

TRANSPORT AND TRANSFORMATION OF UREA SUPER GRANULE AS AFFECTED BY ITS TIME OF PLACEMENT IN RICE SOIL

**A THESIS
SUBMITTED TO
THE ORISSA UNIVERSITY OF AGRICULTURE AND TECHNOLOGY, BHUBANESWAR
IN PARTIAL FULFILMENT OF THE REQUIREMENTS
FOR THE DEGREE OF
MASTER OF SCIENCE IN AGRICULTURE
(AGRICULTURAL CHEMISTRY, SOIL SCIENCE AND BIOCHEMISTRY)**

BY

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COLLEGE OF AGRICULTURE
Orissa University of Agriculture and Technology
BHUBANESWAR
1994**

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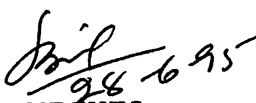
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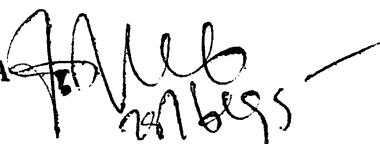
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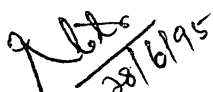
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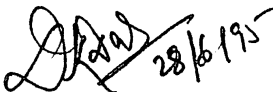

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Certified that the thesis entitled "TRANSPORT AND TRANSFORMATION OF UREA SUPER GRANULE AS AFFECTED BY ITS TIME OF PLACEMENT IN RICE SOIL", submitted in partial fulfilment of the requirements for the award of the degree of MASTER OF SCIENCE IN AGRICULTURE (AGRICULTURAL CHEMISTRY, SOIL SCIENCE AND BIOCHEMISTRY) submitted to the Orissa University of Agriculture and Technology, Bhubaneswar is a faithful record of bona fide research work carried out by Sri Sitaram Misra under my guidance and supervision during the academic year, 1994. No part of the thesis has been submitted for the award of any other degree or diploma. It is further certified that all possible help and sources of information availed during the course of this investigation have been duly acknowledged by him.



(Dr. B.K. Mishra)

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Finally, It is the Supreme, Whose blessings have brought me to this state of life and I bow my head for ever.

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Sitaram Misra

TRANSPORT AND TRANSFORMATION OF UREA SUPER GRANULE AS AFFECTED BY ITS TIME OF PLACEMENT IN RICE SOIL.

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ABSTRACT

A miscible displacement experiment on USG was carried out in soil column of 9cm long. The $\text{NH}_2\text{-N}$ was leached down to an extent of 53.15% of applied USG in 40 h. The rate constant for USG hydrolysis was computed to be 0.023/h at 27.5 C. The velocity of $\text{NH}_2\text{-N}$ was lower (0.3cm/h) than that of the water (0.4cm/h), but more than $\text{NH}_4\text{-N}$ during the displacement. The sorption of $\text{NH}_4\text{-N}$ between the solution and exchange phase was observed to be linear with the $\text{NH}_4\text{-N}$ distribution coefficient of 17.5 during the leaching.

In the medium land field soil of central farm, O.U.A.T., the effect of the time of USG placement was studied with or without the application of P.U split in Kharif Rice. Application of USG or P.U increased the yield attributing characters, N uptake and consequently the grain and straw yields of Kharif rice. Placement of USG at 14 DAT significantly increased the grain and straw yields of rice. The N use efficiency and the apparent N recovery were the largest when the placement of USG was done at 14 DAT in comparison to other times of USG placement or PU split. The relative efficiency of USG placement at 14 DAT was also doubled in comparison to PU split.

The floodwater and soil water samples collected at soil depths of 5 and 10cm periodically for 144 h soon after USG placement @ 76 kg N/ha at 0, 7 and 14 DAT and the broadcast of P.U @ 19 kg N/ha were analysed for both the $\text{NH}_2\text{-N}$ and $\text{NH}_4\text{-N}$. The low recovery of $\text{NH}_2\text{-N}$ both in floodwater and soil water indicated that rate of hydrolysis of USG was more in field soil than in column soil. The diffusion rate of $\text{NH}_2\text{-N}$ from soil to floodwater appeared to be more than the convective diffusion of the same in downward direction. The placement of

USG at 5cm soil depth reduced diffusion of $\text{NH}_2\text{-N}$ from soil to floodwater in comparison to surface broadcast of P.U at one fourth rate. The rate of diffusion of $\text{NH}_2\text{-N}$ from soil to floodwater appeared to be little affected by the period of soil submergence.

The concentration of $\text{NH}_4\text{-N}$ in floodwater or in soilwater appeared to be related to the rate of hydrolysis of $\text{NH}_2\text{-N}$ in the respective phases. The diffusion of $\text{NH}_4\text{-N}$ from soil water to floodwater was less than the convective diffusion of the same in downward direction. Increasing the period of soil submergence decreased the rate of hydrolysis of $\text{NH}_2\text{-N}$ in floodwater. The concentration of $\text{NH}_4\text{-N}$ in soil water was more than that in floodwater. Further increasing the period^{of} soil submergence, the downward displacement of $\text{NH}_4\text{-N}$ was decreased, concurrently retention of $\text{NH}_4\text{-N}$ in the rooting zone was increased. Thus the availability of N to rice was increased for USG placement at 14 DAT.

In an observation strip of six plots the effect of USG dose and its placement depth at 2.5 and 5.0cm on nitrogen transformation was studied in a rice field. The increase in N dose upto 96 kg N/ha was found to increased the rice grain and straw yields. Further the placement of USG at 5.0cm soil depth also appeared to increase the yield more than its shallow placement(2.5cm soil depth).

The rate of diffusion of $\text{NH}_2\text{-N}$ from soil water to floodwater was more at high dose of USG placement irrespective of placement depths. The concentration of $\text{NH}_4\text{-N}$ was also more both in floodwater and soil water at high dose of N application. This indicates that the rate of hydrolysis of USG was increased with increase in N dose. The convective diffusion of $\text{NH}_4\text{-N}$ from applied USG was increased with increase in the placement depth and N dose. The placement of USG applied @ 96 kg N/ha at 5cm soil depth increased the leaching loss of $\text{NH}_4\text{-N}$ in comparison to shallow placement or low dose of USG placement.

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CHAPTER I
INTRODUCTION

INTRODUCTION

Rice being the staple food of more than 90% people of Eastern India, it is quite needed to increase the production and productivity, keeping pace with the rising population growth. However among all the inputs applied to Rice for increasing crop production, fertilizer plays an important role especially for the high yielding varieties and the modern hybrid cultivars which grow both under irrigated and rainfed conditions. At the present economic scenario of our nation, every effort is to be taken to increase the fertilizer use efficiency since fertilizer is a costly input.

Among the essential plant nutrients needed by rice crop, Nitrogen plays a major role. But nitrogen deficiency is being observed in plants grown in almost all soils of our country. Nitrogen fertilizer requirement for rice is estimated to be 40% of total nitrogenous fertilizer used for all the crops. It also accounts for about 67% of the fertilizers (N + P + K) applied to rice crops and more than 90% of the fertilizer-N consumption by rice is in the urea form (Vlek and Byrens 1986). Urea being the cheapest form of fertilizer - N in the market becomes a Universal choice of most of rice growing farmers for application in waterlogged soil.

Like the other nitrogenous fertilizers, when urea is applied to waterlogged rice soil, it is subjected to sequential transformations of hydrolysis, nitrification, nitrate reduction and volatilization besides leaching. The recovery of applied urea appears to be hardly 30- 40% depending upon the environmental conditions as reported by Mitsui (1954). However a little quantity of applied nitrogen is reported to be lost through immobilization by weeds, algae, and other unwanted plants (Bromodbent 1978, Craswell and Vlek 1979). This nitrogen losses not only increase the cost of cultivation, but more importantly, it leads to pollution of groundwater and the atmosphere. It has been observed that concentration of $\text{NO}_3\text{-N}$ as high as 45 PPM in groundwater makes drinking water unfit for consumption. Further the release of N_2O from soil due to denitrification affects the ozone layer in the aerial atmosphere resulting serious health hazard to human beings. Thus the scientists concerned in nitrogen management have concentrated their attention for the best utilization of nitrogen fertilizers in soil.

Following the postulation that the distinct oxidized and reduced zones exist in a flooded rice soil (Mortimar, 1939), attempts have been made to improve the efficiency of fertilizer-N by placement in the reduced zone. The point placement in form of paper packets or mudballs was introduced by the Japanese farmers in 1945 for waterlogged rice soil

(Mitsui 1977). Being encouraged by the results, research was initiated in developing large particulars of solid fertilizers (Stangel, 1974). Subsequently supergranules known by now as USG was prepared first by Norsk Hydro company of Norway through International Fertilizer Development Center (IFDC). The most commonly researched material is the one gram urea supergranule (46% N) produced by IFFCO in India and other agencies in International level.

