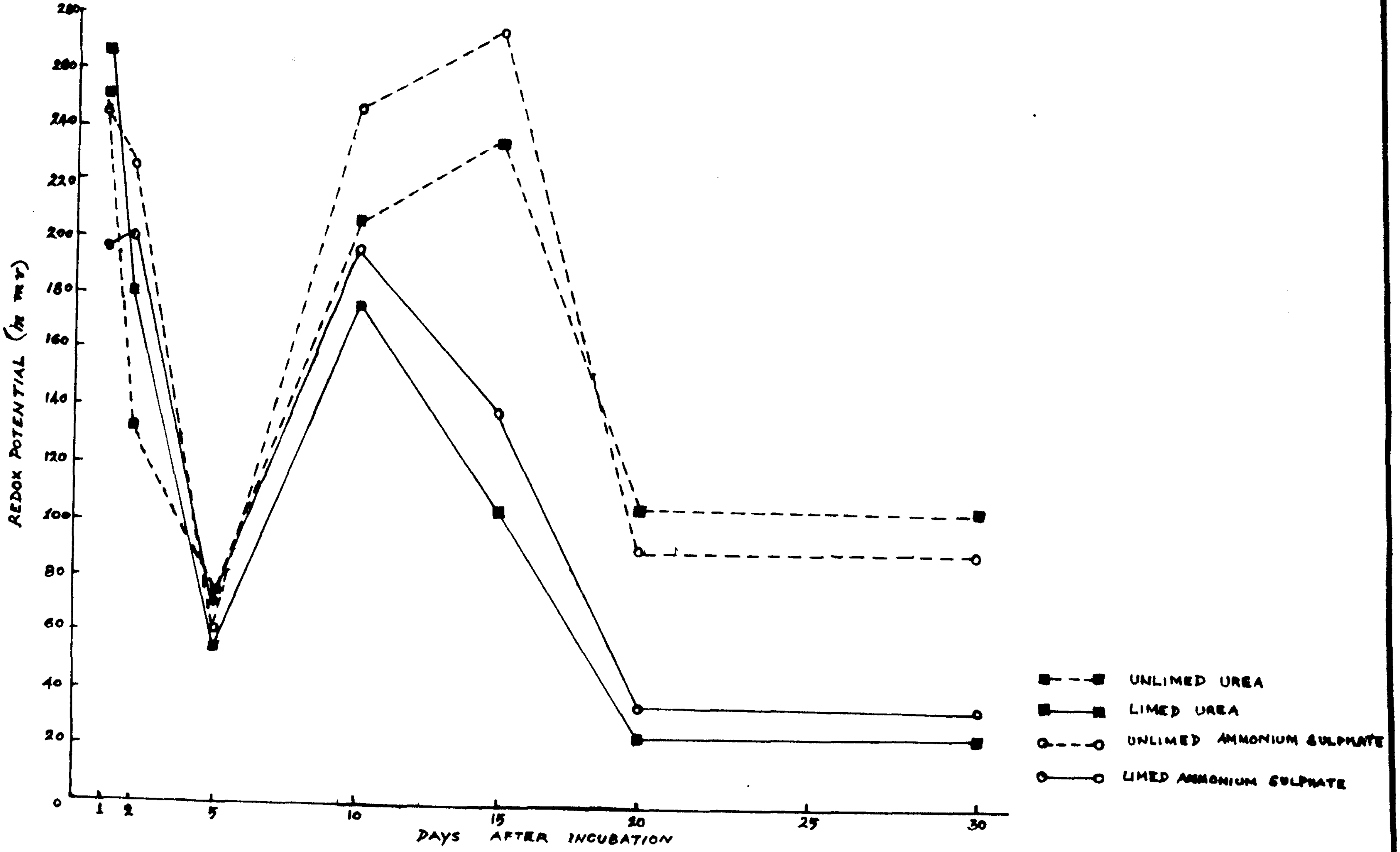
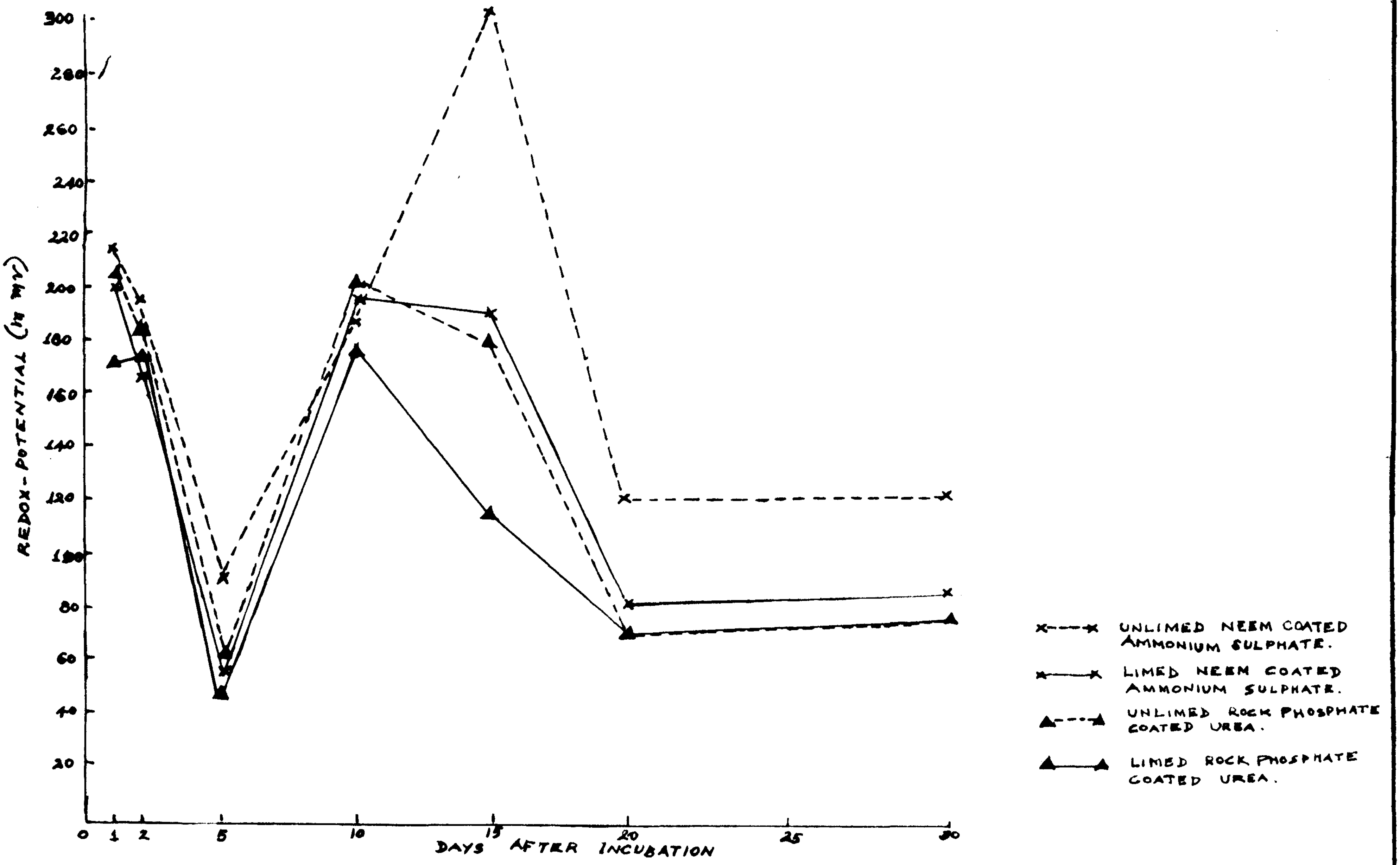


FIG. 4. CHANGES IN REDOX-POTENTIAL OF THE SOIL AS INFLUENCED BY COATED N-SOURCES AND LIME.



drastic upto the 10th day. Between the coated and uncoated fertiliser treatments, there was only a very slight variation.

Discussion: There was a rapid decline in Eh immediately on submergence upto the 5th day followed by a sharp increase upto the 10th day. This initial rapid drop in Eh might be due to the production of hydrogen on submergence (Tamane and Okazaki, 1982) or due to the release of reducing substances accompanying oxygen depletion before Mn (IV) and Fe (III) oxide hydrates can mobilize their buffering capacity. There was a gradual decline in Eh from the 10th day to the 20th day before the value got stablised at 30th day. The decrease in Eh after the 10th day might be due to the decreased activity of the oxidised phase, an increased activity of the reduced phase and accompanied by an increase in pH. Results of this observations are in confirmity with that of Ponnamperuma (1977).

The Eh values of +105 mv to +25 mv on the 30th day of submergence indicated that the main redox system operating under this situation was ferric - ferrous and manganic - manganous systems. The high amount of iron present in the soil would have prevented the decline of Eh to the negative values. Hence, the reduction of sulphate to sulphides would not have occured under the present situation.

Nitrogen sources were not found to influence soil Eh. This might be because, no nitrates, which would have affected the Eh could be detected in any of the N-source upto 30th day of submergence. There was a decrease in Eh value for limed treatments compared to the unlimed treatments. This could be due to the increase in pH of the limed treatment. Eh varies inversely as pH (Redman and Patrick, 1965).

Experiment - 3. Studies on the electrical conductivity of Karappadom soil.

This experiment was conducted to study the change in EC due to submergence and also the effect of N fertiliser material and lime on the EC. The data are presented in Table.4 and those of a few representative treatments in Fig. 5 and 6.

The EC values increased gradually with time of incubation. Between treatments it ranged from 0.28 to 0.77 mmhos/cm, on the 1st day and from 0.49 to 1.15 mmhos/cm on the 90th day. The treatments with N sources had higher values when compared to control. For both limed and unlimed control, EC increased steadily from the 15th day onwards, whereas, in the treatments with N sources the increase was noted from the 5th day itself. On the first day the highest value of EC was for the treatment with NCA followed by that with ammonium sulphate (AS). All the other treatments maintained similar values. By the 90th day, for NCA the increase was from 0.75 to 1.15 mmhos/cm and for AS it was from 0.64 to 0.95 mmhos/cm. There was little variation between other N sources on any day of incubation.

Table 4. Changes in electrical conductivity (EC) of the soils as influenced by N sources and liming (in mmhos cm^{-1})

Treatments	Days after incubation 1	2	5	10	15	20	30	45	60	75	90
L_oC	0.30	0.30	0.28	0.29	0.30	0.33	0.34	0.42	0.58	0.55	0.65
LC	0.31	0.28	0.34	0.34	0.39	0.40	0.38	0.39	0.46	0.55	0.48
L_oU	0.26	0.28	0.33	0.34	0.41	0.43	0.43	0.38	0.43	0.55	0.73
LU	0.36	0.34	0.41	0.40	0.40	0.41	0.39	0.35	0.42	0.50	0.68
L_oAS	0.64	0.61	0.63	0.64	0.69	0.68	0.67	0.72	0.85	1.00	0.95
LAS	0.65	0.55	0.61	0.61	0.66	0.66	0.68	0.70	0.87	1.00	0.95
L_oNCU	0.28	0.28	0.36	0.36	0.37	0.37	0.40	0.38	0.44	0.65	0.89
LNCU	0.29	0.43	0.47	0.45	0.47	0.47	0.42	0.39	0.42	0.50	0.50
L_oNCA	0.77	0.72	0.73	0.74	0.80	0.82	0.81	0.77	0.91	1.00	1.15
LNCA	0.72	0.77	0.89	0.79	0.89	0.89	0.88	0.84	0.97	1.05	1.15
L_oGCU	0.28	0.26	0.34	0.34	0.40	0.39	0.39	0.36	0.52	0.65	0.73
LGCU	0.27	0.44	0.47	0.51	0.55	0.55	0.52	0.55	0.60	0.60	0.75
L_oRPU	0.22	0.27	0.34	0.36	0.41	0.42	0.43	0.39	0.48	0.50	0.75
LRPU	0.40	0.39	0.43	0.43	0.42	0.44	0.46	0.43	0.57	0.70	0.70

FIG. 5. CHANGES IN ELECTRICAL CONDUCTIVITY OF THE SOIL AS INFLUENCED BY UNCOATED N- SOURCES AND LIME.

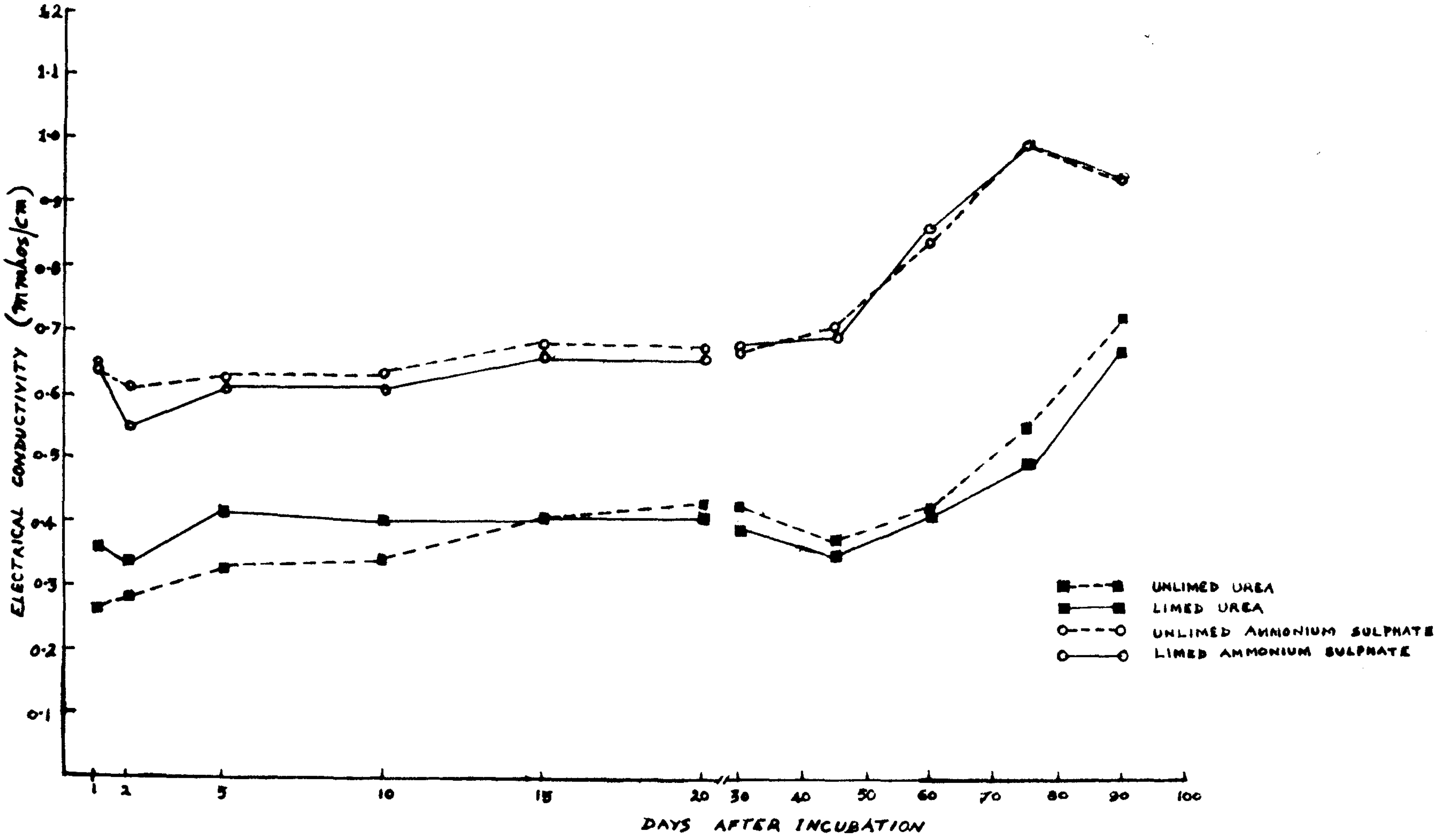
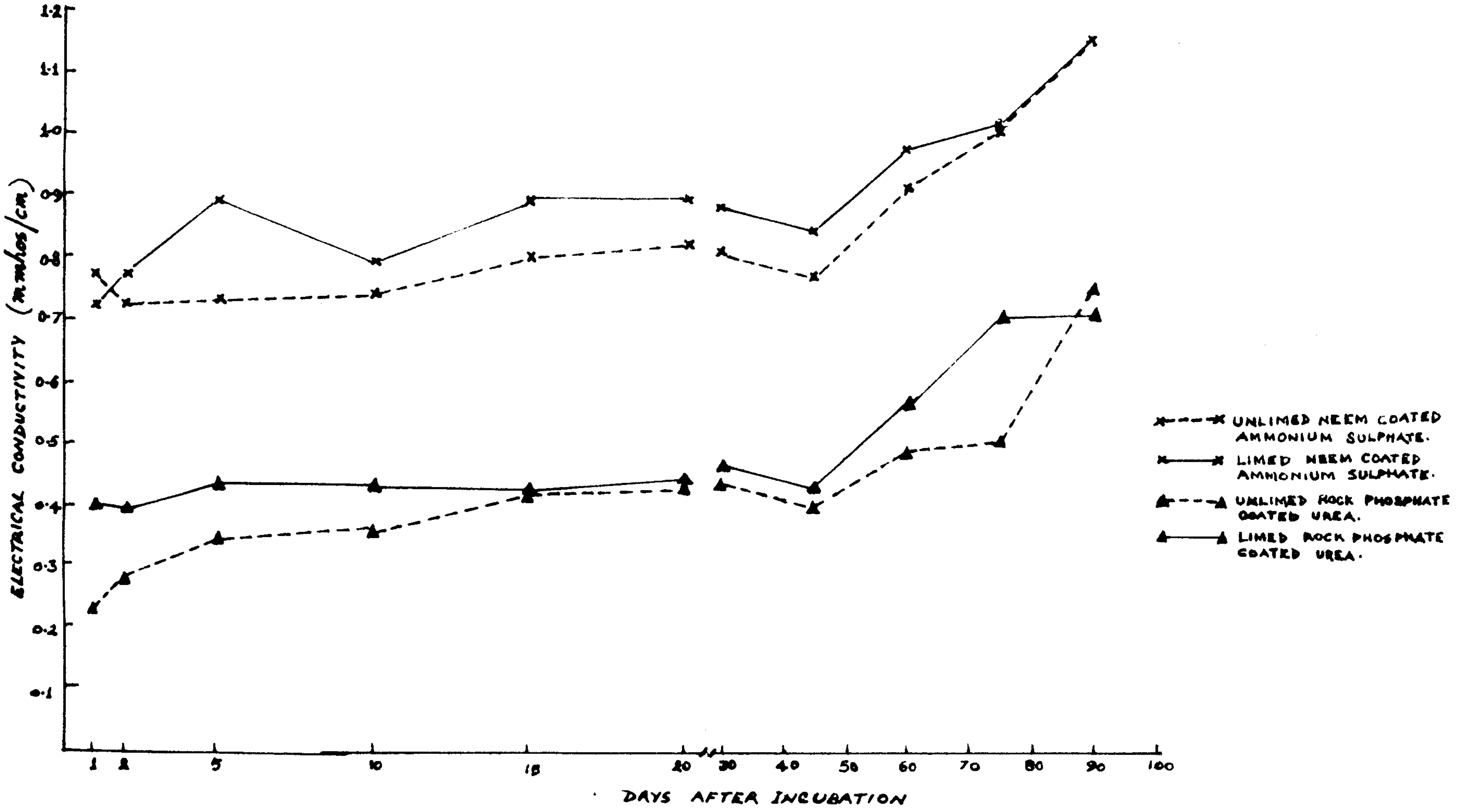


FIG. 6. CHANGES IN ELECTRICAL CONDUCTIVITY OF THE SOIL AS INFLUENCED BY COATED N-SOURCES AND LIME



Between the limed and unlimed treatments, limed treatments recorded higher EC values. The difference, was notable upto the 20th day, it narrowed gradually, reaching similar values from the 60th day.

Discussion: There was an increase in EC following submergence of the soil, for all treatments. This increase in EC might be due to the release of Fe^{+2} and Mn^{+2} following reduction of insoluble ferric and manganic hydrous oxide, accumulation of NH_4^+, HCO_3^- and $RCOO^-$ and displacement of cations from soil colloids by Fe^{+2} and Mn^{+2}. Ponnanperuma, (1976) also reported an increase in Eh on submergence. The higher EC values recorded by NCA and AS, compared to the other N sources was probably due to the dissociation of ammonium sulphate producing ammonium and sulphate ions. There was an increased value for EC in limed treatments compared to unlimed treatments. Liming might have indirectly influenced the EC by increasing the ionic concentration. Liming might have increased the concentration of hydroxyl ions phosphates, molybdates etc. (Brady, 1974). Towards the end of the incubation study, the values for limed and unlimed treatments, were found to be more or less the same. The expected reason for this is the similarity in ions between the limed and unlimed treatments, with period of submergence.

Experiment - 4. Studies on the nitrifying organisms of Karappadom soil.

As it is difficult to isolate the nitrifying organisms they were determined by their most probable numbers (MPN). The incubation was carried out for 3 weeks. At the end of the period they were tested for NO_2^- - N with Griess - Illosvay reagent. It was found that the tubes set for determining MPN of Nitrosononas as well as that set for Nitrobacter gave negative results.

