POSSIBILITIES OF USING UNSYMMETRICAL DIMETHYL UREA AS UREASE/NITRIFICATION INHIBITOR FOR INCREASING THE EFFICIENCY OF NITROGENOUS FERTILIZERS

By

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THESIS

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DECLARATION

I hereby declare that this thesis entitled "Possibilities of using unsymmetrical Dimethyl Urea as Urease/Nitrification inhibitor for increasing the efficiency of Nitrogenous fertilizers" 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 of any degree, diploma, associateship, fellowship, or other similar title, of any other University or Society.

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CERTIFICATE

Certified that this thesis, entitled "Possibilities of using unsymmetrical Dimethyl Urea as Urease/Nitrification inhibitor for increasing the efficiency of Nitrogenous fertilizers" is a record of research work done independently by Smt. Asha Varughese, 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.

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ASHA VARUGHESE

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Introduction

INTRODUCTION

Increasing the efficiency of nitrogenous fertilizers is the single priority area of research on a global scale for the next decade, due to the escalation in prices per unit of nitrogen used in agriculture. At present, the fertilizer efficiency of nitrogen is only about 40 to 60 percent and is guided by the soil conditions, hydrology, crop and varieties grown in addition to the nature of N carrier fertilizer. A 10 percent increase in N efficiency mean that 547 urea fertilizer plants each with 1000 tonnes of urea per day need not be established in view of the savings. It is worth Rs.200/- crores to India per annum in fertilizer-nitrogen use. Any saving in the consumption of fertilizer, adopting low cost technology without sacrificing productivity of crops, will therefore be economically advantageous to farmers.

The rice crop alone in the country consumes about 32 percent of nitrogenous fertilisers used in India. However, the applied nitrogen is not being fully utilised by the crop on account of variations in soil types, cultural methods and water management practices under which it is raised. Thus the low efficiency of fertilizer nitrogen in rice is well documented. The nitrogen efficiency in rice largely ranges between 25 to 35 percent and seldom exceeds 50 percent. Nitrogen may be lost from the soil through ammonia volatalization, nitrification, denitrification, leaching, run off, biological immobilization by soil organic matter and NH_4 fixation by clay minerals.

N use efficiency under alternate flooding and drying or continuous flooding has been shown to be respectively 26 percent and 64 percent. Alternate flooding and drying depresses the crop yield as a function of direct effect of moisture stress-induced changes in nutrient availability, and results in reduced total N uptake and lower nitrogen use efficiency. In addition, the intermittent drastic shifts in redox equilibria and microbal population under alternate flooding and drying irrigation regime are conducive for substantial loss of nitrogen which, consequently results in poor use efficiency.

The recent energy squeeze, the high cost of the nutrient nitrogen and its low recovery, warrant that research should be directed towards measuring the magnitude of losses of nitrogen and identifying and developing products and practices that will curb losses and increase the efficiency. Among the various approaches followed for conserving the nutrient, the use of slow release fertilizers and biological inhibitors, which reduce the activity of nitrogen in the soil solution, were found to be fairly effective.

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

The best way of improving the efficiency of urea is to inhibit urease activity for sometime to allow it to remain as such for a period in the soil. It is known that substituted ureas such as monouron, diuron, neburon, fenuron etc. which are well known herbicides can inhibit urease activity to the extent of 10 to 40 percent. This offers theoretically a possibility for unsymmetrical dimethyl urea (UDMU) also to possess urease-inhibiting properties.

Unsymmetrical dimethyl urea is an intermediate material obtained during the manufacturing process of propellents for rockets. Thus an investigation to find out the suitability of UDMU as an urease/nitrification inhibitor is of immense importance.

Much work has been done on the use of neemcake as an inhibitor in submerged rice soils and also in some garden lands of low rainfall regions. In well aerated soils of Kerala, with its humid tropical climate, nitrification takes place at a much faster rate. Losses are also comparatively severe, due to heavy rainfall and undulating terrain. Thus a study on the efficacy of the use of neemcake as a nitrification inhibitor is important.

In the light of the above, there is a very good scope for a field study using different levels and combinations of UDMU and neemcake to find out the most desirable combinations to increase N-use efficiency of urea and produce the maximum yield using rice variety, Jaya.

The objectives of the present investigation are as follows:-

(i) To study the possibility of using unsymmetrical dimethyl urea as a urease and nitrification inhibitor in soils.

(ii) To find out the effect of UDMU in increasing the efficiency of urea nitrogen for rice crop under field conditions.

Review of Literature

REVIEW OF LITERATURE

Efficient use of fertilizers is a subject of utmost importance in practical agriculture. It channelises the resources invested in mining, manufacture and movement of fertilizers to the most productive use. The optimum utilization of factors essential for crop production include not only the judicious use of available resources without affecting the long run interest of humanbeing but also making it an economically viable proposition (Khaddar et al. 1987).

Nitrogen is a mobile nutrient and is lost from uncropped as well as cropped lands through several mechanisms. At present the fertilizer efficiency of nitrogen is only about 40 to 60 percent and is guided by the soil conditions, hydrology, crop and varieties grown in addition to the nature of the nitrogen carrier fertilizer. Researches all over the world are being undertaken to retrieve the loss mechanism and recommend methods to improve the efficiency.

2.1 Losses and recovery of applied nitrogen

About 40 percent of the applied nitrogen is lost from the soil through volatilization as ammonia, run off and leaching losses of soluble nitrogen fractions, nitrification, denitrification under flooded conditions, fixation as non-exchangeable ammonium and biological immobilization by soil microorganisms.

Heavy losses of nitrogen through NH_3 volatilization from surface applied nitrogenous fertilizers have been reported by many scientists from India and abroad (Baseleo and Gangwar, 1976; Aulakh et al. 1984; Pedrazzini and Tarsitano, 1986; Balwinder Singh and Bajwa, 1987 and Rao, 1987).

Denitrification loss of mineral nitrogen has been studied in detail by many scientists (Smith and Tiedge, 1979; Terry et al. 1986; Yeomans and Bremner, 1986).

Studies on leaching loss of fertilizer nitrogen have been made by several scientists (Saito and Neptune, 1976; Goh and Haynes, 1977; Bengtson, 1979; Aplatauer, 1979 and Sahrawat, 1982).

Padmaja and Koshy (1978) reported that on draining the surface water on the same day of fertilizer application, upto 70 percent of the applied nitrogen is lost in runoff water.

Loss of nitrogen through biological and chemical immobilization was studied by Craswell and Vlek (1979).

The recovery of applied fertilizer nitrogen from conventional fertilizers is quite low. Average recovery of only 10 to 50 percent by rice plant has been reported by many workers (Prasad and De Datta, 1979; Mahapatra et al. 1980; and Cao et al. 1984). Houng and Liu (1979) based on pot trials with ^{15}N enriched ammonium sulphate obtained 20 percent recovery from basal application, 40 percent from topdressing at tillering, 60 to 90 percent from top-dressing at young panicle stage and 40 to 60 percent from application after heading stage.

In a field trial where rice CV. MAS 2401 was grown on a sandy loam river soil under wetland condition and supplied with 80 kg N ha^{-1} by broadcasting or deep placement, only 26 percent and 35 percent of applied nitrogen was recovered in the grain and 18 percent and 29 percent in the straw with broadcasting and deep placement, respectively (Ayatode, 1980).

Plant recovery of applied nitrogen is dependent on factors such as natural conditions of the soil as well as climatic and cultural practices (De Datta, 1977).

2.2 Possibilities for increasing N-use efficiency

Several methods were tried by scientists for augmenting the efficiency of fertilizer nitrogen. The use of urease and nitrification inhibitors as well as slow-release nitrogen fertilizers are the most important methods among them.

2.2.1 Applicability of urease inhibitors

The rapidly increasing importance of urea as a nitrogenous fertilizer in world agriculture has stimulated research to find compounds that will retard hydrolysis of fertilizer urea by soil urease with a view to reduce the problems encountered in the use of this fertilizer.

Application of urease inhibitors is intended to reduce ammonia volatilization and immobilization by delaying ureahydrolysis until the urea has been leached into the soil profile by rainfall or irrigation. These compounds have received considerable attention in recent years as a means to increase the efficiency of applied urea and urea-ammonium nitrate solutions.

All of the compounds evaluated as urease inhibitors fall into the following categories. The first group of substances inhibit urease activity by blocking essential sulf-hydryl groups at active sites on the enzyme. Metal ions including Ag^{+}, Hg^{2+} and Cu^{2+} belong in the first category forming the metal-sulfide complex. Heterocyclic sulfur compounds, quinones and dihydric phenols are effective inhibitors of urease.

The second class of inhibitors are structural analogues of urea, such as thiourea, methyl urea and substituted ureas. They have structural similarities to urea and inhibit urease activity by competing for the same active site on the enzyme.

The mechanism of urea hydrolysis and urease inhibition have been studied in detail by many workers ([illegible] and [illegible], 1970; Hoult and Mc Garity, 1986; Chonkar and [illegible] Pal, 1987).

[illegible]worth et al. (1980) have mentioned that by adding potassium [illegible] with urea, urease activity can be inhibited and the synthesis of unsubstituted alcohols of low molecular weight were found to be the [illegible] inhibitors of urease.

Bart[illegible] and Bremner (1964) found that phenyl phosphorodiamidate to be an effective urease inhibitor.

[illegible] et al. (1987) recognized phenyl phosphoro-diamidate (PPD) as an effective urease inhibitor for flooded rice and observed that PPD addition increased recovery of urea nitrogen in the plant-soil system from 60 to 82 percent. Plant uptake of labelled nitrogen was increased by 56 percent. Studies have shown that PPD addition had allowed more urea nitrogen to be retained in the soil surface layer in such a way that nitrification-denitrification was substantially reduced.

Fillery and Vlek (1986) studied the effects of ammonium sulphate, urea, urea-amended with the urease inhibitor and phenyl phosphorodiamidate (PPD) on flood water properties concurrently as part of a field NH_3-volatilization study. The results suggested that nitrification-denitrification pattern contributed to the total nitrogen loss from urea.

Sen and Bandhyopadhyay (1986) studied ammonia volatilization from submerged rice field by amending urea with urease inhibitors, P-benzoquinone and pyrocatechol.

Goos et al. (1986) observed that ammonium thiosulphate (ATS) is a common and versatile liquid sulfur fertilizer which has the ability to inhibit urea hydrolysis in soil.

Rao and Ghai (1986) studied the effect of hydroquinone (HQ), phenyl mercuric-acetate (PMA) and phenyl phosphorodiamidate (PPD) at 10 percent w/w urea as urease inhibitors on wheat growth in an alkali soil. PMA had an inhibitory effect and PPD increased drymatter by 38.7 percent. HQ and PPD increased grain yields by 20 and 25.1 percent and N uptake by 7.4 and 13.8 percent respectively. HQ increased total drymatter by 11.1 percent also.

Bremner and Chai (1986) found that N-butyl phosphorothioic triamide (NBPT) is considerably more effective than phenylphosphorodiamidate (PPD) as a soil urease inhibitor. It is seen that the inhibitory effect of NBPT on soil urease increased markedly with the amount of NBPT.

O'Connor and Hendrickson (1987) conducted laboratory incubation studies and showed that phenyl phosphorodiamidate is able to inhibit urea hydrolysis and control ammonia volatilization losses at low temperatures.

Arora et al. (1987) observed that addition of calcium cyanamide to urea delayed ammonification of urea and increased recovery of inorganic nitrogen from 64 to 87 percent.

De Datta (1987) reported that phenyl phosphorodiamidate can be effectively used to delay urease activity in flooded rice soils.

2.4 Mineralisation of urea

When urea nitrogen is applied to agricultural land, it is rapidly transformed to NH_4^+-N through hydrolytic decomposition by the urease enzyme and later subjected to nitrification.

Urease activity is restricted to a small group of urea bacteria eventhough, many non-specific microorganisms are active in producing the enzyme urease.

Usually ureolysis is considered to occur in the immediate soil surface where urease is associated with viable microorganisms and an extracellular moiety adsorbed on moribund cells and soil colloids. Subsequent reduction of losses of nitrogen by volatalization depends on movement of both urea and ammonium below the soil surface where effective adsorption can occur.

Urease activity in soils is known to vary with location, depth, season and forms of nitrogenous fertilizers used (Bhavanandan and Fernando, 1970).

Zaintua and Bremner (1976) have mentioned that soil constituents protect urease against microbial degradation and other processes leading to their inactivation of enzymes and every soil has a stable level of urease activity determined by the ability of its constituents to provide tea protection.

About 57 to 82 percent of added urea nitrogen was mineralised within one day of incubation in fine soils. Most of the applied urea nitrogen was hydrolysed within one day of incubation in saline, non-saline, heavy and light soils and major portion of the loss of urea-N occurred immediately after addition (Sankhayan and Shukla, 1978).

Bremner and Mulvaney (1978) reported that urea was hydrolysed to CO_2 and NH_3 by the enzyme urea amidohydrolase which acts on non-peptide C-N bonds in linear amides.

More and Varade (1982) observed that 65 percent of applied urea nitrogen was hydrolysed within two to four days at various moisture potentials.

Farooqui (1983) found that the hydrolysis of urea under flooded conditions was completed within eleven days after application.

Baruah and Mishra (1984) have reported that urease activity was generally higher in flooded rice soils than in upland rice soils.

Yadav and Shrivastava (1987) reported that applied urea nitrogen was hydrolysed completely within one week in a sandy loam soil.

2.5 Inhibition of Nitrification

Agriculturally there may be some advantages in maintaining mineral nitrogen in the soil as ammonium because both nitrite and nitrate are susceptible to loss by leaching and denitrification (Gasser, 1970).

Keeping the nitrogen in the root zone is of course one means whereby, efficiency of recovery may be increased. Nitrate ion is mobile while ammonium ion is immobile in the soil. Therefore, if the ammonium ion is allowed to remain in the rootzone, the loss of mineral nitrogen can be reduced. Nitrification inhibitors, which are toxic to the nitrifying bacteria may pave way to achieve this.

Many chemicals have been tested in recent years for their ability for selectively inhibiting nitrification in soils. Those tested include substituted pyridines, pyrimidines, acetanilides, anilines, isothiocyanates, derivatives of urea and low cost indigenous materials such as non-edible oilcakes. The efficiency of some of the commonly used nitrification inhibitors are reviewed hereunder.

7. **2.5.1 Substituted Ureas**

It has been reported that triazines such as cyanuricacid, ammelide, ammeline and melamine were effective in increasing nitrogen use efficiency.

Fuller (1963) found that thiourea applied at the rate of 56 kg N Ha^{-1} to clay loam and sand gave a higher yield of barely as compared to ammonium sulphate and showed a marked residual effect.

Schaffer et al. (1964) found that "urea-compounds", consisting of ethylenediurea, 2-ethylene - 3-urea and ethyleurea increased the grain yields.

Sealey and Luckwill (1965) observed that monuron (N' - (4-chlorophenyl) - N, N-dimethylurea) prevented nitrification, followed by neburon (N butyl - N' (3, 4 - dichlorophenyl) - N methyl urea) at 4.0 ppm.

International Rice Commission (1966) reported that in pot experiments IBDU gave 12 percent higher weight of panicles as compared to urea perses. They have also shown that thiourea treated with ammoniumsulphate gave 10 percent higher yield of rice over untreated ammonium sulphate.

Bundy and Bremner (1973) observed that 1-amidino-2-thiourea was effective as nitrification inhibitor.

It is reported that thiourea was able to inhibit nitrification of soil nitrogen and of added ammonium salts ([illegible], 1977 and Malhi and Nyborg, 1984).

Gunasena et al. (1979) showed that sulphur coated urea can be effectively used for increasing N use efficiency.

Stepanov (1984) found that replacement of part of the urea by urea formaldehyde fertilizer in the overall NPK fertilizer composition resulted in a reduction in the loss of soil nitrogen and also loss from fertilizers through denitrification.

Sahota and Sharma (1985) reported that dimethylurea was having nitrification inhibition property.

Yadvinder Singh and Beauchamp (1985) reported that coated ureapills were possessing nitrification inhibitory property.

Mondal et al. (1986) reported that localising urea in a nest produced both its rate of hydrolysis and subsequent nitrification and recovery of added nitrogen was increased.

2.5.2 Neem (*Azadirachta indica*. Juss.) - Seed products

High cost and limited availability of chemical nitrification inhibitors preclude their large scale use. Hence some of the easily available, low cost indigenous materials, have been extensively tested for their nitrification inhibitory property.

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

The nitrifiable properties of non-edible oilcakes, particularly neem, karanja, maroti and mahua have been studied by many scientists (Anjaniya Sharma, 1972; Droupathi Devi et al. 1975; Jain et al. 1980; Vijayachandran and Premadevi, 1982).

Chatterjee et al. (1975) showed that coating of urea with indigenously available fresh neemcake was effective in increasing grain yield viz. 12.5 kg grain per kg of nitrogen as against 9.2 kg with urea alone at 100 kg nitrogen per hectare.

Oommen et al. (1977) found that protein percentage of paddy grain was increased by neemcake blended urea.

Sivaraj (1978) recorded an increase in seed cotton yield with neemcake blended urea.

Subbiah et al. (1980) noted that urea mixed with neemseed crush and neemcake extract increased grain and straw yields in rice crop.

Rajkumar and Sekhon (1981) reported that neemseed cake was effective in inhibiting nitrification of applied nitrogen and increasing the yield of lowland rice in four types of soils; viz., loamy sand, sandy loam with alkaline phase, sandy soil and loamy soil.

Babu Mathew (1985) found that nitrogen recovery percentage was the highest when neemcoated urea was applied in paddy.

Muneshwar Singh and Singh (1986) obtained in lysimeter experiments with neemcake blended urea, reduced leaching loss of nitrogen, increased grain yield and N uptake by wheat compared to urea perse.

Awasthe and Mishra (1987) reported that application of neemcake coated urea was effective in increasing the grain yields and nitrogen uptake in rice crop under submerged conditions.

2.5.3 Other materials effective as nitrification inhibitors

It is found that diazinon, dithane, BHC, PCP, Vapam, sodium chlorate, dicyandiamide, maneb, sodium azide, riogen, iodoacetic acid and 2-mercapto inidazoline, all are effective as nitrification inhibitors.

Peschke (1985) studied the N-dynamic processes in the soil and compared soils on the basis of nitrification delay percentage and found dicyandiamide as an effective nitrification inhibitor.

Sutton et al. (1985) reported that addition of nitrapyrin and etradiazol to manure increased maize yields, compared to manure application with no inhibitor.

From pot and field experiments, Chen and Lu (1985) showed that the inhibitory effect of calcium cyanamide on nitrification in rice soils was greater than that of dicyandiamide under waterlogged conditions.

Walter et al. (1986) studied the effect of 1-carbamoyl - 3 (5) - methyl - pyrazole (CMP) and nitrapyrin. The nitrification process was considerably delayed.

Magalhaes and Chalk (1987) found that nitrapyrin decreased NO_2^-- accumulation and prevented losses of mineral nitrogen as N_2, N_2O and $K MnO_4$-N. Shaviv (1987) found dicyandiamide to be an effective nitrification inhibitor.

2.6 Stage of inhibition in the mineralisation of urea

Selective inhibition of *Nitrosomonas sp* by neemcake was reported by Mishra et al. (1975). Nair and Sharma (1976) found that activity of *Nitrosomonas sp* was at its peak on the 22nd day and that of *Nitrobacter sp* on 42nd day of fertilizer application.

Sathianathan (1982) found that inhibition of nitrification took place at the NH_4^+-N oxidation step mediated mainly by *Nitrosomonas sp* and *Nitrosococcus sp* and not at nitrite oxidation step.

2.7 Period of retention of NH_4^+-N in soil

Reddy and Prasad (1975) found neemcake as effective in retarding nitrification of urea for two weeks.

In a laterite soil kept in a moist aerobic condition, NH_4^+-N showed an increase during initial stages, which dropped sharply in 20 days and then gradually upto 70 days of incubation and NO_3^--N content was found to increase with time (Biddappah and Sarkunam, 1979).

Subbiah et al. (1980) observed that blending of urea with neemcake significantly increased NH_4^+-N on 10th day which gradually declined on the 30th day due to its conversion to NO_3^--N in rice soils.

Sathianathan (1982) found that urea-neemcake at 5:3 ratio recorded maximum accumulation of NH_4^+-N on 12th day in redloam upland soil and then showed faster decrease, accompanied by an increase in NO_3^--N content.

Thomas and Prasad (1983) reported that the inhibition of nitrification of urea by neemcake was maximum by the end of first week in alluvial and blackcotton soils; and by the end of second week in laterite and acidsulphate soils.

2.8 Increasing the yield and N-use efficiency for wetland rice

Lowland rice production is unique; Flooding imposes a completely different chemical regime on the soil and nutrients. Rice grows under field conditions varying from flooded to well drained. In fields subjected to occasional flooding, the situation is much worse. Here the ammonium or amide nitrogen gets ample opportunity to get oxidized while the fields are drained. After flooding, the reduced conditions are created and the nitrates get denitrified.

Prasad et al. (1970) obtained increased rice yields by 600 to 700 kg ha^{-1} in a field experiment with wetland rice using N serve, AM and IBDU.

Bains et al. (1971) reported that there was increase in panicle length, number of grains per panicle and increased yield for neemcake treated urea under normal irrigation schedule.

Arunachalam and Morachen (1974) found that non-edible oilcake extracts treated urea were effective in increasing thousandgrain weight in rice crop.

Sivanappan et al. (1974) also obtained increased thousandgrain weight.

Shiga and Ventura (1976) reported that available nitrogen in the soil plays a crucial role in growth and yield of rice plants.

Increased nitrogen availability showed significant effect on plant nitrogen content and total nitrogen uptake as compared to no application of nitrogen, and this effect is quite expected in rice where inorganic fertilization contributes sizeably to the nitrogen content in plants (Khan and Pathak, 1976 and Talha et al. 1981).

Sharma and Prasad (1980) observed that neemcake coated urea at 100 kg N ha^{-1} was more effective in increasing paddy yields than urea perse.

Jadhev et al. (1983) reported that application of 75 kg N ha^{-1} as neemcake coated urea gave higher paddy yields than 100 kg N ha^{-1} as prilled urea.

Mahendra Singh and Yadev (1985) observed that coating of urea with neemcake and sulphur was highly beneficial in improving N-recovery and rice yields.

Govindasamy and Kaliyappa (1986) found that N use efficiency of lowland rice with application of neemcake blended urea was significantly superior to prilled urea.

Materials and Methods

MATERIALS AND METHODS

An investigation was carried out to find the most desirable level and combination of unsymmetrical dimethyl urea (UDMU) and neemcake (NC) as urease/nitrification inhibitors, to increase the N-use efficiency of urea and produce the maximum yield. The study was conducted by estimating the rate of nitrification in the soil and crop performance in relation to different levels and combinations of UDMU and neemcake under field conditions.