Since mid 70s research was undertaken in India and in International level to evaluate the efficiency of USG under different agroclimatic conditions by the International Fertilizer Development Center. Later on the International Rice Research Institute (IRRI), ICAR and IFFCO have carried on a large number of research and field trials to evaluate the efficiency of USG in respect of its agronomic efficiency particularly for lowland and/or waterlogged rice soil. Many researchers have also tried to evaluate the comparative efficiency of USG with other slow release nitrogen fertilizers for low land rice. The relative efficiency of USG has been reported to vary from 15-25% although the additional cost involved in respect of USG preparation is reported to be 10% more than PU.

By now the work on evaluating the agronomic efficiency of USG is voluminous, but the practical utility of

CHAPTER II

REVIEW OF LITERATURE

REVIEW OF LITERATURE

Rice is a semiaquatic plant. It grows well in waterlogged soil. Waterlogging in soil creates a standing water layer on the surface, an oxidised surface layer of one to two centimeters and the underlying reduced layer. Among the three major nutrients applied to rice, the efficient nitrogen management depends on the physical and physico-chemical properties of these three layers. The nitrogen is mostly applied to soil in forms of amide, ammonium, and nitrate. The amide nitrogen being weekly adsorbed in soil (Broadbent et al 1958), is usually hydrolysed into $\text{NH}_4\text{-N}$ from before being moved up and down through the soil. A part of the applied amide nitrogen gets lost in form of volatilized ammonia from floodwater.

The mobility of applied or hydrolysed $\text{NH}_4 - \text{N}$, is very slow. It has been observed that most of $\text{NH}_4\text{-N}$ gets adsorbed in soil before being moved up and down through mass flow and/or diffusion. Since $\text{NH}_4\text{-N}$ retention is mostly confined to the top few centimeter of surface soil, serving as oxidised layer, a portion of it is nitrified to $\text{NO}_2\text{-N}$ and subsequently to $\text{NO}_3\text{-N}$ besides being absorbed by the plant and lost as ammonia gas through volatilization.

Unless the ammonium concentration is very high or the soil reaction is highly alkaline, the stability of $\text{NO}_2\text{-N}$ is very short. It is quickly oxidised to $\text{NO}_3\text{-N}$ ⁱⁿ oxidised soil, thus a negligible amount of $\text{NO}_2\text{-N}$ is found in neutral or acidic soil.

The applied or nitrified $\text{NO}_3\text{-N}$ being highly soluble and mobile gets leached down to the reduced layer or into the groundwater where it is reduced to gaseous nitrogen and nitrous oxide and at last lost from the soil system. Thus the efficiency of applied urea which is a common nitrogen fertilizer for waterlogged rice is low due to leaching and volatilization during its transport and transformation in soil.

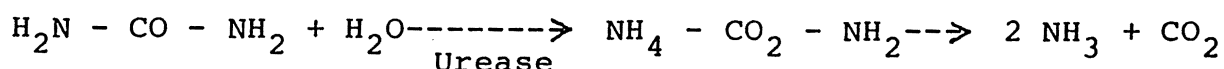
2.1 UREA TRANSFORMATION PROCESS :

When urea comes in contact with soil it undergoes a series of transformation processes mediated by the soil micro-organisms present in situ. The different processes are urea hydrolysis, volatilization, Nitrification, denitrification, immobilization and fixation.

2.2.1 Hydrolysis of Urea :

Hydrolysis of urea is mediated by the extracellular enzyme, Urease, present in soil or soil living aerobic micro-organisms. The biochemical reaction representing urea

hydrolysis is given as follows :



The simplest mechanism of the enzyme catalysed reaction is given by :



Where E is the enzyme, S is the substrate, P is the product, ES is the enzyme substrate complex; K_1 , K_{-1} , K_2 , K_{-2} are the relevant rate constants.

The urea hydrolysis is brought about by urease, which occurs universally and is abundant in soils. Large number of bacteria, fungi, and actinomycetes in soils possess urease. Activity of urease tends to increase with the size of the soil microbial population and increases with organic matter content. The presence of relatively fresh plant residues often results in abundant supplies of urease. The greatest activity of urease is reported to occur in the rhizosphere, where microbial activity is high and where it can be excreted from plant roots. Activity of rhizosphere urease varies depending on plant species and the season of the year (Anonymous, 1990).

Factors affecting Urea hydrolysis :

The pathways of urea hydrolysis are affected by various factors such as pH, organic matter content, soil moisture condition, temperature, aeration, type of micro-organisms involved besides other environmental conditions (Sahrawat 1979). Urea hydrolysis is faster in soils having high pH and high organic matter content than soils having lower pH and lower organic matter content (Sinha and Prasad 1967, Beri et al. 1978, Pal and Chhonkar (1981). Pal and Chhonkar (1979) studied thermal sensitivity, pH optima, and reaction rate constants for urease in alluvial soils and have reported that soil urease activity was not adversely affected between 40° and 70° C, but at 80° C and above the enzyme was completely denatured.

Sukov and Kidin (1982) reported that the rate of urea decomposition depended also on soil temperature and moisture. The rate of urea decomposition increased with increasing temperature from 4° to 25° C and with increasing soil moisture from 80% of field capacity to field capacity. Below and above these limits the rate decreased. The rate of urea hydrolysis in soil decreased also under flooding.

Urea hydrolysis under submerged Soil :

So far wetland soils are concerned Savant and De Dutta 1979 (unpublished data) reported that the rate of urea

hydrolysis was faster in oxidised surface soil than the underlying reduced soil in the same site. The level of urease activity is lower in flood water than in the underlying soil (Savant and De Datta unpublished data 1978). Savant et al. (1985) observed that depletion of O_2 in submerged soils had retarded the rate of urea hydrolysis. Therefore the order of hydrolysis rate was:

Oxidised soil > reduced soil > Flood water

Savant et al. (1983) reported that under non-flowing floodwater conditions (without percolation) most of the broadcasted or top dressed urea had hydrolysed to ammonium in flood water, particularly at the floodwater-soil interface as reported by Vlek and Fillery (1984).

Waterlogged soils seem to hydrolyze urea rapidly even when it is point placed. Craswell and Vlek (IFDC, unpublished data 1977) found in laboratory studies that 460 mg urea-N (as supergranule) placed in 100cm^3 of waterlogged soil was completely hydrolyzed in three days. In contrast Savant and De Datta (1979) reported a less than 10% of amide-N that remained at placement site one day after application of supergranule urea (USG) in a wetland rice soil. They stated that the mechanisms of urea movement were based on diffusion and/or convective transport before it was transformed to ammonium in soil (Savant and De Dutta 1980).

Hydrolysis rate constant (K_u) :

The magnitude of urea hydrolysis has been studied by many workers. Vinod Kumar and Wagnet (1984) studied the kinetics of urea transformation as a function of temperature in panoche and wellsville soils. They reported the urea hydrolysis to be first order rate constant (K_u), and the values of K_u were 0.2518 h^{-1} and 0.0842 h^{-1} at 10°C for Wellsville and panoche soil, respectively. The values of K_u were raised to 0.4375 h^{-1} and 0.1194 h^{-1} at 20°C and 0.5222 h^{-1} and 0.1919 h^{-1} at 30°C for the two soils, respectively. Khanda (1985) observed a first order rate constant for urea hydrolysis in Bhubaneswar medium land soil and reported the values of K_u to be 0.038 h^{-1} , 0.068 h^{-1} and 0.14 h^{-1} at 24°C and 35°C , respectively. On the other hand Erikson and Kjeldby (1987) reported zero order Kinetics for urea hydrolysis under incubation study when USG was deep placed (10 cm) in two puddled and flooded soils of Norway at 30°C .

Yadav et al. (1987) studied the effect of soil moisture on urea hydrolysis-rate constant (K_u) in high pH soil and reported that increasing the moisture content from 20% to field capacity the values of K_u ranged from 0.019 to 0.044 h^{-1} for sandy loam soil and 0.049 to 0.095 h^{-1} for clay loam soil. The rate constant decreased to 0.023 h^{-1} for the sandy loam soil and to 0.078 h^{-1} for the clay loam soil when a 2 cm water was ponded on the soil surface.

Lindau et al. (1989) measured urea hydrolysis rates in one calcareous and three acid rice soil suspensions under oxidising and reducing conditions when the soil was incubated with urea at the rate of 50 microgram per gm of soil. The K_u of urea hydrolysis ranged from 0.054 to 0.094 h^{-1} in oxidised soil suspensions and from 0.028 to 0.062 h^{-1} in reduced soil suspensions. Later on Hongprayoon et al (1991) reported that the rate of urea hydrolysis in the flooded soil columns increased with time and followed first order reaction kinetics. The rate constants were reported to vary from 0.036 to 0.288 h^{-1} at 30°C in the Crowley silt loam soil.