Discussion: The test tubes set for determining MPN of Nitrosomonas contained ammonium ions in the medium. Had there been sufficient organisms to convert this to nitrite, the test would have given positive results with Griess-Illosvay reagent. As the results were negative it could be concluded that there ware no sufficient organism to carry out this reaction. Similarly, for determining MPN of Nitrobacter, the medium had nitrite. Since there were no organisms to convert this nitrite to nitrate the test gave negative result (by producing pink colour with Griess - Illosvay reagent). It could be assumed that the rate of nitrification in Karappadom soil was either slow or negligible.

Experiment - 5. Nitrogen transformations in Karappadom soils at submerged moisture regime.

This study was conducted to understand the nitrogen transformation of different N sources as affected by liming in flooded soil.

As no NO_3 - N could be detected till the 30th day, another set of samples were incubated for sampling from

45^{th} to 90^{th} day.

NH_4^+ - N content:- The data are given in Table 5 (a) and 5 (b). Few representative treatments are illustrated in Fig. 7 and Fig. 8. The analysis of variance is presented in Appendix. II.

The NH_4^+ - N content increased gradually till the 4^{th} day and then decreased till the 30^{th} day. Similarly, on the 45^{th} day high values were recorded which decreased by the 90^{th} day. On an average, liming increased the NH_4^+ - N content.

On the 1^{st} day after fertiliser application NH_4^+ - N was maximum for ammonium sulphate the content in all other treatments were on par and least value was recorded by RPU. Liming did not significantly influence the NH_4^+ - N content. The effect of interaction was significant and maximum value was reported by AS, which significantly decreased on liming. The NH_4^+ - N content in RPU and NCU increased significantly with liming.

On the 2nd day, the NH_4^+ - N content increased in all sources except AS. The maximum content was recorded by NCA followed by GCU. There was significant reduction in NH_4^+ - N content on liming. Interaction of N sources and lime was significant with highest values recorded by unlimed coated fertilisers (NCA, GCU, RPU). The limed treatments showed

Table 5 (a). Effect of N-sources and lime on the ammoniacal nitrogen content (ppm) of the soil at submerged moisture regime (1-30 days)

Treatments	1st day			2nd day			4th day			5th day		
	source	unlimed	limed	source	unlimed	limed	source	unlimed	limed	source	unlimed	limed
Urea	58.15	48.82	67.48	69.63	71.79	67.48	83.99	83.28	84.71	73.94	83.27	64.61
AS	83.28	89.02	77.54	78.94	74.60	83.28	85.43	74.66	96.20	65.33	66.05	64.61
NCU	56.00	40.21	71.79	72.51	71.79	73.23	90.45	87.58	93.32	60.30	53.12	67.48
NCA	63.17	70.36	55.99	83.28	90.45	76.10	83.28	86.15	30.41	75.38	78.97	71.79
GCU	54.56	58.87	50.22	82.20	86.87	77.53	86.14	83.27	89.02	60.30	53.13	67.48
RPU	52.43	41.64	63.23	75.38	78.97	71.79	84.71	77.54	91.89	85.87	97.63	74.12
Mean		(58.15)	(64.38)		(79.08)	(74.90)		(82.08)	(89.30)		(72.03)	(68.35)

	'F' test	CD(5%)	SEm±	'F' test	CD(5%)	SEm±	'F' test	CD(5%)	SEm±	'F' test	CD(5%)	SEm±
Source	Sig**	12.68	4.17	Sig**	5.51	1.81	NS	-	3.38	Sig**	10.50	3.45
lime	NS	-	2.4	Sig*	3.18	1.05	Sig*	5.99	1.97	NS	-	1.99
Interaction	Sig**	17.93	5.82	Sig**	7.79	2.53	NS	-	4.76	Sig**	14.85	4.82

AS : Ammonium sulphate NCU : Neem coated Urea NCA : Neem coated ammonium sulphate

GCU : Gypsum coated urea RPU : Rock phosphate coated urea.

Contd......

Table 5(a) (Contd...)

9th day			11th day			16th day			23rd day			30th day		
Source	un-limed	limed	Source	un-limed	limed	Source	un-limed	limed	Source	un-limed	limed	Source	un-limed	limed
61.49	54.06	68.92	70.57	71.79	69.35	72.51	77.53	67.48	64.25	68.92	59.58	68.05	68.77	67.33
68.20	74.66	61.74	50.97	63.89	38.04	51.69	64.61	38.77	61.74	68.92	54.56	51.69	73.08	30.71
62.10	56.72	67.48	61.36	59.58	63.17	55.99	40.20	71.79	53.84	50.25	57.43	55.84	69.77	42.92
64.61	70.35	58.87	68.35	67.48	69.22	54.59	41.64	67.55	55.19	48.64	61.74	57.28	48.66	65.90
58.30	51.99	64.61	51.68	40.20	63.17	54.20	54.56	53.84	66.76	64.61	68.92	62.41	53.18	71.64
80.05	67.48	92.61	78.74	74.22	33.28	63.89	53.12	74.66	71.07	76.10	56.05	68.76	64.46	73.07
	(62.54)	(69.04)		(62.86)	(64.37)		(65.28)	(62.35)		(62.90)	(61.38)		(62.82)	(58.59)

'F'test	CD(5%)	SEm±	'F'test	CD(5%)	SEm±	'F'test	CD(5%)	SEm±	'F'test	CD(5%)	SEm±	'F'test	CD(5%)	SEm±
NS	-	4.22	Sig**	10.39	3.41	NS	-	7.37	NS	-	7.5	Sig**	10.79	3.54
NS	-	2.43	NS	-	1.64	NS	-	4.25	NS	-	4.32	NS	-	2.05
NS	-	6.68	Sig**	14.69	4.76	NS	-	10.29	NS	-	10.46	Sig**	15.27	4.95

Table 5 (b). Effect of N-sources and lime on the ammoniacal nitrogen content of the soil at submerged moisture regime (45 to 90 days)

	45th day			60th day			90th day		
Treatments	Source	unlimed	limed	Source	unlimed	limed	source	unlimed	limed
Urea	76.81	77.53	76.10	71.54	74.66	68.41	68.38	73.22	63.53
AS	82.18	74.62	89.74	66.74	69.41	64.08	60.66	66.77	54.56
NCU	83.63	83.99	83.28	62.81	58.14	67.48	56.70	48.79	64.61
NCA	83.28	88.30	78.25	64.66	69.78	59.53	55.25	45.85	64.64
GCU	84.17	85.07	83.28	58.43	47.43	69.44	60.73	59.59	61.88
RPU	80.04	78.25	81.84	74.67	70.37	78.97	67.48	64.61	70.38
Mean		(81.30)	(82.08)		(64.97)	(67.99)		(59.81)	(63.26)

	'F'test	CD(5%)	SEm±	'F'test	CD(5%)	SEm±	'F'test	CD(5%)	SEm±
Source	NS	-	4.8	Sig**	8.48	2.78	NS	-	3.77
Lime	NS	-	2.78	NS	-	1.26	NS	-	2.18
Interaction	NS	-	6.74	Sig**	9.47	3.07	NS	-	5.27

FIG. 7. AMMONIACAL NITROGEN CONTENT IN SUBMERGED SOIL AS INFLUENCED BY N-SOURCES.

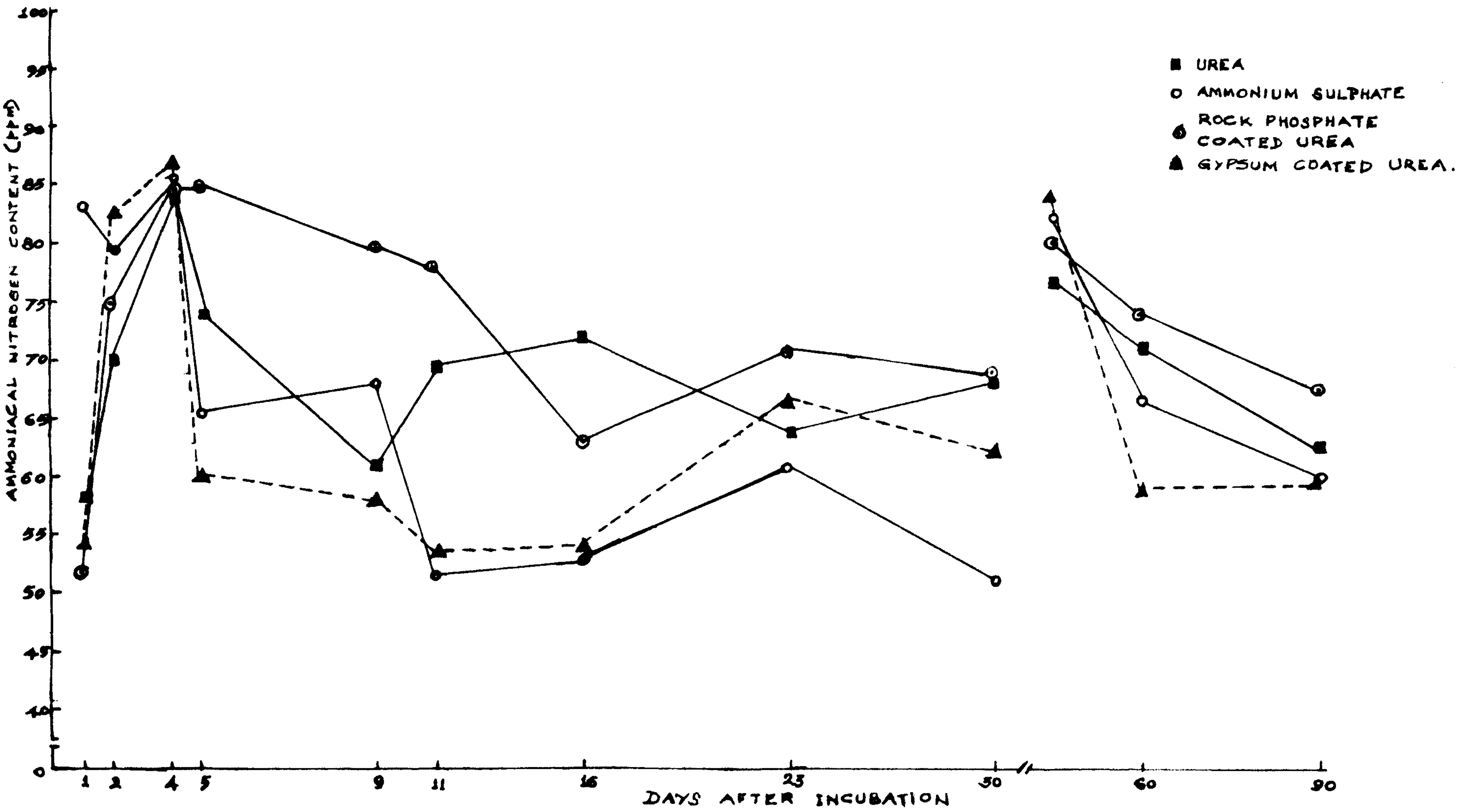
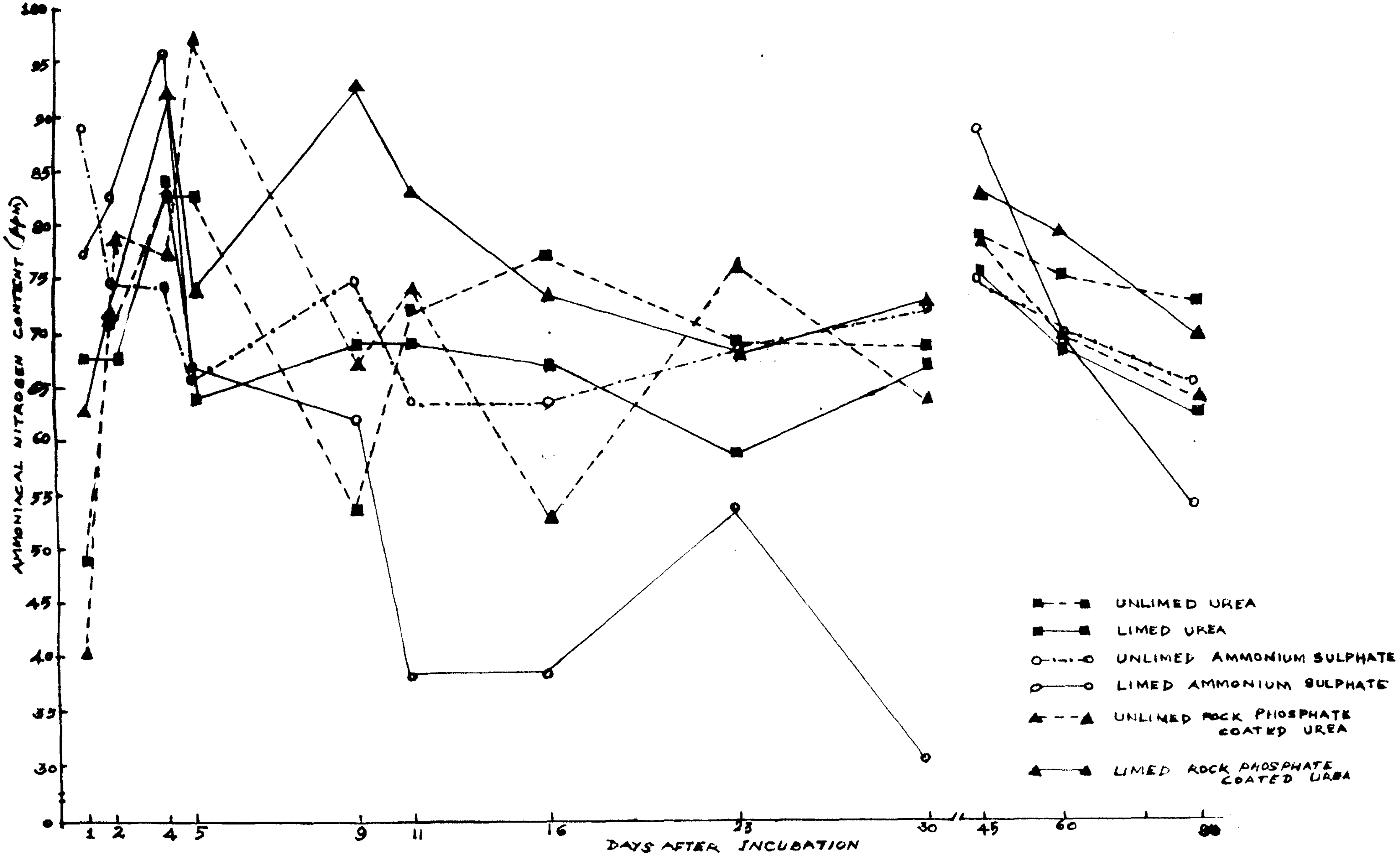


FIG. 8 AMMONIACAL NITROGEN CONTENT IN SUBMERGED SOIL AS INFLUENCED BY LIMING.



almost the same value ranging from 67.48 to 83.28 ppm irrespective of the source.

On the 4th day also, the content increased, with the highest value being for NCU closely followed by GCU. All the treatments were on par. Effect of liming was significant in increasing NH_4^+ - N content. Whereas, the effect of interaction was statistically insignificant.

On the 5th day, the effect of N sources and interaction were significant. However, the effect of lime was insignificant. RPU recorded the maximum content followed by NCA. NCU and GCU gave the lowest values. Urea, AS, NCA were on par. RPU without lime recorded high values but for GCU liming increased the content of NH_4^+ - N.

On the 9th day neither the effect of N sources, liming or interaction was significant. RPU recorded the highest content, among the different N sources.

The NH_4^+ - N content on the 11th day was significantly influenced by the N sources and interaction. Treatments with RPU, NCA and Urea were on par and those with AS, NCU, and GCU were on par. In combination with lime, the NH_4^+ - N content decreased for AS, whereas, for RPU the content increased.

Though RPU maintained high values on the 16th and 23rd day, there was no significant influence on the NH_4^+ - N content by the N sources, lime or interaction.

The effect of N sources and interaction of N sources and lime were significant on the 30th day. RPU and Urea were on par but, superior to all other sources. Liming increased the NH_4^+ - N content for RPU, GCU and NCA. Lowest value was recorded by AS in combination with lime.

On the 45th and 90th day neither the effect of N sources, lime or interaction was significant. On the 60th day effect of N sources and interaction significantly influenced the NH_4^+ - N content. RPU and Urea gave higher values when compared with the other sources. In general, liming increased NH_4^+ - N content on all days.

NO_3^- - N content:- Nitrate nitrogen was detected only from the 45th day. The data are presented in Table 6 and analysis of variance given in Appendix III.

With lime, the NO_3^- - N content increased till the 60th day and thereafter it decreased. The nitrogen sources had significant effect on the content of NO_3^- - N on the 45th day, with maximum values being for RPU followed by NCU. All the other source were on par. On the 60th day urea recorded the highest value followed by AS which were significantly higher than NCA, GCU and RPU. On the 90th day, effect of sources were insignificant.

Effect of lime was insignificant on all days. On the whole, liming reduced the concentration on the 60th and 90th

Table 6. Effect of N-sources and lime on the nitrate nitrogen (ppm) of the soil at submerged moisture regime.

Treatment	45th day			60th day			90th day		
	Source	unlimed	limed	source	unlimed	limed	source	unlimed	limed
Urea	1.99	2.00	1.98	5.13	5.09	5.17	3.03	3.34	2.72
AS	2.03	2.31	1.74	4.82	5.09	4.55	3.47	3.93	3.02
NCU	2.55	2.33	2.78	4.72	4.96	4.46	3.07	2.77	3.37
NCA	1.82	1.77	1.87	3.70	3.20	4.20	3.30	2.73	3.86
GCU	2.24	2.06	2.43	4.26	5.45	3.08	3.55	3.88	3.23
RPU	2.86	2.45	3.26	4.45	4.40	4.50	3.68	3.73	3.64
Mean		(2.15)	(2.35)		(4.7)	(4.3)		(3.39)	(3.30)

	'F'test	CD(5%)	SEm±	'F'test	CD(5%)	SEm±	'F'test	CD(5%)	SEm±
Source	Sig*	0.60	0.19	Sig*	0.76	0.25	NS	-	0.34
Lime	NS	-	0.11	NS	-	0.14	NS	-	0.19
Interaction	NS	-	0.27	Sig*	1.08	0.35	NS	-	0.48

day, however, there was an increase in value on the 45th day.

Interaction of N sources with lime affected NO_3^- - N content significantly only on the 60th day. There was an increase in content for urea, NCA, and RPU. The reverse was noticed for AS, GCU and NCU.

Discussion: On the first day ammoniacal nitrogen content was found to be maximum in AS treatment. The high value recorded could be due to the NH_4^+ ions released from $(NH_4)_2SO_4$. It was also noted that this high content was not recorded in NCA, probably because of the coating of neem, which might have retarded the dissociation of $(NH_4)_2SO_4$. Contrary to the normal rate of urea hydrolysis being completed within 2 to 3 days, it was observed that maximum NH_4^+ - N content was on the 4th day for urea treatment. Hence it may be likely that urea hydrolysis takes place slowly in this soil.

For the neem coated materials also maximum NH_4^+ - N content was noted within 3 to 5 days and thereafter it decreased. The decrease was similar to that for the corresponding uncoated fertilizer. For GCU also the ammoniacal nitrogen content was found to follow the same trend as for urea, in the initial period. It might be due to the easy dissolution of the gypsum coating which exposes urea and hence GCU might have behaved similar to that of urea. Whereas, in the case of RPU there was a gradual increase in NH_4^+ - N from the 2nd to 9th day. This might be because of the compartively less soluble coating of rock-phosphate over urea which might have resulted in a progressive release of nitrogen and subsequent hydrolysis. Hence, there was no sharp increase as in the case of AS.

From the 5th day onwards, it was observed that the NH_4^+ - N content decreased for all N source expept for RPU. High concentration of ammonium accumulation within the first 3 days would have resulted in an increased content of NH_3 (aqueous) concentration in the soil solution which would have been lost through NH_3 volatilization. The rate of nitrification was less, as indicated by very low to negligible quantities of nitrate nitrogen during the period of study. It was also revealed by the microbial studies. Hence, N loss through denitrification might not be substantial under this situation. The data revealed that RPU was the best source of N in reducing the N losses probably because the rate of release of urea was comparitively slower.

Between the unlimed and limed treatments, higher NH_4^+ - N was maintained by unlimed treatments. For limed AS there was a decrease in content of NH_4^+ - N compared to unlimed AS (Fig. 7). This difference could be attributed to the higher pH values noted in limed AS, which would have resulted in drastic losses of NH_3 from the system. In the case of unlimed RPU an alternate increase and decrease in NH_4^+ - N content was noticed. It could be due to the periodic release of nitrogen. However, for limed RPU this pattern was noticed only till the 10th day, thereafter there was a gradual decrease in the content. This indicated that liming affected the release of nitrogen from RPU. The reasons for this however, could not be explained.

<u>Experiment - 6</u>. Nitrogen transformation in Karappadom soils at non-submerged moisture regime.

This study was conducted to understand the nitrogen transformation of different N sources, taking place at 70 per cent of field moisture capacity and the effect of lime on these transformation. Since, no NO_3^- - N could be detected till 21st day, a separate set was incubated for sampling from 30th to 90th day.