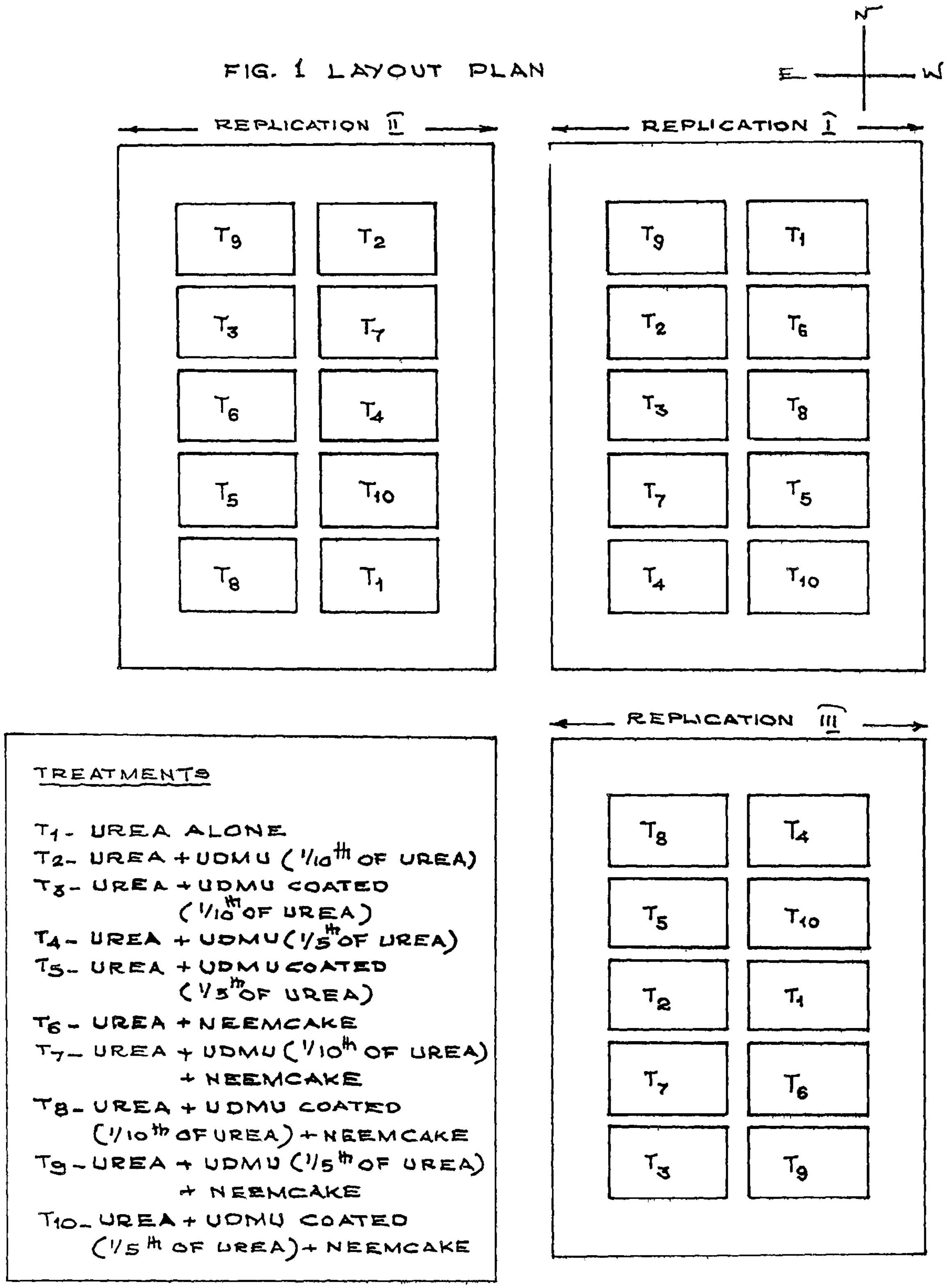
Experimental details

A field experiment was laid out in the wetland at Palappur area, on the western side of the Instructional Farm, College of Agriculture, Vellayani, taking paddy as the test crop. The experimental site was under a bulk crop of rice during the previous two seasons and the trial was carried out in the first crop season, 1987.

Design and treatments

The experiment was laid out in simple randomised block design with ten treatments and three replications. The layout plan of the experiment is given in Fig. I.

FIG. 1 LAYOUT PLAN



Treatments

The NPK dose for all the treatments were 90:45:45 and nitrogen was given in the form of urea.

Treatments	Materials added	Dose
T_1	Urea alone	90 kg N ha^{-1}
T_2	Urea + UDMU	90 kg N ha^{-1} + UDMU (1/10th of urea)
T_3	Urea + UDMU coated	90 kg N ha^{-1} + UDMU (1/10th of urea)
T_4	Urea + UDMU	90 kg N ha^{-1} + UDMU (1/5th of urea)
T_5	Urea + UDMU coated	90 kg N ha^{-1} + UDMU (1/5th of urea)
T_6	Urea + Neemcake	90 kg N ha^{-1} + Neemcake (40 kg ha^{-1})
T_7	Urea + UDMU + Neemcake	90 kg N ha^{-1} + UDMU (1/10th of urea) + Neemcake (40 kg ha^{-1})
T_8	Urea + UDMU coated + Neemcake	90 kg N ha^{-1} + UDMU (1/10th of urea) + Neemcake (40 kg ha^{-1})
T_9	Urea + UDMU + Neem-cake	90 kg N ha^{-1} + UDMU (1/5th of urea) + Neemcake (40 kg ha^{-1})
T_{10}	Urea + UDMU coated + Neemcake	90 kg N ha^{-1} + UDMU (1/5th of urea) + Neemcake (40 kg ha^{-1})

Size of the plot

Gross plot size 4.2 x 2.7 m

Net plot size 3.4 x 2.1 m

Spacing 20 x 15 cm

Variety The rice variety used for the experiment was Jaya; which is a medium duration variety of about 120-125 days.

Seeds Paddy seeds obtained from Cropping Systems Research Centre, Karamana was used for the experiment, which showed 90 percent germination. A seed rate of 80 kg ha^{-1} was adopted.

Fertilizers

Urea, Superphosphate and Muriate of Potash were used as the sources of N, P and K, analysing 46 percent N, 16 percent P_2O_5 and 60 percent K_2O respectively.

Urea was applied in three split doses. Superphosphate and Muriate of Potash were given as per the package of practices recommendations of the Kerala Agricultural University (Anon. 1986).

UDMU and neemcake

Unsymmetrical dimethyl urea (UDMU), used in the present study, is an intermediate material obtained during the manufacturing process of propellents for rockets.

Structural formula is

$$\begin{matrix} CH_3 & & \\ & N - CO - NH_2 \\ CH_3 & & \end{matrix}$$

Molecular weight 88

UDMU used in the present study was supplied by the Chemicals Division, Vikram Sarabhai Space Centre, Thumpa, Trivandrum. Neemcake was purchased from the local market at Trivandrum.

UDMU was used for the experiment along with urea as mixed and in the coated form. Coating of UDMU over urea was done as follows. UDMU was made into a slurry and sprayed over urea and allowed to dry to give a proper coating over the granules before application. Neemcake was finely powdered and mixed with urea granules, prior to soil application.

UDMU was applied along with urea during the three split applications at the rate specified for each treatment.

Neemcake was added at the rate of 40 kg ha^{-1}.

Cultivation details

The nursery area of 60 m^2 was ploughed well and raised beds of 1.5 m width and 15 cm height were prepared with drainage channels in between. Sprouted seeds were broadcasted uniformly on 6th June 1987. Irrigation was commenced on the 5th day after sowing and depth of water level was maintained at 5 cm depending upon the growth of the seedlings.

Mainfield:- The main field was ploughed twice and plots of 4.2 x 2.7 m were laid out with ten plots in each of the three blocks. The blocks and plots were separated from each other with bunds of 50 cm and 30 cm width respectively. Irrigation and drainage channels were provided for all plots. Cowdung was applied at the rate of 5 t ha^{-1} and incorporated with the soil.

Twentyfive day old healthy seedlings were uprooted from the nursery and transplanted in the mainfield at a spacing of 20 x 15 cm with two seedlings per hill. Transplanting was done on 2nd July 1987. Ten days later gap-filling was done wherever necessary. A water level of 1.5 cm was maintained initially and later increased to 5 cm.

The plots were handweeded twice on the 23rd day and 40th day after transplanting. One spraying with Ekalux (0.025%) was given to the crop at tillering stage against gall midge. Later at milking stage metacid (0.05%) was sprayed as a prophylatic measure against ricebug.

About ten days before harvest the field was drained. The field was harvested at full maturity collecting the produce of net plots and borderstrips separately. From threshed, cleaned and dried produce weights of grain and straw were recorded separately for each net plot.

3.1 Biometric studies

The following observations to the growth and yield characteristics of the crop were recorded from each treatment.

One squaremetre area of plants were marked out in each plot and set apart for taking observations.

1. Plant height at flowering stage and after harvest.
2. Number of tillers per squaremetre area at the panicle initiation stage.
3. Number of earheads per squaremetre area.
4. Net plot grain yield.

Table 1 Characteristics of the Soil

A Physical Characteristics		B Chemical Characteristics	
1) Particle size distribution		1) Soil Reaction (pH)	4.2
a) Coarse sand (%)	31.40	2) Electrical conductivity (mmhos cm^{-1})	0.08
b) Fine sand (%)	20.60	3) Organic matter (%)	0.83
c) Silt (%)	21.40	4) Total nitrogen (%)	0.064
d) Clay (%)	25.20	5) Total phosphorus (% P_2O_5)	0.09
Textural Classification - Sandy clay loam		6) Total potassium (% K_2O)	0.037
2) Bulk density	1.62 g cc^{-1}	7) Total calcium (% CaO)	0.047
3) Particle density	2.4 g cc^{-1}	8) Total magnesium (% MgO)	0.105
4) Pore Space (%)	51.7	9) Available nitrogen	156.8 kg ha^{-1}
5) Volume expansion on wetting (%)	4.23	10) Available P_2O_5	35.84 kg ha^{-1}
6) Water Holding Capacity (%)	32.53	11) Available potassium	53.76 kg ha^{-1}
		12) Exchangeable calcium (me/100 g)	1.9
		13) Exchangeable magnesium (me/100 g)	0.32
		14) Cation exchange capacity	5.9 c mol kg^{-1} of soil

5. Net plot straw yield.

6. Thousand grain weight.

3.2 Chemical Studies

3.2.1 Soil Analysis

Composite soil samples were collected from the experimental site before starting the field experiment and analysed for nutrient status.

The soil sample was airdried in shade, ground with wooden mallet, sieved through 0.2 mm mesh and screenings were collected and stored in labelled stoppered glass-bottles. The soil was analysed for the following physico-chemical characteristics and the data are presented in Table 1.

I. Mechanical Analysis:- The mechanical composition of the soil was determined by International Pipette Method after oxidation of organic matter with hydrogen peroxide. Cementing agents were removed by treating with HCI and dispersed with sodium hydroxide (Piper, 1967).

2. Soil reactions:- The soil pH was measured in a 1:2.5 soil water suspension using a photovolt pH meter with a combined glass/reference electrode.

3. Electrical conductivity:- Specific conductivity was determined in 1:5 soil water extract using an Elico Soil Bridge.

4. Cation Exchange Capacity:- CEC was determined using neutral normal ammonium acetate (Jackson, 1973).

5. Physical Constants:- This was determined by the method of Keen and Raizkowskii (Wright, 1938).

6. Organic Carbon:- Organic Carbon was estimated by the Walkley and Black's rapid titration method (Jackson, 1973).

7. Total Nitrogen:- Total nitrogen status of the soil was determined by the microkjeldahl digestion and distillation method (Jackson, 1973).

8. Total Phosphorus:- Total P_2O_5 was determined by Vanadomolybdophosphoric Yellow Colour Method (Hesse, 1971).

9. Available Phosphorus:- Available phosphorus was estimated by extracting the soil with Bray No.I extractant (0.03 N, NH_4F and 0.025 N, HCI) and thereafter developing Chloromolybdic acid blue colour and reading in Klett Summerson photoelectric colorimeter using red filter (Jackson, 1973).

10. <u>Available Nitrogen</u>:- Available nitrogen content of soil was determined by the alkaline permanganate method (Subbiah and Asija, 1956).

11. <u>Exchangeable bases</u>

a) Available potassium: By Neutral normal ammonium acetate extraction method using EEL Flamephotometer (Jackson, 1973).

b) Available calcium: By Neutral normal ammonium acetate method using Perkin Elmer 3030 AAS and the spectrum of absorption was determined at a wavelength of 422.7 nm (Jackson, 1973).

c) Available magnesium: By Neutral normal ammonium acetate extraction method using PE.3030 AAS at a wavelength of 285.2 nm (Jackson, 1973).

3.2.2 Periodical Analysis of Soil Samples

From each plot wet soil samples were collected periodically starting from the day just before fertilizer application and continued on 1st, 2nd, 3rd, 4th and 5th days after fertilization. Soil samples were collected at the above interval for all the three split applications of fertilizers during the experiment.

Soil samples from each treatment were kept in separate plastic bags for analysis.

Moisture percentage of each soil sample was determined and the fractionation of each soil sample for forms of inorganic nitrogen was done immediately on the same day of soil collection itself to study the mineralisation pattern of urea in the various treatments.

1. Determination of Moisture percentage of soil

20 grams of wet soil from each sample was taken in a container and dried in an air oven at 105°C to constant weight. Moisture percentage was calculated from weight loss.

2. Estimation of Urea Nitrogen

Colorimetric method using diacetylmonoxine solution and acid reagent and determined at a wavelength of 525 nm (Douglas and Bremner, 1972).

3. Estimation of Ammonia Nitrogen

KCI extract of soil sample was prepared and after nesslerisation, NH_4^+-N was measured colorimetrically using blue filter (Jackson, 1973).

4. Estimation of Nitrate nitrogen

Calcium sulphate extract of the soil sample was prepared and NO_3^--N was measured colorimetrically by phenoldisulphonic acid method using blue filter (Keeney and Nelson, 1982).

5. Estimation of Nitrite nitrogen

NO_2^--N was colorimetrically determined using green filter by standard Griess-Iiosvay method with sulphanilic acid and -naphthyl-amine reagents (Black, 1968).

3.3 Rate of nitrification and inhibition percentage

Rates of nitrification were computed from the concentrations of NH_4^+-N, NO_2^--N and NO_3^--N at different periods of fertilizer application of the soil samples from each experimental plot.

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

(Sahrawat, 1980)

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

$$\text{Percent Inhibition} = \frac{\left\{ \begin{array}{l}\text{Nitrification rate (\%)} \\ \text{in the untreated urea} \\ \text{plots}\end{array} - \begin{array}{l}\text{Nitrification rate (\%)} \\ \text{in the UDMU/NC/UDMU +} \\ \text{NC treated urea plots}\end{array} \right\}}{(\text{Nitrification rate (\%) in the untreated urea plots})} \times 100$$

3.4 Plant Analysis

Marked plants from each treatment were pulled out at different stages of crop and analysed for total nitrogen separately with leaves and roots. Total nitrogen in straw and grain also were estimated after harvest.

The grain, straw and root samples from each plot were kept in separate paper bags and dried at 60°C in an air oven. These samples were powdered separately in an electrical grinding mill and used for chemical analysis.

Total nitrogen contents of the straw, grain and root were determined by Modified microkjeldahl method (Jackson, 1973).

3.5 N uptake studies

The total nitrogen uptake of the crop at different stages was computed for each treatment, based on N content in the straw, grain and root and also from their dryweights respectively.

3.6 Statistical Analysis

The data generated from the field experiment and laboratory studies were analysed statistically and the results were obtained.

Data relating to various biometric characters were analysed statistically following the methods of Snedecor and Cochran (1967). For the mineralisation studies, soil samples were drawn at various periods from the experimental plots after application of fertilizers. These soil samples were analysed periodically to estimate forms of inorganic nitrogen in the soil and hence the statistical analysis was done as follows (Gomez and Gomez, 1984).

Analysis of variance

Source of variation	Degrees of freedom
Replication	2
Treatment (T)	9
Error (1)	18
Stages (S)	2
T x S	18
Error (2)	40
Total	89

Important correlations were also worked out.

Results

RESULTS

This chapter presents the various results obtained in the investigation. The experimental data and the biometric observations made on rice crop at various growth stages were subjected to statistical analysis and the results were recorded. The salient findings of the experiment are presented below.

4.1 Periodic Soil Analysis

Soil samples were periodically collected from the experimental plots for analysis a day before the application of fertilizers, immediately after fertilizer application, on the same day and after one, two, three and four days. Soil samples were drawn at the above interval after the basal application and the first and second top-dressings. The fractionation of each soil sample for various forms of inorganic nitrogen was done immediately after collection to study the release pattern of nitrogen in the various treatments.

4.2 Mineralisation pattern of Urea + (UDMU/NC/UDMU + NC) blends during basal application of fertilizers

4.2.1 Urea nitrogen

Table 2 contains the mean values in ppm of urea-N in the various treatments immediately after fertilizer application and thereafter one, two, three and four days interval.

On studying the data in the table, it was seen that, the mean value of urea-N with respect to the control plot (T_1), dropped from 13.12 ppm on zero day, to 2.78 ppm on one day after manuring. This is equivalent to a fall of 79 percent in the urea-N content of the zero day. T_6 (urea + neemcake) showed a reduction of 78 percent in urea-N. On the other hand, corresponding reduction in the urea-N for T_2 was 57.3 percent. The values showing fall in urea-N content for T_4, T_8 and T_9 were 51 percent, 50 percent and 48.5 percent respectively.

On the second day of manuring, T_1 showed a total reduction of 90 percent and T_6, 86 percent. Corresponding decrease with respect to the treatments T_2, T_3, T_4 and T_5 was 74 percent on an average and for T_9, it was 73 percent.

The residual urea-N contents ascertained on the 3rd day were 3.5 percent of that of the first day in the control plot and 3.75 percent for T_6. With respect to the treatments T_2, T_3 and T_4, the respective values were

17.5 percent, 14.7 percent and 16.2 percent. The residual urea-N for T_7 and T_9 were 16 percent and 16.8 percent respectively on the third day of fertilizer application.

Analytical data on urea-N for samples collected on the 4th day of manuring revealed that hydrolysis of urea was almost complete in T_1 (99.8 percent) and T_6 (99.76 percent).

In contrast to the above results, the values on the amount of urea hydrolysed for T_2 and T_4 were 97.2 percent and 96.3 percent respectively. The corresponding values for T_7 and T_9 were 96.7 and 96.2 percent respectively.

Split plot ANOVA Table for the urea-N contents of the experimental plots is given in Appendix I a. Based on the ANOVA Table, the rate of urea hydrolysis in the various treatments on each day of sampling were assessed with respect to its urease inhibition property.

T_9 (Urea + UDMU (1/5th of urea + neemcake) was found superior with regard to urease inhibition. However it was found that T_8, T_9 and T_{10} were on par. T_5 and T_7 were statistically on par and less efficient than T_{10}. T_2 follows T_7, and T_2 was statistically on par with T_3.

Table 2 Urea-N content (mean values in ppm) in the experimental plots during Basal Application of Fertilizers

Treatments	Immediately after application	1st day	2nd day	3rd day	4th day
T_1	13.12	2.78	1.34	0.46	0.03
T_2	13.79	5.90	3.60	2.39	0.38
T_3	13.70	6.20	3.51	2.01	0.47
T_4	13.86	6.80	3.61	2.22	0.51
T_5	13.90	6.24	3.64	2.13	0.50
T_6	13.21	2.98	1.92	0.51	0.03
T_7	13.82	6.09	3.61	2.21	0.46
T_8	13.80	6.95	3.60	2.24	0.51
T_9	13.92	7.21	3.74	2.33	0.53
T_{10}	13.82	6.68	3.64	2.20	0.51

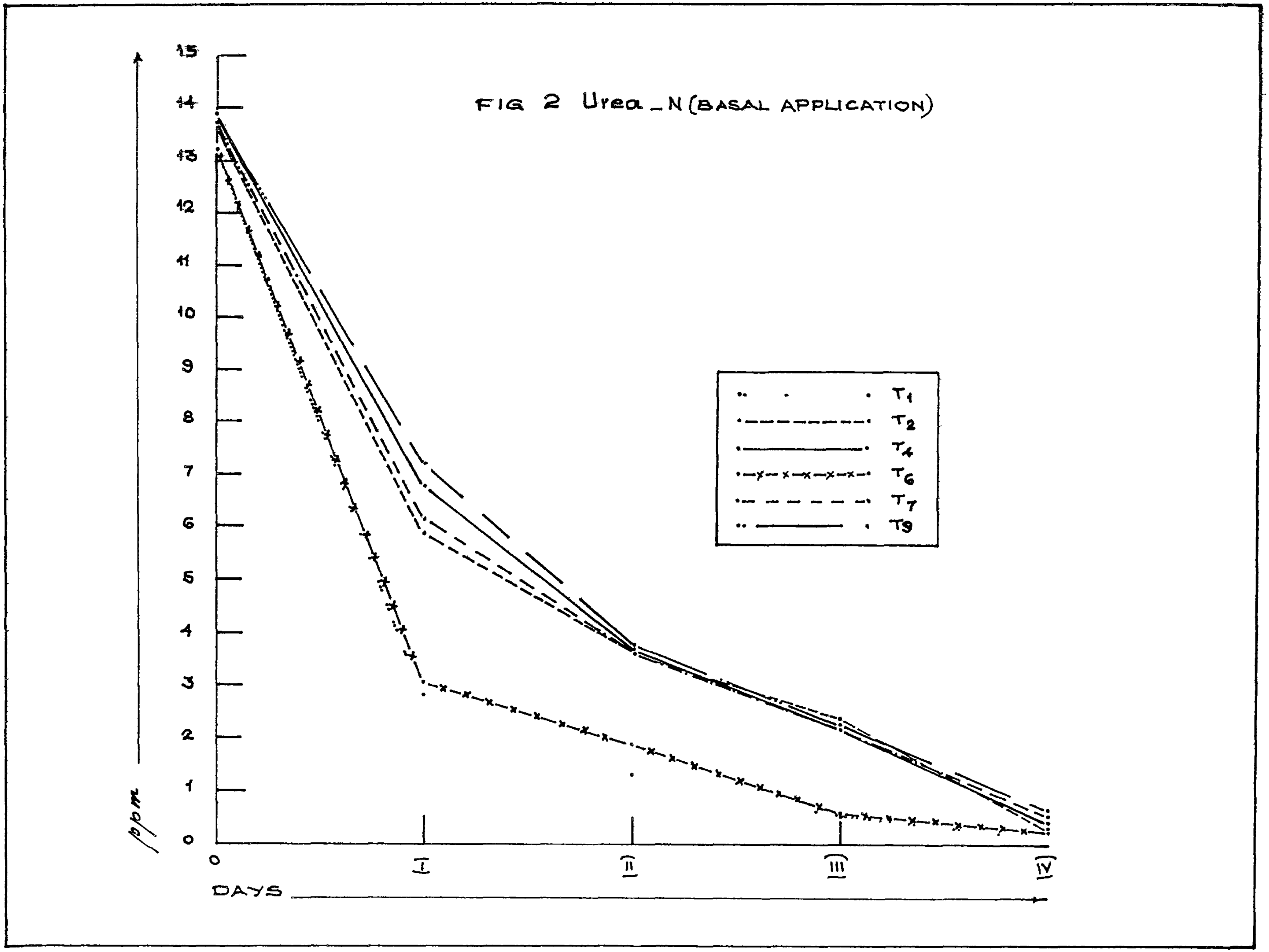


FIG 2 Urea _ N (BASAL APPLICATION)
ppm
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
0
I
II
III
IV
DAYS
T1
T2
T4
T6
T7
T9

T_6 was found inferior to T_3. The control plot (T_1) showed the lowest urease inhibition.

The data on urea-N content for the treatments during the said period is graphically represented (Fig. 2).

From the graph it is clear that urease inhibition is maximum for T_9. T_4 follows T_9. T_7 is less efficient than T_4. With respect to inhibition of urease activity, T_6 was seen inferior to T_2. Rate of hydrolysis of urea is rapid for the control plot (T_1).