Column leaching of Urea and USG :

Various workers have also worked on urea hydrolysis by leaching the solution pulse of urea. The first work carried on leaching appeared by Wagnet et al. (1977) who described the fate of applied ^{15}N urea (95% a.e.) leaching through the soil column. They quantitatively measured the spatial and temporal distribution of $\text{NH}_2\text{-N}$, $\text{NH}_4\text{-N}$ and $\text{NO}_3\text{-N}$ and also estimated the magnitude of the first order microbial transformation coefficients of nitrogen. The rate constants for enzyme hydrolysis of urea, K_1 , oxidation of ammonium, K_2 ; and reduction of Nitrate, K_3 ; were estimated to be 0.016, 0.010, and 0.001 h^{-1} , respectively, at the ambient temperature of 19.5°C.

Khanda (1985) leached a solution pulse of Urea (containing 400 mg/L of $\text{NH}_2\text{-N}$) in 15 cm-long columns of Bhubaneswar sandy loam soil. He reported that the rate constant of urea hydrolysis increased from 0.079 h^{-1} to 0.086 h^{-1} in presence of sucrose and decreased from 0.077 to 0.018 h^{-1} in presence of inhibitors like neemcake and PMA (polyvinyl mercuric acetate).

Beri et al. (1978) studied the movement of surface applied urea in a laboratory soil column for 24h by maintaining 1cm water head on the soil surface. They found that the urea leached down with the water front in the initially dry soil. At an initial 50% of field capacity, urea moved behind the wetting front. A part of the applied N remained close to the soil surface when water was applied 20h after urea application. Application of commercial urease prevented the urea from moving down the wet soil but had little effect on initially dry soil.

Jena et al. (1988) studied the fate of applied 15N urea in Bhubaneswar upland soil in presence of rice, pigeonpea and rice + pigeonpea systems. They assumed that the sequential transformation of applied urea obeyed the first order rate kinetics as follows :

$$\frac{C}{C_0} = e^{-k_u t}$$

$$\frac{C_1}{C_0} = \frac{K_u}{K_1 - K_u} (e^{-k_u t} - e^{-k_1 t})$$

$$\frac{C_2}{C_0} = \frac{K_u - K_1}{(K_1 - K_u)(K_2 - K_u)} e^{-k_u t} + \frac{K_u - K_1}{(K_u - K_1)(K_2 - K_1)} e^{-k_1 t}$$

$$+ \frac{K_u - K_1}{(K_u - K_2)(K_1 - K_2)} e^{-k_2 t}$$

Where C_0 is the initial concentration of $\text{NH}_2\text{-N}$ added, C , C_1 and C_2 are the concentration of $\text{NH}_2\text{-N}$, $\text{NH}_4\text{-N}$ and $\text{NO}_3\text{-N}$ respectively, at time t and k_u , k_1 and k_2 are the rate coefficient for urea hydrolysis, ammonium oxidation and nitrate reduction, respectively.

The mean rate coefficients of K_u , K_1 and K_2 were estimated to be 0.03, 0.05 and 0.02 h^{-1} for rice root zone, 0.035, 0.035 and 0.035 h^{-1} for pigeonpea root zone, 0.035, 0.027 and 0.034 h^{-1} for rice + pigeonpea root zone and 0.041, 0.038 and 0.027 h^{-1} for the bare ultisol profile at Bhubaneswar, respectively.

2.1.2 Ammonia Volatilization:

When urea undergoes hydrolysis it gives rise to $\text{NH}_4\text{-N}$. At high concentration $\text{NH}_4\text{-N}$ is volatilised to Ammonia that ultimately lost to the atmosphere at normal temperature and pressure. Ammonia is a basic gas and hence it has affinity for

water and other acidic compounds. Hence it is the fundamental determinant of the rate of volatilization.

Following Simpson (1981) and Vlek et al (1981) the various reactions which govern ammonia loss may be represented as

NH_3 (gas in atmosphere)

NH_3 (gas in soil)

Adsorbed $\text{NH}_4 \rightleftharpoons \text{NH}_4$ (in solution) $\rightleftharpoons \text{NH}_3$ (in solution)

Thus the rate of NH_3 volatilization is controlled by three steps:

- i) Conversion of NH_4 (in solution) to ammonia (in solution)
- ii) Conversion of ammonia (in solution) to ammonia (gas in soil)
- iii) Transfer of ammonia (gas in soil) to ammonia (gas in atmosphere)

The driving force for ammonia volatilisation from a moist soil (or solution) is normally considered to be the difference between the partial pressure of Ammonia in equilibrium with liquid phase and that in the ambient atmosphere (Denmead et al. 1982). The equilibrium vapour pressure of ammonia is controlled by the ammonia concentration in the adjacent solution which in the absence of other ionic species is affected by the NH_4^+ ion concentration and pH. So the high concentration of ammonium-N in the food water

enhances the Ammonia volatilisations besides temperature and CEC of the soil.

Vlek and Fillery (1984) stated that when the prilled urea was broadcasted in submerged soil hydrolysis of urea, leads to high concentration of ammonium-N in the floodwater, which is eventually lost by ammonia volatilization.

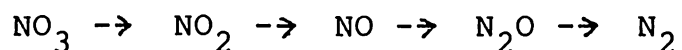
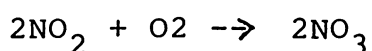
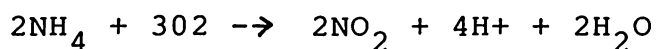
But the point placement of USG in waterlogged soil develops a neutral soil reaction at the placement site. The USG dissolves within an hour of its placement and produces a very high localized concentration of urea at placement site. Most of urea in this reaction zone stays in solution. Except the case when the holes are not closed after its point placement, a little of urea-N/ ammonium -N diffuse into the flood water from the deep layer, so the volatilization loss is minimized below 1% and is almost negligible (De Datta 1981, Panda and Pattanaik 1989).

The ammonium NH_4 -N may also be lost through the following mechanisms:

- (a) Absorption by the rice plant (root-sink effect)
- (b) Concurrent nitrification-denitrification resulting in nitrogen loss
- (c) Immobilization and fixation
- (d) Deep percolation below root zone.

2.1.3 Nitrification-Denitrification

The undergoing oxidation and reduction of ammonium - N in soil are follows :



The wetland soil system forms a complex matrix consisting of aerobic and anaerobic zones. The two aerobic sites are the oxidized surface soil layer (Site I) and the rhizosphere (Site II). Both of them favour the nitrification. The reduced soil is highly conducive to biological denitrification, during which the NO_3 is readily reduced mainly to nitrous oxide or N_2O , or both. In other words, concurrent nitrification and denitrification process is inevitable in the wetland rice soils.

Many workers have also reported the kinetics of nitrification in wetland rice soil. Mahapatra et al (1983) reported that the concentration of $\text{NH}_4\text{-N}$ in both floodwater and soil solution was the lowest for placement of USG among various sources of fertilizers like PU, neemcake coated urea.

Francis et al. (1991) studied the rate of transformation of surface applied granular urea in an irrigated barley crop. They found that the hydrolysis rates of

urea were similar both in the field and in the column soils. Urea was transformed to ammonium within 48 h and subsequently to nitrate-N within 192 h of application. Sudhakar (1984) compared the efficiency of both PU and USG in soil columns. He stated that at two weeks the application of USG in soil resulted in more retention of ammonium-N and less of nitrate-N than the PU. So they stated that since ammoniacal-N could be retained for a long period in rice soils, it resulted in high efficiency of USG in comparison to PU.

2.2 TRANSPORT OF NITROGEN :

Before transformation, a number of physical and physico-chemical processes are taking place when fertilizer nitrogen is applied to soil. Out of which transport of different forms of applied N is a significant factor to study its transformation kinetics and subsequent availability to plant.

In a wetland soil, when $\text{NH}_2\text{-N}$ is broadcasted or point placed in form of PU, USG, SCU, or mudball urea (MBU), the nitrogen at first gets dissolved in soil water and immediately a high concentration is built up in soil before its transport. The mechanism of transport appears to be a diffusion type (Savant and De Datta, 1979). On the other hand when PU, SCU, USG and MBU were deep-placed at soil depth of 10 cm despite a steep concentration gradient, ammonium-N could

hardly reach the soil water interface in the presence of transplanted rice. By and large the movement of ammonium-N was found to be more towards downward > lateral > upward from the deep placement site (Savant and De Datta 1980; Savant 1982). The ammonium concentration gradient disappeared earlier in dry season than in wet season because of faster transport of ammonium-N and/or more root-sink effect in dry season (Savant and De Datta 1979).