The data are presented in Table 7 (a) and 7 (b) and few represantative treatments are illustrated in Fig. 9 and 10. The analysis of variance is given in Appendix IV.

<u>NH_4^+ - N content</u>: The NH_4^+ - N content increased progressively reaching, maximum values by 14th day and then decreased by 21st day in all the N sources, except for NCA, where maximum value was noticed on the 7th day itself.

<u>N Sources</u>:- There was significant difference between sources on all the sampling days. On the first day highest value was for AS (70.89 ppm). Urea recorded the least value (21.53 ppm)

Table 7 (a). Effect of N-sources and lime on the ammoniacal nitrogen content (ppm) of the soil at 70 percent of field moisture capacity (1 to 21 days)

Treat-ment	1st day			7th day			14th day			21st day		
	Source	unlimed	limed	source	unlimed	limed	source	unlimed	limed	source	unlimed	limed
Urea	21.53	17.67	25.39	75.81	76.47	75.16	92.33	93.55	91.12	85.16	83.88	86.48
AS	70.89	65.33	76.44	92.89	91.65	94.10	93.15	95.31	90.99	88.80	90.54	87.07
NCU	37.91	23.51	52.31	66.25	63.02	69.48	82.33	92.17	72.50	73.61	85.55	61.68
NCA	49.34	57.17	41.50	88.39	95.82	80.97	83.05	90.05	76.05	75.74	83.15	68.34
GCU	49.01	58.28	39.73	74.97	79.59	70.34	89.61	89.68	89.55	82.20	87.77	76.63
RPU	42.99	36.75	49.22	86.54	79.26	93.83	97.24	97.16	97.33	96.06	94.37	97.75
Mean		(43.12)	(47.44)		(80.97)	(80.65)		(92.98)	(86.26)		(87.54)	(79.65)

	'F'test	CD(5%)	SEm±	'F'test	CD(5%)	SEm±	'F'test	CD(5%)	SEm±	'F'test	CD(5%)	SEm±
Source	Sig**	6.00	1.98	Sig**	6.52	2.14	Sig**	3.01	0.99	Sig**	3.01	0.99
Lime	Sig*	3.46	1.13	NS	-	1.23	Sig**	1.73	0.57	Sig**	1.72	0.56
Inter-action	Sig**	8.49	2.75	Sig**	9.22	2.99	Sig**	4.26	1.38	Sig**	4.25	1.38

Table 7 (b). Effect of N-sources and lime on the ammoniacal nitrogen content (ppm) of the soil, at 70 percent of field moisture capacity (30 to 90 days)

Treat-ments	30th day			45th day			60th day			90th day		
	source	unlimed	limed	source	unlimed	limed	source	unlimed	limed	source	unlimed	limed
Urea	80.68	79.68	61.68	72.46	76.87	68.05	89.00	89.88	88.13	83.54	81.64	85.44
AS	87.53	89.77	84.93	89.68	87.79	91.57	90.13	90.69	89.57	87.00	91.07	82.91
NCU	69.77	81.08	58.47	64.42	65.71	63.13	70.56	74.54	66.58	76.75	81.20	72.30
NCA	71.72	82.06	61.38	83.93	91.84	76.02	84.29	91.91	76.67	76.93	82.15	71.72
GCU	73.09	77.27	68.92	74.56	81.41	67.72	76.55	83.18	67.92	82.20	81.34	83.06
RPU	89.64	87.12	92.17	82.45	74.52	90.38	80.38	76.07	84.69	87.99	91.33	84.65
Mean		(82.83)	(71.25)		(79.69)	(76.15)		(84.38)	(78.93)		(84.79)	(80.02)

	'F'test	CD(5%)	SEm±	'F'test	CD(5%)	SEm±	'F'test	CD(5%)	SEm±	'F'test	CD(5%)	SEm±
Source	Sig**	6.14	2.62	Sig**	5.14	1.69	Sig**	4.22	1.38	Sig**	5.89	1.94
Lime	Sig**	3.54	1.16	Sig*	2.96	0.97	Sig**	2.44	0.80	Sig*	3.40	1.12
Inter-action	Sig**	8.69	2.82	Sig**	7.27	2.36	Sig**	5.97	1.93	NS	8.34	2.70

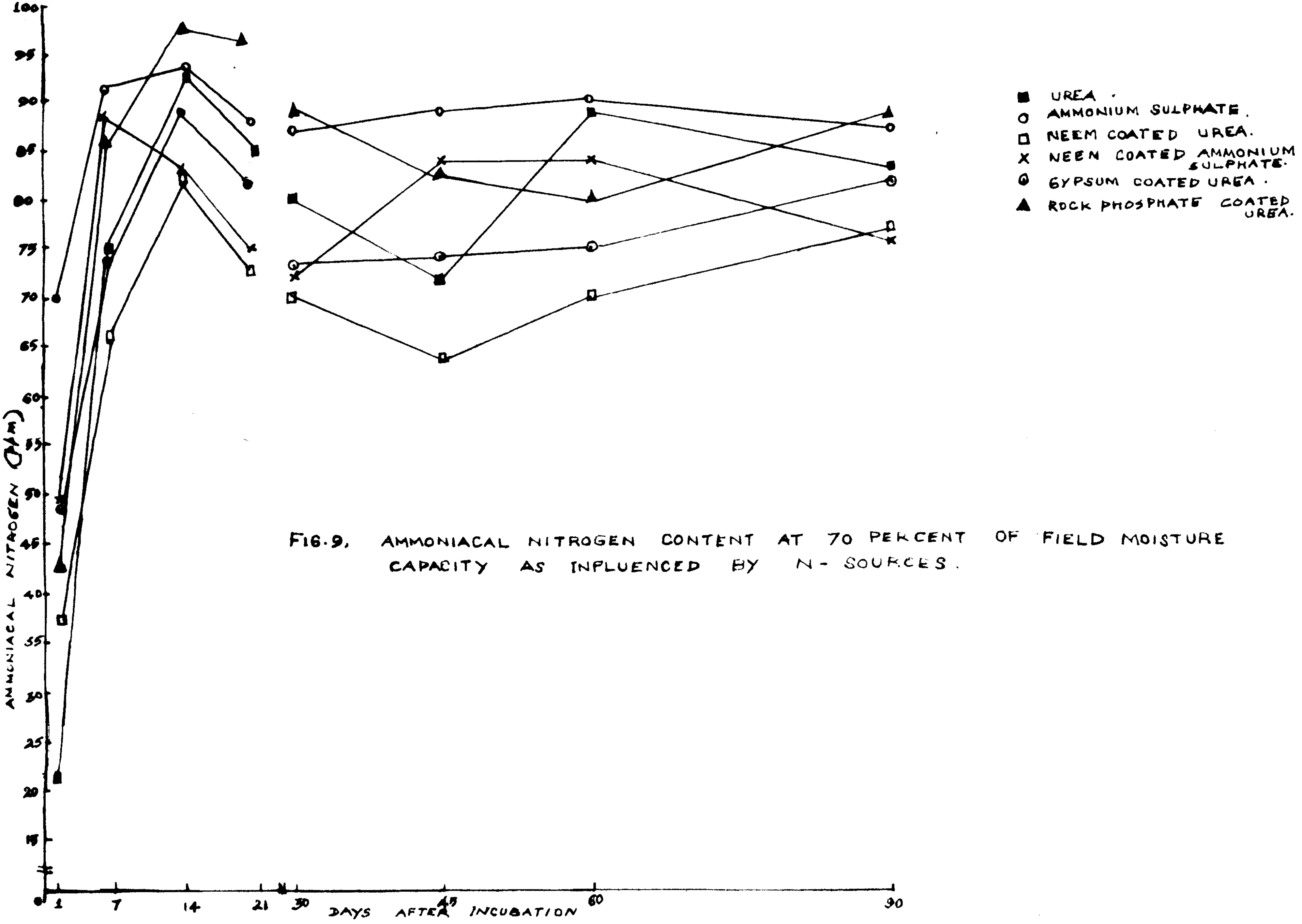
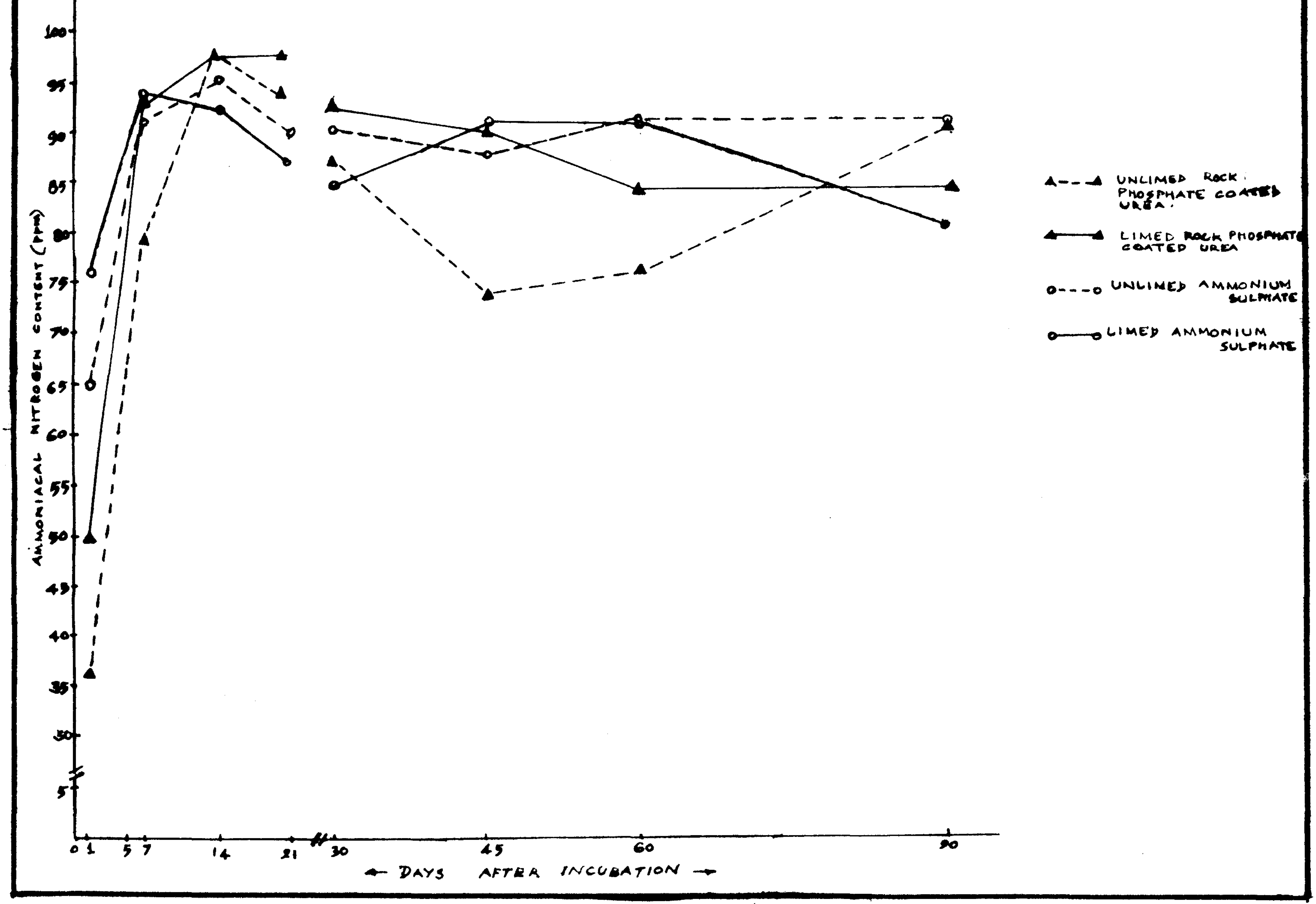


FIG. 9. AMMONIACAL NITROGEN CONTENT AT 70 PERCENT OF FIELD MOISTURE CAPACITY AS INPLUENCED BY N-SOURCES.

FIG. 10. AMMONIACAL NITROGEN CONTENT AT 70 PERCENT OF FIELD MOISTURE CAPACITY AS INFLUENCED BY LIMING



NCU and RPU were on par and NCA and GCU were on par. On the 7th day, maximum content was recorded by AS (92.89 ppm) followed by NCA and RPU. NCU gave the lowest value. Urea and GCU were on par. Highest content of NH_4^+ - N was for RPU on the 14th day, followed by AS, twhich were on par. Lowest was for NCU. Urea and GCU were on par. On the 21st day also RPU recorded the maximum content (96.06 ppm) followed by AS. Urea, NCA and NCU were on par.

Liming:- Liming had significant effect on the NH_4^+ - N content on all days except on the 7th day. Liming reduced the content on all days of sampling except on the 1st day.

Interaction:- The effect of interaction of N sources and lime was statistically significant on all 4 days of sampling. The addition of lime reduced the content for GCU and NCA on the 1st day. Whereas, it increased the content in all other treatments. On the 7th day AS with lime recorded maximum value of 94.1 ppm. The increase in content in limed RPU was significant, whereas on the 11th day the content for all the sources in combination with lime decreased. The reduction being significant for NCA and NCU. On the 21st day, lowest value was recorded by limed NCU and highest by limed RPU.

From 30th to 90th day.

As on the previous dates of sampling there was significant effect of N sources on all the sampling days. On the 30th day treatments with RPU recorded the highest content followed by AS which were on par. They were significantly superior to all other sources. NCU, NCA and GCU were on par. On the 45th day maximum content was for AS followed by NCA and RPU which were on par and the least for NCU (64.42 ppm). On the 60th day maximum value was recorded by AS which was on par with urea. RPU and NCA recorded significantly higher NH_4^+ - N content than urea and GCU. On the 90th day highest value was for RPU followed by AS, GCU and urea which were on par but significantly superior to NCU and NCA.

Liming:- The effect of Liming was significant on all days. Liming reduced the NH_4^+ - N content on all days.

Interaction:- The effect of interaction was significant on the 30th day. RPU with lime recorded the maximum NH_4^+ - N content and NCU in combination with lime, had the least value. On the 45th day also RPU with lime had a high value. On the 60th day when all treatments with lime gave lower NH_4^+ - N content, RPU with lime gave a higher concentration of NH_4^+ - N. On the 90th day effect of interaction was not significant.

NO_3^- - N :- The data pertaining to this are presented in Table 8 and the analysis of variance in Appendix V.

The NO_3^- - N content increased from 30th to 60th day and decreased from 60th to the 90th day. Lowest value was for urea on all days. On the 30th day, the effect of sources

Table 8. Effect of N-sources and lime on the nitrate nitrogen content (ppm) of the soil at 70 percent field moisture capacity.

Treatment	30th day			45th day			60th day			90th day		
	Source	unlimed	limed	source	unlimed	limed	source	unlimed	limed	source	unlimed	limed
Urea	1.64	1.80	1.49	3.56	3.09	4.03	5.21	5.08	5.34	4.35	4.97	3.74
AS	2.30	2.49	2.11	4.98	4.90	5.07	6.25	5.84	6.66	4.58	4.64	4.52
NCU	2.63	2.12	3.13	4.08	4.59	3.57	6.19	6.06	6.32	4.95	5.76	4.14
NCA	2.13	2.00	2.26	3.78	3.65	3.91	5.56	5.54	5.57	4.72	4.32	5.12
GCU	2.21	2.00	2.41	4.65	4.32	4.98	6.06	6.63	5.49	5.33	5.84	4.82
RPU	2.34	3.02	1.66	4.44	5.23	3.65	5.35	5.16	5.54	4.58	4.98	4.19
Mean		(2.24)	(2.18)		(4.30)	(4.20)		(5.70)	(5.80)		(5.09)	(4.42)

	'F'test	CD(5%)	SEm±	'F'test	CD(5%)	SEm±	'F'test	CD(5%)	SEm±	'F'test	CD(5%)	SEm±
Source	Sig**	0.35	0.11	NS	-	0.33	NS	-	0.33	NS	-	0.28
Lime	NS	-	0.06	NS	-	0.19	NS	-	0.19	Sig*	0.48	0.16
Interaction	Sig**	0.503	0.16	NS	-	0.46	NS	-	0.46	NS	-	0.39

and interaction was significant but the effect of liming was insignificant. The highest content was recorded by NCU followed by RPU, which were on par. AS and GCU were on par. NCU with lime followed by RPU with lime recorded maximum NO_3^- - N. The effect of N sources was not significant on the 45th, 60th and 90th day. On the 90th day liming reduced NO_3^- - N content, except, for NCA, where in the content increased significantly.

Discussion:- Just as in the case of submerged moisture regime, at 70 per cent of field moisture capacity also, it was noted that the NH_4^+ - N content for AS was higher, but for NCA it was less by 20 ppm. This could be attributed to the dissociation of $(NH_4)_2SO_4$ producing NH_4^+ ions. The neem coating in NCA might have prevented this dissociation to a certain extent and so the content was lower for NCA.

For all the urea sources both coated and uncoated, it was found that maximum value was obtained only on the 14th day of incubation, which clearly indicated that rate of hydrolysis was much slower compared to that under submerged condition. In the submerged soil, there was a sharp decline in NH_4^+ - N content after the 4th day (except for RPU) which indicated a faster rate of urea hydrolysis in submerged soil than in an aerated soil. However, this is in contrary to the observation by Delaune and Patrick (1970) that urea hydrolysis was slower under submerged conditions. Here also, RPU maintained a higher NH_4^+ - N content which showed that the release of N is much slower.

From the 30th day, the NH_4^+ - N content was maintained between 70 to 90 ppm; which indicates that the rate of nitrification was inherently low. This was confirmed in the submergence and microbial studies also. The NH_4^+ - N content for all N sources was higher on all days of incubation when compared to that of submerged soil. The NH_4^+ - N released might have gone into soil solution, in the case of submerged soil and lost by volatilisation, whereas at 70 per cent of field moisture capacity, it would have been adsorbed on to the clay complex.

Ammonium sulphate maintained a higher content than that of urea indicating that it was better than urea. Coated fertilisers were not superior in retaining NH_4^+ - N content compared to uncoated fertilisers, as there was not much variation in the content of NH_4^+ - N on any day of incubation.

POT CULTURE EXPERIMENT

A. PLANT.

Growth parameters

i) Plant height: The data on height of the plant are given in Table 9. The analysis of variance is given in Appendix VI.

The height of the plant during panicle initiation

Table 9. Height of the rice plant at various growth stages as influenced by N-sources and liming (in cm)

Growth stages	Panicle initiation			Flowering			Harvest		
Treatments	Source	unlimed	limed	source	unlimed	limed	source	unlimed	limed
Control	38.3	41.0	35.7	54.3	62.1	46.5	61.7	64.0	59.5
Urea	42.6	42.5	42.7	67.1	67.3	67.0	69.0	70.5	67.5
AS	45.2	40.5	50.0	66.5	62.1	70.8	67.4	63.4	71.4
NCU	43.5	41.5	42.5	61.0	56.9	65.2	67.2	64.5	70.0
NCA	42.2	42.0	42.5	59.2	59.4	59.1	64.7	66.0	63.5
GCU	44.7	43.0	46.5	68.7	68.5	68.8	70.7	68.6	71.5
RPU	52.1	51.5	53.5	75.2	73.5	77.0	76.4	74.5	78.4
Mean		(43.1)	(45.2)		(64.2)	(64.9)		(67.3)	(68.8)

	'F'test	CD(5%)	SEm±	'F'test	CD(5%)	SEm±	'F'test	CD(5%)	SEm±
Source	Sig**	6.16	2.03	Sig*	10.40	3.43	Sig**	6.33	2.08
Lime	NS	-	1.08	NS	-	1.76	NS	-	1.02
Interaction	NS	-	2.87	NS	-	4.84	NS	-	2.95

flowering and harvest was significantly influenced by the different sources of nitrogen. Effect of liming and interaction of lime with sources did not significantly influence the height at any of these stages.

At all the stages, RPU recorded the maximum height and control the least. At flowering and harvest GCU closely followed RPU. Among the N sources, NCA recorded the least height. All the other sources were on par.

ii) Number of tillers per plant: The data on number of tillers are presented in Table 10 and Fig. 11. Appendix VII gives its analysis of variance.

The number of tiller was affected significantly by the different sources at the PI stage. NCA recorded the maximum number of tillers followed by GCU and RPU, which were on par. Control gave the lowest value. Though not statistically significant the same trend was observed during flowering and harvest. On the whole, tiller production was more in coated fertilizer treated pots at all stages, both under limed and unlimed condition.