4.2.2 Ammonia Nitrogen

The mean values of NH_4^+-N in the soil samples for the various treatments were tabulated (Table 3).

On appraisal of the data, it can be found that NH_4^+-N values in ppm for T_1 were 0.32, 7.35, 2.92, 2.01 and 1.92 the zero day, 1st, 2nd, 3rd and 4th days respectively. Corresponding values for T_6 were 0.32, 7.19, 2.99, 3.6 and 2.64. With respect to the plots treated with UDMU, the NH_4^+-N values obtained for T_2, for the zero day, 1st, 2nd, 3rd and 4th days were 0.35, 5.3, 6.4, 5.3 and 3.25 respectively. The respective values for T_4 were 0.33, 5.26, 6.64, 5.46 and 5.43. With regard to T_9, the corresponding values were 0.36, 5.33, 7.05, 5.60 and 5.29 respectively.

The control plot showed a rapid rise in NH_4^+-N content on the day after fertilizer application itself, followed by a sudden fall during 2, 3 and 4 days after. A similar trend was observed for T_6 also.

On the contrary, in the UDMU treated plots the release of NH_4^+-N showed a slow rate. The value reaches the maximum on the second day and thereafter it shows a slow decreasing rate of ammonification. On the 1st day there was an increase of 7.02 NH_4^+-N in T_1 and 6.99 ppm in T_6. The corresponding values for T_2, T_5, T_8 and T_{10} were 4.95 and 5.08, 4.9 and 5.0 respectively.

On the 2nd day of manuring, the NH_4^+-N contents in T_1 and T_6 were decreased by 4.43 ppm and 4.2 ppm respectively. In contrast to this, the UDMU treated plots showed an increasing trend. With respect to the treatments T_3, T_4, T_7, T_9 and T_{10}, the values of increase in NH_4^+-N contents were 1.16, 1.38, 1.32, 1.72 and 1.46 respectively on the 2nd day.

The NH_4^+-N values obtained on the 3rd day of manuring with respect to T_1 and T_6 were 2.01 and 3.6

Table 3 Ammonia Nitrogen status (mean values in ppm) in the experimental plots during basal application of fertilizers

Treatments	Immediately after application	1st day	2nd day	3rd day	4th day
T_1	0.32	7.35	2.92	2.01	1.92
T_2	0.35	5.30	6.40	5.30	5.25
T_3	0.32	5.24	6.46	5.29	5.24
T_4	0.33	5.26	6.64	5.46	5.43
T_5	0.35	5.43	6.68	5.58	5.36
T_6	0.32	7.19	3.0	3.60	2.64
T_7	0.38	5.26	6.58	5.57	5.32
T_8	0.36	5.26	6.27	5.49	5.20
T_9	0.36	5.33	7.05	5.60	5.30
T_{10}	0.34	5.34	6.80	5.39	5.24

respectively. For the treatments T_2, T_4, T_5, T_7, T_8 and T_9 the NH_4^+-N values were 5.3, 5.46, 5.58, 5.49 and 5.6 respectively.

Four days after fertilization, the NH_4^+-N contents for T_1 was 1.92 ppm and the respective value for T_6 was 2.64 ppm. With respect to the treatments T_2, T_4, T_5, T_7 and T_9, the corresponding values were 5.25, 5.43, 5.36, 5.32 and 5.29 respectively.

Split plot ANOVA Table for the NH_4^+-N contents during the said period is given in Appendix I a.

Comparing the treatments based on NH_4^+-N content, T_9 was found to be superior. Treatments T_5, T_4, T_{10} and T_7 were statistically on par. Besides, T_3 and T_2 were also on par. T_6 was much inferior to T_2 and the control plot (T_1) was found to be having the lowest performance.

The data on NH_4^+-N content of the treatments are graphically represented (Fig. 3).

It was observed that NH_4^+-N status reaches the maximum value on the first day for the control plot (T_1) and thereafter decreases rapidly. T_9 was seen superior. T_4, T_7 and T_{10} were found statistically on par. Retention of NH_4^+-N in T_6 was found better than that of T_1.

FIG. 3 NH_4^+ - N (BASAL APPLICATION)

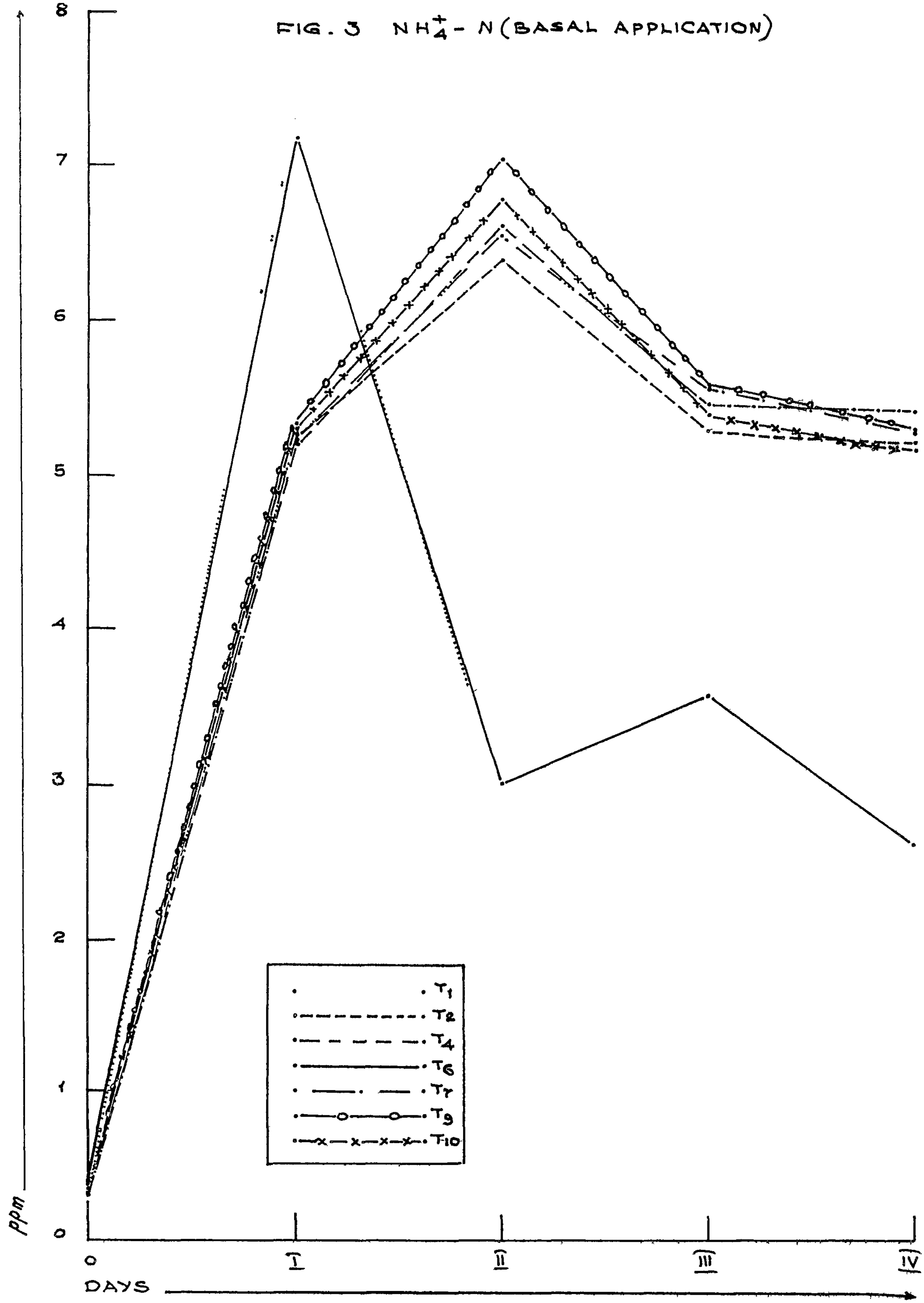


FIG 4 NH_4^+ - N (BASAL APPLICATION)

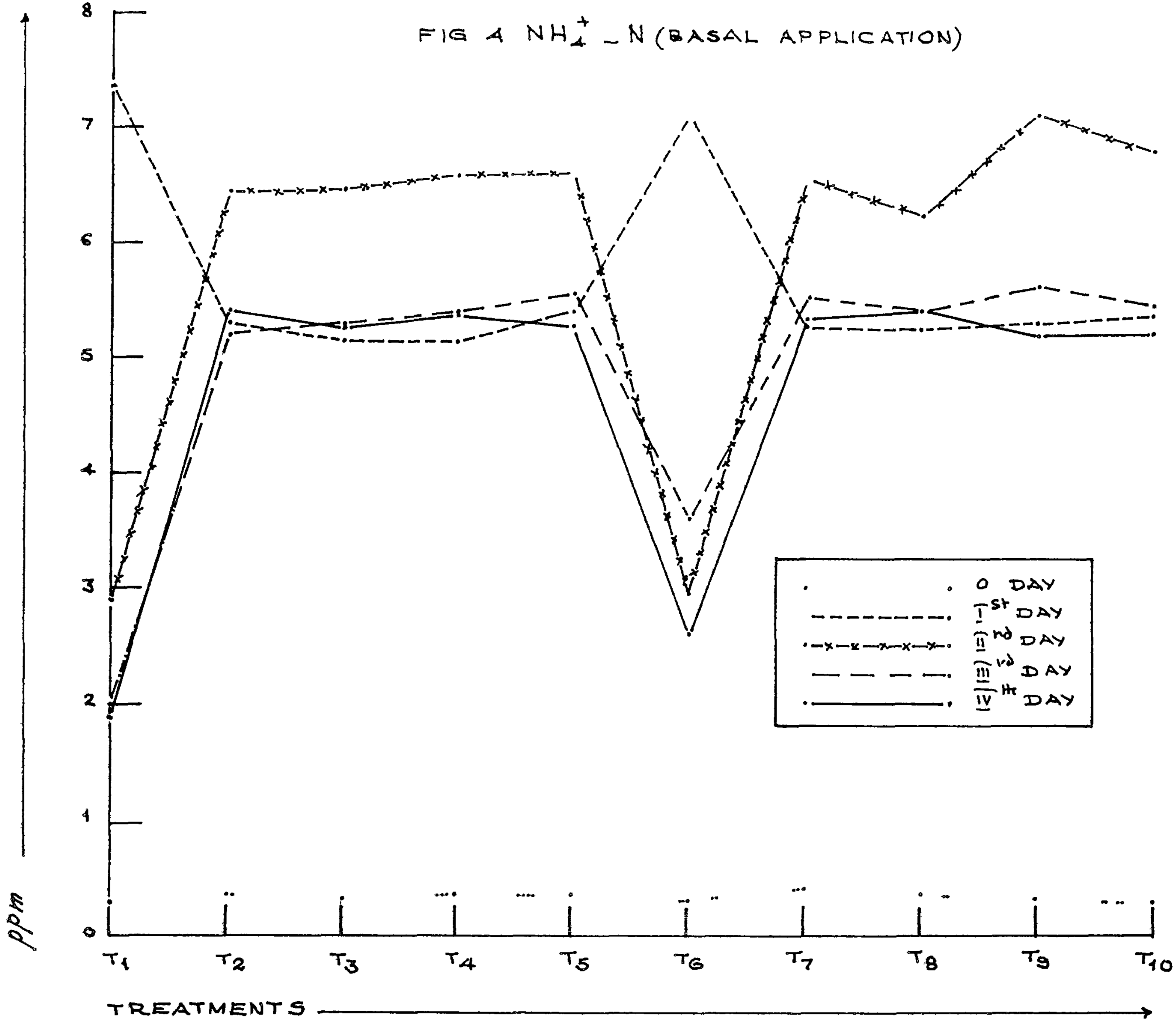


Fig. 4 furnishes the data on NH_4^+-N content after basal application of fertilizers graphically represented in a different way, with the ten treatments plotted on the X-axis and NH_4^+-N values in ppm on the Y-axis.

On the first day the value of NH_4^+-N was seen maximum with regard to the control plot. T_6 also recorded a higher value for NH_4^+-N on the first day. But with respect to the other treatments, viz. T_2, T_3, T_4, T_5, T_7, T_8, T_9 and T_{10} much lower values were obtained on the first day. On the second day of application of fertilizers, NH_4^+-N status was found decreasing rapidly for T_1 as well as for T_6. On the other hand, with regard to all other treatments, NH_4^+-N status was found increasing on the second day.

Maximum retention of NH_4^+-N was found with respect to T_9.

All the treatments showed a decreasing trend on the third and fourth days of fertilizer application.

4.2.3 Nitrate Nitrogen

The mean values in ppm of NO_3^--N in the soil samples for the various treatments are given in Table 4.

On perusal of the data, it was observed that for the control plot, value of nitrate nitrogen increases from 0.25 to 4.1 ppm on the first day.

On the second day, it reaches the maximum value of 7.74 ppm and thereafter it decreases at a rapid rate.

In contrast to this, it was observed that the maximum value of NO_3^--N was reached only on the 3rd day of manuring. The decrease in NO_3^--N status thereafter was noted at a very slow rate for these treatments. NO_3^--N contents with regard to T_6 for 1st, 2nd, 3rd and 4th days were 3.08, 7.2, 4.84 and 3.94 respectively. It was seen that NO_3^--N values with respect to 2nd, 3rd and 4th day of manuring for T_1 were higher than the corresponding values for T_6.

With regard to T_2, the NO_3^--N contents for 1, 2, 3 and 4 days after fertilization were 2.56, 4.41, 6.19 and 5.42 respectively. The respective values for T_9 were 2.45, 4.31, 5.98 and 5.34.

Split plot ANOVA table for the mean values of NO_3^--N of the various treatments after basal application of fertilizers is given in Appendix I a.

T_9 was found to be superior among the treatments.

Table 4 Nitrate-N content (mean values in ppm) in the experimental plots during basal application of fertilizers

Treatments	Immediately after application	1st day	2nd day	3rd day	4th day
T_1	0.25	4.10	7.74	4.19	3.12
T_2	0.20	2.56	4.41	6.19	5.42
T_3	0.24	2.51	4.42	6.22	5.37
T_4	0.27	2.23	4.36	6.08	5.44
T_5	0.26	2.43	4.45	6.14	5.59
T_6	0.22	3.08	7.20	4.84	3.94
T_7	0.26	2.59	4.43	5.93	5.45
T_8	0.26	2.52	4.55	6.14	5.40
T_9	0.25	2.45	4.31	5.98	5.34
T_{10}	0.25	2.49	4.44	6.14	5.40

It was seen that T_7, T_{10}, T_3, T_2, T_5 and T_8 were statistically on par. The control plot was much inferior with regard to nitrification inhibition property than all other treatments.

The data on the NO_3^--N contents is graphically represented in Fig. 5. From the graph, it was observed that nitrification rate is maximum for T_1.

T_6 showed a comparatively lesser rate of nitrification than T_1. T_9 was found superior with regard to inhibition of nitrification.

4.2.4 Nitrite Nitrogen

Analysis of NO_2^--N showed that the contents were found to be meagre compared to the other forms of inorganic nitrogen.

Table 5 contains the mean values in ppm of nitrite-N in the treatments after basal application of fertilizers. In general, a slight increasing trend in the content of nitrite was noticed. Though treatments showed significant differences, the variation did not follow any consistent pattern to draw a conclusion.

From the split plot ANOVA Table, it was found that

FIG 5 NO_3^--N (BASAL APPLICATION)

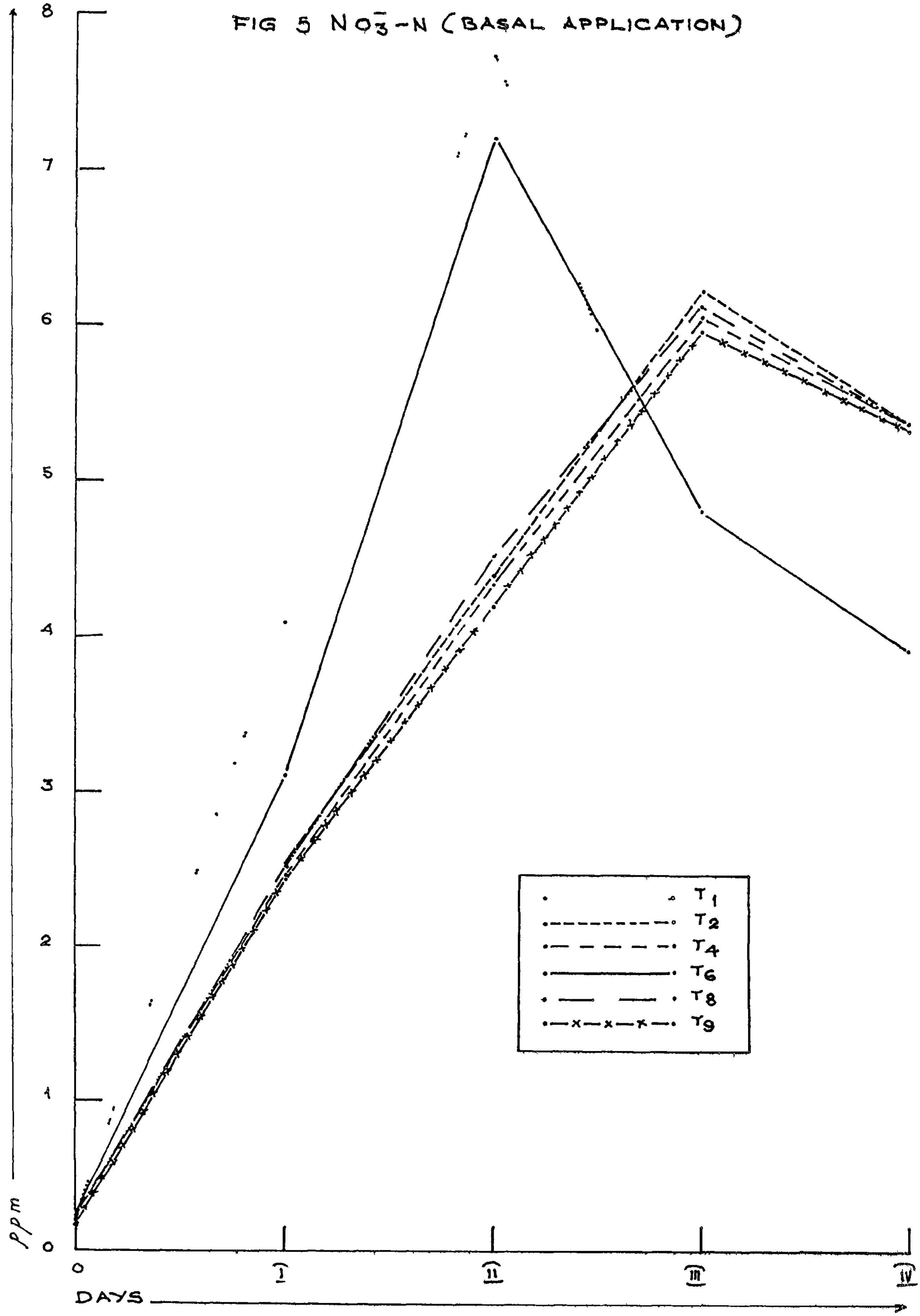


Table 5 Nitrite-N content (mean values in ppm) in the experimental plots during basal application of fertilizers

Treatments	Immediately after application	1st day	2nd day	3rd day	4th day
T_1	0.009	0.16	0.25	1.08	0.76
T_2	0.009	0.22	0.64	0.35	0.59
T_3	0.008	0.19	0.63	0.39	0.71
T_4	0.008	0.22	0.56	0.35	0.60
T_5	0.0084	0.23	0.28	0.34	0.69
T_6	0.009	0.27	0.52	0.71	0.75
T_7	0.01	0.23	0.50	0.46	0.63
T_8	0.009	0.22	0.48	0.43	0.57
T_9	0.008	0.23	0.27	0.43	0.68
T_{10}	0.008	0.18	0.23	0.39	0.57

the treatments T_{10}, T_5, T_9, T_8 and T_4 were statistically on par with regard to amounts of nitrite nitrogen. T_1 showed the lowest performance.

4.2.5 Rate of nitrification and percentage - inhibition

Table 6 presents the rate of nitrification (percent) in the soil under different treatments and the percentage inhibition of nitrification imparted by UDMU and neemcake in different combinations during the basal application of fertilizers.

The data showed that the untreated urea maintained a higher nitrification rate compared to all other treatments.

With regard to T_1, the values of nitrification percentage on 2nd, 3rd and 4th days after fertilizer application were 73.23, 72.39 and 66.87 respectively. For T_6, the corresponding values were 72.12, 60.66 and 63.97 respectively. During two, three and four days after fertilizer application the nitrification percentage for T_2 were 44.10, 55.20 and 53.37 respectively. For T_4, the values were 42.41, 54.06 and 52.64 respectively. Corresponding values of nitrification percentage with respect to T_9 were 39.39, 52.74 and 53.36 respectively.

Table 6 Percentage Nitrification and Inhibition

Treatments	2nd day		3rd day		4th day	
	Nitrification	Inhibition	Nitrification	Inhibition	Nitrification	Inhibition
T_1	73.23	-	72.39	-	66.87	-
T_2	44.10	39.78	55.20	23.74	53.37	20.19
T_3	43.88	40.08	55.50	23.33	53.68	19.72
T_4	42.41	42.09	54.06	25.32	52.64	21.28
T_5	41.398	43.48	53.74	25.76	53.95	19.32
T_6	72.12	1.53	60.66	16.20	63.97	4.34
T_7	42.84	41.50	53.42	26.20	53.32	20.26
T_8	44.49	39.25	54.46	24.77	53.43	20.10
T_9	39.39	46.21	52.74	27.14	53.36	20.20
T_{10}	40.69	44.44	54.78	24.33	53.26	20.35

Among the treatments, T_9 was showing the minimum value for nitrification percentage.

With regard to inhibition percentage, the values for 2, 3 and 4 days after fertilization for T_6 were 1.53, 16.2 and 4.34 respectively. For T_2, the corresponding values were 39.78, 23.74 and 20.19 respectively. With respect to T_5, the respective values were 43.48, 25.76 and 19.32. Pertaining to T_9, the inhibition percentage values for 2nd, 3rd and 4th days of manuring were 46.21, 27.14 and 20.2 respectively. Among the treatments T_9 showed the maximum value for inhibition percentage.

From Fig. 6 it is evident that T_6 (urea + neemcake) is having the ability to inhibit nitrification. But the treatments applied with UDMU were observed to be superior to T_6 in this regard. The values obtained as inhibition percentages with regard to T_6 on the second, third and fourth days of application of fertilizers were found much lesser than that for the other treatments. T_9 was found superior.