In a wetland field study at IRRI Ventura and Yosida (1978) also noticed that the horizontal movement of $\text{NH}_4\text{-N}$ from the placement site was restricted to the four adjacent hills of Rice. In a clay soil core, Savant and De Datta the downward movement of ammonium-N was confined to 12-14 cm soil depth four weeks after surface application of USG.

Panda and Pattanaik (1989) studied the transformation and spatial distribution of $\text{NH}_4\text{-N}$ in puddled rice soil from the point placement of USG at 5.0 cm depth. They stated that the movement of N was mostly restricted to a horizontal distance of 2.5-5.0 cm and to a vertical distance of 5.0 cm from the point of placement. Restricted lateral movement of N from USG in puddled lowland rice soil was noticed from the yield and low N uptake values of rice plants when the lateral distance of placement from the plant was increased. Working in a silty loam soil Pandey et al. (1989)

reported that the movement of $\text{NH}_4\text{-N}$ was restricted upto 15 cm in downward, to the soil surface in upward direction and upto 6-10 cm in lateral direction when USG was deep placed at a soil depth of 5-10 cm.

The physical and physico-chemical properties of soil are also shown to affect the nitrogen movement in soil. The movement of ammonium-N (Motousch 1982) was three times faster and that of $\text{NO}_3\text{-N}$ one and half times faster in sandy soil than in clay loam soil. Soil compaction to the bulk density of $1.72\text{-}1.75\text{ g/cm}^3$ was also reported to reduce the leaching loss of nitrogen below the root zone by cutting down percolation rate, especially in light textured soils (Anonymous 1978). Vlek et al. (1980) reported that deep placement of USG in Wetland soil having percolation rate more than 5 mm/day could be very serious since convective transport of ammonium-N was a major factor for downward movement. Puddling a soil decreases water movement through it and as a result may decrease leaching loss of $\text{NH}_4\text{-N}$. This generalization is of particular significance for sandy soils or well aggregated oxisols and inceptisols in the tropics, where puddling is often essential for wetland rice cultivation.

It has been reported by Panda and Pattanaik (1989) that in highly percolating upland rice soil at Cuttack (Orissa) about 2/3 of the applied urea was observed to be lost

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as such through 4 hours of leaching under a constant head of water. In 24 h of leaching, this loss increased to 74-92% of applied N indicating high potentiality of leaching loss in upland soil in high rainfall areas and unsuitability of deep placement of USG in such soils, rather broadcast and incorporation of PU gave better results.

Motousch (1982) also reported that the presence of phosphoric and potassic fertilizers in the soil increased the movement of $\text{NH}_4\text{-N}$ by 1.8 times. Further the increase in the nitrogen dose appeared to increase nitrogen movement in soil.

Split application of fertilizer N may reduce NH_4 leaching, but a single basal application of N during the early stage of transplanted rice may favour the loss through leaching (Daftar Dar et al. (1979). This is partly due to the absence of well developed rice roots during the early part of plant growth.

The movement of $\text{NH}_4\text{-N}$ in soil is also affected by the physicochemical properties of soil. Coarse textured wetland soil or soils with appreciable amount of oxides and hydroxides of Fe and Al may enhance $\text{NH}_4\text{-N}$ leaching (Anonymous 1982). Such soils having low C.E.C. are most likely to contain $\text{NH}_4\text{-N}$ in soil solution and thus encourage the downward transport of $\text{NH}_4\text{-N}$.

Mahajan et al. (1991) reported that cumulative nitrogen leaching losses after application of coated urea, USG and urea were less under saturated conditions than during intermittent wetting. Under saturated condition the major form of N loss was $\text{NO}_3\text{-N}$ for the lac, sulfur and neem coated urea treatments, whereas it was as urea and $\text{NH}_4\text{-N}$ for the USG treatment. However in unsaturated conditions the major form of N was urea-N for all treatments. N losses occur more rapidly under saturated conditions.

2.3 FACTORS AFFECTING USG APPLICATION :

2.3.1 Method of application :

Pant and Singh (1989) reported that USG deep placement was superior to USG broadcast and incorporation as well as P.U. splits both in terms of grain yield and nitrogen use efficiency. The superiority of USG deep placement is attributed to less loss through ammonia volatilization as a result of low pH, and low concentration of ammoniacal nitrogen in the floodwater in comparison to USG broadcast and incorporation and PU splits. The surface application of USG (Anonymous 1986), was no better than PU split application. For better results USG should be deep placed at the center of four hills. There fore Tandon (1989) reported that point placement of USG might be practised at pre- determined depth, manually or by a mechanical device, so as to check nitrification as well as runoff loss in floodwater. However Palaniappan and

Balasubramanyan (1989) reported that there was not much difference in grain yield between the two methods when USG was either deep placed or broadcast and incorporated in clay loam soil.

2.3.2 Depth of placement :

As suggested by Rao et al. (1989) that the grain yield of rice was high when USG was deep placed at a soil depth of 8 cm, remained at par at 12 cm placement depth and was greatly reduced at 16 cm placement depth. The straw yield was also increased when USG was placement lowered to 8 cm soil depth but remained at par at deeper placement depth. The root weight and root length of rice were also increased by lowering placement depth to 8 cm and then fell off steeply at 12 cm placement depth. The results suggested that best result could be obtained when USG were applied at about 8 cm soil depth. Heenan and Bacon (1989) reported that grain yield of rice and apparent N recovery were more when urea was drilled into the soil then its surface application but the difference in yield was not significant when urea was drilled in between 3 to 7 cm soil depth. Dupuy et al. (1990) also reported that dry matter at maturity, N yield, N content and grain yield were the maximum due to application of supergranules and minimum with urea prills. Yield and N contents were found more for 10 cm placement depth than 1 cm placement for all the fertilizers.

2.3.3 Time of application :

A lot of work has been done by the scientists of CRRI, Cuttack with regard to the time of application of USG for rice. Rao et al. (1989) suggested that at normal date of transplanting USG could be applied at any time upto 20 days after planting without any sacrifice in the yield for long duration Kharif rice and short duration Rabi rice.

In general they stated that the time of application of USG can be delayed to 15 days of transplanting for a very short duration rice variety (100 days), upto 20 days for a medium duration rice (120 days) and upto 30 days for a long duration (140-160 days) rice variety. But Sharma (1989) reported that in transplanted rice USG placement might be delayed upto 15-20 days on clay, clay loam, silty clay loam soils and upto 5 days in sandy loam soils in eastern part of India. Sharma et al. (1989) had worked on split placement of USG. They stated that application of USG in two splits (50% at final puddling or 10 DAT and rest 50% at PI) produced more, longer heavier panicles, more grains/panicle, higher 1000 grain weight and higher grain and straw yield than single application either at final puddling or 10 DAT. Deep placement of USG at 10 DAT was better than the application at the time of final puddling. Since rice seedlings require 5-7 days for establishment after transplanting, Nitrogen is subject to more losses when applied at puddling.

However Pallaniappan and Balsubramanyan (1989) have reported that in clay loam soil there was no significant yield difference of rice when USG was placed in the center of 4 hills at 5, 10, 15, 20 DAT. So USG in fine textured soil could conveniently be placed either at planting or at 20 DAT without causing any significant reduction in yield (AICRIP 1982).

2.3.4 Effect of soil Properties :

When followed by immediately sealing of the holes, the deep placement of USG helps retain nearly all urea-N near the placement site in medium and fine textured rice soil having low percolation rate or high cation exchange capacity. This retention of urea-N markedly decreases the concentration of urea-N and/or $\text{NH}_4\text{-N}$ in floodwater and therefore minimizes N loss due to low rates of ammonia volatilization, the nitrification and denitrification in the surface soil layers and surface runoff (Vlek and Craswell 1979, Savant et al. 1983, Rao et al. 1984a, 1984b). But in coarse textured soil having high percolation rate and low CEC, the deep placement of USG results in downward movement of urea and/or $\text{NH}_4\text{-N}$ and consequently the serious leaching losses of deep placed N (Katyal et al. 1984, 1985a, 1985b). Working in coarse textured soils, Rekhi et al. (1989) observed the superiority of PU split over USG. They have stated that application of PU in splits increases grain yield and nitrogen recovery more than one time placement of USG at 8-10 cm soil depth.

Katyal (1988) observed that leaching losses of deep placed USG in permeable soil could be decreased upto 20% by deep placement of four 0.25 g granules at four points instead of one 1 g granule at one point.