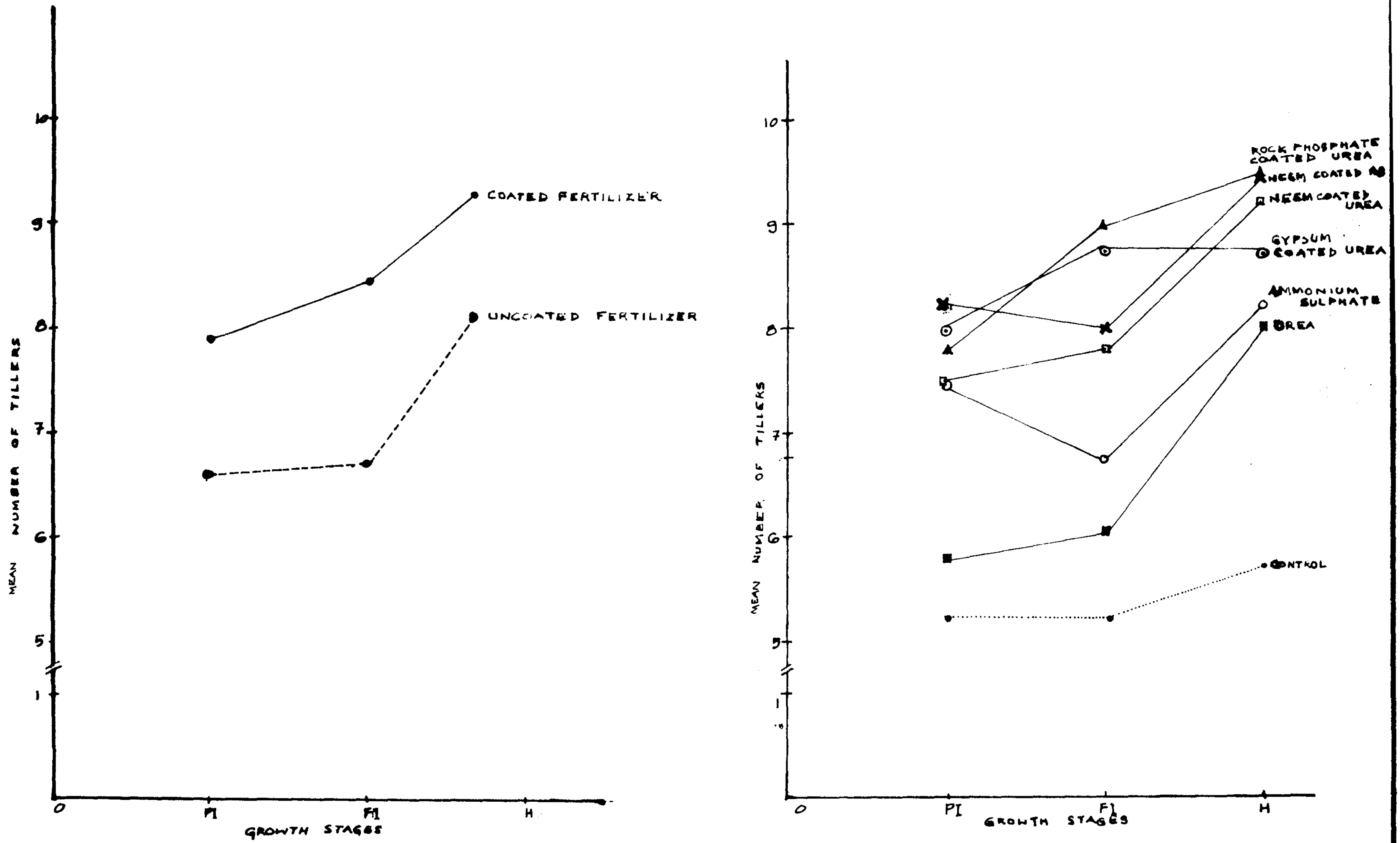
Liming reduced the number of tillers at PI stage, however, the effect was not significant at any other stage. The effect of interaction of N-source and lime was also statistically insignificant.

Table 10. Mean number of tillers/plant at various growth stages of rice plant as influenced by N-sources and liming.

Growth stages	Panicle initiation			Flowering			Harvest		
Treatments	source	unlimed	limed	source	unlimed	limed	source	unlimed	limed
Control	5.25	5.50	5.00	5.25	5.00	5.50	5.75	6.50	5.00
Urea	5.75	6.00	5.50	6.00	6.50	5.50	8.00	8.00	8.00
AS	7.50	7.50	7.50	6.75	6.50	7.00	8.25	7.50	9.00
NCU	7.50	8.00	7.00	7.75	7.00	8.50	9.25	6.50	12.00
NCA	8.25	8.50	8.00	8.00	7.50	8.50	9.50	10.50	8.50
GCU	8.00	7.50	8.50	8.75	8.50	9.00	8.75	8.50	9.00
RPU	7.75	9.00	6.50	9.00	9.00	9.00	9.50	9.50	9.50
Mean		(7.43)	(6.85)		(7.14)	(7.57)		(8.14)	(8.71)

	'F'test	CD(5%)	SEm±	'F'test	CD(5%)	SEm±	'F'test	CD(5%)	SEm±
Source	Sig**	1.51	0.49	NS	-	0.84	NS	-	0.96
Lime	NS	-	0.26	NS	-	0.45	NS	-	0.51
Interaction	NS	-	0.70	NS	-	1.19	NS	-	1.36

FIG. 11. TILLER NUMBER PER PLANT AS INFLUENCED BY N-SOURCES AT VARIOUS GROWTH STAGES OF RICE



(PI: Panicle initiation FI : Flowering H: Harvest)

There was a gradual increase in the number of tillers from PI to harvest.

iii) Leaf area index: The data on LAI are presented in Table 11 and its analysis of variance in Appendix VIII. It is graphically represented in Fig. 12 (a) and (b).

The LAI was significantly affected by the different N-sources at PI, flowering and harvest. It was not significantly affected by liming or N-source and lime interaction. The LAI increased from MT to flowering but decreased from flowering to harvest.

Between the different sources, maximum LAI was for coated fertilizers, during all the stages, it being highest for GCU during MT and PI stages followed by NCU. During flowering and harvest the maximum LAI was recorded by RPU followed by NCU and GCU. During both the stages they were significantly superior to control.

Liming reduced LAI at all stages, higher values of LAI were obtained for N sources without lime. During harvest, maximum value was for unlimed RPU.

iv) Dry matter accumulation: The data pertaining to dry matter accumulation are presented in Table 12 and Fig. 13 (a) and (b). The analysis of variance is given in Appendix IX.

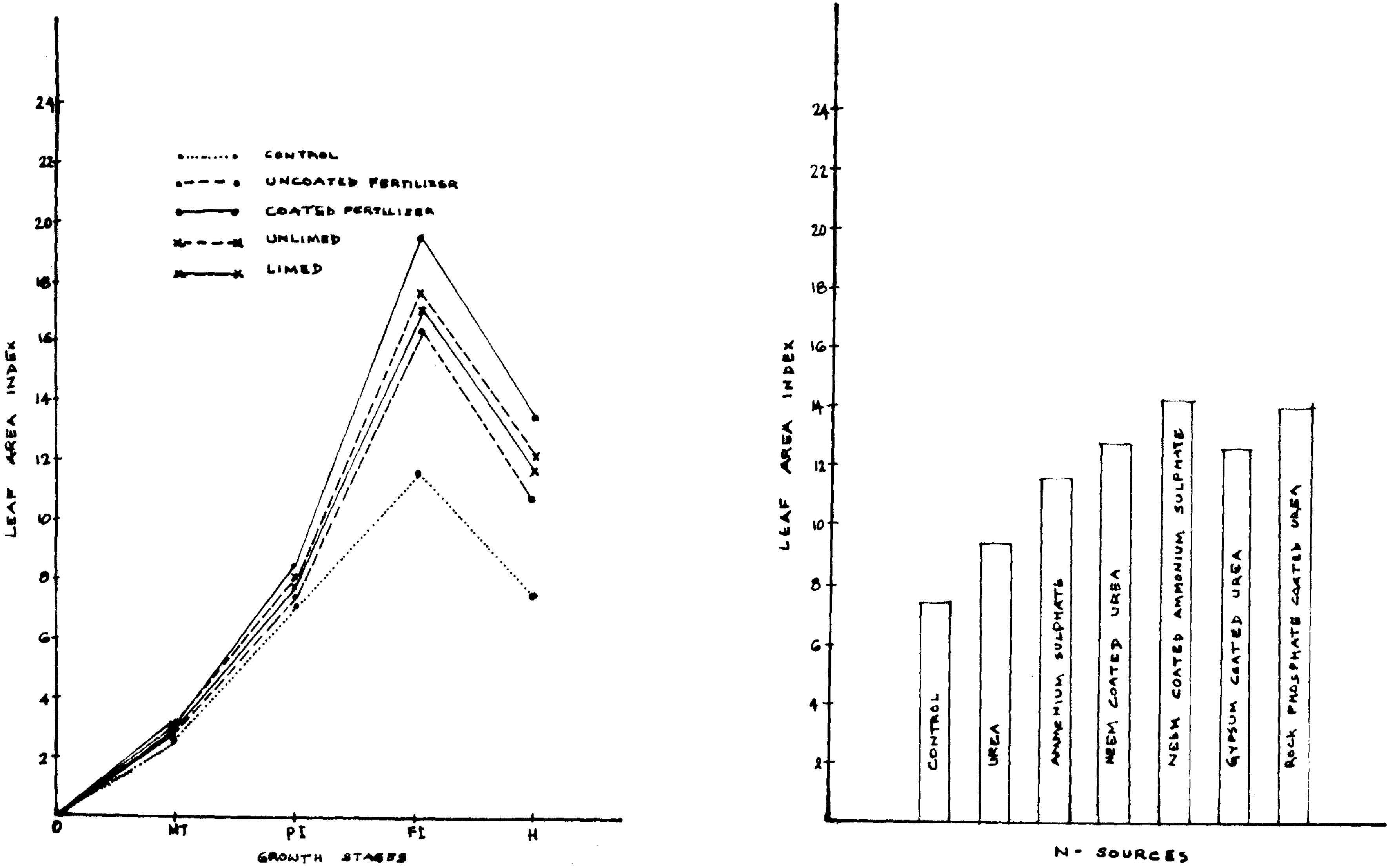
The dry matter accumulation was significantly influenced by N-sources during the PI stage and harvest. Effect of lime

Table 11. **Leaf area index (LAI) at various growth stages of rice plant as influenced by N-sources and liming.**

Growth Stages / Treatments	Maximum tillering			Panicle initiation			Flowering			Harvest		
	source	unlimed	limed	source	unlimed	limed	source	unlimed	limed	source	unlimed	limed
Control	0.42	0.48	0.37	1.47	1.24	1.70	1.58	1.52	1.64	1.36	1.24	1.49
Urea	0.48	0.70	0.26	1.80	1.70	1.90	2.50	2.52	2.48	1.96	2.17	1.75
AS	0.45	0.53	0.36	0.96	1.27	0.65	3.21	3.56	2.87	2.56	2.92	2.19
NCU	0.60	0.56	0.63	1.97	2.17	1.77	3.27	3.60	2.94	2.71	2.96	2.46
NCA	0.52	0.46	0.58	1.73	2.18	1.27	2.83	3.02	2.64	2.08	2.08	2.08
GCU	0.57	0.46	0.68	2.47	2.58	2.37	3.24	2.96	3.51	2.59	2.42	2.77
RPU	0.30	0.44	0.15	1.68	1.79	1.57	3.39	3.63	3.14	2.84	3.24	2.44
Mean		(0.52)	(0.43)		(1.84)	(1.60)		(2.98)	(2.74)		(2.43)	(2.17)

	'F'test	CD(5%)	SEm±	'F'Test	CD(5%)	SEm±	'F'test	CD(5%)	SEm±	'F'test	CD(5%)	SEm±
Source	NS	-	0.08	Sig**	0.66	0.21	Sig**	0.83	0.27	Sig**	0.56	0.18
lime	NS	-	0.01	NS	-	0.12	NS	-	0.12	NS	-	0.10
interaction	NS	-	0.12	NS	-	0.30	NS	-	0.39	NS	-	0.26

FIG: 12. LEAF AREA INDEX OF RICE PLANT :



a) AT VARIOUS STAGES OF GROWTH AS INFLUENCED BY N-SOURCES AND LIMING.

b) AT FLOWERING AS INFLUENCED BY N-SOURCES

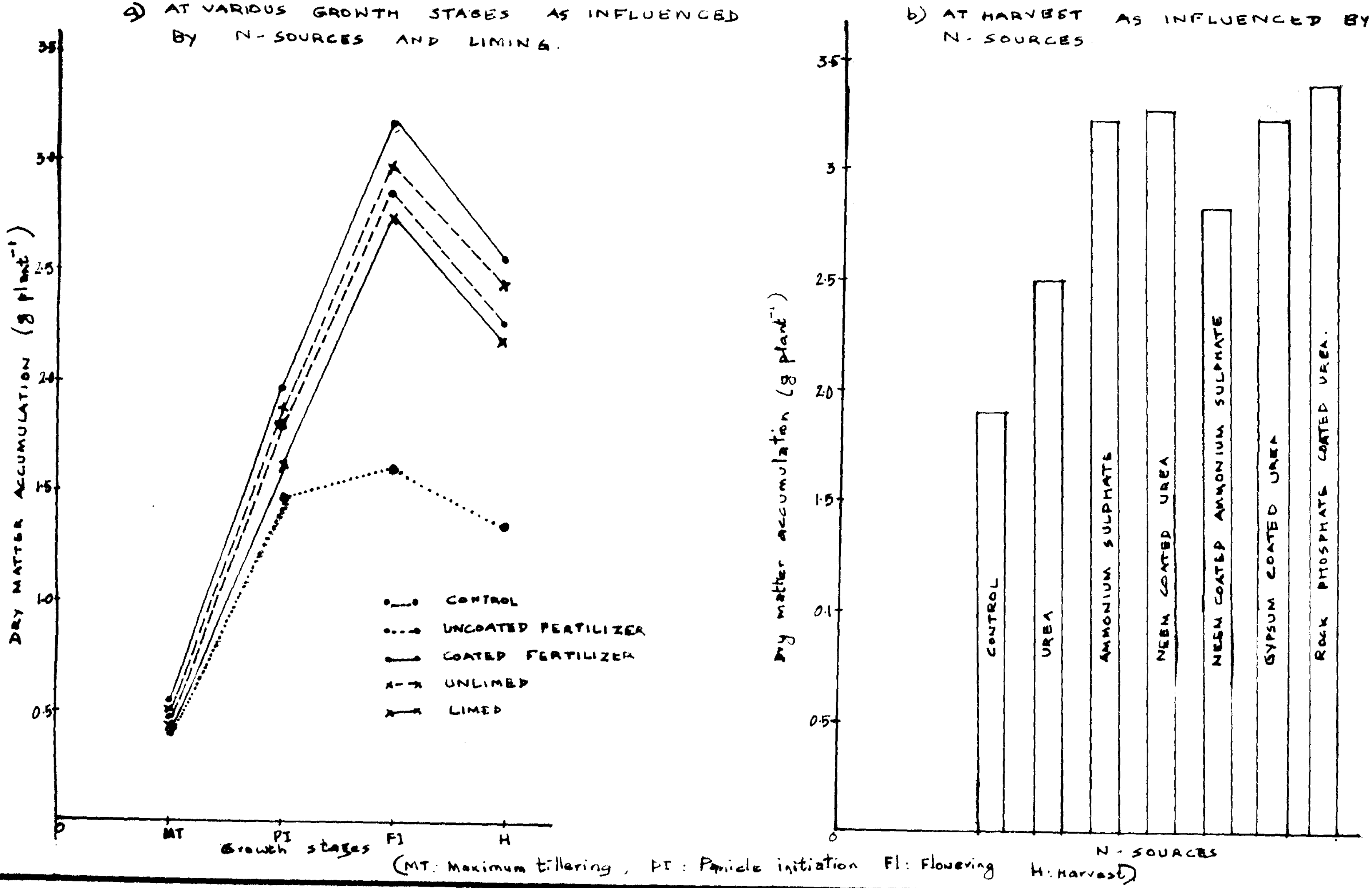
(MT : Maximum tillering PI : Panicle initiation FI : Flowering H : Harvest.)

Table 12. Dry matter accumulation at various growth stages of rice plant as influenced by N-sources and liming (in g plant^{-})

Growth stages Treatments	Maximum tillering			Panicle initiation			Flowering			Harvest		
	source	unlimed	limed	source	unlimed	limed	source	unlimed	limed	source	unlimed	limed
Control	2.68	2.80	2.56	6.92	7.23	6.61	11.55	10.72	12.39	7.45	8.94	5.96
Urea	2.68	2.81	2.55	7.93	7.87	8.00	17.11	14.46	19.76	9.55	9.07	10.04
AS	2.80	2.99	2.62	6.76	7.54	5.98	15.82	16.57	15.05	11.58	10.02	13.15
NCU	2.82	2.89	2.75	8.15	8.33	7.96	21.04	25.58	16.51	12.83	11.80	13.86
NCA	2.90	3.11	2.69	7.51	7.87	7.15	18.02	18.95	17.09	14.23	15.32	13.15
GCU	3.06	2.96	3.16	9.57	9.09	10.05	20.81	17.74	23.89	12.59	12.14	13.05
RPU	2.79	2.81	2.78	7.43	7.30	7.56	18.09	19.59	16.60	13.94	16.40	11.40
Mean		(2.91)	(2.73)		(7.89)	(7.62)		(17.66)	(17.32)		(11.95)	(11.45)

	'F' test	CD(5%)	SEm±	'F' test	CD(5%)	SEm±	'F' test	CD(5%)	SEm±	'F' test	CD(5%)	SEm±
Source	NS	-	0.06	Sig**	1.16	0.38	NS	-	2.69	Sig**	1.99	0.65
lime	NS	-	0.03	NS	-	0.20	NS	-	1.44	NS	-	0.35
interaction	NS	-	0.08	NS	-	0.54	NS	-	3.81	Sig**	2.82	0.93

FIG. 13. DRY MATTER ACCUMULATION OF RICE PLANT:



a) AT VARIOUS GROWTH STAGES AS INFLUENCED BY N-SOURCES AND LIMING.

b) AT HARVEST AS INFLUENCED BY N-SOURCES

(MT: Maximum tillering, PI: Panicle initiation FI: Flowering H: Harvest) was not statistically significant at any of the stages. Interaction of N-sources and lime was statistically significant only during harvest. The dry matter accumulation increased from PI to flowering, but decreased from flowering to harvest.

Comparing between the different N-sources it was found that coated fertilizers gave maximum values compared to urea, ammonium-sulphate as well as control. During PI stage, GCU was significantly superior to all other sources. During harvest NCA recorded the maximum value but was on par with RPU, GCU and NCU.

In the case of interaction, unlimed RPU gave the highest dry matter followed by unlimed NCA. Unlimed RPU was significantly superior to all the sources in combination with lime.

Yield parameters.

i) Number of panicles per plant: The data on number of panicles are given in Table 13 and Fig. 14. The analysis of variance is given the Appendix X.

The different sources of nitrogen had significant influence on the number of panicles. The highest value was noted for NCA followed by RPU which were on par, but, significantly superior to control, urea and ammonium sulphate. In general coated fertilizers gave a higher count of panicles.

The effect of liming and interaction of N sources with lime were insignificant.

Table 13. Mean number of panicles/plant and spikelets/panicle of rice as influenced by N-sources and liming.