As the rate of nitrification increased, the percentage inhibition was found decreasing. In all the treatments the percentage inhibition showed peak values

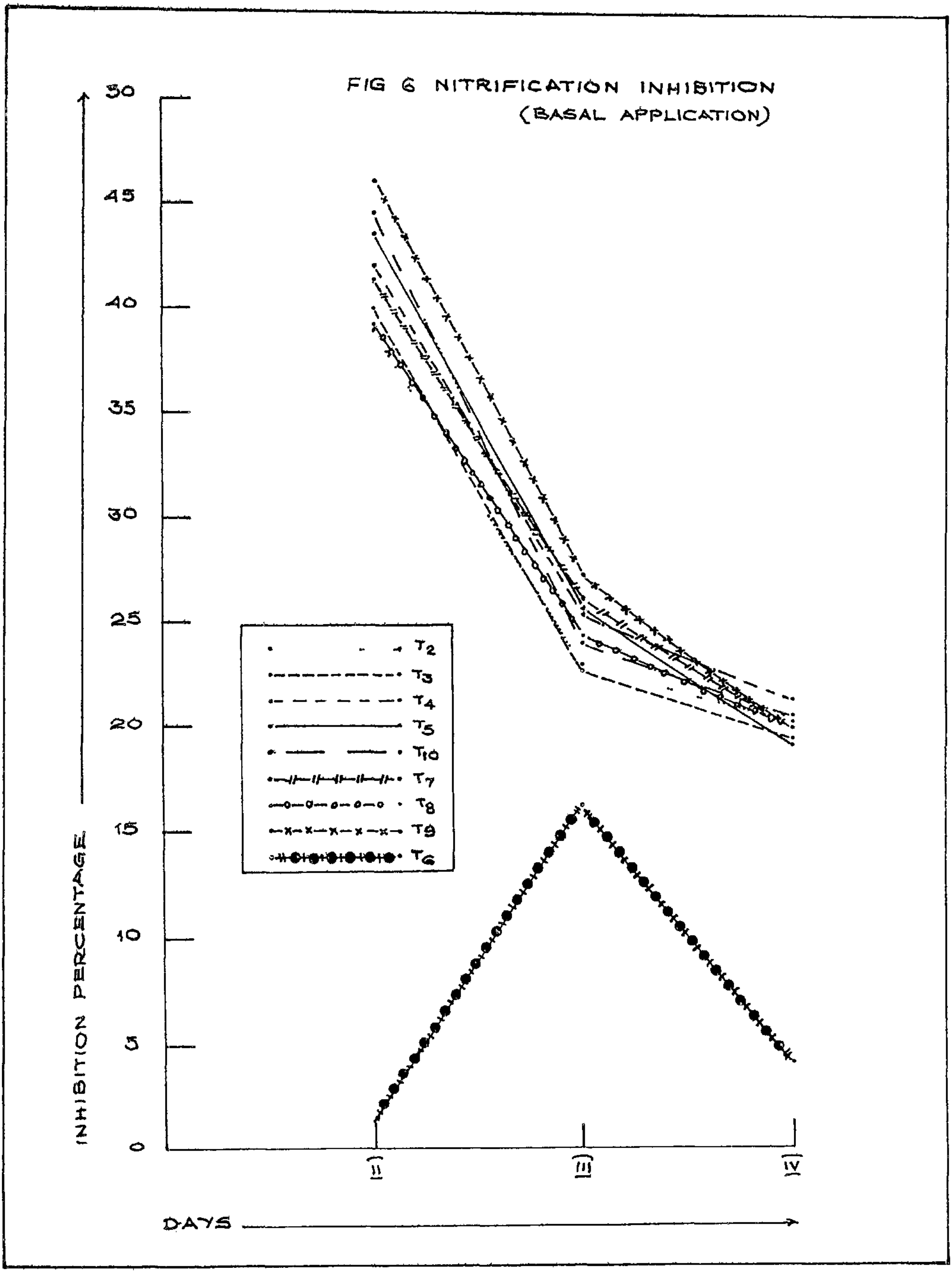


FIG 6 NITRIFICATION INHIBITION
(BASAL APPLICATION)
50
45
40
35
30
25
20
15
10
5
0
INHIBITION PERCENTAGE
T2
T3
T4
T5
T10
T7
T8
T9
T6
II
III
IV
DAYS

on the second day of fertilizer application. In general, application of neemcake was observed to be imparting nitrification inhibition property. But inhibition percentage was found to be much inferior compared to that by UDMU. In addition, it was also found that the cumulative effect of neemcake and UDMU was higher than that of UDMU only. Besides, it was also observed that plots treated with greater concentration of UDMU increased the rate of inhibition.

4.3 Mineralisation pattern of Urea + (UDMU/NC/UDMU + NC) blends during the first topdressing of fertilizers

4.3.1 Urea nitrogen

Table 7 furnishes the mean values of urea-N in the experimental plots during day before immediately after and one, two, three and four days respectively after first topdressing.

Data showed that before fertilizer application the content of urea-N in the plots were only in traces and statistically there was no significant differences among them.

With respect to the control plot (T_1) the mean value of urea-N decreased from 12.73 ppm as on zero day to 2.7 ppm on one day after manuring. This corresponds to a drop of about 79 percent in urea-N from that of the first day and corresponding reduction for T_6 was 76 percent. For the treatments T_2, T_4, T_8 and T_9, the respective values of reduction in urea-N were 53.5 percent, 48.5 percent, 45 percent and 44.9 percent.

For control plot (T_1) there was a total decrease of about 89.5 percent on the second day and with regard to T_6, the reduction was about 87 percent. But the total reduction in urea-N content with respect to the treatments T_2, T_4, T_8, T_9 and T_{10} were 73.3 percent, 71.6 percent, 72.6 percent, 71.9 percent, and 71.4 percent respectively.

The amount of urea-N hydrolysed upto the 4th day of manuring was recorded as 99.8 percent for T_1 and T_6. On the contrary, the corresponding values ascertained for the treatments T_2, T_4, T_9 and T_{10} were 96.3 percent, 97 percent, 97.5 percent and 97 percent respectively.

It was observed that rate of hydrolysis of urea was very rapid in plots treated with urea alone (T_1). T_6 also followed a similar pattern. On the other hand, in the plots treated with UDMU, the rate of hydrolysis of urea was at a much slower rate.

Table 7 Urea-N contents (mean values in ppm) in the experimental plots during first topdressing of fertilizers

Treatment	Day before application	Immediately after application	1st day	2nd day	3rd day	4th day
T_1	0.002	12.73	2.70	1.34	0.30	0.02
T_2	0.001	12.85	6.00	3.44	2.29	0.47
T_3	0.0009	12.94	6.27	3.33	2.25	0.37
T_4	0.001	12.81	6.61	3.65	2.29	0.38
T_5	0.001	12.80	6.24	3.66	2.22	0.42
T_6	0.001	12.69	3.04	1.67	0.31	0.02
T_7	0.0007	12.92	6.47	3.48	2.31	0.39
T_8	0.002	12.95	7.15	3.55	2.26	0.34
T_9	0.001	12.99	7.16	3.65	2.36	0.32
T_{10}	0.001	12.87	6.48	3.68	2.31	0.39

From the split plot ANOVA Table (given in Appendix I b) of urea-N values obtained in the six days test after first top dressing, statistically significant differences were obtained for the different treatments under study.

It was seen that the treatments T_9 and T_8 were statistically on par and superior to all other treatments. Then comes the treatments T_4, T_{10}, T_7 and T_5 which were found to be on par by statistical scrutiny. T_6 was found inferior to those treatments applied with UDMU. T_1 showed the lowest performance with regard to urease-inhibitory property.

Fig. 7 represents the urea hydrolysis pattern in the various treatments. The control plot showed a rapid rate of hydrolysis of urea. T_6 also followed a similar trend. T_9 and T_8 were found statistically on par and superior to all other treatments.

4.3.2 Ammonia Nitrogen

The mean values of NH_4^+-N in the soil samples for the various treatments during six days were tabulated (Table 8).

On analysis of the data it was revealed that NH_4^+-N

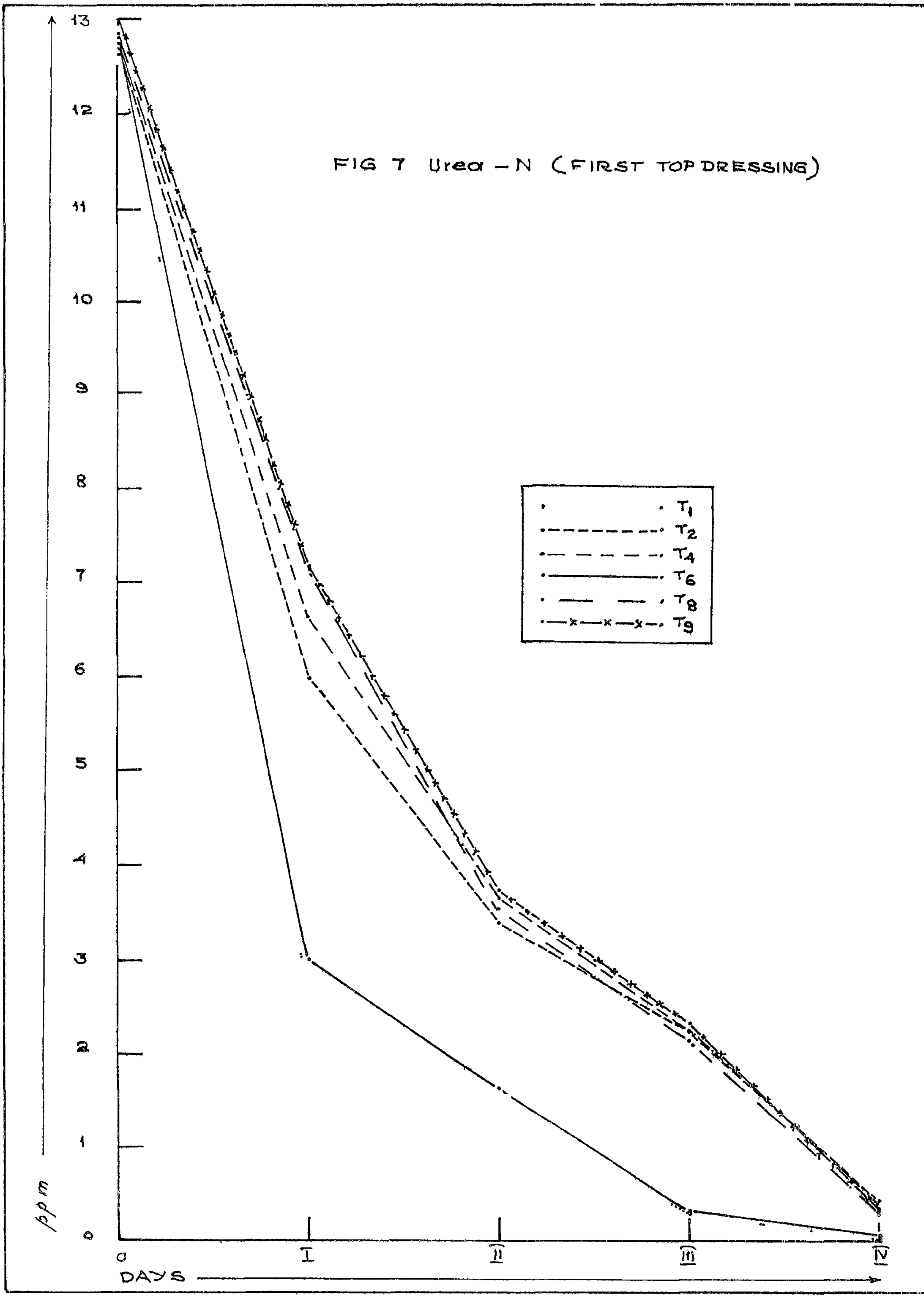


FIG 7 Urea – N (FIRST TOP DRESSING)
T1
T2
T4
T6
T8
T9
13
12
11
10
9
8
7
6
5
4
3
2
1
0
ppm
0
I
II
III
IV
DAYS

values for control plot were 0.007, 0.25, 7.26, 2.88, 2.66 and 2.09 for the day before manuring, zero day, 1st, 2nd, 3rd and 4th days respectively. Regarding the treatment (T_6) with neemcake, the respective values were 0.003, 0.30, 7.09, 2.8, 3.43 and 2.52.

With respect to T_2, the corresponding values were 0.007, 0.24, 5.37, 6.27, 5.28 and 5.16 respectively and for T_4 the respective values were 0.28, 5.23, 6.53, 5.43 and 5.29.

For T_7, the NH_4^+-N contents ascertained for the day before manuring, zero day, 1st, 2nd, 3rd and 4th days were 0.004, 0.27, 5.24, 6.35, 5.46 and 5.22 respectively. With regard to T_9, the respective values were 0.007, 0.33, 5.32, 6.98, 5.56 and 5.22.

Pertaining to the control plot, the maximum value of NH_4^+-N was recorded on 1st day of manuring (7.26 ppm) and it dropped rapidly to 2.88 ppm on the next day. A similar trend was observed in T_6 also. But with respect to the plots treated with UDMU, an entirely different pattern of ammonification was observed. For T_3, the maximum value of NH_4^+-N was recorded on the second day (6.43) and next day onwards, the NH_4^+-N contents were found

Table 8 NH_4-N contents (mean values in ppm) in the experimental plots during first topdressing of fertilizers

Treatments	Day before application	Immediately after application	1	2	3	4
T_1	0.006	0.25	7.26	2.83	2.66	2.09
T_2	0.007	0.24	5.37	6.27	5.28	5.16
T_3	0.003	0.27	5.20	6.43	5.24	5.21
T_4	0.005	0.28	5.23	6.53	5.43	5.29
T_5	0.005	0.31	5.37	6.54	5.37	5.31
T_6	0.003	0.30	7.09	2.80	3.43	2.52
T_7	0.004	0.27	5.24	6.35	5.46	5.22
T_8	0.005	0.30	5.25	6.30	5.36	5.32
T_9	0.007	0.33	5.32	6.98	5.56	5.22
T_{10}	0.006	0.30	5.31	6.80	5.38	5.23

decreasing at a slow rate. The values recorded on 3rd and 4th day were 5.24 and 5.21 respectively. With regard to T_5, the maximum value of 6.54 was obtained on second day of manuring and this dropped slowly to 5.37 on 3rd day and 5.31 on 4th day respectively. For T_{10}, the maximum value was 6.80 on two days after fertilizer application, followed by 5.38 and 5.23 on the subsequent days respectively.

It was observed that in the UDMU treated plots NH_4^+-N contents were more or less at a uniform rate without sudden fall and in the control plot a higher value of NH_4^+-N was obtained on the day after manuring followed by a rapid reduction in the subsequent days.

Split plot ANOVA Table of the NH_4^+-N contents for the said period is given in Appendix I b.

It was observed that the treatments T_9 and T_{10} were statistically on par and superior to all other treatments. Besides, the treatments T_{10}, T_5, T_7 and T_8 were also statistically on par. T_6 was found statistically much inferior to those treatments applied with UDMU and T_1 was the least effective treatment.

The data on NH_4^+-N content for the treatments are

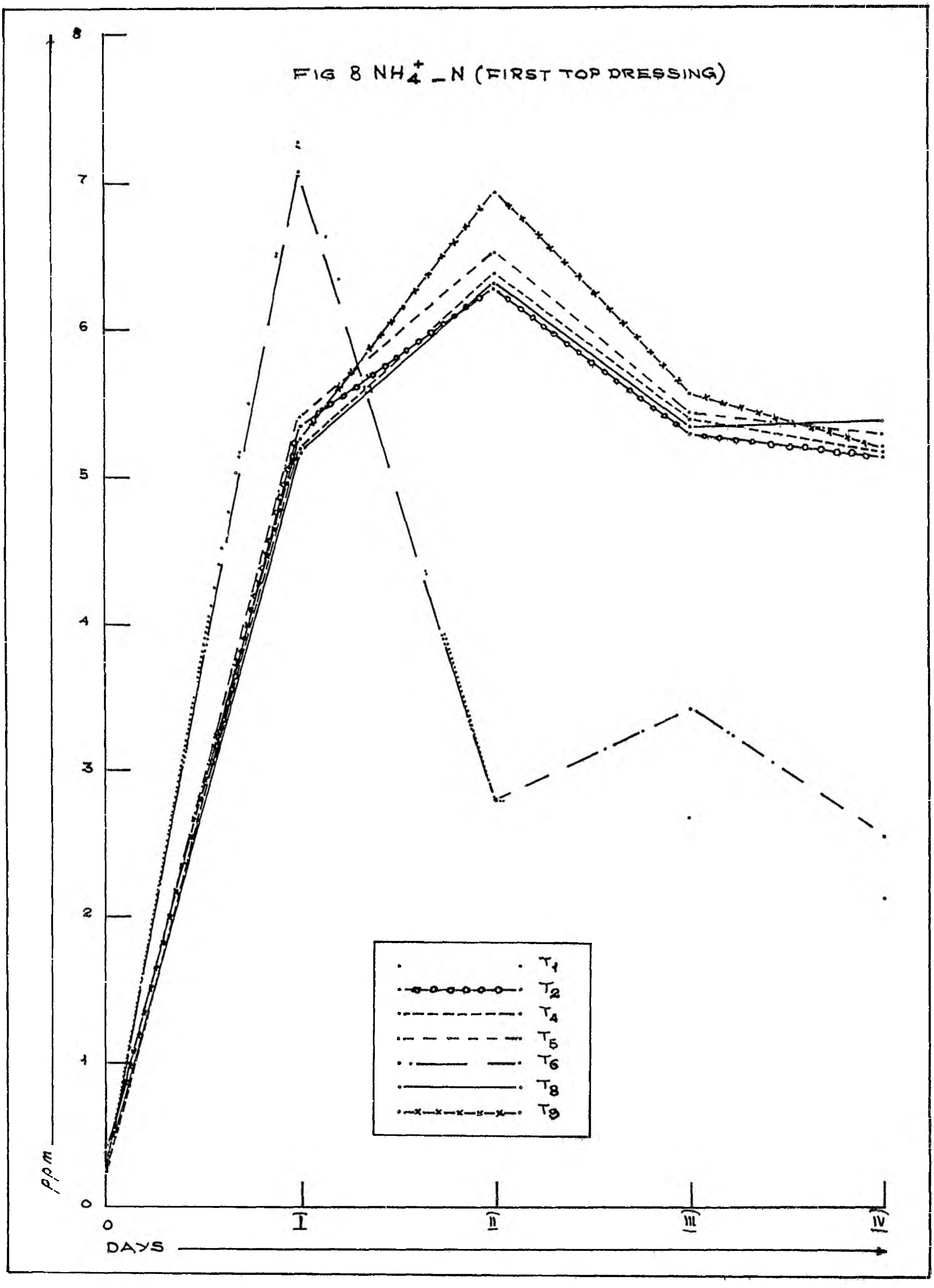


FIG 8 NH4+ – N (FIRST TOP DRESSING)
ppm
8
7
6
5
4
3
2
1
0
0
I
II
III
IV
DAYS
T1
T2
T4
T5
T6
T8
T9

graphically represented (Fig. 8).

With regard to T_1, it was found that the maximum value was reached on the first day and dropped rapidly on the second day. T_9 was found superior with regard to retention of NH_4^+-N.

4.3.3 Nitrate Nitrogen

The table 9 furnishes the data on mean values of Nitrate-N in the soil samples from the experimental plots during the said period.

The value of NO_3^--N for T_1 was 4.24 ppm on first day and 3.85 ppm was the respective value for T_6. It was observed that for plots treated with UDMU, lower values of NO_3^--N were obtained when compared to T_1 and T_6. For T_2, the NO_3^--N value was 2.91 and with respect to T_4, T_5, T_8, T_9 and T_{10} the values recorded were 2.59, 2.72, 2.53, 2.69 and 2.57 respectively.

It was seen that on the second day, a maximum value of 7.27 ppm was recorded for the control plot. After the second day of fertilizer application, it was found that the NO_3^--N contents were decreasing at a rapid rate for the control plot. The NO_3^--N values recorded for control plot for 3rd and 4th days of manuring were 4.51 and 3.72 respectively. For T_6, the maximum value of 6.22 was recorded on the second day and NO_3^--N values recorded on 3rd and 4th days were 4.93 and 4.29 respectively. It was found that with respect to T_6 (urea + neemcake) the nitrification was not so rapid as that for the control plot (T_1).

On the other hand, for the UDMU treated plots the maximum value of NO_3^--N was reached on the 3rd day of manuring. Thereafter, NO_3^--N status decreases at a very slow rate.

Split plot ANOVA Table of the NO_3^--N values during the said period is given in Appendix I b.

From the split plot ANOVA Table, it was found that the treatments T_7, T_8, T_4, T_{10}, T_9 and T_5 were statistically on par. T_1 was having the lowest nitrification inhibitory property.

The data on NO_3^--N content for the treatments after first topdressing are graphically represented (Fig. 9).

Nitrification was seen rapid with regard to the control plot (T_1). T_6 showed inhibition of nitrification

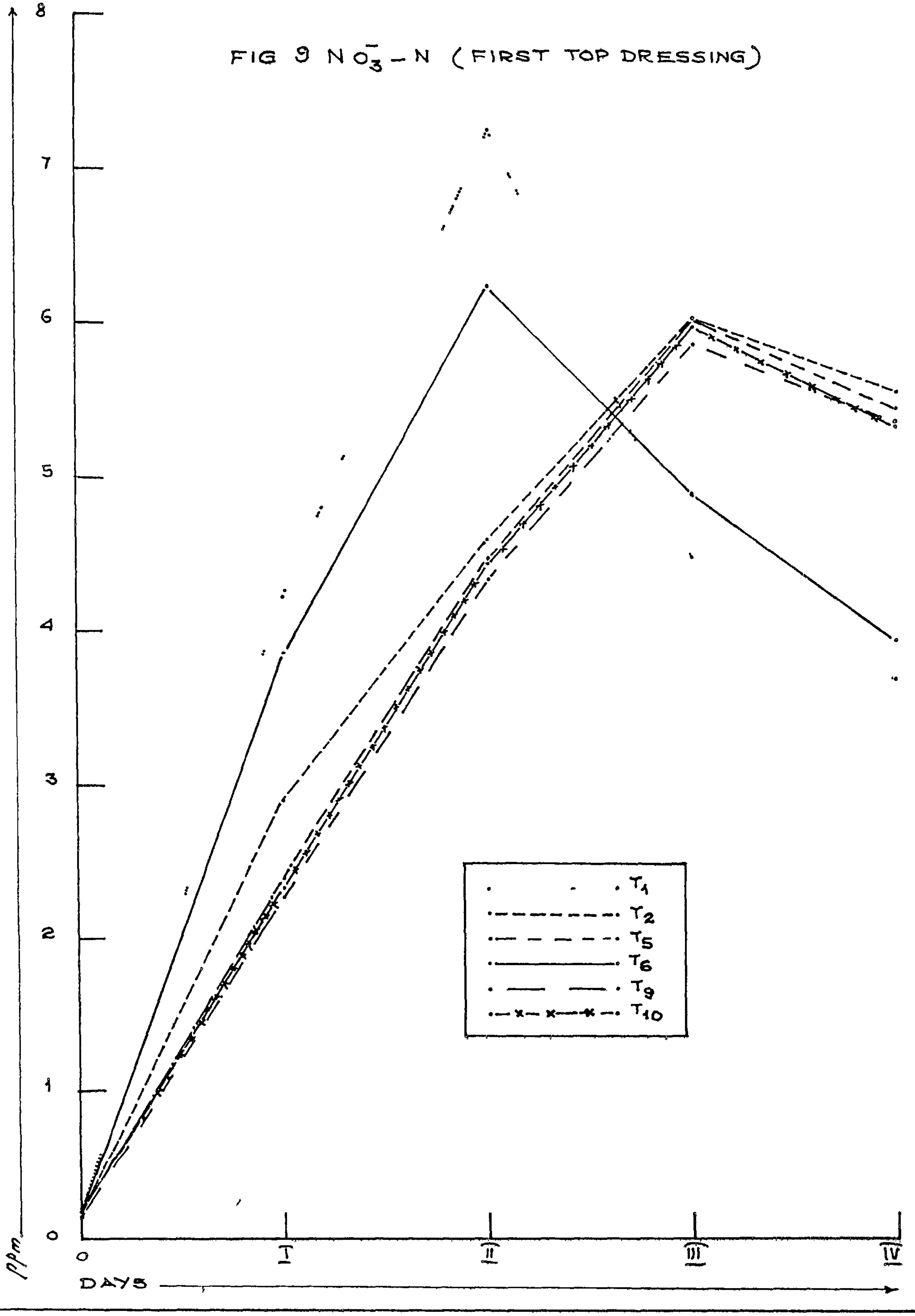


FIG 9 $NO_3^- - N$ (FIRST TOP DRESSING)
ppm
8
7
6
5
4
3
2
1
0
0
I
II
III
IV
DAYS
T_1
T_2
T_5
T_6
T_9
T_{10}

Table 9 Nitrate-N contents (mean values in ppm) in the experimental plots during first topdressing of fertilizers

Treatments	Day before application	Immediately after application	I	II	III	IV
T_1	0.05	0.18	4.24	7.27	4.51	3.72
T_2	0.62	0.17	2.91	4.60	6.07	5.59
T_3	0.05	0.18	2.90	4.55	6.21	5.58
T_4	0.07	0.19	2.59	4.42	6.096	5.48
T_5	0.05	0.21	2.72	4.49	6.07	5.42
T_6	0.06	0.15	3.85	6.22	4.93	4.29
T_7	0.05	0.20	2.48	4.61	6.04	5.47
T_8	0.06	0.19	2.53	4.57	6.03	5.47
T_9	0.06	0.19	2.69	4.41	5.94	5.57
T_{10}	0.04	0.18	2.57	4.52	6.06	5.46

but its rate of nitrification inhibition was found inferior to other treatments.