For this Savant and Stangel (1985) Summarised that the placement of USG becomes effective in soils with low percolation rate (5-10 mm/day) and for cation exchange capacity more than 10 meq/100g soil. In course textured soils the N uptake by rice plant was markedly decreased in case of USG placement due to high water percolation rate (Natrajan and Manicam 1991).

2.3.5 Effect of water regime :

Under alternate wetting and drying, the yield advantage with USG was small both in timely as well as in late planting of rice (Ponnamperuma 1975, De Datta 1982) due to induced N loss. It had been shown that the retention of $\text{NH}_4\text{-N}$ in soil was low under alternate wetting and drying as compared to a saturated soil with 5 mm floodwater. This could be attributed to high $\text{NH}_4\text{-N}$ oxidation under unsaturated condition and upland condition where leaching and denitrification loss of $\text{NO}_3\text{-N}$ is very high. Pandey et al. (1989) also reported that USG proved superior to split application of urea under 0-5 cm of floodwater in timely as well as in late planting of Kharif rice in a silt loam soil. But retention of $\text{NH}_4\text{-N}$ in soil from

USG placement was consistently high under flooding and low under alternate wetting and drying condition.

2.4 NITROGEN RECOVERY IN RICE :

Rice plant can use ammonium, nitrate, and even urea-N (Mitsui and Kurihara 1962) but the nitrogen uptake by plant depends on the time of application of fertilizer N since the root activity ~~is~~ different at different growth stages in waterlogged soils (Tanaka et al. 1959). Nitrogen uptake in plant is slow within 5 to 7 days of transplanting. It increases during the vegetative and reproductive stages of the crop separated by a lag period during which there was either no increase or a small increase in N uptake (Samantaray et al. 1990). Venkateswarlu et al. (1982) reported that nitrogen uptake was different at various growth stages of rice. It was maximum (1.39%) at tillering, then decreased to 0.42% at flowering and then increased to 1.243% in grain and 0.614% in straw at maturity. On the whole, the nitrogen uptakes by grain and straw of rice were estimated to be 52.55 kg/ha and 20.47 kg/ha., respectively.

The efficiency of USG is also computed in terms of apparent recovery. Experiments conducted in IARI (1982) indicated that apparent recovery was 34.3% for rice. Research conducted in medium land soil at Bhubaneswar also estimated the apparent recovery of USG to vary from 39 to 56%.

However nitrogen uptake and apparent recovery of nitrogen depends upon the source of fertilizer N. Prasad et al. (1989) reported from the results of 10 years of experiment in a sandy clay loam soil at (IARI, New Delhi) that on an average the placement of USG had given 10.7% more grain, 13.2% more nitrogen uptake and 17.5% higher apparent recovery of N than P.U. in Kharif and the apparent N recovery to an extent of 54% in dry season.

Schnier et al. (1991) conducted an experiment in dry season taking rice cv IR 64 at Phillipines to study the effect of method of application of urea and reported that both the band placement of liquid urea and point placement of USG increased grain field and reduced the partial pressure of Ammonia in the floodwater compared to the conventional broadcasting and incorporation of urea. They also reported that the total N recovery (plant + soil) in transplanted rice was 64, 92, 96% from the broadcast and incorporated, bandplaced and pointplacement of urea, respectively. The corresponding values for the direct sown rice were 72, 98, 97%.

Natarajan and Manickam (1991) studied the fate and efficiency of various N tagged urea in flooded rice soil. They have reported that at active tillering stage of rice, the N uptake was higher from single deep placed USG than the PU

split and PPDU (phenyl phosphoro diamidate urea) but the ^{15}N recovery by the crop remained same among all the three sources. ^{15}N recovery was also greater with USG than PU and PPDU at panicle initiation stage of rice. Although a similar trend in ^{15}N recovery was observed both at flowering stage and at panicle initiation stage, the magnitude of N uptake was more at P.I. stage. Thus the amount of fertilizer ^{15}N recovered by rice grain was 18.6 kg/ha with single deep placed USG 17.9 kg/ha with split broadcast application of PPDU and 16.6 kg/ha for PU.

In a field experiment at IRRI, Craswell et al. (1981) reported an apparent N recovery of 75% for IR36 in 1979 dry season and 85% for IR46 in the 1979 wet season. Subsequent field studies conducted using ^{15}N -labelled USG have conformed similar higher uptake to deep placed USG-N as compared with that of broadcast incorporated prilled urea.

2.5 GRAIN YIELD, TOTAL BIOMASS PRODUCTION AND NITROGEN USE EFFICIENCY :

Martinez (1983) conducted a large number of farmers' field trials, in eastern India and reported that agronomic efficiency of both USG and sulfer coated urea are equivalent, but greater than the efficiency of PU. The grain yield has been found to increase from 25to-60% from an application of USG or SCU @ 50 kgN/ha over P.U. They reported from 162 field

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trials that average agronomic efficiencies were equal to 15.9, 21.0, 21.8 kg of paddy/kg of N applied in the form of PU, USG and SCU respectively.

Mitra et al. (1989) conducted field experiment in the lateritic soils of Bhubaneswar during 1986-87 and reported that USG deep placement at 5-7 cm depth could reduce the fertilizer dose to half in comparison to PU splits in both the seasons to get the equivalent yield of rice.

On the other hand, from the field experiments over 10 years, Tandon (1989) reported that mean yield advantage of USG varied from 190 kg to 1080 kg/ha over PU splits.

Rao et al. (1989) also reported that the grain production of rice could be increased by 11,6.4 and 4.9 kg grain/kg N by placing USG at 29, 58 and 87 kg N/ha in place of PU.

From the above literature it is evident that a lot of work has been done during the past 15-20 years to find out the suitability of USG for lowland rice in comparison to the PU. However the efficient utilization of USG is found to vary under different agroclimatic conditions. Further, little work has been done so as to study the transformation and transport of USG in water logged soil.

CHAPTER III

MATERIALS AND METHODS

MATERIALS AND METHODS

3.1 MATERIALS

3.1.1 Experimental site and soil characteristic :

The site of the present field experiment is located in a medium land of the Central Research Station, Orissa University of Agriculture and Technology, Bhubaneswar (Latitude 20 5' N, longitude 85 50' E, altitude 100 m above mean sea level). The topography of land is gently sloppy and is bonded. The soil is found to belong to a member of fine loamy mixed hyperthermic family of haplaquept as per the 7th approximation of soil classification.

3.1.2 Column study :

A laboratory study was undertaken in a soil column to determine the transformation and movement of N stemming from surface application of USG(containing 395.784 mg of $\text{NH}_2\text{-N}$). The experimental set up is presented in Photo plate 1.

3.1.2.1 Preparation of soil column :

An Iron cylinder of 8 cm internal diameter and 10.3 cm length was used to prepare the soil column. Prior to packing of soil, one of the ends of the cylinder was closed with Whatman No. 1 filter paper by using aralite gum. The soil was collected from the field experimental site, air dried and

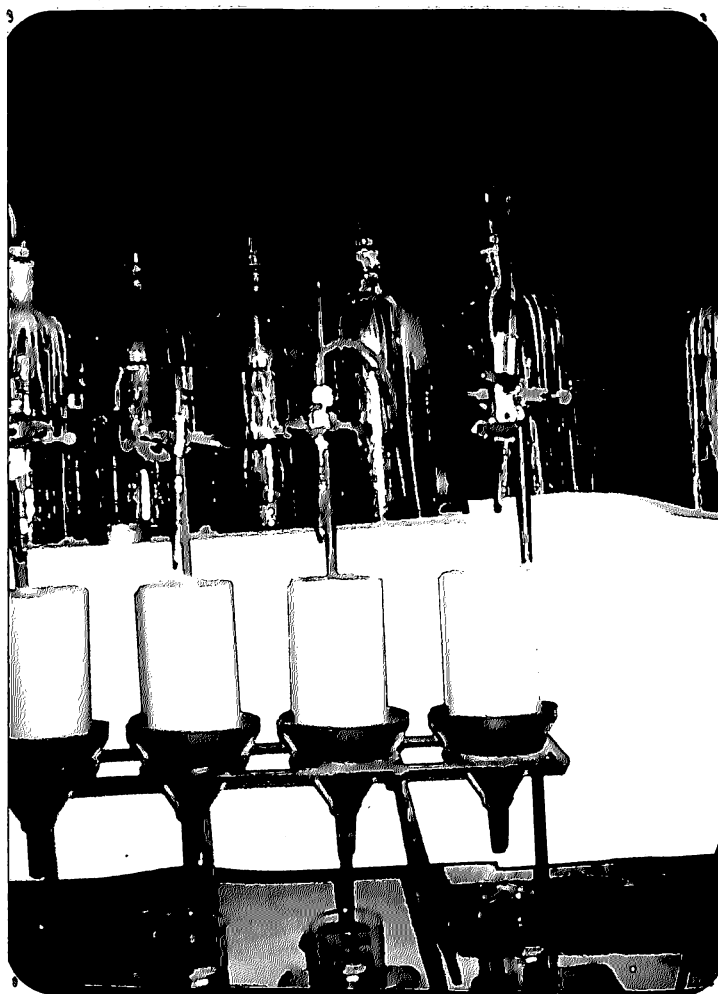


Photo Plate 1.