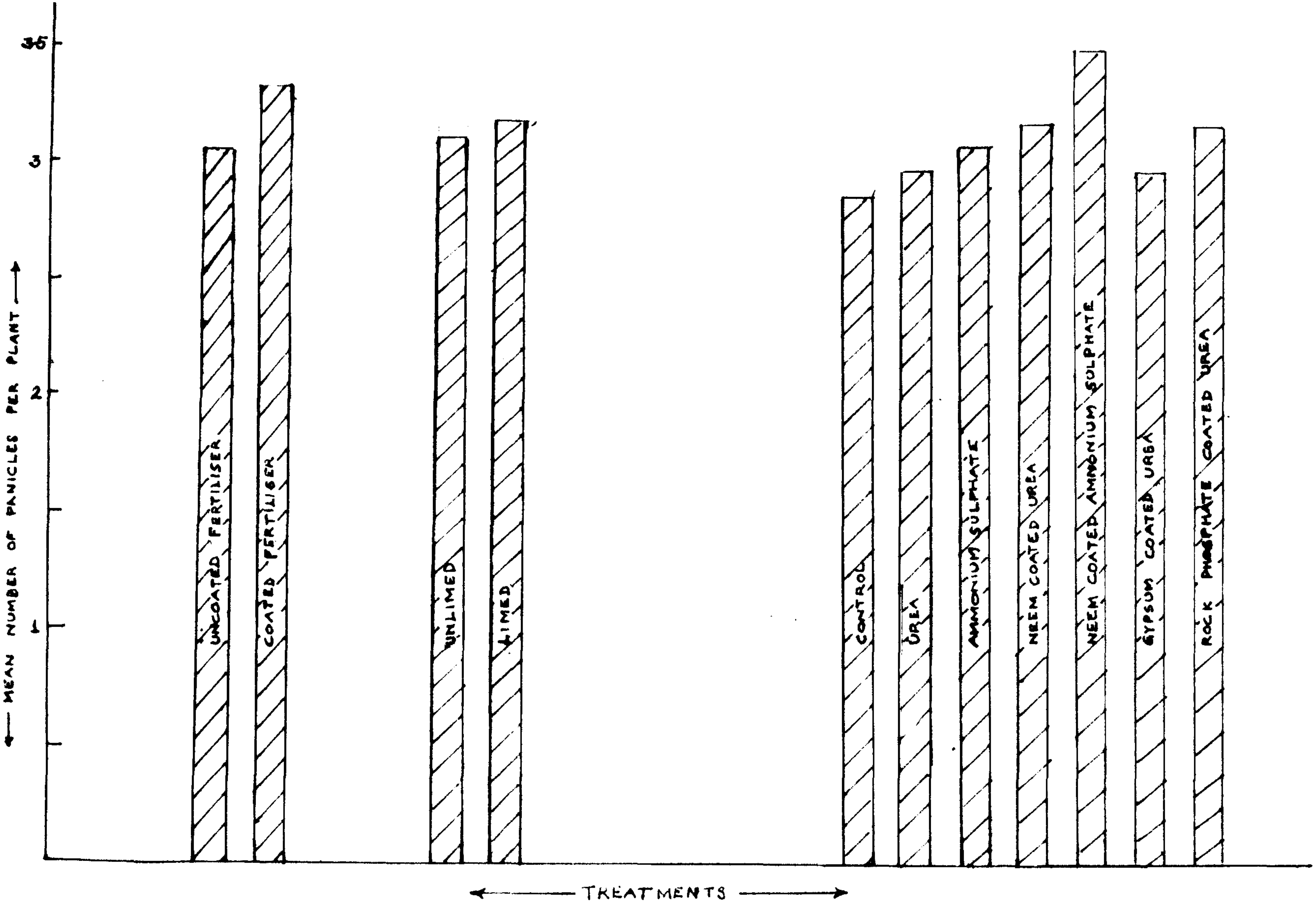
Mean number of panicles/plant			
Treatments	source	unlimed	limed
Control	2.87	2.87	2.87
Urea	2.94	3.00	2.57
AS	3.18	3.12	3.25
NCU	3.31	3.25	3.37
NCA	3.50	3.37	3.62
GCU	2.94	2.87	3.00
RPU	3.31	3.25	3.37
Mean		(3.10)	(3.19)

	'F' test	CD(5%)	SEm±
Source	Sig*	0.36	0.11
lime	NS	-	0.06
interaction	NS	-	0.16

Mean number of spikelets/panicle			
Treatments	source	unlimed	limed
Control	31.58	33.95	29.22
Urea	53.85	48.08	59.62
AS	40.43	43.94	36.92
NCU	45.51	52.30	38.71
NCA	49.54	48.75	50.33
GCU	46.18	51.95	40.41
RPU	48.55	41.29	55.82
Mean		(45.75)	(44.43)

	'F' test	CD(5%)	SEm±
Source	NS	-	5.19
lime	NS	-	2.77
interaction	NS	-	7.33

FIG. 14 EFFECT OF N-SOURCES AND LIMING ON THE NUMBER OF PANICLES PER PLANT IN RICE.



ii) Number of spikelets per panicle: The data on number of spikelets are presented in Table 13 and its analysis of variance given in Appendix X.

Neither liming nor N sources nor the interaction of sources and lime was found to influence the spikelet number significantly.

Grain yield, straw yield and harvest index:- The data on grain yield, straw yield and harvest index are given in Table 14. The analysis of variance is presented in Appendix XI. Grain and straw yield are graphically presented in Fig. 15.

The different sources of nitrogen had significant effect on the grain yield. The lowest yield was from the control, and highest from NCA. In general, coated fertilizers were found to give higher yields than urea and ammonium sulphate. Coated fertilisers NCA, NCU, GCU and RPU were on par. RPU and NCA were significantly superior to urea and control. Interaction of lime and sources of nitrogen significantly affected the grain yield. Maximum yield was recorded by unlimed RPU which was on par with unlimed NCA and GCU. There was significant yield reduction when RPU was combined with lime.

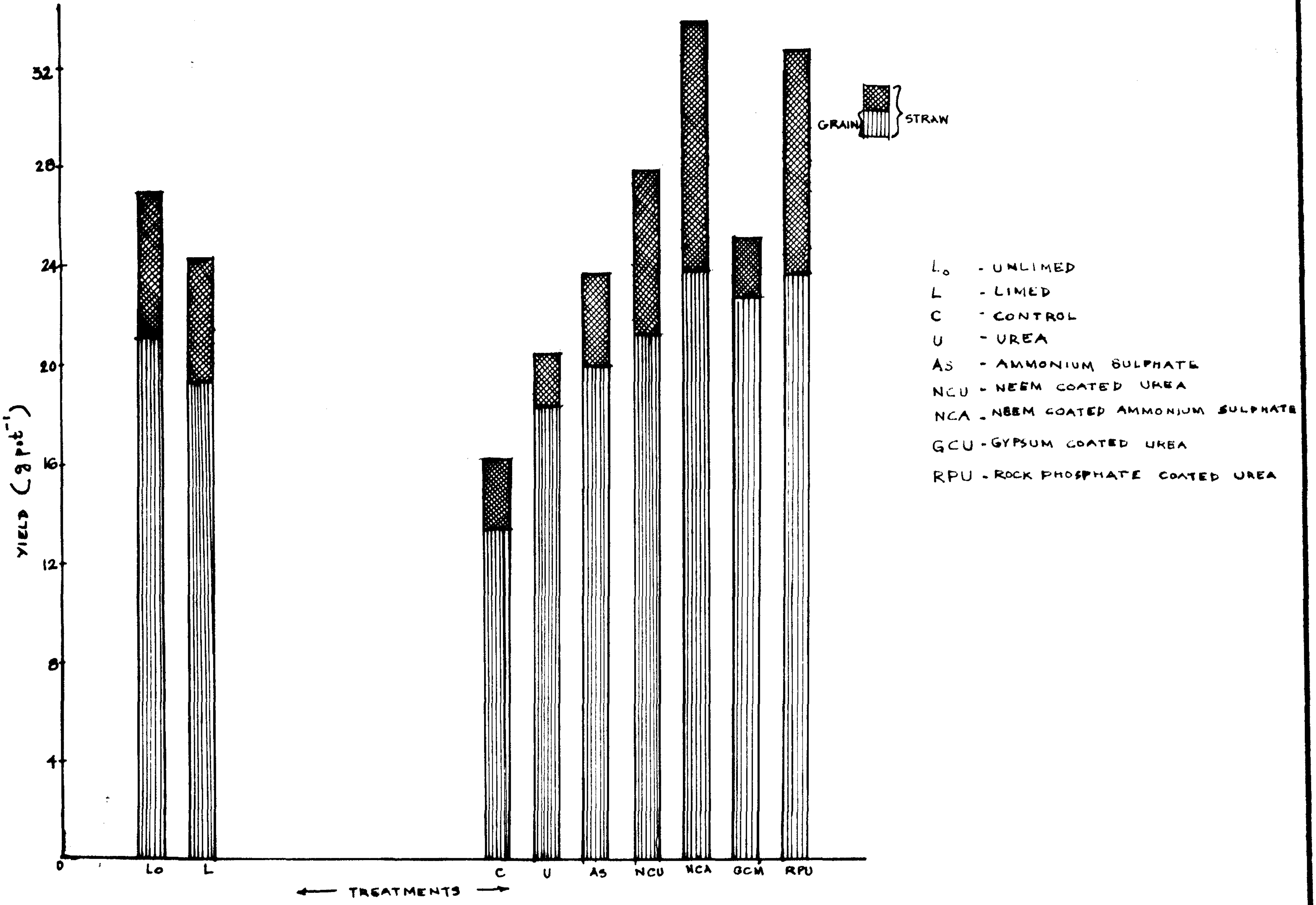
Regarding the effect of nitrogen sources on straw yield, the same trend as that for grain yield was noticed. Among the sources NCA recorded maximum straw yield, followed

Table 14. Grain and straw yield (g pot^{-1}) and harvest index as influenced by N-sources and liming.

Treatments	Grain yield			straw yield			harvest index		
	source	unlimed	limed	source	unlimed	limed	source	unlimed	limed
Control	13.24	14.98	11.50	16.57	20.80	12.35	0.45	0.41	0.48
Urea	18.06	17.95	18.17	20.17	18.35	22.00	0.47	0.49	0.45
AS	19.62	18.12	21.12	23.40	21.22	25.57	0.45	0.46	0.44
NCU	21.11	19.62	22.60	27.73	28.62	26.85	0.43	0.40	0.45
NCA	23.47	24.60	22.35	33.47	36.70	30.25	0.41	0.40	0.43
GCU	22.47	23.40	21.50	24.90	25.10	24.70	0.47	0.48	0.43
RPU	23.28	29.07	17.50	32.48	36.55	28.42	0.41	0.44	0.46
Mean		(21.11)	(19.25)		(26.76)	(24.30)		(0.44)	(0.44)

	'F'test	CD(5%)	SEm±	'F'test	CD(5%)	SEm±	'F'test	CD(5%)	SEm±
Source	Sig**	4.27	1.40	Sig**	6.3	2.07	NS	-	0.018
lime	NS	-	0.75	NS	-	1.11	NS	-	0.009
interaction	Sig**	6.04	1.99	NS	-	2.94	NS	-	0.02

FIG. 15. EFFECT OF N. SOURCES AND LIMING ON THE GRAIN AND STRAW YIELD OF RICE.



by RPU, which was significantly superior to control urea and ammonium sulphate. Straw yield was also higher for coated fertilizers as in the case of grain yield. Lime reduced the straw yield though it was not statistically significant. Interaction of N sources and lime was also statistically insignificant. Unlimed NCA and RPU recorded highest values and the yield reduced when in combination with lime, in both the cases.

Neither did the different N sources, liming nor the interaction of sources and lime significantly influence the harvest index.

N,P, and K content in rice plant as influeneed by N sources and liming at various growth stages.

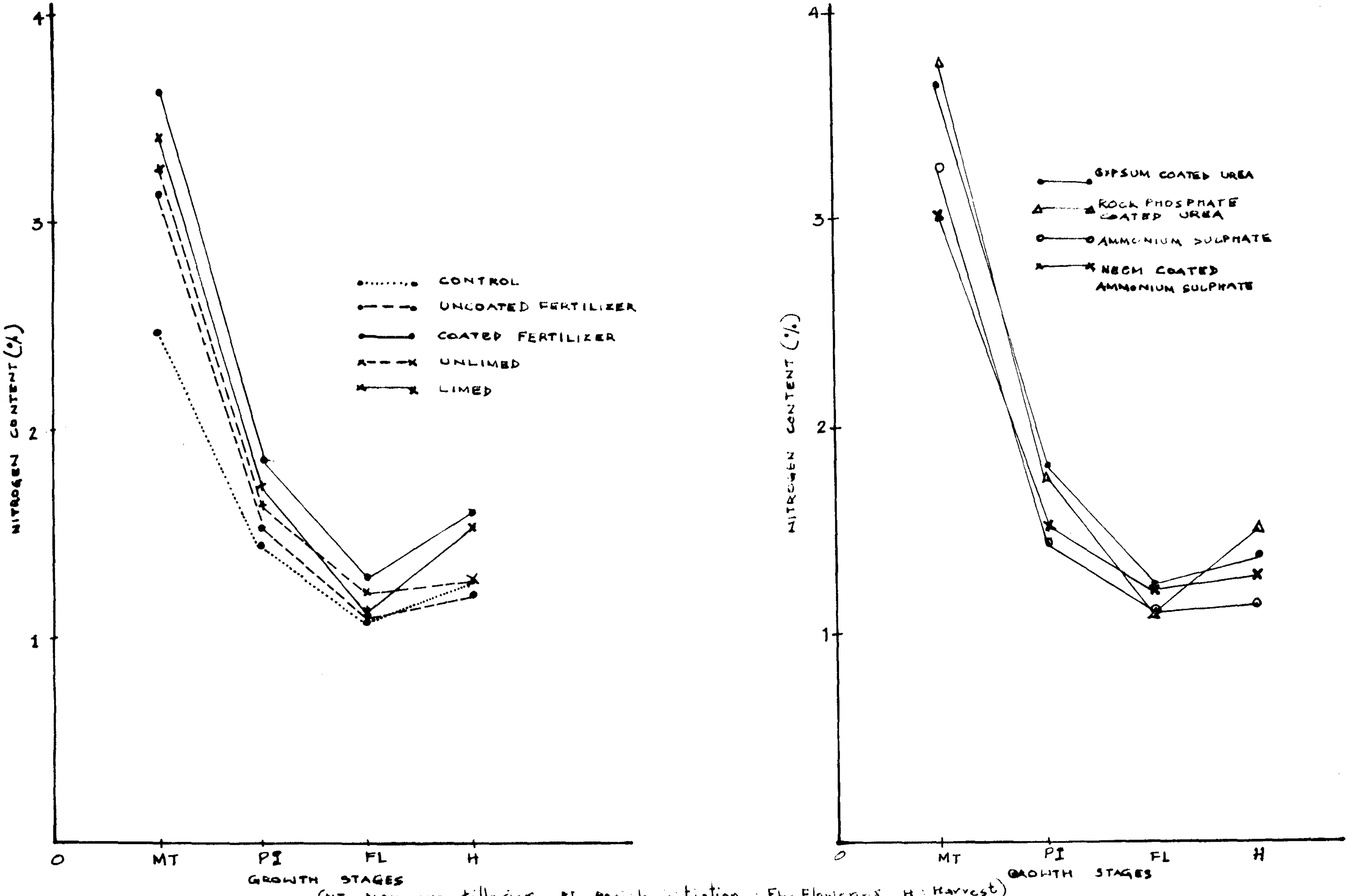
N content: The data are presented in Table 15. The analysis of variance is given in Appendix XII. Figure 16 presents the N content of a few representative treatments. The different sources of nitrogen, liming or interaction of N sources and lime did not have any significant effect on the nitrogen content either at MT, PI or flowering stages. However, the effect of sources had significant influence on the nitrogen content of the grain. The maximum value was recorded by RPU followed by GCU which were an par. They were significantly superior to AS, NCA, NCU and urea. The content decreased from MT to flowering and was maintained till harvest.

Table 15. Nitrogen content (%) in the rice plant at various stages of growth as influenced by N sources and liming.

Growth stages	Maximum tillering			Panicle initiation			Flowering			Harvest					
										Straw			grain		
Treatments.	source	un-limed	limed	source	un-limed	limed	source	un-limed	limed	source	un-limed	limed	source	un-limed	limed
Control	2.47	2.78	2.16	1.44	1.13	1.75	1.12	1.24	1.01	0.43	0.40	0.47	0.81	0.87	0.76
Urea	3.09	3.21	2.97	1.60	1.35	1.85	1.21	1.35	1.08	0.50	0.48	0.52	0.76	0.82	0.70
AS	3.28	3.24	3.32	1.44	1.40	1.48	1.11	1.14	1.08	0.47	0.53	0.41	0.68	0.68	0.68
NCU	3.78	4.15	3.42	1.82	1.89	1.75	1.17	1.14	1.19	0.44	0.40	0.49	0.72	0.66	0.79
NCA	3.51	2.90	4.12	1.89	2.03	1.74	1.15	1.22	1.08	0.52	0.52	0.51	0.68	0.57	0.79
GCU	3.66	3.41	3.91	1.80	1.86	1.73	1.23	1.24	1.21	0.50	0.44	0.57	0.89	0.86	0.91
RPU	3.74	3.24	4.24	1.73	1.67	1.78	1.09	1.11	1.07	0.49	0.53	0.45	0.96	0.88	1.04
Mean		(3.22)	(3.43)		(1.62)	(1.73)		(1.21)	(1.11)		(0.47)	(0.49)		(0.76)	(0.81)

	'F' test	CD(5%)	SEm±	'F' test	CD(5%)	SEm±	'F' test	CD(5%)	SEm±	'F' test	CD(5%)	SEm±	'F' test	CD(5%)	SEm±
Source	NS	-	0.28	NS	-	0.19	NS	-	0.07	NS	-	0.06	Sig	0.16	0.05
lime	NS	-	0.15	NS	-	0.10	NS	-	0.03	NS	-	0.03	NS	-	0.03
interaction	NS	-	0.40	NS	-	0.27	NS	-	0.10	NS	-	0.08	NS	-	0.07

FIG. 16. NITROGEN CONTENT IN RICE PLANT AT VARIOUS GROWTH STAGES AS INFLUENCED BY N-SOURCES AND LIMING.



(MT: Maximum tillering PI: Panicle initiation ; FL: Flowering H: Harvest)

Table 16. Phosphorus content (%) in the rice plant at various stages of growth as influenced by N sources and liming.

Growth stages	Maximum tillering			Panicle initiation			Flowering			Harvest					
										Straw			Grain		
Treatments	source	un-limed	limed	source	un-limed	limed	source	un-limed	limed	source	un-limed	limed	source	un-limed	limed
Control	0.26	0.25	0.28	0.19	0.18	0.20	0.28	0.31	0.25	0.12	0.16	0.09	0.22	0.21	0.23
Urea	0.19	0.21	0.17	0.23	0.21	0.25	0.26	0.26	0.26	0.17	0.18	0.16	0.21	0.23	0.20
AS	0.21	0.12	0.29	0.16	0.18	0.15	0.21	0.21	0.21	0.15	0.15	0.15	0.21	0.21	0.21
NCU	0.27	0.23	0.31	0.19	0.21	0.18	0.25	0.28	0.21	0.16	0.15	0.16	0.22	0.21	0.23
NCA	0.28	0.28	0.28	0.18	0.18	0.18	0.23	0.23	0.23	0.14	0.17	0.11	0.23	0.21	0.25
GCU	0.25	0.28	0.21	0.18	0.18	0.18	0.28	0.28	0.27	0.13	0.13	0.14	0.22	0.23	0.21
RPU	0.25	0.31	0.20	0.17	0.20	0.14	0.24	0.26	0.21	0.15	0.15	0.15	0.22	0.24	0.21
Mean		(0.24)	(0.25)		(0.19)	(0.18)		(0.26)	(0.24)		(0.16)	(0.14)		(0.22)	(0.22)

	'F' test	CD(5%)	SEm±	'F' test	CD(5%)	SEm±	'F' test	CD(5%)	SEm±	'F' test	CD(5%)	SEm±	'F' test	CD(5%)	SEm±
Source	NS	-	0.03	NS	-	0.013	NS	-	0.02	NS	-	0.009	NS	-	0.013
lime	NS	-	0.02	NS	-	0.007	NS	-	0.01	NS	-	0.004	NS	-	0.07
interaction	NS	-	0.04	NS	-	0.02	NS	-	0.03	NS	-	0.016	NS	-	0.02

Table 17. Potassium content (%) in the rice plant at various stages of growth as influenced N sources and liming.

Growth stages	Maximum tillering			Panicle initiation			Flowering			Harvest					
										Straw			grain		
Treat-ments	source	un-limed	limed	source	un-limed	limed	source	un-limed	limed	source	un-limed	limed	source	un-limed	limed
Control	2.92	2.97	2.87	1.49	1.52	1.46	1.76	1.76	1.76	1.72	1.80	1.64	0.43	0.41	0.45
Urea	2.61	2.30	2.92	1.51	1.50	1.52	1.72	1.70	1.74	1.61	1.69	1.53	0.50	0.50	0.49
AS	2.28	2.67	1.90	1.66	1.60	1.73	1.60	1.49	1.71	1.63	1.57	1.69	0.52	0.55	0.50
NCU	1.75	1.55	1.95	1.90	1.88	1.93	1.71	1.61	1.81	1.66	1.66	1.67	0.51	0.48	0.54
NCA	2.06	2.15	1.97	1.91	1.75	2.08	1.59	1.57	1.60	1.52	1.77	1.27	0.53	0.57	0.50
GCU	2.40	2.35	2.45	1.85	1.94	1.77	1.55	1.62	1.48	1.08	1.38	1.04	0.50	0.57	0.50
RPU	2.51	2.45	2.57	2.00	1.97	2.04	1.56	1.58	1.65	1.21	1.14	1.29	0.49	0.44	0.55
Mean		(2.35)	(2.37)		(1.73)	(1.79)		(1.62)	(1.66)		(1.54)	(1.44)		(0.49)	(0.51)

	'F' test	CD(5%)	SEm±	'F' test	CD(5%)	SEm±	'F' test	CD(5%)	SEm±	'F' test	CD(5%)	SEm±	'F' test	CD(5%)	SEm±
Source	NS	-	0.24	NS	-	0.23	NS	-	0.13	NS	-	0.28	NS	-	0.03
lime	NS	-	0.12	NS	-	0.12	NS	-	0.07	NS	-	0.15	NS	-	0.02
interaction	NS	-	0.34	NS	-	0.32	NS	-	0.18	NS	-	0.40	NS	-	0.04

P content: The data are given in Table 16 and its analysis of variance in Appendix XIII. The phosphorus content in the plant was not significantly affected by the N sources or liming or source and lime interaction at any of the growth stages. With stage of the crop, there was a decrease in content from MT to PI and a gradual increase from PI to harvest.

K content: The data are presented in Table 17 and its analysis of variance given in Appendix XIV. The same trend as that of P content was noticed here also, during all the growth stages. The effect of N-sources, liming and interaction of sources with lime was not statistically significant. The content decreased from MT to PI.

N, P, K uptake by the rice plant at various growth stages as influenced by N sources and liming.

N uptake: The data on uptake of nitrogen are given in Table 18 and its analysis of variance in Appendix XV. It is presented in Fig. 17.

As in the case of N-content, the uptake was affected significantly only during harvest. The uptake by grain differed due to the difference in sources of nitrogen used.