Rate of nitrification inhibition was found maximum for T_9.

4.3.4 Nitrite nitrogen

Table 10 furnishes the mean values of nitrite-N in the various treatments during said period.

The data showed that the values of nitrite-N for all the treatments during six days after the first top dressing were below 1 ppm.

It was observed that the treatments T_5, T_{10}, T_3, T_8 and T_9 were statistically on par. T_1 showed the least performance.

4.3.5 Rate of Nitrification and percentage inhibition

Table 11 furnishes the rate of nitrification (%) in the soil under different treatments and the percentage inhibition of nitrification imparted by the treatment combinations during the first top dressing, after transplanting of the paddy crop.

On appraisal of the data, it was observed that

Table 10 NO_2^--N contents (mean values in ppm) in the experimental plots during the second application of fertilizers

Treatments	Day before application	Immediately after application	I	II	III	IV
T_1	0.054	0.003	0.037	0.233	0.921	0.870
T_2	0.062	0.003	0.035	0.158	0.507	0.552
T_3	0.054	0.004	0.040	0.151	0.421	0.388
T_4	0.072	0.005	0.036	0.142	0.431	0.466
T_5	0.050	0.003	0.034	0.148	0.433	0.320
T_6	0.055	0.004	0.037	0.155	0.925	0.847
T_7	0.045	0.004	0.041	0.220	0.413	0.400
T_8	0.057	0.003	0.040	0.140	0.458	0.365
T_9	0.059	0.004	0.036	0.143	0.433	0.411
T_{10}	0.047	0.003	0.040	0.138	0.413	0.363

control plot was having the highest rate of nitrification. Nitrification rate obtained was comparatively lesser for T_6, and much lesser nitrification percentages were got for plots treated with UDMU.

With regard to the control plot, the values of nitrification percentage on 2nd, 3rd and 4th days after fertilizer application were 72.28, 67.12 and 68.68 respectively. For T_6, the corresponding values were 69.48, 63.06 and 67.06 respectively.

The nitrification percentage for T_2 were 43.14, 55.44 and 54.36 respectivdly. For T_5, the values were 41.49, 54.79 and 51.95 respectively. Corresponding values of nitrification percentage with respect to T_9, were 39.78, 53.41 and 53.4 respectively. T_9 showed the least nitrification percentage.

The inhibition percentage values with respect to T_6 were 3.87, 6.05 and 2.36 respectively on 2nd, 3rd and 4th days of fertilization. For T_2, the inhibition percentages recorded were 40.31, 17.4 and 20.83. Respective values with regord to T_5 were 42.59, 18.39 and 24.36. Inhibition percentages recorded on 2nd, 3rd and 4th days for T_7 were 40.23, 19.34 and 22.98 respectively. Corresponding values for T_9 were 45.38, 20.42 and 22.25 respectively.

Table 11   Percentage Nitrification and Inhibition

Treatments	2nd day		3rd day		4th day	
	Nitrification	Inhibition	Nitrification	Inhibition	Nitrification	Inhibition
T_1	72.28	-	67.12	-	68.68	-
T_2	43.14	40.31	55.44	17.40	54.36	20.85
T_3	42.24	41.56	55.88	16.75	53.39	22.26
T_4	41.13	43.09	54.58	18.68	52.9	22.98
T_5	41.49	42.59	54.79	18.39	51.95	24.30
T_6	69.48	3.87	63.06	6.05	67.06	2.36
T_7	43.20	40.23	54.14	19.34	52.90	22.98
T_8	42.76	40.84	54.76	18.40	52.31	23.84
T_9	39.78	45.38	53.41	20.42	53.40	22.25
T_{10}	40.65	43.76	54.61	18.64	52.67	23.31

Fig. 10 furnishes the nitrification inhibition pattern in the various treatments. Percentage inhibition was observed maximum for T_9.

It was observed that with increase in rate of nitrification, the percentage inhibition was seen decreasing, and percentage inhibition showed higher values on second day of manuring.

4.4 Mineralisation pattern of urea + (UDMU/NC/UDMU + NC) blends during the second topdressing of fertilizers

4.4.1 Urea Nitrogen

Table 12 gives the data on urea-N contents in the different treatments under investigation during day before, immediately after and one, two, three and four days after 2nd topdressing of fertilizers.

Data revealed that on the day before manuring the urea nitrogen was present only in small quantities in the soil and statistically there was no significant differences among the various treatments. The mean value of urea-N was 11.42 on zero day and it drops to 1.89 ppm day after application with regard to the control plot. For T_6, the urea-N value dropped from 11.36 to 2.05 ppm. On the other

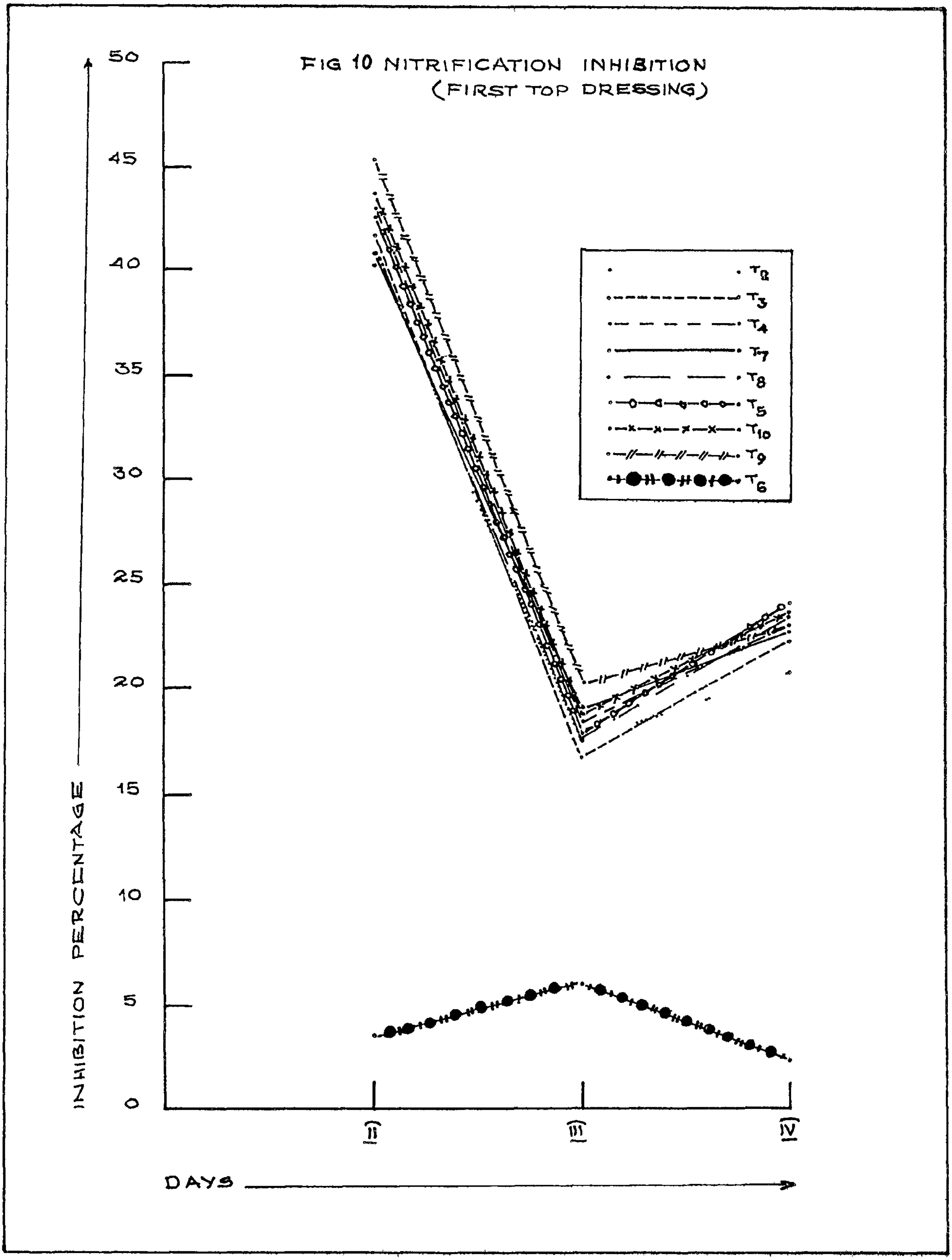


FIG 10 NITRIFICATION INHIBITION
(FIRST TOP DRESSING)
50
45
40
35
30
25
20
15
10
5
0
INHIBITION PERCENTAGE
T2
T3
T4
T7
T8
T5
T10
T9
T6
II
III
IV
DAYS

Table 12 Urea-N contents (mean values in ppm) in the experimental plots during the second topdressing of fertilizers

Treatments	Day before application	Immediately after application	I	II	III	IV
T_1	0.0002	11.420	1.890	1.32	0.19	0.02
T_2	0.0003	11.391	4.370	3.25	2.00	0.22
T_3	0.0002	11.616	4.356	3.29	1.98	0.33
T_4	0.0002	11.715	4.406	3.30	2.16	0.42
T_5	0.00004	11.696	4.330	3.23	2.15	0.32
T_6	0.0001	11.359	2.050	1.66	0.21	0.01
T_7	0.0002	11.665	4.340	3.28	2.05	0.44
T_8	0.0003	11.724	4.413	3.25	2.06	0.34
T_9	0.0001	11.789	4.493	3.26	2.13	0.41
T_{10}	0.0003	11.760	4.436	3.27	2.10	0.32

hand, it was observed that in the UDMU treated plots, the fall in urea-N was not so rapid.

For T_2, the urea-N dropped from 11.59 on zero day to 4.37 on day after manuring. With regard to T_4, it was from 11.72 to 4.41. Urea-N contents were 11.79 on zero day and 4.49 on 1st day with respect to T_9. For T_{10}, the respective values were 11.76 and 4.44.

The drop in urea-N was 89 percent for the control plot in the second day compared to zero day. Corresponding reduction for T_6 was 85.5 percent.

The reduction in urea-N in the second day for T_2 was 62.3 percent. The corresponding values for treatments T_4, T_5, T_8, T_9 and T_{10} were 62.4, 62.99, 62.4, 61.8 and 62.2 respectively.

It was observed that ureolysis was practically over on 4th day after fertilizer application in the control plot. More or less a similar trend was observed for T_6 also. In contrast to the above result, residual urea-N was recorded in plots treated with UDMU on the 4th day of manuring. Split plot ANOVA Table for urea-N contents during the said period is given in Appendix I b. From the table it was observed that treatments T_9, T_4, T_{10},

T_7, T_8, T_5 and T_3 were statistically on par. It was also observed that the treatments T_6 and T_1 were not effective in urease inhibition.

Fig. 11 furnishes the graphical representation of the data on urea-N content after second topdressing.

4.4.2 Ammonia Nitrogen

The mean values of NH_4^+-N in the soil samples for the various treatments were tabulated (Table).

On appraisal of the data it was observed that for T_1, the NH_4^+-N values were 0.007, 0.15, 6.63, 2.64, 2.53 and 1.92 respectively for the day before application of fertilizers, zero day, 1st, 2nd, 3rd and 4th days of manuring, the respective values for T_6 were 0.003, 0.99, 6.57, 2.47, 3.2 and 2.41.

The corresponding values of NH_4^+-N recorded as above for T_2 were 0.001, 0.12, 4.85, 5.94, 4.79 and 4.83 respectively. The respective values for T_4 were 0.006, 0.11, 4.76, 6.11, 4.74 and 4.75.

With respect to T_7, the NH_4^+-N values obtained during the said period were 0.006, 0.14, 4.76, 5.88, 4.7 and 4.64 respectively. The respective values recorded

FIG 11 Urea - N (SECOND TOP DRESSING)

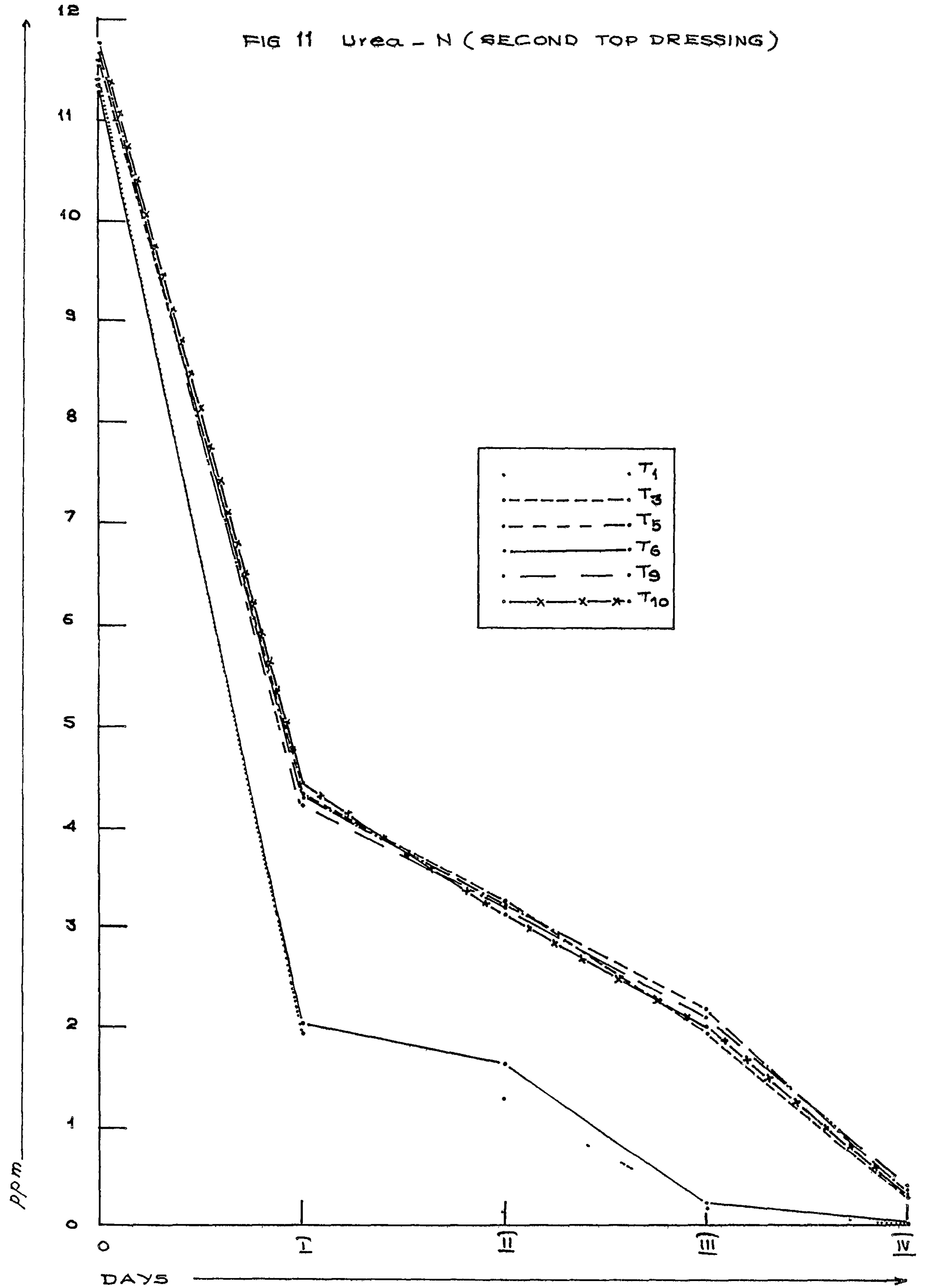


Table 13 NH_4^+-N contents (mean values in ppm) in the experimental plots during the second topdressing of fertilizers

Treatments	Day before application	Immediately after application	1	2	3	4
T_1	0.002	0.15	6.63	2.64	2.53	1.92
T_2	0.001	0.12	4.85	5.94	4.79	4.83
T_3	0.006	0.12	4.77	6.01	4.75	4.66
T_4	0.006	0.11	4.76	6.11	4.74	4.75
T_5	0.006	0.13	4.77	5.85	4.71	4.64
T_6	0.003	0.99	6.57	2.47	3.19	2.41
T_7	0.006	0.14	4.76	5.88	4.70	4.64
T_8	0.004	0.46	4.70	5.86	4.63	4.55
T_9	0.002	0.15	4.76	6.03	4.66	4.79
T_{10}	0.002	0.15	4.63	5.99	4.56	4.67

for T_9 were 0.002, 0.15, 4.76, 6.03, 4.66 and 4.79.

With regard to the control plot, the maximum value of NH_4^+-N was reached on the first day of manuring and it was reduced to 2.64 ppm on 2nd day. A similar reduction in NH_4^+-N contents was also recorded for T_6. On the contrary, it was observed that the maximum value of NH_4^+-N was reached only on the second day for the plots treated with UDMU and thereafter, the values were found decreasing at a very slow rate. A prolonged retention of NH_4^+-N was noticed in the UDMU treated plots.

Split plot ANOVA Tables for the NH_4^+-N contents during the said period is given in Appendix I b. From the table it was observed that the treatments T_2, T_4, T_9, T_3 and T_7 were statistically on par. T_1 was having the lowest performance.

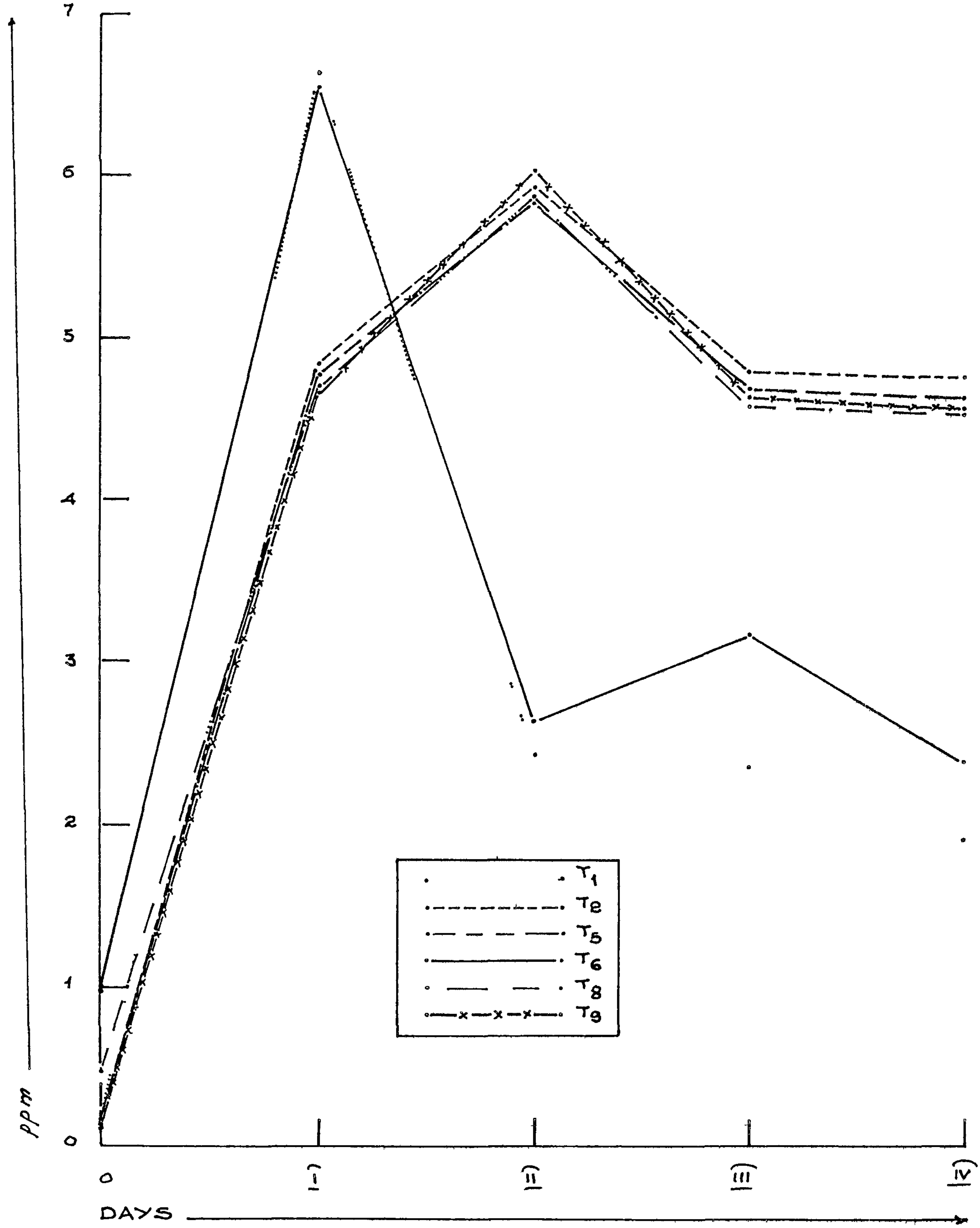
The data on NH_4^+-N contents after second topdressing are graphically represented (Fig. 12).

4.4.3 Nitrate Nitrogen

The table 14 summarises the data on NO_3^--N in the soil samples during the third application of fertilizers.

The NO_3^--N values were recorded to be in traces

FIG 12 NH_4^+ - N (SECOND TOP DRESSING)



for the day before application of fertilizers.

The values of NO_3^--N obtained for the control plot were 4.20, 7.52, 4.28 and 2.23 during 1st, 2nd, 3rd and 4th days of manuring. The corresponding values for T_6 were 3.36, 6.85, 4.96 and 2.94 respectively.

With regard to the control plot, the maximum value (7.52) was recorded on 2nd day of manuring and thereafter they were found decreasing at a rapid rate. Similarly the highest value of 6.85 was obtained for T_6 on the 2nd day, followed by a rapid reduction.

In contrast to the above observation, maximum values of NO_3^--N were obtained on the third day of fertilizer application, for the plots treated with UDMU, followed by a slow rate of reduction in NO_3^--N contents. Split plot ANOVA Table for the NO_3^--N contents is presented in Appendix I b. From the table, it was observed that T_9 was superior to all other treatments, followed by T_4. It was seen that the treatments T_7 and T_3 were statistically on par. T_6 was much inferior to plots treated with UDMU. T_1 showed the least performance.