Experimental setup of the column leaching study.

passed through 2mm sieve. About 80.384 g of soil was taken in a lot for uniform packing upto 1 cm thick in the cylinder with the help of a rubber mallet. Before introducing the next lot, the surface of the soil already packed was gently scratched by means of a glass rod. In this manner the total mass of soil was packed upto a length of 9cm in order to attain a desired bulk density (1.6 g/cm^3).

3.1.2.2 Marriott device :

Winchester bottles of 2.5 liters capacity loaded with $0.01 \text{ N CaSO}_4 \cdot 2\text{H}_2\text{O}$ solution (which served as the leaching solution) were employed to leach soil column. The winchester bottles were made perfectly air tight by means of rubber corks. Two long glass tubes were inserted into the bottle through the rubber cork. One of them served as solution delivery tube and the other as the air inlet. A capillary tube was fitted to the outer end of the delivery tube by means of rubber tubing.

3.1.2.3 Preparation of leaching solution.

Analytical grade $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$ weighing 21.5 g was transferred to a corboy containing 25 liters of distilled water. The contents were next stirred continuously by means of a magnetic stirrer for nearly 10 hours till the salt got completely dissolved. This served as the leaching solution containing 0.01 N CaSO_4 .

3.1.2.4 Soil Saturation :

The soil column set up in the iron cylinder was saturated with 0.01 N CaSO_4 solution from bottom upwards so as to drive out the pore air as completely as possible. As the soaking proceeded, air from the soil pores was expelled out. The soaking operation continued for 12 h to saturate the soil.

3.1.2.5 Leaching of USG :

The CaSO_4 -saturated soil column was placed on buchner funnel supported on tripod stand. This was then leached with 0.01 N CaSO_4 solution at a steady state rate of $7.7 \text{ cm}^3/\text{h}$ for 24 h by maintaining a constant head of 1 cm solution. Then an USG containing (395.784 mg $\text{NH}_2\text{-N}$) was placed on the soil surface and was displaced with the same solution at same rate for 126 h. The effluents were collected in test tube for 15 minutes at an interval of one hour upto 36 h and then at an interval of 4, 6, 12, 24 h in the following days. A few drops of 50 PPM PMA solution was immediately added to each test tube to inhibit microbial growth. The samples were stored in refrigerator at 5 C for subsequent analysis of $\text{NH}_2\text{-N}$, $\text{NH}_4\text{-N}$ and $\text{NO}_3\text{-N}$.

3.1.2.6 Determination of water and KCl extractable N :

At the end of the leaching experiment the soil column was sliced into equal six pieces. Each piece was subdivided into 3 parts : the first part of approximately 10g

was treated with 100ml of 2M KCl-PMA extractant solution for determination of exchangeable $\text{NH}_2\text{-N}$ and $\text{NH}_4\text{-N}$, the second part was taken for determination of water extractable $\text{NH}_4\text{-N}$ and $\text{NH}_2\text{-N}$ and the remaining part was used for the determination of water content by gravimetric method.

3.1.3 Field Experiment :

3.1.3.1 Time of application of USG on kharif rice :

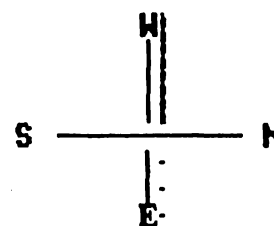
During Kharif 1994, a field experiment was laid out (Fig. 1) in order to evaluate the effect of time of placement of USG on medium duration rice cultivar, Lalat(120-125 days) and to study the transport and transformation of N in soil. A randomised block design was followed with four replications. The treatments allocated to the trial were as follows :

- T1 - 76 kg N/ha as P.U. (Splits in ratio of 1:2:1)
- T2 - 76 kg N/ha as USG at the time of transplanting (0 DAT)
- T3 - 76 kg N/ha as USG at 7 days after transplanting (7 DAT)
- T4 - 76 kg N/ha as USG at 14 days after transplanting (14 DAT)
- T5 - 76 kg N/ha as USG at 21 days after transplanting (21 DAT)
- T6 - Control (No nitrogen fertilizer was applied)

Land preparation :

The land was ploughed twice, cleaned free of weeds and leveled. About 24 plots of 4 x 3m each were prepared with

LAYOUT OF RBD FOR KHARIF RICE



T6	T2	T3	T4	T1 _*	T5
T1 _*	T4	T2	T5	T3	T6
T6	T2	T3	T1 _*	T5	T4
T1 _*	T3	T5	T4	T2	T6

Fig 1

TREATMENTS:

T1: 76 Kg N/ha AS PU(1:2:1:0

T2: 76 Kg N/ha AS USG AT 0 DAT

T3: 76 Kg N/ha AS USG AT 7 DAT

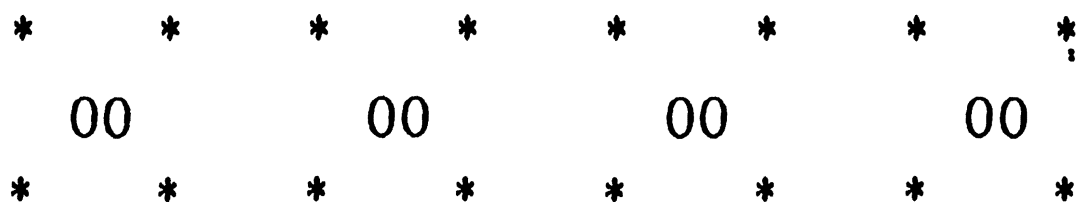
T4: 76 Kg N/ha AS USG AT 14DAT

T5: 76 Kg N/ha AS USG AT 21DAT

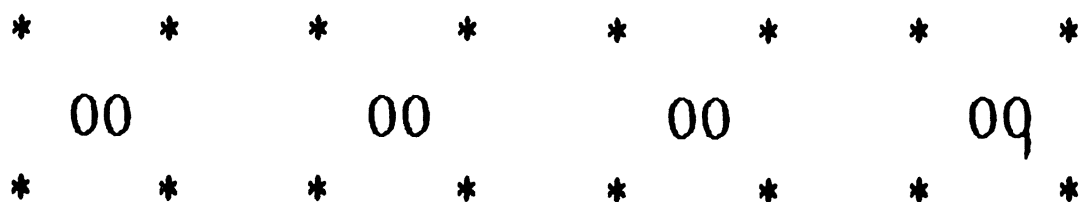
T6: CONTROL (NO NITROGEN)

PLACEMENT PATTERN OF USG

N DOSE : 76 Kg N/ha



TRAFFIC LINE



Legend: *=Rice hill, 0=USG 1gm granule

Fig 2

provision for irrigation and drainage channels. Soils were also collected by Augur boring upto 90 cm for determination of physico-chemical properties of soil.

Preparation of Nursery beds :

A plot of 10 X 5m size was prepared near the main plot for raising the rice seedlings. About 4 kg rice (cultivar Lalat) treated with seed treatment chemical Bavistin at the rate of 3g/kg of seeds was sprayed on a raised and well pulverised soil bed. The nursery bed was spread with water initially. When rice seedlings were 2-3 cm tall, a standing water of 1 cm was maintained in the field.

Transplanting of Rice in Main plot

Thirty days old rice seedlings (cultivar Lalat) were transplanted on 5th Aug.1994 at a spacing 20 X 15cm in treatments of T1 and T6. An alternate line spacing of 15 cm and 25 cm, and a plant spacing of 15 cm were followed for transplanting the rice seedlings in treatments T2, T3, T4, and T5 (Fig. 2) according to IFDC design (Anonymous 1990). It may be stated that these two types of spacing maintained the same plant population (i.e. 33 hills m^2). and the alternate line spacing of 25 cm served as traffic line for manual placement of USG in the field. A common dose of single super phosphate (@ 50 kg P_2O_5 /ha) and muriate of potash (@50 kg K_2O /ha) was applied to each plot.

The full dose of USG as 76 kg N/ha was point placed manually at 5cm soil depth at 0 DAT, 7 DAT, 14 DAT and 21 DAT for treatments T2, T3, T4 and T5, respectively. This was done by placing manually 2 USG (weighing approx. 1 g) at a soil depth of 5 cm in the centre of four hills. The prilled urea was broadcasted @ 76 kg N/ha in proportion of 1:2:1 at the time of transplanting, maximum tillering, and PI stage in treatment T1. No nitrogen fertilizer was applied in the control treatment, T6.