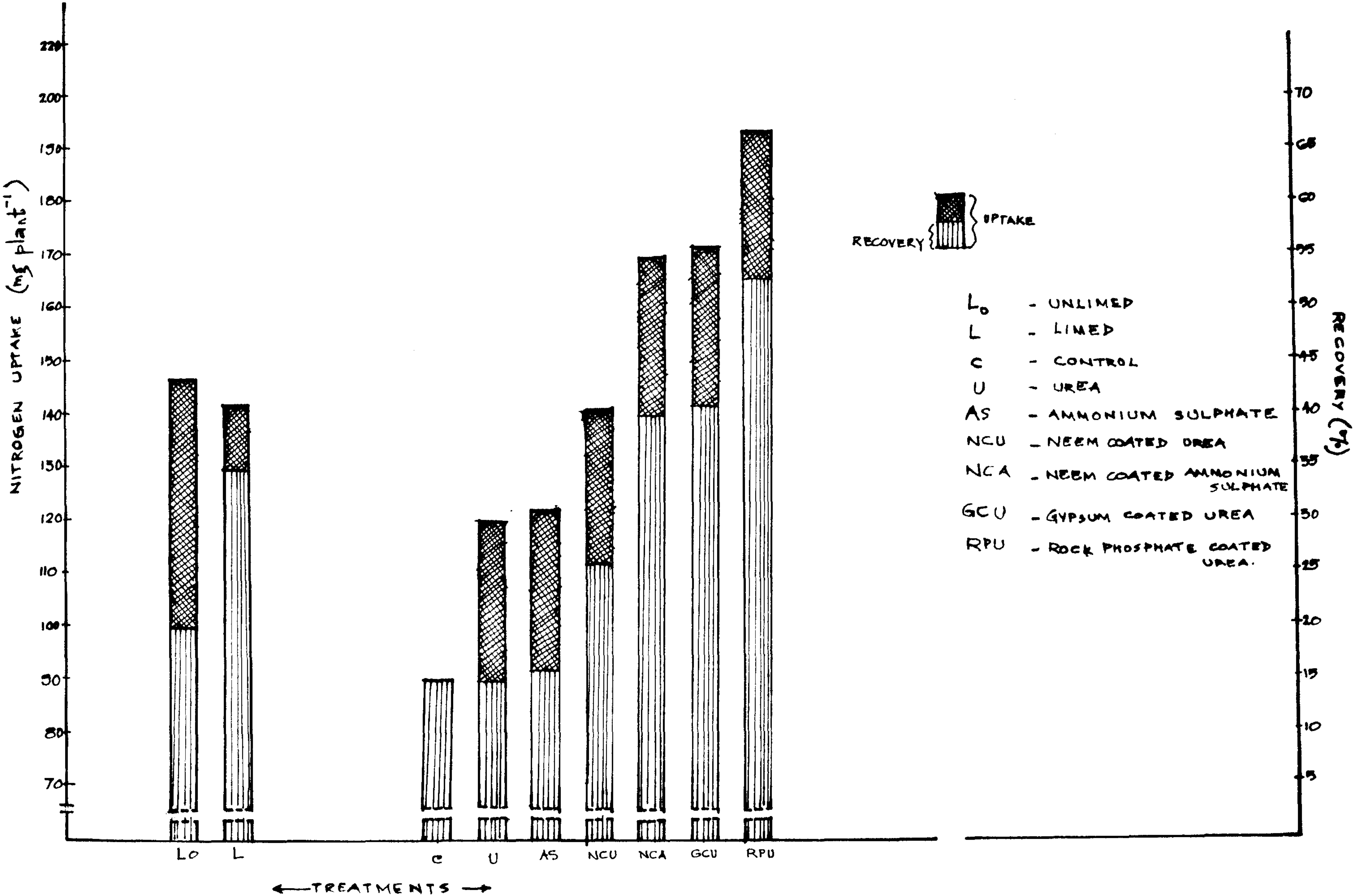
With advancing stage of the crop, from MT to flowering the uptake increased for all treatments with nitrogen, but reduced at harvest.

Table 18. Nitrogen uptake (mg plant^{-1}) at various stages of growth of rice as influenced by N sources and liming.

Growth stages	Maximum tillering			Panicle initiation			Flowering			Harvest					
										Straw			Grain		
Treatments	source	unlimed	limed	source	unlimed	limed	source	unlimed	limed	source	unlimed	limed	source	unlimed	limed
Control	86.53	85.63	87.43	99.17	92.26	106.09	129.86	134.29	125.44	35.80	42.20	28.40	54.80	64.58	44.02
Urea	83.02	90.30	75.73	127.39	106.31	148.16	204.49	195.34	213.65	49.46	43.10	53.82	71.14	73.92	68.38
AS	91.62	97.01	86.23	97.07	106.98	87.16	177.63	190.59	164.67	55.24	56.60	53.90	66.48	61.70	73.26
NCU	107.15	120.20	94.11	146.49	156.61	136.38	224.22	290.85	157.59	62.76	59.90	66.60	78.46	69.70	89.22
NCA	100.69	90.39	110.90	141.24	159.33	123.15	186.09	188.61	183.57	88.24	96.78	79.70	82.18	70.74	93.62
GCU	112.52	101.31	123.70	174.08	172.08	176.08	258.38	222.24	294.52	70.52	55.06	86.00	101.28	102.46	100.10
RPU	104.61	91.46	117.75	129.40	123.23	135.57	198.42	219.73	177.12	83.82	102.98	64.66	110.64	128.04	93.24
Mean		(99.47)	(102.28)		(129.54)	(131.84)		(205.50)	(188.08)		(65.38)	(62.02)		(81.72)	(80.26)

	'F' test	CD(5%)	SEm±	'F' test	CD(5%)	SEm±	'F' test	CD(5%)	SEm±	'F' test	CD(5%)	SEm±	'F' test	CD(5%)	SEm±
Source	NS	-	7.93	NS	-	17.28	NS	-	33.92	NS	-	12.30	Sig*	28.82	9.48
lime	NS	-	4.23	NS	-	9.22	NS	-	18.10	NS	-	6.56	NS	-	5.06
interaction	NS	-	11.24	NS	-	24.49	NS	-	48.08	NS	-	17.40	NS	-	13.44

FIG. 17. EFFECT OF N-SOURCES AND LIMING ON THE TOTAL NITROGEN UPTAKE AND RECOVERY IN RICE



Comparing between sources, the uptake was higher for coated fertiliser treatment than that with urea or ammonium sulphate. The same was noted at all stages.

The uptake by grain was least in control and high for coated fertilisers. RPU recorded the maximum value followed by GCU and NCA which were on par. RPU and GCU were significantly superior to control, AS and urea. The uptake by straw was maximum for NCA followed by RPU. Overall the uptake was higher for coated fertiliser treated plants.

Effect of liming and interaction of N sources with lime had no significant effect on uptake at any of the stages.

P uptake: The data are presented in Table 19. The analysis of variance is given in Appendix XVI.

The uptake of P increased from MT to flowering for all treatments. Liming did not have any significant effect during any of the stages.

During PI stage, there was significant difference between N-sources. The lowest value was recorded by AS. Highest value was for urea recorded followed by GCU. At flowering higher uptake was noted for GCU followed by urea.

The uptake by grain was significant with high values recorded by NCA. The uptake by straw was maximum with NCU,

Table 19. Phosphorus uptake (mg plant^{-1}) at various stages of growth of rice as influenced by N sources and liming.

Growth stages	Maximum tillering			Panicle initiation			Flowering			Harvest					
										Straw			Grain		
Treatments	source	unlimed	limed	source	unlimed	limed	source	unlimed	limed	source	unlimed	limed	source	unlimed	limed
Control	7.10	7.05	7.15	13.55	13.60	13.50	31.95	33.00	30.95	12.28	16.90	7.68	14.62	15.76	13.46
Urea	5.32	6.15	4.50	19.00	17.50	20.50	45.02	39.50	50.55	15.76	14.70	16.82	20.54	21.06	20.02
AS	5.67	3.55	7.80	11.42	13.20	9.65	33.77	34.60	32.95	18.24	16.54	19.94	21.46	19.82	23.12
NCU	7.82	6.80	8.85	16.37	18.50	14.25	36.60	35.75	37.45	24.52	26.80	22.16	24.76	22.86	26.66
NCA	8.15	8.75	7.55	13.82	14.45	13.20	42.65	44.95	40.35	23.76	31.52	16.00	27.38	26.84	27.90
GCU	7.65	8.35	6.95	17.50	17.00	18.00	59.27	51.65	66.90	19.28	16.72	21.84	25.42	27.74	23.10
RPU	7.17	8.75	5.60	12.67	14.85	10.50	43.97	52.10	35.85	22.16	22.16	22.18	26.36	34.00	18.74
Mean		(7.05)	(6.01)		(15.58)	(14.22)		(41.65)	(42.14)		(20.68)	(18.14)		(24.00)	(10.94)

	'F' test	CD(5%)	SEm±	'F' test	CD(5%)	SEm±	'F' test	CD(5%)	SEm±	'F' test	CD(5%)	SEm±	'F' test	CD(5%)	SEm±
Source	NS	-	0.80	Sig*	4.52	1.49	NS	-	6.39	Sig**	5.24	0.162	Sig*	7.06	2.32
lime	NS	-	0.43	NS	-	0.79	NS	-	3.41	NS	-	0.92	NS	-	0.124
interaction	NS	-	1.14	NS	-	2.10	NS	-	9.06	Sig**	7.42	2.44	NS	-	3.28

Table 20. Potassium uptake (mg plant^{-1}) at various stages of growth of rice as influenced by N sources and liming.

Growth stages	Maximum tillering			Panicle initiation			Flowering			Harvest					
										Straw			Grain		
Treatments	source	unlimed	limed	source	unlimed	limed	source	unlimed	limed	source	unlimed	limed	source	unlimed	limed
Control	78.40	83.31	73.50	102.68	108.68	96.67	204.75	191.00	218.50	287.76	186.82	390.48	28.58	30.92	26.26
Urea	75.21	75.93	74.50	118.91	116.22	121.60	297.99	254.57	341.42	146.42	159.02	153.82	46.76	45.46	48.04
AS	64.95	79.91	50.00	113.22	122.32	104.12	252.58	246.42	258.74	198.78	167.08	230.50	51.48	45.62	53.32
NCU	59.01	64.41	53.62	153.96	151.37	156.55	345.58	398.39	292.77	228.72	230.22	227.22	55.44	50.10	60.80
NCA	60.06	66.99	53.13	144.18	138.37	149.98	286.30	297.55	275.06	261.62	327.60	195.62	63.22	70.04	56.40
GCU	73.27	69.71	76.83	175.61	174.69	176.53	324.37	288.86	359.88	148.52	141.62	155.44	56.54	52.74	60.34
RPU	69.93	68.42	71.43	150.50	146.40	154.60	282.06	310.32	253.80	193.40	203.68	182.12	56.54	67.72	45.38
Mean		(69.81)	(64.72)		(136.86)	(137.15)		(283.87)	(285.70)		(202.00)	(219.46)		(52.36)	(25.00)

	'F' test	CD(5%)	SEm±	'F' test	CD(5%)	SEm±	'F' test	CD(5%)	SEm±	'F' test	CD(5%)	SEm±	'F' test	CD(5%)	SEm±
Source	NS	-	6.71	NS	-	18.85	NS	-	44.00	NS	-	61.94	Sig**	14.70	4.82
lime	NS	-	2.98	NS	-	10.06	NS	-	23.48	NS	-	33.06	NS	-	2.58
interaction	NS	-	7.92	NS	-	26.72	NS	-	62.35	NS	-	87.76	NS	-	6.86

followed by NCA and RPU, which were significantly higher than control, urea or AS.

Effect of interaction of source and lime was not significant at any of the stages, except at harvest where unlimed NCA gave significantly higher uptake for straw.

K uptake: The data pertaining to uptake of K, are given in Table 20 and analysis of variance in Appendix XVII.

The uptake of K increased from MT to flowering. There was no significant difference in uptake due to the difference in liming or source-lime interaction during any of the stages. There was a higher uptake for plants treated with coated fertilizers.

Uptake by grain was significantly increased with N-sources only. Maximum value being with NCA. The effect of all coated fertilizers were on par.

B. SOIL

Effect of N-sources and lime on NH_4^+ - N and NO_3^- - N content of the soil at various stages of the crop.

Ammoniacal nitrogen content.

The data on NH_4^+ - N content (mean of two replications) are presented in Table 21. The content in the control pot remained almost the same throughout the period. Fertilizer

Table 21. **Ammoniacal nitrogen content (ppm) in the soil at different stages of the rice crop as influenced by N-sources and lime.**

Treatments	Growth stages			
	Maximum tillering	Panicle initiation	Flowering	Harvest
L_oC	10.65	10.22	9.44	10.15
LC	14.42	10.97	9.68	11.20
L_oU	22.60	19.37	10.94	8.19
LU	42.46	11.58	11.16	7.74
L_oAS	18.96	22.70	16.13	14.80
LAS	21.65	15.85	11.78	13.23
L_oNCU	83.46	19.28	11.22	15.31
LNCU	18.37	7.28	8.23	10.33
L_oNCA	16.86	13.40	7.27	6.23
LNCA	8.12	8.36	10.05	8.42
L_oGCU	19.80	9.76	11.25	8.84
LGCU	77.24	13.00	13.05	10.86
L_oRPU	28.68	13.40	9.54	8.02
LRPU	20.73	10.80	10.12	10.53

Table 22. Nitrate nitrogen content (ppm) in the soil at different stages of the rice crop as influenced by N-sources and lime.

Treatment	Growth stages			
	Maximum tillering	Panicle initiation	Flowering	Harvest
L_oC	1.27	0.19	0.61	0.20
LC	1.90	0.67	0.32	0.10
L_oU	1.86	0.27	0.46	0.17
LU	1.76	0.63	0.20	0.13
L_oAS	1.59	0.30	0.22	0.28
LAS	1.28	0.71	0.24	0.20
L_oNCU	1.43	0.35	0.37	0.26
LNCU	0.86	0.59	0.17	0.31
L_oNCA	2.06	0.60	0.08	0.29
LNCA	0.64	0.23	0.53	0.30
L_oGCU	1.78	0.37	0.10	0.19
LGCU	0.63	0.63	0.79	0.24
L_oRPU	1.55	0.37	0.34	0.21
LRPU	1.56	0.66	0.90	0.05

was applied at tillering stage. The content increased at MT, for all sources when compared to control. Liming reduced the NH_4^+ - N content in RPU, NCU and NCA (Exceptionally high values were noted for L_oNCU and LGCU). At PI stage, comparing between the different treatments, the limed treatments showed lower content for all sources, than its corresponding unlimed treatment. The content decreased from PI to harvest.

Nitrate Nitrogen content:-

The data are presented in Table 22. At MT stage, application of lime reduced NO_3^- - N content with all the sources except GCU. Comparing between the stages, flowering and harvest the NO_3^- - N content decreased, the decrease being more in the limed treatments. In general, the NO_3^- - N content increased on fertiliser application and decreased progressively with advancing stages of the crop.

Effect of N-sources and lime on the pH and EC of the soil at different stages of the crop (μmhos/cm)

pH:- The data are given in Table 23. Liming was done a week before transplanting. Before fertilisation but after liming, the pH of the soil increased. Soon after fertilizer application there was a drastic reduction in pH with AS. After the application of the second dose of fertilizer, the pH was maintained without much fluctuations from PI till harvest.

Table 23. Effect of different N-sources and liming on pH of the soil, at various stages of the rice crop.

Treatments	Growth stages				
	Before fertilizer application	Maximum tillering	Panicle initiation	Flowering	Harvest
L_oC	6.12	4.82	4.77	5.00	4.97
LC	6.15	5.87	6.25	5.85	6.15
L_oU	5.80	5.60	5.57	5.25	5.65
LU	6.12	6.12	5.85	5.75	5.87
L_oAS	5.20	4.75	6.07	5.90	6.17
LAS	6.15	5.25	5.90	4.75	5.65
L_oNCU	6.07	5.67	5.32	5.45	5.20
LNCU	5.95	5.92	5.25	5.25	5.50
L_oNCA	5.12	5.27	5.12	5.75	6.05
LNCA	5.42	5.42	6.32	5.75	6.20
L_oGCU	5.15	5.52	6.10	5.85	6.15
LGCU	6.05	5.72	5.60	6.02	6.10
L_oRPU	5.25	5.57	5.92	5.10	5.45
LRPU	5.95	5.77	6.10	5.50	6.15

In the control pot, there was a decrease in pH from 6.12 to 4.97 at harvest. The limed treatments were found to have a higher pH value than the corresponding unlimed treatments at harvest. Among the limed treatments, NCU, NCA and GCU did not show much variation in pH during the vegetative and reproductive stages.

Overall, there was no significant difference in pH due to the different nitrogen sources used.

EC:- The data are presented in Table 24. Before fertilizer application, the EC varied from 50 to 90 μmhos cm^{-1} between limed and unlimed pots. After fertilizer application the EC increased in all the cases. At MT high values were recorded by AS and urea compared to the other sources. However, at PI stage there was no much variation in EC values between sources. There was a gradual reduction in EC at PI stage and thereafter till harvest.

Liming reduced the EC values with urea, AS, NCU and RPU at PI, flowering and harvest.

Correlation of grain yield with soil factors and yield attributes.

The details of correlation study are given in Appendix XVIII.

Correlation of grain yield with the ammoniacal nitrogen content in soil at MT, PI, flowering and harvest was not significant. The nitrate nitrogen content due to different

Table 24. Effect of different N-sources and liming on the electrical conductivity (µmhos/cm^{-1}) of the soil, at various stages of the rice crop.

	Growth stages				
Treatments	Before fertilizer application	maximum tillering	panicle initiation	Flowering	Harvest
L_oC	70.0	350.0	45.0	9.5	9.5
LC	50.0	340.0	77.5	9.5	10.5
L_oU	77.5	230.0	50.0	14.0	13.0
LU	75.0	370.0	35.0	7.0	6.5
L_oAS	50.0	350.0	80.0	15.5	15.0
LAS	75.0	320.0	37.5	15.0	12.5
L_oNCU	92.5	300.0	52.5	12.0	11.5
LNCU	75.0	40.0	30.0	4.5	6.0
L_oNCA	55.0	80.0	55.0	13.5	14.5
LNCA	55.0	95.0	65.0	6.5	7.0
L_oGCU	55.0	95.0	40.0	9.5	8.0
LGCU	55.0	125.0	77.5	11.5	10.5
L_oRPU	60.0	130.0	70.0	14.0	13.5
LRPU	80.0	100.0	35.0	12.0	10.5

N sources and liming had no significant correlation with yield during the different stages of the crop. Though not statistically significant there was a positive correlation between grain yield and NO_3^- - N content at MT and harvest.

Dry matter acumulation and grain yield was significantly correlated only at harvest. The number of tillers and the leaf area index at flowering and harvest had significant positive correlation with grain yield.

The number of panicles/plant and 100 grain weight though statistically insignificant gave a near positive correlation with grain yield.

Discussion:- The beneficial effect of N on growth and yield attributing characters of rice are well known and established. Application of N significantly increased the growth and yield characters in rice. Dry matter accumulation was less in the initial stages and increased from PI to flowering (Fig.13). The effect of N on grain and straw yield were significant with N application (Table 14). Increase in grain and straw yield due to N application has been reported by a large number of workers (Saho et al. 1980; Pandey and Dayanad, 1984).

The concentration of N (Table 15) and N uptake (Table 18) by rice plant was increased by N application. The content decreased from PI to flowering due to the rapid metabolic utilisation of N for greater biomass production and subsequent distribution in a larger mass of dry matter.

Phosphorus concentration (Table 16) and uptake (Table 19) increased and gradually decreased at harvest. The decrease in content may be due to the increased translocation and accumulation of starch in grain. The relation between carbohydrate metabolism and phosphorus has been already well established.

Potassium concentration also decreased from MT to PI and was maintained thereafter. This decrease in K uptake might be due to the competition of K^+ with NH_4^+ ions for the absorption site. Such antagonistic relation between K^+ and NH_4^+ ions was observed by Cox and Reisenauer (1973).

Results clearly showed that coated fertilizers (RPU, GCU, NCU and NCA) gave higher yields than uncoated fertilisers (urea and ammonium sulphate). Coated fertilisers positively influenced the morphological and yield attributing characters like height, tiller number, leaf area index (LAI), dry matter accumulation, panicle number, spikelet number. The increase in grain yield was mainly due to increase in number of panicles per plant (Fig. 14). The correlation studies (Appendix XVIII) have indicated a significant correlation between yield and LAI at flowering and harvest, dry matter accumulation and number of tillers at flowering and an almost significant correlation with 100 grain weight. It has been shown that the main sink, the panicle number per unit field area is determined during the vegetative stage (De Datta, 1981). Higher uptake and utilisation of N by the coated fertiliser treated plants (Fig. 17) gave a higher tiller number (Fig. 11), consequently reflecting in the higher dry matter accumulation. The higher LAI at flowering, for coated fertilisers (Fig. 12) clearly indicated that more photosynthates were produced at the time of flowering. Photosynthate accumulation after flowering is directly related to carbohydrate accumulation in grain. About 70-80% of the carbohydrate in the grain are synthesized after flowering (Ishizuke and Tanaka, 1953).