Fig. 13 gives the graphical representation of the data on NO_3^--N content after second topdressing.

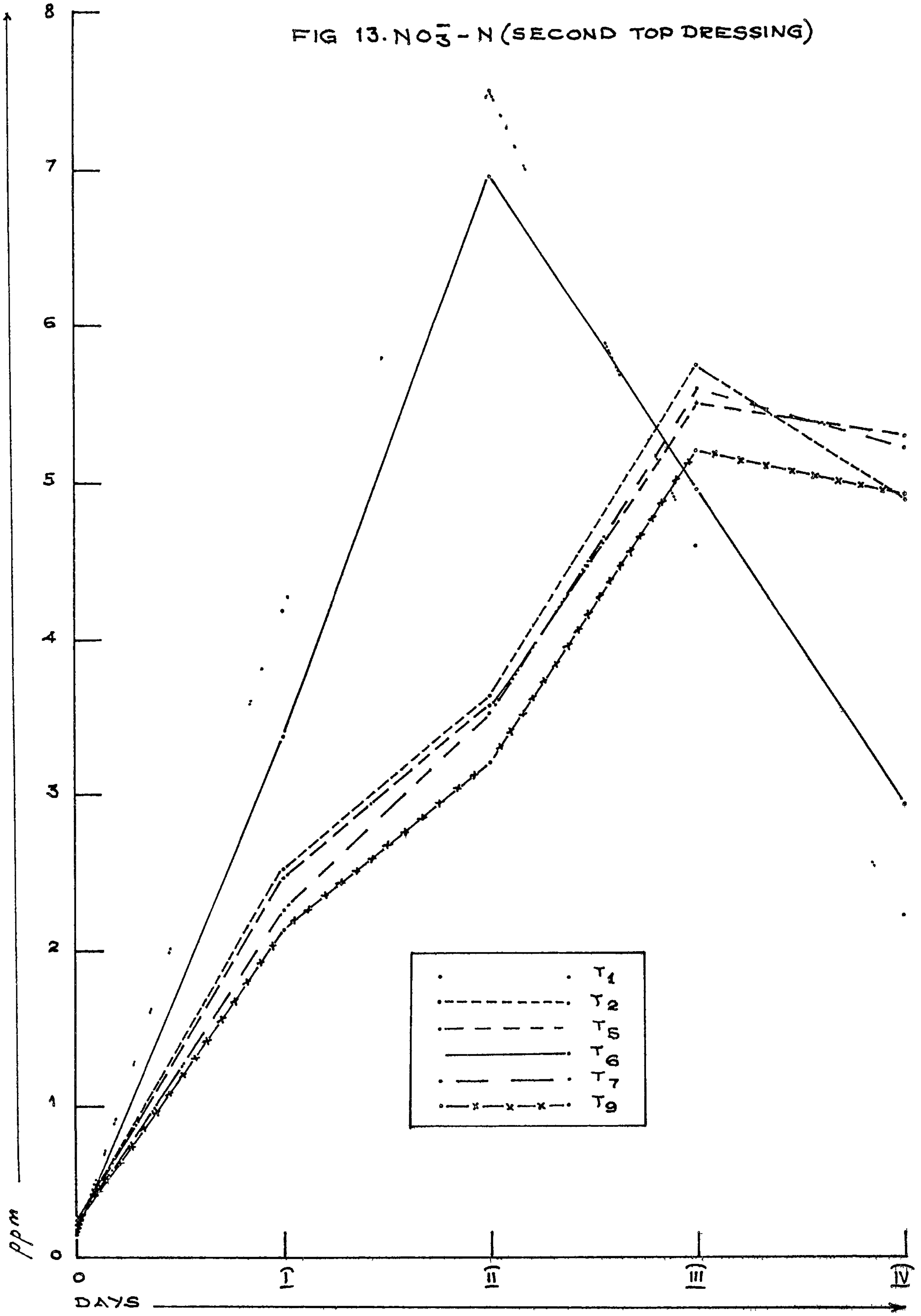


FIG 13. NO_3^- - N (SECOND TOP DRESSING)
ppm
8
7
6
5
4
3
2
1
0
DAYS
0
I
II
III
IV
T_1
T_2
T_5
T_6
T_7
T_9

Table 14 NO_3^--N contents (mean values in ppm) of the experimental plots during the second topdressing of fertilizers

Treatments	Before application	Immediately after application	I	II	III	IV
T_1	0.020	0.19	4.20	7.52	4.28	2.25
T_2	0.009	0.22	2.52	3.58	5.69	4.85
T_3	0.008	0.22	2.39	3.58	5.56	5.14
T_4	0.010	0.25	2.18	3.26	5.31	5.09
T_5	0.008	0.25	2.40	3.56	5.31	5.28
T_6	0.006	0.14	3.36	6.85	4.96	2.94
T_7	0.008	0.22	2.26	3.52	5.63	5.24
T_8	0.007	0.25	2.41	3.53	5.64	5.33
T_9	0.112	0.26	2.14	3.22	5.21	4.95
T_{10}	0.011	0.26	2.14	3.22	5.21	4.95

4.4.4 Nitrite Nitrogen

Table 15 presents the mean values of nitrite-N in the various treatments.

The nitrite-N contents recorded were comparatively low in all the experimental plots.

Split plot ANOVA Table for the nitrite-N contents is presented in Appendix I b.

It was seen that the treatments T_9, T_8, T_{10}, T_3, T_7, T_4 and T_2 were statistically on par. T_6 and T_1 were observed to be the least effective treatments.

4.4.5 Rate of nitrification and percentage inhibition

The rate of nitrification (%) in the soil under different treatments and the percentage inhibition of nitrification imparted by the treatment combinations were tabulated (Table 16).

It was recorded that nitrification rate was the highest for the control plot (T_1). This was followed by T_6. With respect to the plots treated with UDMU much smaller rates of nitrification were recorded.

The percentage nitrification obtained with regard

Table 15 NO_2^--N contents (mean values in ppm) in the experimental plots during the second topdressing of fertilizers

Treatments	Day before application	Immediately after application	1	2	3	4
T_1	0.002	0.13	0.06	0.36	0.72	0.84
T_2	0.002	0.12	0.03	0.30	0.64	0.53
T_3	0.001	0.11	0.03	0.27	0.58	0.49
T_4	0.001	0.11	0.04	0.28	0.58	0.56
T_5	0.001	0.122	0.04	0.34	0.62	0.57
T_6	0.001	0.101	0.05	0.37	0.82	0.77
T_7	0.001	0.107	0.04	0.33	0.56	0.54
T_8	0.001	0.117	0.04	0.33	0.51	0.45
T_9	0.001	0.122	0.03	0.28	0.54	0.45
T_{10}	0.001	0.121	0.03	0.31	0.53	0.49

to T_1 on 2nd, 3rd and 4th days of manuring were 74.92, 66.43 and 61.54 respectively. Corresponding values for T_6 were 74.51, 64.38 and 60.78 respectively. Respective values with regard to T_2 were 38.61, 56.52 and 52.71. For T_4 the above values were 36.7, 55.45 and 53.31 respectively. Similarly for T_8 the nitrification percentages recorded were 39.67, 57.04 and 55.94 respectively. With respect to T_9 the corresponding values were 36.72, 55.27 and 53.02 respectively.

The percentage inhibition was found to be decreasing with advancement of nitrification. The inhibition percentages obtained for T_2 on 2nd, 3rd and 4th day of manuring were 48.48, 14.92 and 14.35 respectively and for T_3, the respective values were 47.85, 15.13 and 11.02. With respect to T_5 the above values were 46.6, 14.86 and 9.41 respectively.

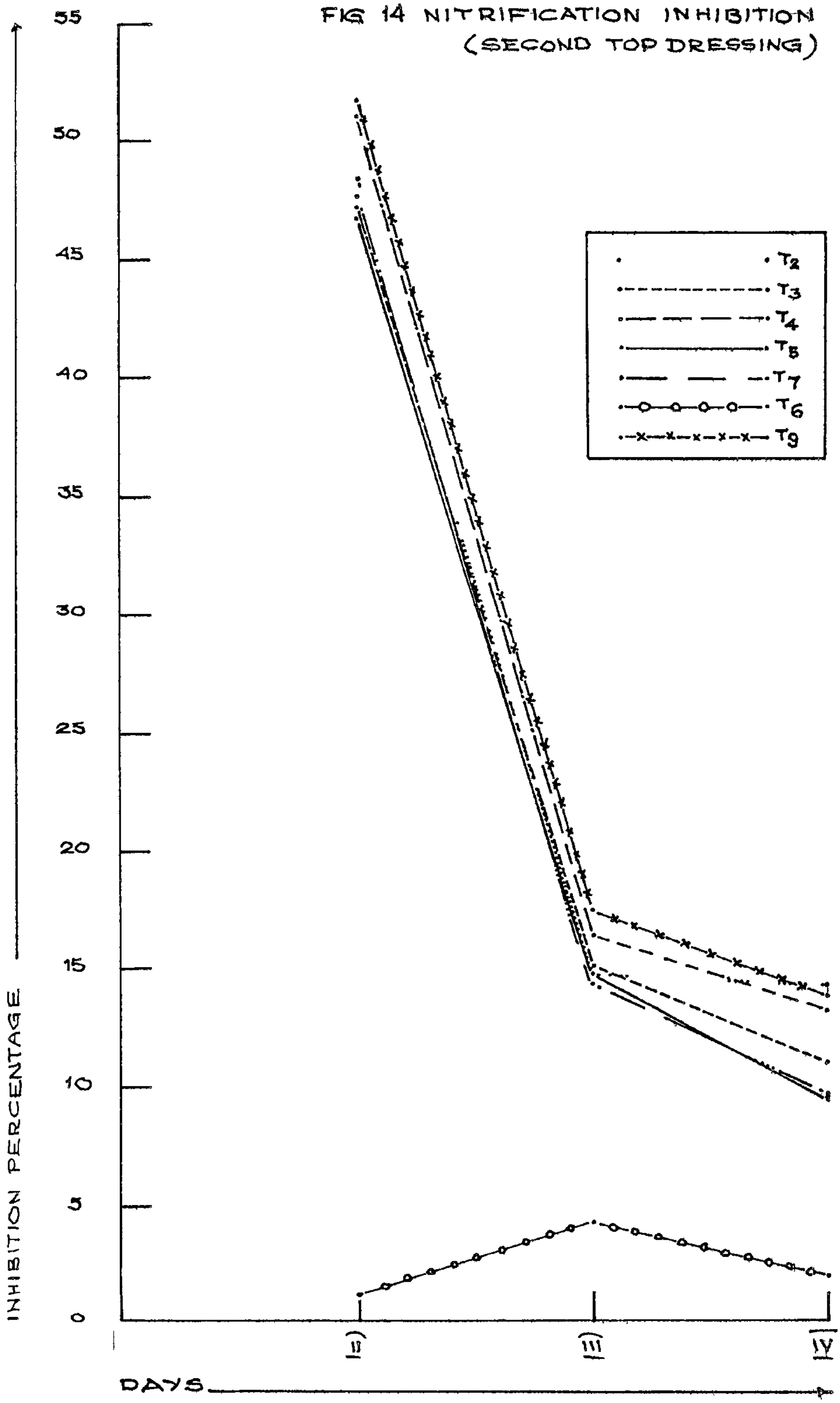
The inhibition percentage values recorded for T_7 during the above period were 47.16, 14.44 and 9.93 respectively. With respect to T_9, the corresponding values were 50.99, 16.8 and 13.84 respectively and for T_{10} the respective values were 48.77, 14.07 and 10.45.

Fig. 14 furnishes the graphical representation of

Table 16 Percentage Nitrification and Inhibition

Treatments	2nd day		3rd day		4th day	
	Nitrification	Inhibition	Nitrification	Inhibition	Nitrification	Inhibition
T_1	74.92	-	66.43	-	61.54	-
T_2	38.61	48.48	56.52	14.92	52.71	14.35
T_3	39.07	47.85	56.38	15.13	54.76	11.02
T_4	36.70	51.01	55.45	16.53	53.31	13.37
T_5	40.01	46.6	56.56	14.86	55.75	9.41
T_6	74.51	0.55	64.38	3.09	60.78	1.56
T_7	39.59	47.16	56.84	14.44	55.43	9.93
T_8	39.67	47.06	57.04	14.44	55.94	9.10
T_9	36.72	50.99	55.27	16.80	53.02	13.84
T_{10}	38.38	48.77	57.08	14.07	55.11	10.45

FIG 14 NITRIFICATION INHIBITION
(SECOND TOP DRESSING)



the data on the inhibition percentage after second top-dressing.

4.5 Biometric Observations

The biometric observations made on the rice crop at the various growth stages and uptake of nitrogen were statistically analysed and the results are given hereunder.

A. Growth Characters

I. Height of plants

The height measurements recorded at active tillering and panicle initiation stages and at harvest are presented in Table 17 and the abstract of analysis of variance in Appendix II.

I a. Active tillering stage

I was observed that there was statistically significant differences in plant height among the various treatments. UDMU treated plots were found to be superior to other plots. However, all the plots treated with UDMU were found to be statistically on par. T_6 was noted as inferior to UDMU applied treatments. T_1 showed the lowest performance.

Table 17 Height of plant (in cm) (mean values)

Treatments	Active Tillering stage	Panicle initiation stage	Harvest
T_1	37.16	51.80	85.30
T_2	40.47	58.73	99.50
T_3	39.13	58.50	99.50
T_4	40.57	59.73	102.77
T_5	40.03	59.43	99.90
T_6	38.43	55.57	89.70
T_7	39.93	61.33	99.60
T_8	40.63	59.49	100.93
T_9	40.83	62.40	103.70
T_{10}	40.20	60.83	100.57

I b. Panicle initiation stage

The data revealed that with respect to plant-height, T_9 was statistically on par with T_7 and T_{10}. It was observed that T_7, T_{10} and T_4 were on par. Besides, it was also seen that T_4, T_8, T_5, T_2 and T_3 were statistically on par. T_6 was seen inferior to T_3. T_1 showed the lowest plant height.

I c. Harvest stage

It was observed that plots treated with UDMU were superior to T_6 and T_1 with respect to plant height. However, it was seen that the UDMU treated plots were statistically on par in this regard. T_6 was found inferior to T_2. T_1 showed the least plant height.

II. Number of tillers per square metre at panicle initiation stage

The data on mean values of number of tillers per square metre at panicle initiation stage are presented in Table 18 and the analysis of variance in Appendix III.

It was found that T_9 and T_4 were statistically on par and superior to all other treatments. T_{10}, T_5 and T_7 were also observed to be on par and comes after T_4 in

Table 18 Number of Tillers per square metre

Treatments	R_1	R_2	R_3	Mean
T_1	379	356	368	367.7
T_2	410	401	415	408.7
T_3	402	397	405	401.3
T_4	425	429	438	430.7
T_5	428	414	432	424.7
T_6	388	382	385	385.0
T_7	419	421	425	421.6
T_8	405	411	422	412.6
T_9	440	432	428	433.3
T_{10}	420	429	427	425.3

performance. T_6 was inferior to T_2. T_1 showed the lowest number of tillers.

B. Yield Attributes

1. Number of earheads per square metre

The mean values are presented in Table 19 and the analysis of variance in Appendix IV. With regard to this parameter, T_9 was the superior treatment. T_4 and T_{10} were found to be statistically on par. Besides, T_2 and T_3 were on par. T_6 was inferior to T_3. T_1 was having the least performance.

2. Thousand grain weight

The data on thousand grain weight are presented in Table 20 and the analysis of variance in Appendix V.

Application of UDMU was found to increase the thousand grain weight. The lowest value was recorded for the control plot with urea alone. T_6 (urea and neem-cake) was better than T_1. T_1 was found to be statistically inferior to all other treatments. It was seen that treatments T_9, T_7, T_8, T_{10}, T_4, T_3 and T_5 were statistically on par with regard to thousand grain weight. In addition, it was also seen that T_2 and T_6 were on par.

Table 19 Number of earheads per square metre

Treatments	R_1	R_2	R_3	Mean
T_1	214	195	203	204.0
T_2	240	236	245	240.3
T_3	240	232	236	236.0
T_4	275	258	262	265.0
T_5	260	252	253	255.0
T_6	204	218	220	214.0
T_7	258	244	242	248.0
T_8	245	249	240	244.7
T_9	275	269	270	271.3
T_{10}	270	264	254	262.7

Table 20 Thousand grain weight (g)

Treatments	R_1	R_2	R_3	Mean
T_1	24.7	25.0	24.9	24.9
T_2	25.7	25.3	26.2	25.7
T_3	25.9	26.6	26.1	26.2
T_4	26.4	26.8	25.8	26.3
T_5	25.4	26.7	25.9	26.0
T_6	24.8	25.1	25.2	25.0
T_7	26.2	26.4	26.7	26.4
T_8	25.6	27.2	26.4	26.4
T_9	26.1	26.9	27.0	26.7
T_{10}	26.9	26.5	25.8	26.4

3. Grain Yield

The values for the yield of grain are given in Table 21 and the analysis of variance in Appendix VI.

It was observed that the effect of UDMU was significant in increasing grain yields of rice. The maximum grain yield was obtained for T_9. It was observed that the treatments T_9, T_4, T_{10} and T_5 were statistically on par. Besides, the treatments T_5, T_7 and T_8 were on par. T_6 was inferior to UDMU applied treatments. The lowest grain yield was obtained for the control plot (T_1).

Graphic representation of the grain yield obtained for the various treatments is given in Fig. 15.

4. Yield of Straw

The values are presented in Table 22 and the analysis of variance in Appendix VII.

Application of UDMU was found to be having significant effect in increasing straw yields. T_9 was found to be statistically on par with T_4, T_7, T_8, T_5 and T_{10}. Besides, the treatments T_7, T_8, T_5, T_{10}, T_2 and T_3 were found to be on par. T_6 and T_1 were the inferior treatments recorded in this connection and T_6 and T_1 were statistically on par.

Table 21 Grain Yield (kg ha^{-1})

Treatments	R_1	R_2	R_3	Mean
T_1	2469.1	2292.8	2557.4	2439.8
T_2	3362.8	3186.4	3127.5	3225.6
T_3	3318.7	2965.9	3054.2	3112.9
T_4	3450.9	3398.1	3386.4	3411.8
T_5	3362.8	3350.2	3295.6	3336.2
T_6	2557.5	2580.6	2733.7	2623.9
T_7	3380.4	3186.5	3310.4	3292.4
T_8	3292.2	3318.7	3215.5	3275.5
T_9	3468.6	3406.9	3539.2	3471.6
T_{10}	3445.9	3410.7	3299.4	3385.3

Table 22 Straw Yield (kg ha^{-1})

Treatments	R_1	R_2	R_3	Mean
T_1	3858.6	3680.5	3995.8	3845.0
T_2	5098.1	4822.6	4716.4	4879.0
T_3	5030.4	4750.1	4615.8	4798.8
T_4	5235.9	5154.2	4910.1	5100.0
T_5	5098.3	4925.4	4987.8	5003.8
T_6	3995.8	3858.6	4171.6	4008.7
T_7	5125.6	4922.1	5029.2	5025.6
T_8	4987.8	5035.6	5014.4	5012.6
T_9	5254.9	5167.5	4919.2	5113.9
T_{10}	5035.5	5120.2	4818.6	4991.4

FIG 16 STRAW YIELD (kg ha^{-1})

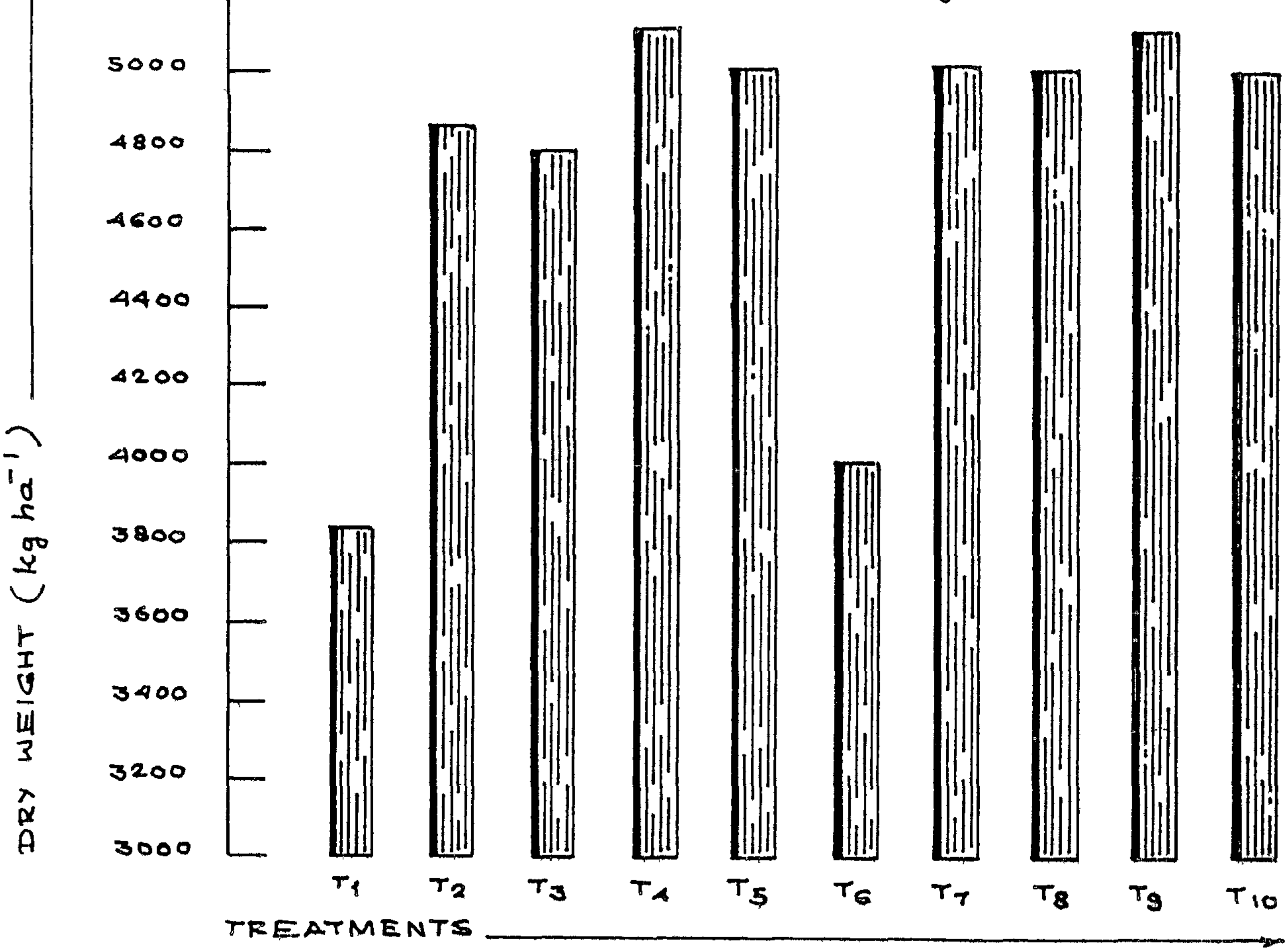


FIG 15 GRAIN YIELD (kg ha^{-1})

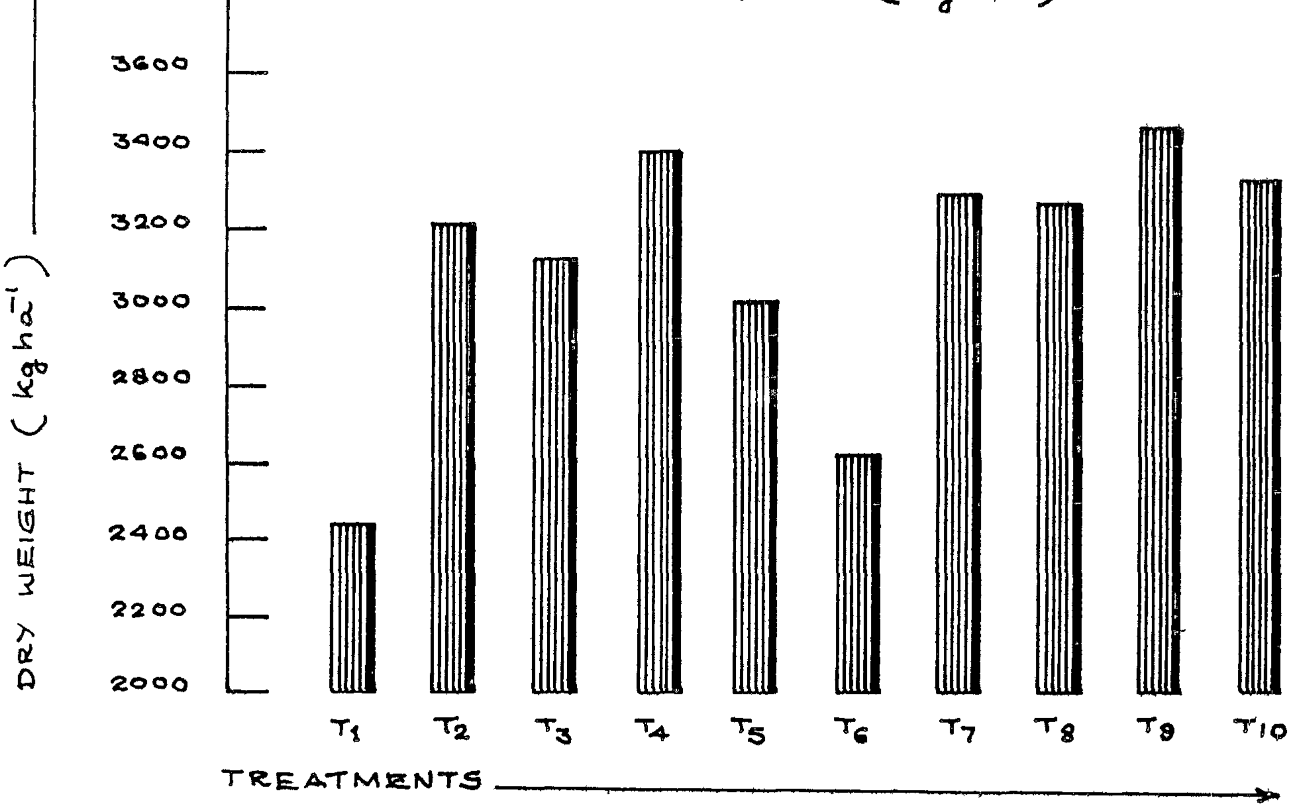


Fig. 16 furnishes the graphic representation of the straw yield obtained for the various treatments.