Intercultural operations :

A hand weeding at 21 DAT was done to suppress weed growth in the plots. Besides this, two sprayings with Demecron and Ekalux was done @ 200 ml/200 lit each at 30 DAT and 50 DAT in order to control the insects, pest diseases. No irrigation water was applied to the plot since the rainfall was sufficient during the crop growth. In each plot provision was made to spill out the water above 10 cm.

Biometric observation at harvest :

For biometric observation ten plants were selected from each plot and the yield attributing characteristics like plant height, panicle length, number of tillers per plant were recorded. In case of plant numbers, about 10 hills were selected at random for recording the plants per hill. At harvest a boarder strip of one line was left and the rest

This experiment was laid out during the same Kharif 1994 (Fig. 3) near the previous replicated trial to observe the effect of placement depth and the dose of N as USG on the grain yield of paddy and the movement of different forms of nitrogen ($\text{NH}_2\text{-N}$, $\text{NH}_4\text{-N}$, $\text{NO}_3\text{-N}$) in soil. The experiment consisted of six unreplicated plots of 2 X 2m each. Rice seedlings of thirty days old were transplanted at an alternate line spacing of 15 cm and 25 cm, and a plant spacing of 15 cm. Before transplanting a common fertilizer dose of P_2O_5 and K_2O @ 50 kg/ha each in the form of SSP and MOP was applied to each plot at the time of final puddling. The following treatments were allocated for the observation strips.

- T1 - 38 kg N/ha as USG at 2.5 cm soil depth.
T2 - 76 kg N/ha as USG at 2.5 cm soil depth.
T3 - 96 kg N/ha as USG at 2.5 cm soil depth.
T4 - 38 kg N/ha as USG at 5.0 cm soil depth.
T5 - 76 kg N/ha as USG at 5.0 cm soil depth.
T6 - 96 kg N/ha as USG at 5.0 cm soil depth.

LAYOUT OF OBSERVATION STRIP

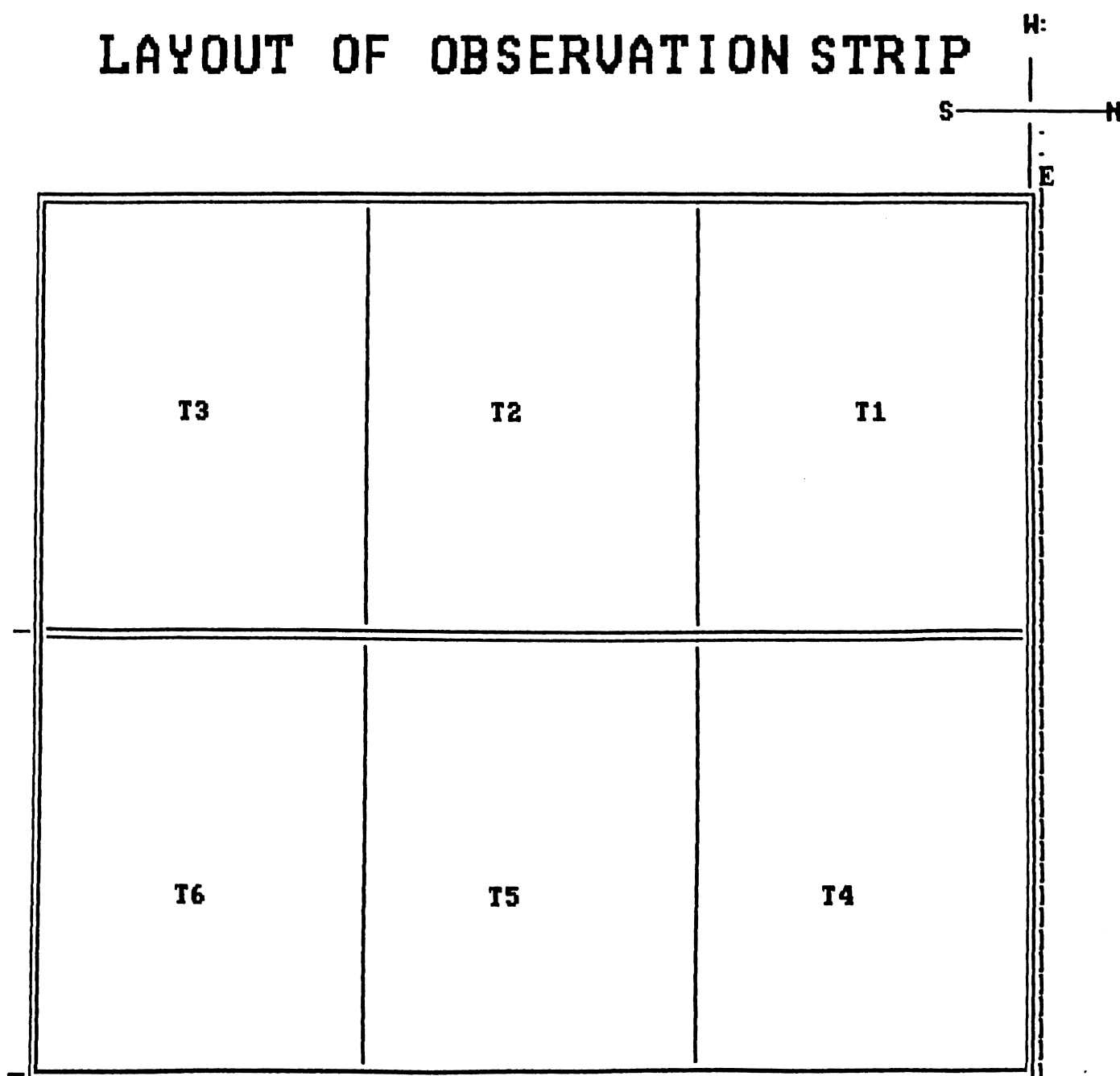


Fig 3

TREATMENTS:

- T1: 38 Kg N/ha AS USG AT 2.5CM(dp)
- T2: 76 Kg N/ha AS USG AT 2.5CM(dp)
- T3: 96 Kg N/ha AS USG AT 2.5CM(dp)
- T4: 38 Kg N/ha AS USG AT 5CM (dp)
- T5: 58 Kg N/ha AS USG AT 5CM (dp)
- T6: 76 Kg N/ha AS USG AT 5CM (dp)

The intercultural operations as well as the biometric observations as described for the replicated trial were also followed for this purpose. The crop was harvested on dated 5th Nov. 94.

3.1.4 Installation of soil solution sampler :

The PVC tubes of i.d. 2cm with ceramic cup at one end and a rubber cork at the other end (having provision for air entry) were used as soil solution sampler. Two days before application of fertilizers, two soil solution samplers at soil depths of 5 cm and 10 cm each were installed at a lateral distance of 5 cm, 10 cm, 15 cm each from the point of placement of USG in case of treatments T2, T3, T4 of first replication. The arrangement in the installation of soil solution samplers is shown in Photo plate 2. In case of treatment T1 (Urea application) only one soil solution sampler was installed at 5cm soil depth before two days of basal application of urea. In case of observation strip six soil solution samplers were installed in the same manner in each of four plots (T1, T3, T4, T6) receiving USG @ 38 kg N/ha and 96 kg N/ha. These soil solution samplers were used to monitor the changes in concentration of $\text{NH}_2\text{-N}$, $\text{NH}_4\text{-N}$ and $\text{NO}_3\text{-N}$ in the rice root zone. A syringe fitted to a narrow rubber tube of i.d 3mm was used to collect the soil solution samples periodically from the soil solution samplers.

3.1.5 Collection of floodwater samples and Soil solution samples

Both in the replicated trial and observation strip soil solution samples (5-7ml) were collected from the respective soil solution samplers with the help of the syringe at 0, 3, 6, 9, 12, 15, 18, 24, 30, 36, 42, 48, 60, 72, 96, 120 and 144 hours of urea/USG application (Photo plate 2). Simultaneously the floodwater samples were collected at each time from these plots. One to two drops of 50 ppm phenyl mercuric acetate (PMA) solution was added to each sample to inhibit microbial growth. These samples were then stored in the refrigerator at 5 C for analysis of $\text{NH}_2\text{-N}$, $\text{NH}_4\text{-N}$, and $\text{NO}_3\text{-N}$.

3.1.6 Collection of soil samples for $\text{NH}_2\text{-N}$ and $\text{NH}_4\text{-N}$ determination :

In case of observation strip the soil cores upto a soil depth of 10 cm were collected from each plot by inserting a PVC pipe (i.d. 6.5cm) at the site of placement of USG after 144 h. Each core was sliced into five pieces of 2 cm each. A portion of each slice containing approximately 10 gm of soil was treated with 100 ml of 2 m KCl-PMA extractable solution to determine the exchangeable $\text{NH}_4\text{-N}$ and $\text{NH}_2\text{-N}$ and the rest portion was used to determine the water content.