In the case of urea the recovery was very low, about 15.2% only (Appendix. XX). Large loss of N from urea would have happened probably due to leaching, or in the pot it would have moved beyond the root zone. This could be expected because the rate of urea hydrolysis was slow in Karappadom soils (Experiment. 4). Liming would have enhanced the N loss from urea, through ammonia volatilisation, as liming was found to enhance the rate of urea hydrolysis and the consequent increase in pH would have helped the volatilisation process. In the case of ammonium sulphate also the probable low recovery of N of 16.29% may be due to ammonia volatilisation, resulting from a high concentration.

The coated fertilisers recorded a higher recovery ranging from 26.32% to 53.10%. Among then, RPU was found to be highly efficient in reducing the N loss. The efficient coating would have enabled a slower rate of release of urea which was more efficiently utilized by the rice crop. The laboratory studies also confirmed this observation.

Neem cake coated fertilisers (especially ammonium sulphate coated with neem cake, NCA) was found to be efficient due to the coal-tar coating than the nitrification inhibition effect of neem. This assumption is based on the fact that nitrification rate is found to be inherently low in this soil (Appendix. XXI). Nitrification in acid soils is low (Alexander, 1977).

Liming did not significantly influence the grain yield in this study. It was found that though liming increased pH in the beginning, later on the limed and unlimed treatments had almost similar pH (Fig. 1 and 2). Therefore, it was concluded that narrowing of pH was mainly due to submergence effect, than the effect of lime. Hence, lime has acted as a calcium source than a pH ameliorant. This has been indicated in the studies on soil reaction (experiment. 1). Kurup and Ramankutty (1969) also reported that there was no response to lime in Kuttanad soils.

The grain yield from limed RPU was very low when compared to unlimed RPU. Liming must have reduced the effectiveness of coating. Liming was also found to increase loss of NH_3 (from laboratory studies). Therefore unlimed RPU with it's gradual release behaviour, gave better yields.

The high dry matter accumulated by unlimed RPU at harvest was due to the high LAI at flowering, which must have contributed to more production of photosynthates. The number of panicles per plant was maintained high when compared to the other treatments. All these factors together must have been contributory reasons for higher yields recorded by plants supplied with RPU without the combination of lime.

Thus it could be concluded from this study that the rate of nitrification in Karappadom soil was low, and liming had very little response in this soil. It also revealed that coated fertilisers performed better than uncoated fertilisers. Rock phosphate coated urea, being the best among the sources tried.

Hence, further studies, including field experiments, would be practically and scientifically relevant.

SUMMARY AND CONCLUSIONS

SUMMARY AND CONCLUSIONS

An experiment on 'the dynamics of applied nitrogen in Karappadom soil' was conducted at the College of Horticulture, Vellanikkara, Trichur to study the mechanism of transformation of applied nitrogen, to find out the effect of interaction of lime and nitrogen on rice and finally to evaluate the best source of nitrogen for rice. They study was conducted in two parts viz. laboratory incubation study and pot culture study (taken up from June to October, 1986).

The soil used for the study was obtained from the Rice Research Station, Moncompu. For the incubation study six different materials viz. Urea, ammonium-sulphate, neem coated urea, neem coated ammonium sulphate, gypsum coated urea and rock phosphate coated urea were used as nitrogen sources. The soil was supplied with 100 ppm N, without lime and in combination with lime. It was maintained under two different moisture regimes - submerged and at 70 per cent of field moisture capacity. Samples were drawn at periodic intervals and NH_4^+ - N and NO_3^- - N contents were estimated. The pH, Eh and EC of the submerged sample were also determined at periodic intervals.

The pot culture study also included the same 6 nitrogen sources and treatments with and without lime. Nitrogen was applied at the rate of 90 kg ha^{-1} in two split doses, at tillering and a week before panicle initiation. The rice variety, Jyothi was grown and observations on the growth characters, content and uptake of N, P and K at periodic intervals and yield were recorded.

The results of the study are summarised below.

1. pH of the soil increased on submergence. Lime application increased the pH in all treatments during the initial period of submergence only.

2. Eh rapidly declined, immediately after submergence. It was followed by an increase and thereafter a gradual decrease and then stablilised. Higher values were obtained for unlimed treatments compared to limed.

3. pH and Eh were negatively correlated.

4. EC of the soil increased on submergence, higher values being recorded for ammonium sulphate. Liming increased the values in all treatments.

5. Between sources, rock phosphate coated urea (RPU) maintained a higher NH_4^+ - N content through out the period of study, due to its efficient coating. However, liming reduced the efficiency of coating.

6. Liming increased the rate of urea hydrolysis.

7. Rate of nitrification was very low and it ranged from 2.4% to 3.4% only, on the 45th day of incubation.

8. At 70 per cent of field moisture capacity also nitrogen transformation was similar to that under submerged condition. Urea hydrolysis was slower, when compared to that under flooded condition.

9. Rate of nitrification was negligible even after 30 days of incubation.

10. Pot-culture experiment showed that coated fertilisers (rock phosphate coated urea, gypsum coated urea, neem coated urea and neem coated ammonium sulphate) gave higher yields compared to uncoated fertilisers (urea and ammonium sulphate).

11. Unlimed RPU recorded the highest yield, but with lime the yield was drastically reduced.

12. Liming had no significant effect on growth and yield of rice.

CONCLUSIONS

i) Rate of nitrification in Karappadom soil is low.

ii) Growth and yield of rice is maximum with coated fertilisers, especially rock-phosphate coated urea.

iii) Liming decreased the efficiency of rock phosphate coated urea and decreased grain yield.

REFERENCES

REFERENCES

Abraham, C., Sadanandan, N. and Sasidhar, V.K. 1975. Study on the comparitive performance of urea and neem coated urea on yield and yield attributes of rice variety, Triveni. Agric. Res. J. Kerala **13** (2): 136-140.

Alexander, M.1965. Most-probable-number method for microbial populations. In C.A. Black (ed.) Methods of soil analysis. Am. Soc. Agron. Inc., Madison, Wisconsin p. 1467-1472.

Alexander,M. 1977. Introduction to soil microbiology 2nd Ed. John Wiley and Sons Inc. New York. pp. 251.

Anandavalli, P., Aiyer, R.S. and Subramoney, N. 1966. Occurence of Blue Green Algae in acid soils of Kerala. Agric. Res. J. Kerala **4** (2): 141-143.

*Ando, H., Shoji, S. and Chiba, T. 1978. The fate of nitrogen fertilisers applied to paddy field and its absorption by rice. Japanese. J. Crop Sci. **47** (3): 388-394.

*Attanandana, T. and Vacharotayam, S.1984. Rock phosphate utilisation on acid sulphate soils of Thailand. FFTC Book Series **27**: 280-291.

Baligar, V.C. and Bennett, O.L. 1986. Outlook on fertiliser use efficiency in tropics. Fert. Res. **10** (1):83-96.

Brady, N.C. 1974. The nature and properties of soil. 8th Ed. Eurasia Publishing House (P) Ltd., New Delhi. pp. 639.

Bremner, J.M. 1965. Nitrogen availability indexes. In Black, C.A. (Ed.) Methods of soil analysis. Am. Soc.Agron. Madison, Wisconsin. p. 1324-1345.

*Broadbent,F.E. 1979. Mineralisation of organic nitrogen in paddy soils. In Nitrogen and Rice. IRRI, Los Banos, Philippines. p. 105-118.

Buresh, R.J. and Patrick, Jr. W.H. 1981. Nitrate reduction to ammonium and organic nitrogen in an estuarine sediment. Soil Biol. Biochem. 13 : 279-283.

Campbell, C.A. and Zenter, R.P. 1984. Effect of fertilizer on soil pH after 17 years of continuous cropping in south west Saskatchewan. Canadian J. Soil Sci. 64 (4): 705-710.

Chahal, R.S., Singh, D., Khedra, A.P. and Kala, R. 1982. Nitrogen use efficiency in rice. Fert. News.30 (3): 17-25.

*Chakravarthy, S.P., Vamadevan, V.K. and Shinde, J.E. 1973. Soil fertility in relation to water management in rice culture. Paper presented at Symp. Water management in Rice. CRRI, Cuttack. April 9-10, 1.

Chakravorthy, S.P. 1979. Effect of application of urea and ammonium sulphate blended with neem cake and compost on N-transformation in soil and yield and nutrition in rice. J. Indian Soc. Soil Sci. 27 (4):449-451.

*Chanchareonsook, J and Panichsakpatna, S. 1984. Nitrogen transformation and management in two important problem soils of Thailand. FFTC Book Series. 27: 303-322.

Colbourn, P. and Dowdell, R.J. 1984. Denitrification.in field soils. Pl. Soil 76 (3): 213-226.

Cox, W.J. and Reisenauer, W.H. 1973. Growth and ion uptake by wheat supplied with nitrogen us nitrate or ammonium or both. Pl. Soil 38: 363.

Criag, J.R. and Wollum, A.G. 1982. Ammonia volatilisation and soil nitrogen changes after urea and ammonium nitrate fertilisation of Pinus Taeda. L. Soil Sci. Soc. Am. J. 46 (2): 409-412.

Datta, M. 1984. Response of rice and other cereals to pressmud and lime in an acid soil of North East India. J. Indian Soc. Soil Sci. 32 (1): 180-182.

Datta, M. and Gupta, K.K. 1983. Response of wheat and maize to lime in acid soils of Nagaland. J. Indian Soc. Soil Sci. 31: 236-240.

De Datta, S.K. 1981. Principles and practices of rice production. John Wiley and Sons, New York.pp.618.

Delaune, R.D. and Patrick, Jr. W.H. 1970. Urea conversion to ammonia in waterlogged soils. Soil Sci. Soc. Am. Proc. 34: 603-607.

Ellington, A. 1986. Ammonia volatilisation losses from fertilisers applied to acid soil in the field. Fert Res. 8 (3): 283-296.

Gajbhiye, K.S. 1980. Effectiveness of liming on rice yield in relation to CEC of soil. Indian J. Agron. 25(2): 302-303.

*Gales, K. 1983. Field variation of wheat and Barley in Britan in relation to crop growth and soil conditions - a review. J. Sci. Food and Ag. 34 (10:1085-1104.

Goodroad, L.L. and Keeney, D.R. 1984. Nitrous oxide production in acrobic soils under varying pH, temperature and water content. Soil Biol. Biochem. 16(1):39-43.

*Ishizuka, Y. and Tanaka, A. 1953. Biochemical studies on the life history of rice plants. II. Synthesis and translocation of organic constituents. J. Sci. Soil manure, Japan. 23: 113-116.

*Ivanov, P. 1981. Possibility and conditions for nitrogen losses from the decomposition of nitrites. Pochvoznaie i Agrokhimiya 16 (2): 47-55.

Jackson, M.L. 1958. Soil chemical analysis. Prentice Hall Inc., U.S.A. pp. 498.

Jadhav, B.B., Patil, H.V. and Kairekar, S. 1983. Effect of neem cake blended urea on rice yield. J. Mah.Agric. Univ. 8 (2): 124-125.

Kabeerthuma, S. 1969. Effect of liming on exchangeable cations and availability of nutrients in acid soil of Kuttanad. MSc.(Ag) Thesis, Kerala Agricultural University.

Kabeerthuma, S. and Chithranjan Nair. 1973. Effect of liming on exchangeable cations and pH of acid soils of Kuttanad. Agric. Res. J. Kerala. 11(1):9-13.

Kabeerthuma, S. and Patnaik. S. 1982. Effect of flooding on the change in lime potential of acid alluvial, red and laterite soils, growing rice. J. Indian Soc. Soil Sci. 30: 275-278.

Kaushik, R.D., Verma, K.S., Dang, Y.P., Sherma, A.P., Verma, S.L. and Pannu, B.S. 1984. Effect of nitrogen and farm yard manure on yield of crops, nutrient uptake and soil fertility of paddy-wheat rotation. Indian J. Agrl. Res. 18 (2): 73-78.

Kresge, C.B. and Satchell, D.P. 1960. Gaseous losses of ammonia from nitrogen fertilisers applied to soil. Agron. J. 52 (1): 104-106.

Kulkarni, K.R., Sadasiviah, T., Maharudrappa, R., Raghumurthy,M. and Shakuntalaraju, A.R. 1975. Studies with slow release nitrogen fertilisers on paddy and sorghum. Mysore J. agric. Sci. 9(2): 258-267.

Kumar, S.D. and Sharma, H.C. 1980. Response of direct own rice to levels of nitrogen under rainfed conditions. Indian J. Agron. 25 (4): 717-718.

Kumura, A. 1956. Studies on the effect of internal nitrogen concentration of rice plant on the constitutional factor of yield. Proc. Crop. Sci. Soc. Japan. 24: 177-180.

Kurup Balakrishna, T.K. 1967. Fertility investigations on rice soils of Kuttanad. Thesis M.Sc.(Ag), Kerala Agricultural University.

Kurup, R.R. and Ramankutty, N.N. 1969. Response of rice to different form of phosphatic fertilisers and lime in the acid soils of Kuttanad. Agric. Res. J. Kerala. 7 (2): 97-99.

*Kuruvilla, V.O. 1973. Problems of acid sulphate soils of Kerala and their amelioration Symp. Acid sulphate and other acid soils of India. College of Agriculture, Trivandrum, India.

Madhusoodhanan, N.K. and Padmaja, P. 1982. Efficiency of primed rock phosphate for grain production in rice. Agric. Res. J. Kerala. 20(2): 31-36.

Mahajan, K.K. and Kaistha, B.L. 1974. A note on nitrogen for rice on Grey Brown Podzol Soil. Indian J. Agron. 19 (2): 160-161.

Mahendra Singh and Singh, D.Y. 1985. Nitrogen use efficiency in rice. Fert. News 30 (3):17

Manickam, T.S., Selvaseelan, D.A. and Krishnamoorthy, K.K. 1976. Nitrification of urea treated with nitrification inhibitors, coated fertilisers and slow acting fertilisers in soil. Fert. News. 21(9):64-65.

Maria, V., Kifert, J. and Smoke, L. 1985. Effect of liming on nutrient fraction in the soil, on nutrient contents of grape vine leaves and grape yield. Pl. Soil. 83: 55-63.

Martikainer, P.J. 1985. Nitrification in forest soil of different pH, as affected by urea, ammonium sulphate and potassium sulphate. Soil. Biol. Biochem. 17(3): 363-367.

Meelu, O.P. 1980. Efficiency of nitrogen in Indian rice culture. Fert. News. 25 (10): 27-30.

*Merzlyakov, L.A., Reshetnikova, N.V. and Yudin, F.A. 1981. The transformation of nitrogen fertilisers in derno-podzolic soil treated with open hearth slag. Izvestiya Timiryazevskii Sel'skokhozyaistvennoi Akademii 2: 85-91.

Mian, M.H. 1985. Detection of denitrification by a ^{15}N tracer technique of nitrogen released from Azolla and BGA in a flooded soil. Australian J. Soil Res. 23(2): 245-252.

Misra, B. 1980. A system approach to fertiliser management practices in rice-wheat cropping system. Fert. News. 25(8): 14-18.

*Murali, N.S. and Nielsen, J.M. 1978. Lime and nitrogen effect on nutrient concentration and yield of SJ-2 Soyabean. *Thai. J. Agric. Sci.* **2**(2):105-110.

*Murata, Y. 1961. Studies on the photosynthesis of rice plant and its culture significance. *Bull. Nat. Inst. Agric. Sci.* Japan. **9**:1-16.

Murphy, L.S. and Follett, H. 1979. Liming-taking another look at basics. *Solutions* **23** (1):53-57.

Oertti, J.J. 1980. Controlled release fertilisers. *Fert.Res.* **1**(2): 103-123.

Operational Research Project Report. 1980. Rice Research Station, Moncompu. Kerala Agricultural University.

Padmaja, P. and Koshy, M.M. 1978. A note on the run-off losses of major plant nutrients in waterlogged rice soils. *Agric. Res. J. Kerala.* **16** (1): 63-65.

Pandey, O.P. and Dayanad, S. 1980. Nitrogen management of rice on saline soils. *Indian J. Agron.* **25**(4):738-740.

Pandey, O.P. and Dayanad, S. 1984. Nitrogen Management of rice in saline soils. *Indian J. Agron.* **29**(3):413-415.

Panse, V.G. and Sukatme, P.V. 1967. Statistical methods for agricultural workers. 2nd Ed. I.C.A.R., New Delhi. pp. 347.

*Patrick, Jr. W.H. 1960. Nitrate reduction in a submerged soil as affected by redox-potential. *Trans. 7th Int. Congr. Soil Sci.* **2**: 494-500.

*Patrick, Jr. W.H. 1964. Extractable iron and phosphorus in a submerged soil at controlled redox-potential. *8th Int. Congr. Soil Sci.* Bucharest, Romania iv.66, 605-609.

Patrick, Jr. W.H. and Wyatt, R. 1964. Soil nitrogen loss as a result of alternate submergence and drying. *Soil Sci. Soc. Am. Proc.* **28**:647-653.

Piper, C.S. 1950. Soil and plant analysis. 2nd Ed. University of Adelaide, Australia. pp.368.

Pisharody, P.N. 1965. Forms and distribution of iron and manganese in rice soils of Kerala. M.Sc.(Ag) Thesis, Kerala Agricultural University.

Ponnamperuma, F.N. 1972. The chemistry of submerged soils. Adv. Agron. 24:29-96.

*Ponnamperuma, F.N. 1976. Specific soil chemical characterestics for rice production in Asia. IRRI Res. Pap. Ser.2:18

*Ponnamperuma, F.N. 1977. Physico-chemical properties of submerged soils in relation to fertility. IRRI Res. Ser. 5:32.

Prasad, R. 1980. Relative efficiency of fertiliser for rice. Fert. News. 25(9): 13-18.

Prasad, R. and Rajale, G.B. 1972. The influence of nitrification inhibitors and slow release nitrogen minerals on transformation of fertiliser nitrogen in soils of fluctuating moisture content. Soil Biol. Biochem. 4:451-457.

Puchades, R., Yufera, E.P. and Rubio, J.L. 1984. The release, diffusion and nitrification of nitrogen in soils surrounding sulphur coated urea granules, Pl. Soil. 78(3): 345-356.

Raghavalu, P. and Sreerammurthy, V. 1975. Sources and times of application of nitrogen for low land rice. Indian J. Agron. 20(2): 167-168.

Rao, K.V. and Shinde, J.E. 1985. Transformation of ^{15}N-labelled urea and its modified forms in tropical wet land rice culture. Pl. Soil. 85(3):413-421.

Reddy, K.R. and Patrick, Jr. W.H. 1975. Effect of alternate aerobic and anaerobic conditions on redox-potential, organic matter decomposition and nitrogen loss in a flooded soil. Soil Biol. Biochem. 7:87-94.

Reddy, K.R. and Patrick, Jr. W.H. 1976. Effect of frequent changes in aerobic and anaerobic conditions on redox-potential and nitrogen loss in a flooded soil. Soil Biol. Biochem. 8:491-495.

Reddy, K.R. and Patrick, Jr. W.H. 1977. Effect of placement and concentration of applied ammoniacal nitrogen on nitrogen loss from flooded soil. Soil. Sci. 123(3):142-148.

Reddy K.R. and Patrick, Jr. W.H. 1980. Losses of applied ammonium ^{15}N urea and organic nitrogen in flooded soils. Soil Sci. 130(6):326-330.

Reddy K.R. and Patrick, Jr. W.H. 1986. Fate of fertiliser nitrogen in the rice root zone. Soil Sci. Soc. Am. J. 50(3):649-651.

Reddy, M.D. and Mittra, B.N. 1985. Response of rice to different forms of urea and phosphorus fertilisation under intermediate deep water conditions. Pl. Soil. 84(3): 431-435.

Redman, F.H. and Patrick, Jr. W.H. 1965. Effect of submergence on several biological and chemical soil properties. Louisiana State agricultural experiment Station. Bull. No. 592. pp. 27.

Rethinam, P., Kolandaiswamy, S. and Sankaran, S. 1975. Studies on the comparitive response of nitrogen to tall and dwarf indica varieties of rice. Madras agric. J. 62(2): 89-91.

*Richards, L.A. 1947. Pressure membrance apparatus for construction and use. Agric. Engg. 28:451-454.

*Richards, L.A. 1948. Porous plate apparatus for measuring moisture retension and transmission by soil. Soil Sci. 66:105-110.

Roseberg, R.J. and Christensen, N.W. 1986. Chloride, soil solution osmotic potential and soil pH effects on nitrification. Soil Sci. Soc. Am. J. 50(4):941-945.

Roy, R.K., Jha, J.N. and Ojha, S.N. 1977. Effect of nitrogen management on the performance of rice variety 'Pankaj'. Indian J. Agron. 22(4):260-261.

Sadayappan, S., Kolandaiswamy, S. and Palaniswamy, K.M. 1974. Effect of different levels of nitrogen at critical growth phases on rice. Madras agric. J.61(8):245-248.

Saho, S.K., Pande, S.C. and Das, G.C. 1980. Relative efficiency of nitrogen fertilisers for rice and wheat. Indian J. Agron. 25 (3):530-532.

Saito, M. and Watanabe, I. 1978. Organic production in rice field flood water. Soil Sci. Pl. Nutr.24(3): 427-440.

Saksena, U.P. and Mehrotra, C.L. 1978. Nitrogen mineralisation under flooded paddy conditions. Indian J. Agron. 23(3):273-274.