4.6 Nitrogen concentration in plant parts at various growth stages

Nitrogen content of different plant parts, viz., leaf blade, roots, flower, straw and grain at different growth stages of the crop were determined.

4.6.1 At 35th day after transplanting

Table 23 furnishes the mean values of nitrogen content in percentage in different plant parts. The abstract of analysis of variance is given in Appendix VIII.

4.6.1.1 Leaf blade

The application of UDMU was found to be significantly influencing the lamina-nitrogen content.

It was observed that the treatments T_4, T_9, T_7, T_3, T_{10}, T_2 and T_8 were statistically on par. T_6 and T_1 showed the most inferior performance. T_6 and T_1 were found to be on par.

4.6.1.2 Roots

It was found that the treatments T_9, T_7, T_4, T_2,

Table 23 N content (%) at 35 days of transplanting (mean values)

Treatments	Leaf blade	Roots
T_1	2.02	0.62
T_2	2.58	0.79
T_3	2.60	0.76
T_4	2.74	0.84
T_5	2.37	0.73
T_6	2.09	0.65
T_7	2.62	0.84
T_8	2.50	0.77
T_9	2.71	0.85
T_{10}	2.59	0.76

T_8, T_3, T_{10} and T_5 were statistically on par. T_1 showed the lowest performance in this regard.

4.6.2 At Flowering Stage

Table 24 contains the mean values of treatments applied with UDMU were statistically on par. T_6 and T_1 were the inferior treatments and were found to be on par.

4.6.3 Harvest stage

The data on the nitrogen content (%) in the leaf blade, roots and grains are presented in Table 25.

4.6.3.1 Leaf blade

It was found that the treatments T_9, T_7, T_4 and T_8 were statistically on par. Besides, T_4, T_8, T_3 and T_5 were on par. T_6 and T_1 were the inferior treatments in this connection.

4.6.3.2 Roots

It was observed that the treatments T_9, T_7, T_2, T_8, T_4, T_{10} and T_5 were statistically on par. T_1 was the most inferior treatment.

4.6.3.3 Grains

It was observed that there was statistically

Table 24 Nitrogen concentration in percentages at flowering stage (mean values)

Treatments	Leaf blade	Roots	Flowers
T_1	0.95	0.41	0.24
T_2	1.55	0.72	0.40
T_3	1.38	0.61	0.34
T_4	1.82	0.73	0.38
T_5	1.57	0.68	0.33
T_6	1.23	0.45	0.27
T_7	1.70	0.67	0.39
T_8	1.69	0.58	0.33
T_9	1.83	0.70	0.37
T_{10}	1.73	0.66	0.34

Table 25 Nitrogen concentration (in percentages) at harvest stage (mean values)

Treatments	Leaf blade	Roots	Grains
T_1	0.58	0.23	1.12
T_2	0.74	0.35	1.42
T_3	0.67	0.30	1.37
T_4	0.74	0.35	1.45
T_5	0.66	0.33	1.38
T_6	0.61	0.27	1.28
T_7	0.77	0.37	1.46
T_8	0.74	0.35	1.41
T_9	0.78	0.40	1.40
T_{10}	0.68	0.33	1.42

significant differences between UDMU treated plots and those not treated with UDMU with respect to nitrogen concentration in grains.

It was found that the treatments T_7, T_4, T_2, T_{10}, T_8, T_9, T_5 and T_3 were statistically on par. T_6 was inferior to treatments applied with UDMU. T_1 was having the lowest percentage of nitrogen in grains.

Protein content (in percentage) in grains

The data on protein content in grain are given in Table 26 and the analysis of variance in Appendix IX.

The grains were analysed for total nitrogen. It was observed that T_7 and T_4 were superior to other treatments and were statistically on par. Besides, T_9, T_2, T_8, T_{10}, T_5 and T_3 were on par. T_6 was inferior to treatments applied with UDMU. T_1 showed the lowest value for grain protein content.

4.7 Nitrogen uptake by plant at various growth stages

Fig. 17 furnishes the graphic representation of the data on N uptake of rice at the various growth stages.

a. At 35 days after transplanting

The data on nitrogen uptake at 35 days after

Table 26 Percentage protein content of grains at harvest stage

Treatments	R_1	R_2	R_3	Mean
T_1	6.75	6.98	7.33	7.02
T_2	8.88	8.68	9.13	8.90
T_3	8.25	8.50	8.94	8.56
T_4	9.56	8.89	8.82	9.10
T_5	8.12	9.07	8.73	8.64
T_6	7.91	8.15	7.89	7.98
T_7	9.10	9.31	8.98	9.13
T_8	8.82	9.12	8.47	8.80
T_9	9.05	8.73	9.12	8.97
T_{10}	8.64	8.87	8.70	8.74

Table 27 N uptake of rice at 35 days after transplanting (kg ha^{-1})

Treatments	R_1	R_2	R_3	Mean
T_1	36.55	38.70	39.77	38.34
T_2	52.03	49.02	48.16	49.74
T_3	45.15	47.08	52.67	48.30
T_4	55.68	52.24	54.18	54.03
T_5	49.45	51.17	45.58	48.73
T_6	43.00	40.85	41.06	41.64
T_7	52.67	55.04	52.89	53.53
T_8	49.88	46.22	51.38	49.16
T_9	53.75	51.38	55.90	53.68
T_{10}	51.60	46.44	49.02	49.02

Table 28   N uptake of rice at flowering stage (kg ha^{-1})

Treatments	R_1	R_2	R_3	Mean
T_1	60.20	61.27	59.34	60.27
T_2	75.25	72.45	80.62	76.11
T_3	71.81	69.87	75.23	72.30
T_4	80.41	74.82	78.47	77.90
T_5	67.51	75.25	70.95	71.24
T_6	62.35	64.70	63.42	63.50
T_7	79.12	73.10	75.03	75.75
T_8	77.18	76.12	76.98	76.77
T_9	75.89	79.98	78.69	78.19
T_{10}	70.52	77.83	69.66	72.67

transplanting are given in Table 27 and the abstract of analysis of variance in Appendix X.

The application of UDMU significantly influenced the nitrogen uptake at 35 days after transplanting.

It was seen that T_4, T_9 and T_7 were statistically on par. In addition, the treatments T_2, T_8, T_{10}, T_5 and T_3 were statistically on par. T_6 was inferior to all treatments applied with UDMU. T_6 and T_1 were found to be on par.

b. Flowering stage

The values on nitrogen uptake at flowering stage are given in Table 28 and the analysis of variance in Appendix X.

It was observed that the treatments T_9, T_4, T_8, T_2 and T_7 were on par. In addition, the treatments T_2, T_7, T_{10}, T_3 and T_5 were statistically on par. T_6 and T_1 were also on par and found to be having the lowest N uptake.

c. At harvest stage

The data on nitrogen uptake are presented in Table 29 and the analysis of variance in Appendix X.

Table 29 N uptake of rice at harvest (kg ha^{-1})

Treatments	R_1	R_2	R_3	Mean
T_1	85.10	90.51	94.60	90.37
T_2	109.65	102.83	103.48	105.32
T_3	107.50	110.72	102.44	106.89
T_4	113.95	118.13	112.54	114.88
T_5	105.75	112.66	105.56	107.99
T_6	88.15	99.33	98.04	95.17
T_7	101.05	122.98	110.08	111.37
T_8	116.10	109.43	113.30	112.95
T_9	118.25	117.60	116.99	117.61
T_{10}	111.80	107.07	105.02	107.96

FIG 17 NITROGEN UPTAKE OF RICE (kg ha⁻¹)

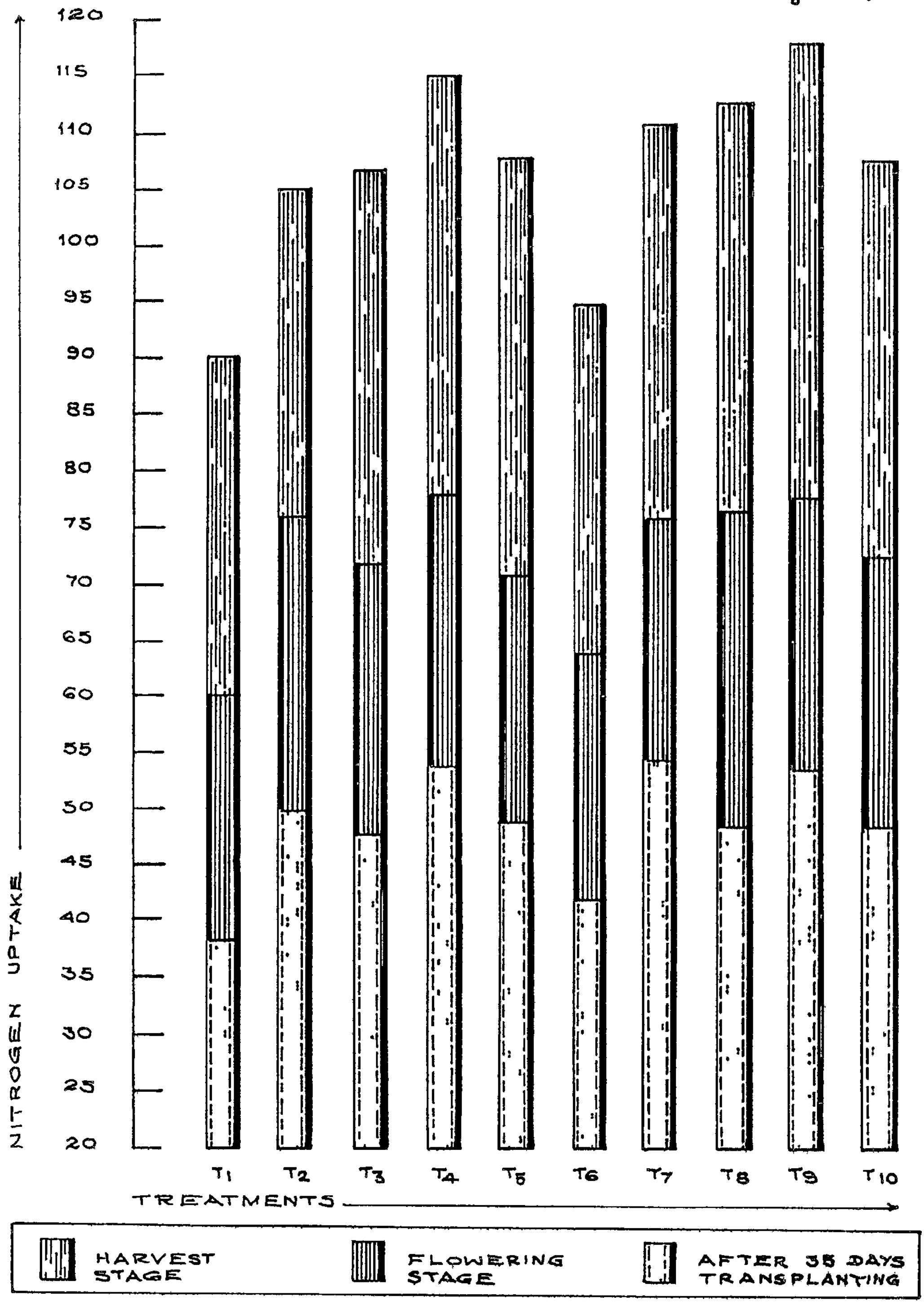


Table 30 Values of Simple Correlation Coefficient

Sl. No.	Characters correlated	Correlation coefficient
1.	N uptake of rice at harvest (kg/ha) and grain yield	0.8158*
2.	Protein content (%) of grains at harvest and grain yield	0.8355*
3.	Ammonia (NH_4^+-N) nitrogen content at 3rd day of fertilizer application and grain yield	0.9331*
4.	Ammonia (NH_4^+-N) nitrogen content at 4th day of fertilizer application and grain yield	0.9392*
5.	Ammonia-nitrogen content at 5th day of fertilizer application and grain yield	0.9320*

* Significant at 0.05 level

It was observed that the treatments T_9, T_4, T_8, T_7, T_5 and T_{10} were statistically on par. T_6 was inferior to all treatments applied with UDMU. T_6 was found to be on par with T_1 with respect to the nitrogen uptake at this harvest stage.

4.8 Correlation studies

The values of simple correlation coefficients are presented in Table 30.

N uptake of rice at harvest was correlated with grain yield. Grain yield was also correlated with protein content (%) of grains and with NH_4^+-N content respectively at 3rd day, 4th day and 5th day after application of fertilizers.

In these studies it was found that the correlation of the grain yield with N uptake of rice at harvest and protein content (%) of grains are highly significant and positive. It was also observed that there was highly significant and positive correlations of grain yield with ammonia form of nitrogen at 3rd, 4th and 5th days after application of fertilizers.

Discussion

DISCUSSION

The results of the field experiment to study the possibilities of using unsymmetrical Dimethyl Urea and neemcake as urease/nitrification inhibitors with the fertilizer urea for increasing the N-use efficiency in wetland rice soils are discussed below.

5.1 Inhibition of urease activity

Urea-N values recorded from the soil samples during the three split applications of fertilizers throw light on the extent of urease inhibition in the various treatments.

On appraisal of the data it is observed that with respect to the control plot there is a rapid rate of urea hydrolysis. The decrease in urea-N contents (expressed in percentages) obtained for control (T_1) after one, two, three and four days of basal application of fertilizers are 79, 90, 96.5 and 99.8 respectively.

T_6 (urea and neemcake) followed a ureolysis pattern much similar to T_1, indicating the lesser influence of neemcake on urea hydrolysis. The values obtained for urea hydrolysis (expressed in percentages) with respect to T_6

are 78, 86, 96 and 99.7 respectively.

T_9 (urea + UDMU (1/5th of urea) + neemcake) is found to be superior to all other treatments with regard to urease-inhibition. The drop in urea-N content (percentages) with regard to T_9 are 48.5, 73, 83.2 and 96.2 respectively after one, two, three and four days. The superior performance of this treatment may be due to the cumulative effect of higher dose of UDMU and neemcake. The above values of reduction in urea-N respectively for T_7 are 55.9, 73.9, 84 and 96.7. T_7 is seen less efficient than T_9. This is perhaps due to the lower dose of UDMU in T_7.

T_{10} (urea + UDMU coated (1/5th of urea) + neemcake) is found to be less efficient than T_9. This indicates that coating of urea with UDMU is not as effective as mixing it with urea.

The amount of urea-N being hydrolysed with respect to T_4 are 51, 74, 83.8 and 96.3. T_4 (urea + UDMU (1/5th of urea) is found to be on par with T_{10}. This is supported by the result that T_7 and T_3 are statistically on par during second topdressing. It is observed that neemcake is not effective as a urease inhibitor.

In general, comparatively faster rate of decline in urea-N content is observed in the plots not treated with UDMU and urea hydrolysis is seen at a slower rate in plots treated with UDMU. This indicates the differential inhibition on urease activity brought about by different levels of UDMU.

The urea-N values recorded in the various treatments showed that there is a relatively faster rate of urea hydrolysis during the first two days after application of fertilizers. Similar observation was made by Thomas and Prasad (1982).

It is observed that for all treatments, in general, more than 90 percent of the urea applied is hydrolysed within four days after application of fertilizers. The quicker disappearance of urea-N under waterlogged condition is due to its more rapid hydrolysis, under the high moisture regime (Sannigrahi and Mandal, 1987). In flooded rice soils urease activity is known to be higher than in upland rice soils (Baruah and Mishra, 1984).

5.2 Ammonification rate as influenced by application of UDMU and neemcake

The data on NH_4^+-N in the soil during the three split applications of fertilizers give a clear picture of the influence of UDMU and neemcake as urease/nitrification inhibitors on the different processes involved in the transformation of applied urea in soil.

In the initial periods after application of urea, both ammonification and nitrification are operative side by side. The first process leads to the generation of ammonium and the other to its utilization to form nitrate.

Urease inhibition will result in a slow rate of ammonification. The fertilizer urea undergoes hydrolysis only at a low rate due to the application of an urease inhibitor. This will lead to release of ammonia nitrogen in small amounts over a prolonged period. The data on urea-N values recorded for the UDMU applied plots indicates that UDMU is having the ability to act as a urease inhibitor.

In addition to the above observation, it is also seen that UDMU is able to act as a nitrification inhibitor. Inhibition will result in a slow rate of formation of NO_3^--N. Hence the NH_4^+-N content will decline only at a slow rate in the UDMU treated plots.

The ability of UDMU to act as urease as well as nitrification inhibitors will lead to retention of NH_4^+-N in high concentrations over a longer period in plots treated with UDMU.

The control plot (T_1) showed a rapid rise in NH_4^+-N on the day after fertilizer application itself, followed by a sudden fall during 2, 3 and 4 days after. The respective values in ppm are 7.3, 2.9, 2.0 and 1.9.

The corresponding values in ppm for T_6 are 7.2, 3.0, 3.6 and 2.6 respectively.

T_9 is observed as superior with regard to retention of NH_4^+-N. For T_9, the maximum value was recorded on the second day of manuring and thereafter NH_4^+-N content is found decreasing at a slow rate. The NH_4^+-N values recorded for T_9 during 1st, 2nd, 3rd and 4th days are 5.3, 7.04, 5.6 and 5.3 respectively. The high availability of NH_4^+-N in T_9 may be due to the cumulative effect of higher dose of UDMU and neemcake. The data on urea-N, NH_4^+-N, NO_2^--N and NO_3^--N indicates that UDMU is effective as a urease as well as a nitrification inhibitor.

T_{10} is seen to be less efficient than T_9, indicating that coating of urea with UDMU is not so efficient as mixing it with urea.

Faster rate of fall in NH_4^+-N content and an accompanied faster rate of formation of NO_3^--N is observed for the control plot.

T_6 (urea + neemcake) is seen superior to T_1 (control). This shows that neemcake is possessing nitrification inhibitory properties. High retention of NH_4^+-N using urea blended with neemcake and urea coated with neemcake was reported by Yadav and Shrivastava (1987).

A high retention of NH_4^+-N and a comparatively low rate of nitrification is exhibited by all the plots applied with UDMU, in general. This is due to the differential inhibition on urease activity as well as nitrification rate brought about by UDMU at different levels. With respect to the ability to act as a nitrification inhibitor, neemcake is observed to be less efficient than UDMU.

It is clear that NH_4^+-N is retained in greater concentration for a longer period in plots treated with UDMU and neemcake than the plots with urea alone. This high availability of NH_4^+-N over a longer period of time in soil is highly beneficial to crops, especially rice.

5.3 Inhibition of Nitrification

NO_3^--N values obtained at the three split applications of fertilizers indicated the degree of nitrification inhibition in the various treatments.

With regard to the control plot (T_1), the NO_3^--N value reaches the maximum on the second day and thereafter it decreases at a rapid rate. For T_1, the NO_3^--N values in ppm recorded on 1st, 2nd, 3rd and 4th days are 4.1, 7.7, 4.2 and 3.1 respectively during basal application of fertilizers.

It is seen that the maximum value of NO_3^--N is reached on the third day of manuring for the plots treated with UDMU. Then the NO_3^--N status is found decreasing at a very slow rate. For example, with regard to T_5, the corresponding values in ppm are 2.4, 4.6, 6.1 and 5.6 respectively.

It is observed that T_9 is superior with regard to inhibition of nitrification. For T_9, the NO_3^--N contents (ppm) recorded during the first, second, third and fourth days after basal application of fertilizers are 2, 5, 4.3, 5.98 and 5.34 respectively. The superiority of T_9 may be due to the cumulative effect of higher dose of UDMU and neemcake.

It is observed that T_6 (urea + neemcake) is much inferior in nitrification inhibition compared to those treatments applied with UDMU. This shows that neemcake is less efficient as a nitrification inhibitor than UDMU.

It is inferred that UDMU might be toxic to the nitrifying bacteria and would have inhibited the nitrification process. This is further supported by the data on NH_4^+-N during the three split applications of fertilizers.

Several studies indicated that substituted ureas are possessing nitrification inhibitory properties (Gunasena et al., 1979; Stepanov, 1984; Sahota and Sharma, 1985; Yadvinder Singh and Beauchamp, 1985 and Monreal et al., 1986).

It is observed that T_6 is better in performance then the control (T_1). The data on NH_4^+-N also supports the ability of neemcake to act as a nitrification inhibitor. Higher NH_4^+-N and low NO_3^--N is obtained with application of neemcake with urea. Biddappah and Sarkunam (1979) also reported the presence of higher NH_4^+-N and lower NO_3^--N by the treatment of urea with neemcake, in an incubation study using laterite soil in moist aerobic condition.