Shanker, H., Ram, B. and Rathe, K.S. 1976. Effect of neem cake blended urea on the yield and uptake of nutrients by rice grown under transplanted and direct sown conditions. J. Indian Soc. Soil Sci.27(2):211-213.

Sharma, S.N. 1973. A note on relative efficiency of SCU and urea in rice soils. Indian J. Agron. 18(3): 399-400.

Sharma, S.N. and Prasad, R. 1980. Relative efficiency of urea, nitrification inhibitors treated urea and SCU for rice. Indian J. Agron. 25(3):403-409.

Sims, J.R. and Jackson, G.D. 1971. Rapid analysis of soil nitrate with chromotropic acid. Soil Sci. Soc. Am. Proc. 35:603-606.

Singalachar, M.A. 1973. Nitrogen response in medium duration rice varieties. Mysore J. agric. Sci.7(2):316-317.

*Singh, V.P. 1978. Nitrogen management in water draining from irrigated rice land. Ph.D thesis, Univ. of Philippines, Los Banos.

Singh, M. and Yadav, D.C. 1985. Nitrogen use efficiency in rice. Fert. News. 30(3):17-25.

Sinha, N.P., Singh, S.N. and Jha, B.K. 1980. Effect of neem and its various extractives on yield and nutrient uptake of rice. J. Indian Soc. Soil Sci. 28(4): 535-536.

Snitwogse, P. and Jirathava, F. 1981. The study on the effect of water management and nitrogen fertiliser practices on the efficiency of fertiliser utilisation. Thai.J.Agric.Sci.14(2):107-121.

Subba Rao, M. and Ahmed, N. 1984. Effect of soil acidity and saturating cation on adsorption of urea in soil. Pl. Soil. 79(3):437-439.

Subbian, P. 1983. Effect of slow release nitrogen fertilisers on rice. Madras agric. J.70(7):465-467.

Subramoney, N. and Sankaranarayanan, C. 1963. Preliminary studies on liming of Kerala soil. Agric. Res. J. Kerala 2:24-29.

Sukumaran, K.M., Balakrishna Kurup, T.K. and Money, N.S. 1971. Studies on the influence of liming on the growth and yield of rice in acid peat soil of Kerala. Agric. Res. J. Kerala. 9(2):44-47.

Sunil, D.M., Kadrekar, S.B. and Dongali, J.H. 1982. Effect of submergence on electrochemical and chemical pro properties of rice soils of Konkan. J. Mah. agric. Univ. 7:122-125.

Surendra Singh and Prasad, R. 1984. New nitrogen carriers for rice. Madras agric.J.71(6):371-374.

Takamura, Y., Tabauchi, T, and Kubota, H. 1977. Behaviour and balance of applied nitrogen and phosphorus under rice field conditions. Jap. Soc. Sci. Soil manure 342-349.

*Tamane, I. and Okazaki, M. 1982. Chemical properties of submerged soils. In Vertisols and rice soils of the Tropics. Symp. Pap. II-12th Int. Cong. Soil Sci. New Delhi, India. 143-157.

*Tanaka, A., Patnaik, S. and Abichandani, C.T. 1959. Studies on the nutrition of rice plant. Proc. Indian. Acad. Sci. Soc. B. 49(4):207-216.

Tenny, F.G. and Waksman, S.A. 1930. Composition of natural organic materials and their decomposition in the soil. Soil Sci. 30:143-160.

Thaigalingam, K., Zulkifli, M.A. and Atanasui, N. 1979.Studies on the alleviation of acid sulphate soil problems by use of organic and inorganic waste materials as well as potassium and phosphorus fertilisers. J. Agron. Pl. Sci. 148(6):467-477.

Tisdale, S.L. and Nelson, W.L. 1975. Soil Fertility and Fertilisers. 3rd Ed. Macmillan publishing Co., Inc., New York, pp. 694.

Usha, S.G. and Alan, D.A. 1982. Denitrification potential of a salt marsh soil:effect of temperature, pH and substrate concentration. Soil Biol.Biochem. 14: 117-125.

Velu Pillay. 1940. Travancore State Manual. Vol.I. pp.88 and Vol.III. pp.285. In Suseela Devi, L. 1965. Studies on the seasonal variations in pH, water soluble salts and bacterial population in Kari soils of Kerala. M.Sc.(Ag) Thesis, Kerala Agricultural University.

Van Cleemput, O. and Patrick, Jr. W.H. 1974. Nitrate and nitrite reduction in flooded gamma irradiated soil under controlled pH and redox potential conditions. Soil. Biol. Biochem. 6:85-88.

Wada, G. and Matsushima, T. 1962. Analysis of yield determining process and it's application to yield prediction and culture improvement of low land rice. Proc. Crop Sci. Soc. Jap. 31:23-26.

Wickramasinghe, K.N., Rodgers, G.A. and Jenkinson, D.S. 1985. Nitrification in acid tea soils of a neutral grass land soil:effect of nitrification inhibitors and organic salts. Soil Biol. Biochem. 17(2): 249-252.

Yatazawa, M. 1977. Cycling of mineral nutrients in agricultural ecosystems. Agro-ecosystems 4:177-179.

* Original not seen.

APPENDICES

Appendix I. Weather data (weekly average) for the cropping period (June 1986 to October 1986)

Week No.	Month	Date	Rainfall (mm)	Temperature (°C)		Relative Humidity (%)
				Maximum	Minimum	
25	June	18–24	206	28.9	22.9	90
26	June	25–1 July	328	27.6	24.0	90
27	July	2–8	18	29.7	22.7	80
28	July	9–15	143	28.8	22.8	88
29	July	16–22	118	29.2	23.3	87
30	July	23–29	64	30.0	23.0	84
31	July	30– 5 Aug.	34	30.0	21.9	84
32	August	6–12	305	27.2	23.3	92
33	August	13–19	20	29.3	23.6	82
34	August	20–26	–	30.0	23.0	80
35	August	27– 2 Sept.	–	31.5	22.0	75
36	September	3– 9	23	30.9	23.0	76
37	September	10–16	3	29.6	22.5	79
38	September	17–23	179	29.3	23.2	87
39	September	24–30	77	30.3	23.1	84
40	October	1– 7	114	30.5	23.3	83
41	October	8–14	27	31.8	23.0	75

Source : Meteorological observatory, Vellanikkara.

Appendix II. Analysis of variance for NH_4^+ - N content of soil at submerged moisture regime.

Source	df	Mean square											
		1st day	2nd day	4th day	5th day	9th day	11th day	16th day	23rd day	30th day	45th day	60th day	90th day
Total	23	-	-	-	-	-	-	-	-	-	-	-	-
Treatments	5	518.87**	117.78**	26.07	404.94**	238.93	485.72**	248.87	178.43	187.82*	31.35	139.38**	117.24
Lime	1	232.85	104.73*	309.17*	81.21	253.03	13.62	299.89	13.95	106.93	3.68	54.68	71.59
Treat. x Lime	5	398.32**	67.20**	92.32	257.11**	234.68	257.16**	520.50	124.46	614.02**	68.87	152.67**	162.50
Error	12	67.75	12.79	45.33	46.48	69.41	45.46	211.79	219.17	49.12	90.97	18.89	55.69

* Significant at 5% level

** Significant at 1% level

Appendix III. Analysis of variance for NO_3^- - N content of soil at submerged moisture regime.

Source	df	6 Mean square		
		45th day	60th day	90th day
Total	23	-	-	-
Treatment	5	0.609*	0.991*	0.281
Lime	1	0.212	0.821	0.048
Treat x Lime	5	0.222	1.270*	0.643
Error	12	0.153	0.248	0.467

Appendix IV. Analysis of variance for NH_4^+ - N content of soil at 70% of field moisture capacity.

		Mean squares							
Source	df	1st day	7th day	14th day	21st day	30th day	45th day	60th day	90th day
Total	23	-	-	-	-	-	-	-	-
Treatment	5	1047.81**	405.98**	139.37**	278.55**	286.61**	334.48**	235.76**	92.44**
Lime	1	111.59*	0.578	271.70**	373.76**	407.31**	75.43*	178.21**	136.56*
TreatxLime	5	329.19**	113.44**	67.16**	113.37**	130.90**	142.47**	85.79**	35.97
Error	12	15.18	17.92	3.82	3.81	15.93	11.15	7.51	14.66

* Significant at 5% level

** Significant at 1% level

Appendix V. Analysis of variance for NO_3^- - N content of soil at 70% of field moisture capacity.

Source	df	Mean squares			
		30th day	45th day	60th day	90th day
Total	23	-	-	-	-
Treatments	5	0.422**	1.163	0.820	0.475
Lime	1	0.024	0.057	0.059	2.671*
Treat. x Lime	5	0.666**	0.983	0.440	0.767
Error	12	0.053	0.433	0.433	0.293

Appendix VI. Analysis of variance for hight of rice plant (cm) as influenced by N-sources and liming at various stages of growth.

Source	df	Mean squares		
		Panicle initiation	Flowering	Harvest
Total	27	-	-	-
Treatments	6	73.99*	191.13*	84.77*
Lime	1	30.03	3.07	14.87
Treat. x Lime	6	20.05	66.11	22.90
Error	14	16.51	47.02	17.47

* Significant at 5% level

** Significant at 1% level

Appendix VII. Analysis of variance for tillers plant^{-1} at various growth stages as influenced by N-sources and liming.

Source	df	Mean squares		
		Panicle initiation	Flowering	Harvest
Total	27	-	-	-
Treatment	6	5.40**	7.90	6.97
Lime	1	2.28	1.28	2.28
Treat. x Lime	6	1.19	0.61	6.11
Error	14	1.00	2.85	3.71

* Significant at 5% level

** Significant at 1% level

Appendix VIII. Analysis of variance for leaf area index (LAI) at various stages of growth of rice as influenced by N-sources and liming.

Source	df	Mean squares Maximum tillering	 Panicle initiation	 Flowering	 Harvest
Total	27	-	-	-	-
Treatment	6	0.041	0.850**	1.662**	1.096**
Lime	1	0.052	0.413	0.401	0.492
Treat. x Lime	6	0.055	0.216	0.220	0.215
Error	14	0.027	0.190	0.303	0.138

* Significant at 5% level

** Significant at 1% level

Appendix IX. Analysis of variance for dry matter accumulation (g plant^{-1}) at various growth stages of rice as influenced by N-sources and liming

Source	df	Mean squares			
		Maximum tillering	Panicle initiation	Flowering	Harvest
Total	27	-	-	-	-
Treatment	6	0.069	3.553**	41.67	24.11**
Lime	1	0.227	0.520	0.80	1.29
Treat. x Lime	6	0.045	0.659	27.50	8.72**
Error	14	0.013	0.587	29.08	1.73

* Significant at 5% level

** Significant at 1% level

Appendix X. Analysis of variance for mean number of panicles/plant and spikelets/panicle as influenced by N-sources and liming.

Source	df	Mean squares	
		panicles/plant	spikelets/panicle
Total	27	-	-
Treatments	6	0.914*	209.34
Lime	1	0.223	12.18
Treat. x Lime	6	0.057	120.71
Error	14	0.223	107.71

* Significant at 5% level

** Significant at 1% level

Appendix XI. **Analysis of variance for grain yield, straw yield and harvest index as influenced by N-sources and liming.**

Source	df	Mean squares		
		Grain yield ($g\ pot^{-1}$)	Straw yield ($g\ pot^{-1}$)	Harvest index
Total	27	-	-	-
Treatment	6	53.07**	153.47**	0.003
Lime	1	24.34	42.26	0.001
Treat. x Lime	6	24.75*	28.71	0.002
Error	14	7.94	17.28	0.002

* Significant at 5% level

** Significant at 1% level

Appendix XII. Analysis of variance for N content (%) at various stages of the crop as influenced by N-sources and liming.

Source	df	Mean squares				
		Maximum tillering	Panicle initiation	Flowering	Harvest	
					straw	grain
Total	27	-	-	-	-	-
Treatment	6	0.374	0.132	0.010	0.004	0.046*
Lime	1	0.697	0.079	0.078	0.002	0.014
Treat. x Lime	6	0.466	0.116	0.013	0.009	0.018
Error	14	0.326	0.150	0.022	0.013	0.012

* Significant at 5% level

** Significant at 1% level

Appendix XIII. Analysis of variance for phosphorus content (%) at various stages of crop as influenced by N sources and liming.

Source	df	Mean squares			Harvest	
		Maximum tillering	Panicle initiation	Flowering	Straw	Grain
Total	27	-	-	-	-	-
Treatment	6	0.004	0.002	0.002	0.001	0.001
Lime	1	0.001	0.001	0.005	0.003	0.001
Treat. x Lime	6	0.009	0.001	0.001	0.001	0.001
Error	14	0.004	0.001	0.002	0.001	0.001

Appendix XIV. Analysis of variance for potassium content (%) at various stages of the crop as influenced by N-sources and liming.

Source	df	Mean squares				
		Maximum tillering	Panicle initiation	Flowering	Harvest	
					Straw	Grain
Total	27	-	-	-	-	-
Treatment	6	0.582	0.173	0.030	0.238	0.005
Lime	1	0.006	0.019	0.015	0.060	0.003
Treat. x Lime	6	0.202	0.024	0.017	0.048	0.004
Error	14	0.235	0.217	0.071	0.326	0.005

Appendix XV. Analysis of variance for N-uptake (mg plant^{-1}) at various stages of the crop as influenced by N-sources and liming.

Source	df	Mean squares				
		Maximum tillering	Panicle initiation	Flowering	Harvest	
					Straw	Grain
Total	27	-	-	-	-	-
Treatment	6	416.99	2920.22	6378.75	702.52	753.08*
Lime	1	55.28	37.12	2235.00	39.58	7.58
Treat. x Lime	6	429.18	860.74	3945.58	245.36	228.02
Error	14	252.91	1199.53	4623.50	303.68	180.62

* Significant at 5% level

Appendix XVI. Analysis of variance for P-uptake (mg plant^{-1}) at various stages of the crop as influenced by N-sources and liming.

Source	df	Mean squares				
		Maximum tillering	Panicle initiation	Flowering	Harvest	
					Straw	Grain
Total	27	-	-	-	-	-
Treatment	6	4.684	30.50*	339.42	39.34**	39.34*
Lime	1	0.143	12.89	1.695	25.42	16.16
Treat. x Lime	6	6.363	8.04	108.00	28.34	21.20
Error	14	2.642	8.90	164.33	6.00	10.82

* Significant at 5%level

Appendix XVII. Analysis of variance for K uptake ($mg\ plant^{-1}$) at various stages of the crop as influenced by N-sources and liming.

Source	df	Mean Squares				
		Maximum tillering	Panicle initiation	Flowering	S Harvest	
					Straw	Grain
Total	27	-	-	-	-	-
Treatment	6	413.82	2721.93	8593.41	5374.06	250.18**
Lime	1	181.61	0.625	24.50	1066.18	18.46
Treat. x Lime	6	191.40	122.64	4720.87	5187.90	71.90
Error	14	125.48	1428.48	7775.73	7705.12	57.08

** Significant at 1% level

Appendix XVIII. Correlation of grain yield with soil factors and yield attributes

Parameters		Correlation coefficient	Significance
		(Table value 5% significance: 0.534)	
NH_4^+ - N content in soil at			
	MT	0.0916	NS
	PI	-0.128	NS
	F	-0.190	NS
	H	-0.06	NS
NO_3^- - N content in soil at			
	MT	0.511	NS
	PI	-0.151	NS
	F	-0.036	NS
	H	0.511	NS
Dry matter accumulation			
	MT	0.021	NS
	PI	0.247	NS
	F	0.487	NS
	H	0.949	Sig **
Number of tillers			
	PI	0.085	NS
	F	0.718	Sig**
	H	0.709	Sig**
Leaf area index (LAI)			
	PI	0.271	NS
	F	0.658	Sig**
	H	0.627	Sig**
Number of panicles/plant		0.481	NS
Number of spikelets/pan.		0.235	NS
100 grain weight		0.508	NS
Nitrogen content	PI	0.361	NS
	F	0.160	NS
Nitrogen uptake	PI	0.377	NS
	F	0.410	NS

Appendix XIX. Hundred grain weight (g) as influenced by N-sources and liming.

N-sources	Unlimed (L_o)	Limed (L)
1. Control (C)	2.54	2.06
2. Urea (U)	3.43	2.93
3. ammonium sulphate (AS)	3.60	3.95
4. neem coated urea (NCU)	3.53	3.95
5. neem coated ammonium sulphate (NCA)	3.16	3.20
6. Gypsum coated urea (GCU)	3.30	3.30
7. Rock phosphate coated urea (RPU)	3.80	3.08

Appendix XX. Nitrogen recovery (%) by rice as influenced by N-sources.

N-sources	Recovery (%)
Urea (U)	15.20
Ammonium sulphate (AS)	16.29
Neem coated Urea (NCU)	26.32
Neem coated ammonium sulphate (NCA)	40.78
Gypsum coated urea (GCU)	41.48
Rock phosphate coated urea (RPU)	53.10

$$\text{Recovery \%} = \frac{\underset{\text{(fertilised pot)}}{\text{Nitrogen uptake}} - \underset{\text{(control pot)}}{\text{Nitrogen uptake}}}{\text{Nitrogen applied}} \times 100$$

Appendix XXI. Nitrification rate (%) as influenced by different N-sources.

(a) Submerged moisture regime

N-sources	45th day	60th day	90th day
Urea (U)	2.7	6.69	10.5
Ammonium sulphate (AS)	2.41	6.73	5.4
Neem coated Urea (NCU)	2.95	6.97	5.13
Neem coated ammonium sulphate (NCA)	2.15	5.41	5.63
Gypsum coated urea (GCU)	2.59	6.79	5.52
Rock phosphate coated urea (RPU)	3.44	8.5	5.13

(b) at 70% of field moisture capacity

N-sources	30th day	45th day	60th day	90th day
Urea (U)	1.9	4.6	5.5	4.9
Ammonium sulphate (AS)	2.5	5.2	6.4	5.0
Neem coated urea (NCU)	3.6	5.9	8.0	6.0
Neem coated ammonium sulphate (NCA)	2.8	4.3	6.1	5.7
Gypsum coated urea (GCU)	2.9	5.8	7.5	6.0
Rock phosphate coated urea (RPU)	2.5	5.1	6.2	4.9

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

DYNAMICS OF APPLIED NITROGEN IN ACIDIC SOILS OF KUTTANAD

I. KARAPPADOM SOIL

By

LIJI JOHN

ABSTRACT OF A THESIS

submitted in partial fulfilment of
the requirement for the degree of

Master of Science in Agriculture

Faculty of Agriculture
Kerala Agricultural University

Department of Agronomy
COLLEGE OF HORTICULTURE
Vellanikkara - Trichur

1987

ABSTRACT

The present study on 'dynamics of applied nitrogen in acidic soils of Kuttanad (Karappadom soil)' was conducted at the College of Horticulture, Vellanikkara, Trichur from January 1986 to December, 1986. A total of six materials viz. urea, ammonium sulphate, neem coated urea, neem coated ammonium sulphate, gypsum coated urea and rock phosphate coated urea were used as N sources. The experiment included limed and unlimed treatments of these sources at two moisture regimes.

The results of the study proved that the rate of nitrification was very low in Karappadom soil and that there was no appreciable conversion of NH_4^+ - N to NO_3^- - N. It also showed that the coated fertilisers performed better than the uncoated fertilisers in this soil.

EC and pH of the soil increased on submergence. Eh and pH of the soil were negatively correlated.

Data on various growth and yield characters of the rice variety Jyothi showed that, nitrogen recovery was higher with coated fertilisers than with uncoated fertilisers. Rock phosphate coated urea gave maximum grain yields, however in the presence of lime its efficiency was reduced drastically.

.....

DYNAMICS OF APPLIED NITROGEN IN ACIDIC SOILS OF KUTTANAD

I. KARAPPADOM SOIL

By

LIJI JOHN

ABSTRACT OF A THESIS

submitted in partial fulfilment of
the requirement for the degree of

Master of Science in Agriculture

Faculty of Agriculture
Kerala Agricultural University

Department of Agronomy
COLLEGE OF HORTICULTURE
Vellanikkara - Trichur

1987

ABSTRACT

The present study on 'dynamics of applied nitrogen in acidic soils of Kuttanad (Karappadom soil)' was conducted at the College of Horticulture, Vellanikkara, Trichur from January 1986 to December, 1986. A total of six materials viz. Urea, ammonium sulphate, neem coated urea, neem coated ammonium sulphate, gypsum coated urea and rock phosphate coated urea were used as N sources. The experiment included limed and ulimed treatments of these sources at two moisture regimes.

The results of the study proved that the rate of nitrification was very low in Karappadom soil and that there was no appreciable conversion of $NH_4^+ - N$ to $NO_3^- - N$. It also showed that the coated fertilisers performed better than the uncoated fertilisers in this soil.

EC and pH of the Soil increased on submergence.Eh and pH of the soil were negatively correlated.

Data on various growth and yield characters of the rice variety, Jyothi showed that, nitrogen recovery was higher with coated fertilisers than with uncoated fertilisers. Rock phosphate coated urea gave maximum grain yields, however in the presence of lime its efficiency was reduced drastically.

- x - x -