Some inhibiting factor present in neemcake might have been toxic to nitrifiers and thus nitrification process might have been slowed down.

It is reported that the low nitrification rate in neemcake blended urea may be due to the presence of active principles, viz., nimbin and nimbidin in the cake (Chakaravarti, 1979).

The low nitrification rate of urea blended with neemcake was reported by Rajkumar and Sekhon (1981), Sathianathan (1982) and Muneshwar Singh and Singh (1986).

With regard to the NO_2^--N, only very small amounts are recorded in the experimental plots. Accumulation of NO_2^--N is not common in soil since there is oxidation of NO_2^--N to NO_3^--N soon after its formation during the nitrification process in which nitrite formation is an intermediate stage.

With respect to the control plot, the NO_2^--N values recorded during first, second, third and fourth days of basal application are 0.16, 0.25, 1.08 and 0.76 respectively. For T_9, the corresponding values in ppm are 0.22, 0.27, 0.43 and 0.68 respectively. With regard to T_4, the respective values (ppm) are 0.22, 0.56, 0.35 and 0.59.

Differences in NO_2^--N content of the soil as influenced by the treatments did not present any consistent pattern to draw a conclusion. Biddappah and Sarkunam (1979) in an incubation study in moist aerobic soil with coaltar and neem coated urea, did not find any treatment influence on NO_2^--N content.

Selective inhibition of neemcake on Nitrosomonas Sp has been observed by Mishra et al. (1975) and Sathianathan (1982).

5.4 The influence of UDMU on the rate of nitrification and percentage inhibition

(a) Rate of Nitrification

Control plot (T_1) maintained a higher nitrification rate for all the three split applications of fertilizers. Percentage nitrification recorded for T_1 during second, third and fourth days are 73.23, 72.39 and 66.87 respectively.

With respect to T_6, percentage nitrification recorded during second, third and fourth days are 72.12, 60.66 and 63.97 respectively.

T_9 (urea + UDMU (1/5th of urea) + neemcake) is found to be superior with respect to inhibition of nitrification. The nitrification percentage for T_9 for 2nd, 3rd and 4th days of manuring are 39.39, 52.74 and 53.36 respectively.

Percentage nitrification is found to be less for plots treated with UDMU and neemcake. It is due to the ability of UDMU to act as a nitrification inhibitor. Neem-cake is also having nitrification inhibitory properties but is observed to be inferior to UDMU.

For T_7, the percentage nitrification values recorded during second, third and fourth days are 42.84, 53.42 and 53.32 respectively. The corresponding values with respect to T_4 are 42.41, 54.06 and 52.64 respectively.

(b) Percentage inhibition

As the rate of nitrification decreases, the percentage inhibition increases.

The percentage inhibition obtained for T_6 during second, third and fourth days are 1.53, 16.2 and 4.34 respectively. On the basis of percentage inhibition T_9 is found superior. The percentage inhibition values obtained for T_9 during second, third and fourth days are 46.21, 27.14 and 20.2 respectively. The corresponding values for T_4 are 42.09, 25.32 and 21.28 respectively. Respective values obtained for T_7 are 41.5, 26.2 and 20.26.

Plots treated with UDMU are found to be superior with regard to inhibition of nitrification. The neemcake is observed to be less efficient in this regard.

5.5 Effect of UDMU and neemcake on the growth and yield characters of rice

I. Plant height

The observations recorded at various stages of plant growth indicated that different levels of UDMU and neemcake had significant influence in increasing the height of plants.

Mean values of plant height (cm) obtained for T_9 at active tillering stage, panicle-initiation stage and harvest stage in cm respectively are 40.8, 62.4 and 103.7. The corresponding values for T_1 are 37.1, 51.8 and 83.3 respectively and for T_6, the values are 38.4, 55.6 and 89.7.

In general, it is seen that application of UDMU is effective in augmenting plant height. The inhibitory property of UDMU might have resulted in a slow mineralisation rate enabling the availability of nitrogen for a prolonged period of time. The nitrogen would have been utilised by the plants for the development of vegetative parts and would have favourably influenced the plant height. This result is in conformity with the findings of Sushama Kumari (1981); Sobhana (1983) and Anon. (1984).

From the results obtained, it is evident that plots treated with neemcake (T_6) are superior, in increasing plant height to the control plots (T_1). Neemcake would have conserved nitrogen to the maximum extent and thus favourably influenced the plant growth to record the maximum plant height. Results obtained by Oommen et al. (1977) and Sathianathan (1982) lend support to this finding.

2. <u>Number of tillers per square metre</u>

Various combinations of UDMU and neemcake showed significant effect on the number of tillers at the panicle initiation stage. Number of tillers per square are observed to be higher in plots treated with UDMU than control plots.

Number of tillers per square metre (mean values) at panicle initiation stage with regard to T_9 is 433.3. The respective values for T_2 and T_7 are 408.6 and 421.6. For T_1 (control) it is 367.7 and with regard to T_6, it is 385.

N uptake recorded at the various stages of growth also revealed that the rice plant has taken more nitrogen in those plots treated with UDMU. Tillering is closely associated with the nutritional condition of the mother plant which supplies nutrients to the tillers upto three leaf stage. The higher intake of nitrogen would have resulted in the production of more number of tillers.

Beneficial effect of nitrogen to enhance tiller production has been reported by many scientists (Gunasena et al. 1979; Ajithkumar, 1984 and Meera, 1986).

A high concentration of nitrogen in the rootzone favours vigorous tillering (Yoshida and Padre, 1981).

3. Number of earheads per squaremetre

The application of UDMU showed significant effect in increasing the number of earheads per squaremetre.

The mean values of number of earheads per squaremetre recorded, for T_9, T_2 and T_7 are 271.3, 240.3 and 248 respectively. With respect to T_1 it is 204 and for T_6, it is 214.

The fact that increased availability of NH_4^+-N was more from UDMU treated urea and neemcake treated urea clearly illustrated the reason for the increase of number of earheads per squaremetre. Nitrogen being the key nutrient both for growth and yield attributes, it is but natural that the production of earheads has also been increased by higher nitrogen uptake.

Similar result was reported by Meera (1986).

4. <u>Thousand grain weight</u>

The results revealed that thousand grain weight increased with application of UDMU.

The mean values of thousand grain weight recorded for T_9, T_7 and T_2 are 26.7, 26.4 and 25.7 respectively. The respective values with regard to T_1 and T_6 are 24.9 and 25.03.

It is but natural to record the lowest thousand grain weight by untreated urea because of the lower availability of nitrogen in the soil. The application of UDMU and neemcake would have inhibited the nitrification process, and thereby prevented the subsequent leaching and runoff losses, making NH_4^+-N available for a longer period. This hypothesis is confirmed by the fact that UDMU and neemcake applied plots gave more NH_4^+-N compared to untreated urea. The availability of nitrogen spread over a longer period resulted in the proper filling of the grains which subsequently increased the thousand grain weight. These results are in agreement with the findings of Oommen et al. (1977) and Meera (1986).

5. Yield of grain

It is observed that UDMU when applied with urea is effective in increasing grain yield.

The mean value of grain yield (kg ha^{-1}) recorded for T_9 is 3471.6. The respective values for T_2, T_4, T_5, T_7, T_8 and T_{10} are 3225.6, 3411.8, 3336.2, 3292.4, 3275.5 and 3385.3 respectively. Corresponding values for T_1 and T_6 are 2439.8 and 2623.9 respectively.

The significant positive effect of UDMU on the yield components like number of productive tillers per squaremetre, number of earheads per squaremetre and thousand grain weight clearly bring out the reason for the positive effect on increasing yield of grain. The fact that nitrogen uptake at various growth stages are also positively correlated with the grain yield, further illustrates the superiority of UDMU.

Plots applied with neemcake were found to have higher grain yields than the control plots, The data showed that higher levels of nitrogen supply due to application of neemcake with urea resulted in a higher grain yield.

Field experiments for comparing the different nitrification inhibitors against untreated urea conducted under various agro-ecological conditions have conclusively proved the importance of nitrification inhibitors in reducing N losses and subsequent increase in the grain yield in rice. (Subbiah et al. 1980; Anon. 1985 and Chen and Lu, 1985).

The cumulative effect of availability of nitrogen in the rootzone on the growth characters and yield components might have resulted in a higher grain yield.

6. Straw yield

The mean value of straw yield (kg ha^{-1}) recorded for T_1 is 3845. With regard to T_6, it is 4008.7. The corresponding values (kg ha^{-1}) with respect to T_2, T_3, T_5, T_7, T_9 and T_{10} are 4879, 4798.8, 5003.8, 5025.6 and 5113.9 respectively. UDMU treated plots are found to be having the maximum straw yield. T_6 (urea + neemcake) is found to be better than T_1. Straw yield was maximum in plots where more nitrogen uptake was recorded. The part played by nitrogen in increasing vegetative growth is well recognised. By providing a steady supply of nitrogen throughout the growing season, UDMU and neemcake might have influenced the plants in producing more vegetative growth which resulted in increased straw yield.

The favourable influence of N on straw yield is very well documented (Surendran, 1985 and Meera, 1986).

7. Nitrogen uptake of plant at various growth stages

Soil mineral nitrogen can be well correlated with nitrogen uptake (Meera, 1986). Periodic soil analysis clearly indicated that application of UDMU and neemcake resulted in higher availability of NH_4^+-N in soil. Nitrogen uptake studies carried out at 35 days after transplanting, flowering and at harvest stages clearly indicate the superiority of UDMU and neemcake in increasing the intake of mineral nitrogen by the plant. Higher availability of nitrogen naturally might have resulted in greater uptake by the plant.

The mean values of N uptake of rice (kg ha^{-1}) obtained at 35 days after transplanting for T_9, T_7, T_5 and T_2 are 53.68, 53.53, 48.73 and 49.74 respectively. The above values for T_1 and T_6 are 38.34 and 41.64 respectively.

The mean values of N uptake (kg ha^{-1}) obtained at harvest stage for T_9, T_7, T_4 and T_2 are 117.61, 111.37, 114.88 and 105.32 respectively. The corresponding values for T_1 and T_6 are 90.37 and 95.17 respectively. Application of nitrification inhibitors resulting in higher uptake of nitrogen has been reported by Sathianathan (1982).

8. Protein content of grain

It is observed that application of UDMU and neemcake increased the protein content of grain.

The mean values (percentages) of protein content of grains at harvest stage for T_2, T_4, T_7 and T_9 are 8.89, 9.09, 9.13 and 8.97 respectively. The corresponding values for T_1 and T_6 are 7.02 and 7.98 respectively.

Higher rates of nitrogen absorption consequent to higher nitrogen availability might have resulted in higher rate of protein synthesis. Thus application of UDMU and neemcake finally resulted in the production of quality grains.

Ajithkumar, 1984; Surendran, 1985 and Meera, 1986 have reported similar results.

9. Correlation studies

The yield attributing characters such as number of productive tillers per squaremetre, number of earheads per squaremetre and thousand-grain weight are found to be significantly higher in plots applied with UDMU and neem-cake. The greater grain and straw yields recorded in these plots are the result of the cumulative and complementary effects of these yield attributing characters.

The nitrogen uptake is seen correlated with grain yield. The value is significant and positive. This indicates that higher nitrogen uptake is responsible for the higher yields in plots treated with UDMU and neemcake.

NH_4^+-N contents recorded at the various stages of plant growth are well correlated with the grain yield. This indicates that UDMU and neemcake are capable of retaining more NH_4^+-N in the soil for a longer period. This higher supply of nitrogen throughout the plant growth resulted in increased number of tillers and earheads and also proper development of filled grains. This resulted in increased thousandgrain weight and finally for the greater grain yields. This may be the reason for NH_4^+-N positively correlated with grain yield.

Summery and Conclusions

SUMMARY AND CONCLUSIONS

An investigation was carried out at the College of Agriculture, Vellayani, during the first crop season of 1987 to find out the possibility of using unsymmetrical dimethyl urea (UDMU) and neemcake (NC) in various combinations as urease/nitrification inhibitors for increasing the nitrogen use efficiency of wetland rice, variety Jaya. UDMU was applied as mixed and in the coated form. Two levels of UDMU, viz., 1/10th and 1/5th of the quantity of urea were used for study. The experiment was carried out in a simple randomised block design with ten treatment and three replications.

The initial analysis of the basic physico-chemical properties of the soil from the experimental site was conducted. The periodical changes in the mineralisation pattern of urea with application of UDMU were studied by estimating urea-N, NH_4^+-N, NO_2^--N and NO_3^--N contents by analysing the wet soil samples withdrawn at various periods after application of fertilizers. The data generated from the field experiment and laboratory studies were subjected to statistical analysis to bring out the significance of the important changes observed in the rate of hydrolysis of urea and nitrification.

The important findings from these studies are summarised below.

(1) A faster rate of hydrolysis of urea, accompanied by a rapid increase in NH_4^+-N was observed in untreated urea plots. On the other hand, a much slower rate of urea hydrolysis and ammonification was found in plots treated with UDMU, indicating the inhibition of urease activity by UDMU.

(2) Increasing the level of UDMU from 1/10th of urea to 1/5th of urea seemed to have a positive effect in augmenting the nitrification inhibitory properties.

(3) Plots treated with (urea + neemcake) followed a pattern of urea hydrolysis similar to untreated plots indicating the lesser influence of neemcake on urea hydrolysis.

(4) T_9 (urea + UDMU (1/5th of urea) + neemcake) was found to be superior based on the nitrification and urease inhibitory properties of the soil as well as crop performance.

(5) Coating of UDMU with urea was found to be less effective as compared to the mixing of urea and UDMU.

(6) Periodic soil analysis during the three split applications of fertilizers indicated that retention of NH_4^+-N was much higher in UDMU treated plots compared to the untreated plots.

(7) A rapid rate of nitrification was exhibited in the control plot, with simultaneous increase in NH_4^+-N content contrary to the much slower rate of nitrification in UDMU treated plots, showing thereby that UDMU possesses nitrification inhibitory properties.

(8) Neemcake (NC) was observed to be possessing nitrification inhibitory properties but it is significantly lower than that of UDMU.

(9) Various combinations of urea with UDMU, with neemcake and both with UDMU and NC showed significant increase in the height of plants at active tillering and panicle initiation stages and also at harvest. Number of tillers per squaremetre at panicle initiation stage was significantly increased due to the application of UDMU.

(10) The yield of grain was significantly increased by the application of UDMU with urea. There was significant increase in straw yield also by UDMU treatment.

(11) The total nitrogen content of soil in UDMU treated plots was high in all the stages of crop growth. Untreated urea gave the lowest nitrogen content in the soil.

(12) Higher nitrogen uptake by the crop was recorded by the treatments applied with UDMU.

(13) Application of UDMU with urea increased the protein content of grain.

(14) Correlation studies revealed that N uptake of rice at harvest (kg/ha) and Ammonia nitrogen (NH_4^+-N) contents of the soil at various periods after application of fertilizers were positively correlated with yield resulting significant increase in the grain yield.

From the investigation carried out, it has been possible to obtain a systematic account of the extent and nature of the different processes involved in the mineralisation of applied urea in soil.

The results of the present study have clearly indicated that unsymmetrical dimethyl urea (UDMU) is effective in inhibiting urease activity as well as nitrification. There has been significant increase in the availability of mineral nitrogen for the crop, as evidenced by the NH_4^+-N contents recorded at various periods. Increased nitrogen uptake by the plant is recorded for plots treated with UDMU. Obviously, the increased yield and better crop performance are due to the more efficient nitrogen conservation in the soil with application of UDMU.

Neemcake is observed to be ineffective in inhibiting urease activity while it is efficient in retardation of nitrification in the soil, though not to the extent of UDMU.

Findings of the present study paved the way for the following future lines of investigation.

(i) To find out the optimum level of UDMU as an urease/ nitrification inhibitor in wetland rice soils.

(ii) To study the effect of application of UDMU with urea on the uptake of other nutrients.

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*Originals not seen.

Appendices

APPENDIX I(a)

Abstract of Split plot ANOVA for Basal application of fertilizers

Source	df	Mean Sum of Squares			
		Urea-N	NH_4^+-N	NO_3^--N	NO_2^--N
Replication	2	0.002	0.019	0.013	0.007
Inhibitors (A)	9	7.880**	5.290**	0.070**	0.050**
Error (1)	18	0.005		0.003	0.010
Interval (B)	4	828.150**	156.240**	156.220	1.880**
A x B	36	0.959	2.950**	2.320	0.053**
Error (2)	80	0.007	0.008	97.210	0.008
Total	149				

* Significant at 5% level

** Significant at 1% level

APPENDIX I(b)

Abstract of Split plot ANOVA

Source	df	Mean Sum of Squares							
		Urea-N		NH_4^+-N		NO_3^--N		NO_2^--N	
		1st top-dressing	2nd top-dressing	1st top-dressing	2nd top-dressing	1st top-dressing	2nd top-dressing	1st top-dressing	2nd top-dressing
Replication	2	0.02	0.004	0.02	0.12	0.002	0.001	0.011	0.004
A	9	6.11**	4.04**	4.54**	3.27**	0.34**	0.078**	0.879**	0.032**
Error (1)	18	0.02	0.02	0.01	0.009	0.002	0.003	0.001	0.002
B	5	699.59**	554.40**	214.86**	179.19**	155.92	197.05	1.85**	2.14**
AB	45	1.21**	0.57**	2.49**	2.06**	2.63	15.007*	0.033**	0.01**
Error (2)	100	0.02	0.007	0.007	0.010	63.40	101.44	0.022	0.003
Total	179								

* Significant at 5% level

** Significant at 1% level

APPENDIX II

Abstract of Analysis of Variance Height of Plants (cm)

Source	df	Mean Sum of Squares		
		Active tillering stage	Panicle initiation stage	Harvest stage
Replication	2	1.18	0.66	7.34
Treatments	9	4.08**	27.96**	122.12**
Error	18	1.41	1.08	6.73
Total	29			

APPENDIX III

Analysis of variance table

Number of tillers per squaremetre				
Source	df	SS	MSS	F
Replication	2	1008.50	504.25	2.89
Treatments	9	13261.00	1473.46	8.45**
Error	18	3140.00	174.44	
Total	29	17409.50		

SE - Treatments 7.63

CD - Treatments 22.66

APPENDIX IV

Analysis of variance table

Number of earheads per squaremetre

Source	df	SS	MSS	F
Replication	2	2517.29	1258.65	6.64**
Treatments	9	10822.88	1202.54	6.35**
Error	18	3411.35	189.52	
Total	29	16751.50		

SE Treatments 7.95

CD Treatments 23.62

APPENDIX V

Analysis of variance table

Thousand grain weight (g)

Source	df	SS	MSS	F
Replication	2	1.15	0.57	2.95
Treatments	9	10.18	1.13	5.76**
Error	18	3.53	0.20	
Total	29	14.86		

SE Treatments 0.26

CD Treatments 0.76

APPENDIX VI

Analysis of variance table
Yield of grains (kg/ha)

Source	df	SS	MSS	F
Replication	2	51648	25824.00	3.08
Treatments	9	3257152	361905.80	43.20**
Error	18	150784	8376.89	
Total	29	3459584		

SE Treatments 52.84

CD Treatments 157.01

APPENDIX VII

Analysis of variance table
Straw yield (kg/ha)

Source	df	SS	MSS	F
Replication	2	136256	68128.00	3.67*
Treatments	9	5707392	634154.70	34.19**
Error	18	333824	18545.78	
Total	29	6177472		

SE Treatments 78.63

CD Treatments 233.62

APPENDIX VIII

Abstract of Analysis of variance

Nitrogen concentration in percentage

Source	df	Mean sum of squares							
		at 35 days after transplanting		at flowering stage			at harvest stage		
		Leaf	Roots	Leaf	Roots	Flowers	Leaf	Roots	Grains
Replication	2	0.034	0.015	0.009	0.002	0.003	0.007	0.003	0.001
Treatments	9	0.186**	0.019	0.236**	0.037**	0.008**	0.014**	0.008*	0.031**
Error	18	0.022	0.005	0.018	0.010	0.002	0.003	0.002	0.003
Total	29								

APPENDIX IX

Analysis of variance table

Percentage protein content of grains

Source	df	SS	MSS	F
Replication	2	0.09	0.04	0.47
Treatments	9	11.04	1.23	13.37**
Error	18	1.65	0.09	
Total	29	12.78		

SE Treatments 0.18

CD Treatments 0.52

APPENDIX X

Abstract of analysis of variance

N uptake of rice (kg/ha)

Source	df	Mean sum of squares		
		at 35 days after transplanting	at flowering stage	at harvest
Replication	2	4.85	1.60	120.74*
Treatments	9	78.42**	111.86**	234.41**
Error	18	5.59	9.18	34.30
Total	29			

POSSIBILITIES OF USING UNSYMMETRICAL DIMETHYL UREA AS UREASE NITRIFICATION INHIBITOR FOR INCREASING THE EFFICIENCY OF NITROGENOUS FERTILIZERS

By

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ABSTRACT OF A THESIS

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ABSTRACT

An investigation was carried out at the College of Agriculture, Vellayani, during the first crop season of 1987 to study the efficacy of the use of unsymmetrical dimethyl urea (UDMU) and neemcake (NC) in various combinations as urease/nitrification inhibitors for increasing the nitrogen use efficiency in wetland rice soils of Kerala.

The initial analysis of the basic physico-chemical properties of the soil from the experimental site was done. UDMU was applied along with urea as mixed and in the coated form. Two levels of UDMU, viz. 1/10th and 1/5th of the quantity of urea were used for study. Neemcake was added at the rate of 40 kg/ha. Soil samples were withdrawn periodically from the experimental plots and analysed in the laboratory for estimating urea-N, NH_4^+-N, NO_2^--N and NO_3^--N contents in order to study the rate of mineralisation of urea. The experiment was carried out in a simple randomised block design with ten treatments and three replications.

The study has revealed that unsymmetrical dimethyl urea is effective in inhibiting urease activity as well as

nitrification. Increasing the level of UDMU from 1/10th to 1/5th of urea has a positive effect in increasing the nitrification inhibitory properties. Neemcake was found to be ineffective in inhibiting ureahydrolysis, eventhough it can act as a nitrification inhibitor. Coating of UDMU with urea was observed less effective compared to the mixing of urea and UDMU.

Periodic soil analysis during the three split applications of fertilizers indicated that retention of NH_4^+-N was much higher in UDMU treated plots compared to the untreated plots. A faster rate of ammonification was observed in untreated urea plots. On the other hand, a much slower rate of urea hydrolysis was seen in UDMU treated plots, indicating the inhibition of urease activity by UDMU. The control plots showed a rapid rate of nitrification contrary to the much slower rate of nitrification in the plots treated with UDMU.

All the plots applied with UDMU showed significant increase in the number of productive tillers and earheads per squaremetre as well as thousand grain weight.

T_9 (urea + UDMU (1/5th of urea) + neemcake) recorded the maximum grain and straw yields. Nitrogen uptake during the various stages of crop growth was also maximum in UDMU treated urea plots. Maximum protein content in grain was obtained in plots treated with UDMU.

Correlation studies revealed that number of productive tillers, number of earheads per squaremetre, thousand grain weight, NH_4^+-N content of the soil at various periods and nitrogen uptake at different growth stages were positively correlated with yield.

The results of the study have clearly brought out the suitability of using UDMU as urease as well as nitrification inhibitors.