Photo Plate 2.

Collection of soil water samples.

3.1.7 Collection of plant samples for study of nitrogen uptake.

For determination of nitrogen content and uptake, the overground plant samples were collected from each plot of replicated and observation trials at tillering, P.I. and at harvest stages. These samples were oven dried at 60 C, ground by Willey mill through 50 mesh sieve and analyzed for total N content.

3.2 EXPERIMENTAL METHODS (PHYSICAL)

3.2.1 Bulk density (BD) :

Bulk density of the experimental soil was determined in each of treatment of replicated trial for one replication R_1 , taking two soil cores of 5 cm length from 0-5 cm and 5-10 cm depth. Brass cores of 5 cm were employed (Black 1965).

3.2.2 Particle size analysis :

Particle size analysis was done by means of hydrometer method (Piper, 1950).

3.3 EXPERIMENTAL METHOD (CHEMICAL)

3.3.1 Soil pH

The pH of the soil (1:2 ratio) was determined by means of glass electrode with the help of a Elico made digital pH meter.

3.3.2 Electrical Conductivity (EC)

The electrical conductivity of the soil water suspension (1:2 ratio) was determined by means of an Elico made conductivity bridge.

3.3.3 Cation Exchange Capacity (CEC)

Cation exchange capacity of the soil was determined by the method described in "Soil chemical Analysis" (Black, 1965).

3.3.4 Organic Carbon

Organic carbon content of the soil was determined by walkley and Black and rapid titrtation method following Jackson (1973).

3.3.5 Available Phosphors^{ov}

The available P content of the soil was determined following Olsen's method employment NaHCO_3 extractant buffered at pH 8.2 (Jackson 1973).

3.3.6 Available Nitrogen of Soil

Available nitrogen content of soil was determined by alkaline potassium permanganet method (Subia and Asija).

3.3.7 Nitrogen content in plant sample was determine following the method outlined in AoAc (1970). The results were expressed on oven dry basis (60 C).

3.3.8 Preparation of soil samples for determination of $\text{NH}_2\text{-N}$ and $\text{NH}_4\text{-N}$:

Immediately ~~qffer~~^t collection from the field or laboratory, soil samples weighing 20 gm each were taken in 250 ml conical flasks containing 200 ml 2M KCl-PMA solution. Then the flasks were shaken by a mechanical shaker (International make) for one hour. The suspensions were then filtered through a Whatman No.1 filter paper. These filtrate samples were stored in refrigeration at 5 °C for analyses of $\text{NH}_2\text{-N}$ and $\text{NH}_4\text{-N}$ as per procedure described below.

3.3.8.1 Determination of $\text{NH}_2\text{-N}$:

The content of $\text{NH}_2\text{-N}$ of KCl Extract/ Soil solution/ flood water/ leachate was determined colorimetrically following modified diacetyl monoxime method (Mulraney and Breonner 1979) as given below. (Page 1982)

Reagents :

- A. Acid reagent : To prepare 1 lit acid reagent 20 ml H_2SO_4 was added to 500 ml H_3PO_4 and the final volume was made up with water.
- B. DAM (Di acetyl monoxime) solution. 2.5 gm of DAM was dissolved in 100 ml water.
- C. TSC (Thiosemicarbazide) : 0.25 gm of TSC was dissolved in 100 ml water.

- D. Colour reagent : It was prepared just before use by adding 25 cc DAM and 15 cc TSC to acid reagent, the final volume should be made up to 500 cc with acid reagent.
- E. 5 ppm-PMA solution : 50 mg phenyl mercuric acetate (PMA) was dissolved in 1 lit water to give 50 ppm-PMA solution and 100 ml of 50 ppm-PMA solution was diluted to 1 lit to give 5 ppm-PMA solution.
- F. Standard $\text{NH}_2\text{-N}$ (Urea-N) Solution of 100 PPM strength.

Exactly 214.3 mg of laboratory reagent urea (oven dried at 30°C and cooled in a desiccator) was dissolved in 5 ppm-PMA solution and the volume was adjusted to one litre.

Procedure :

2 cc of water sample was taken in a 50 cc volumetric flask and to it 8 cc of 5 ppm-PMA solution was added. Then 30 cc of colour reagent was added to it. The flask was heated at 84°C in a water bath for 30 min for colour development. It was then cooled under running water at 12-15°C for 10 min. Then the volume was adjusted to 50 cc by distilled water and the colorimetric reading was taken by Klett-Summerson Photo-electric colorimeter through a green filter (No 54 i.e. at a wave length of 527 nm).

In case of analysis of $\text{NH}_2\text{-N}$ from KCl extract of soil sample, 8cc of 2 M KCl-PMA was used instead of 5 ppm-PMA solution.

Preparation of standard :

For analysis of $\text{NH}_2\text{-N}$ from water samples standard graph was prepared from the primary stock solution of 100 ppm of urea-N. The secondary solution of 10 ppm $\text{NH}_2\text{-N}$ was prepared by diluting 10 ml of primary solution to 100 ml by 5ppm-PMA solution. Then 0 cc, 1 cc, 2 cc, 3 cc, 4 cc, 5 cc of 10 PPM $\text{NH}_2\text{-N}$ standard solutions were diluted to 10 cc by adding 5 PPM PMA solution. For KCl extract $\text{NH}_2\text{-N}$ analysis, the standard solution were prepared by diluting with 2 M KCl-PMA solution instead of 5 ppm-PMA solution before addition of colour reagent.

3.3.8.2 Estimation of $\text{NH}_4\text{-N}$ in KCl-PMA Extract

The determination of $\text{NH}_4\text{-N}$ from the KCl-PMA extract was used by distillation method following the procedure described by Black (1965).

3.3.8.3 Determination of $\text{NH}_4\text{-N}$ in flood water/Soil solution/ leachate :

The content of $\text{NH}_4\text{-N}$ in flood water/soil solution/ leachate was determined Colorimetrically by Indophenol blue method (Dorich and Nelson, 1983) as per the following procedure.

Reagents :

- A. Standard ammonium solution : 0.1417 gm of dry, reagent grade $(\text{NH}_4)_2 \text{SO}_4$ was dissolved in water and diluted to a volume of 1 litre to give 100 ppm of $\text{NH}_4\text{-N}$. This solution was stored in a refrigerator. Immediately before use, the secondary solution of 10 ppm was prepared by diluting, 10 ml of the stock 100 ppm $\text{NH}_4\text{-N}$ solution to 100 ml.
- B. Phenol - Nitroprusside reagent : 7 gm of phenol and 34 mg of $\text{Na}_2 \text{Fe}(\text{CN})_5 \text{NO} \cdot 2\text{H}_2\text{O}$ were dissolved in 80 ml of $\text{NH}_4\text{-free}$ water and diluted to 100 ml. This was mixed well in a dark coloured air tight bottle and stored in a refrigerator.
- C. Buffered hypochlorite reagent : 1.48 gm of NaOH was dissolved in 70 ml of NH_4 free water. Then 4.98 g of sodium monohydrogen phosphate (Na_2HPO_4) and 20 ml of sodium hypochlorite (5% NaOCl) solution were added to it. The pH of the solution was adjusted in between 11.4 and 12.0 by adding few drops of NaOH if necessary and then diluted to a final volume of 100 ml.
- D. Ethylenediaminetetra acetic acid (EDTA) reagent : 6 gm of disodium EDTA was dissolved in 80 ml of distilled water. The pH of the solution was adjusted to 7.0 and then diluted to a final volume of 100 ml.

Procedure :

2 cc of the aliquot was pipetted into a 50 cc volumetric flask. 1 cc of EDTA reagent was added to it and mixed thoroughly. The mixture was allowed to stand for 2 minutes. To the mixture, 2 cc of phenol nitroprusside reagent followed by 4 cc of buffered hypochlorite reagent was added and then diluted immediately with NH_4 free water to 50 cc. The contents of the flask mixed thoroughly by inverting several times. The flasks were kept in a water bath maintained at 40 C for 30 minutes for colour development. Then the flasks were removed from the waterbath and cooled to room temperature. The absorbance of the coloured complex was determined at a wave length of 636 nm against the reagent blank solution.

The NH_4 -N concentration of the sample was determined with reference to a standard graph of NH_4 -N. To prepare the standard graph aliquotes of 0, 0.5, 1, 2, 3, 4, 5 ml of 10 PPM NH_4 -N solution were taken in a 50 ml volumetric flask to get 0, 0.1, 0.2, 0.4, 0.6, 0.8, 0.8, 1.0 ppm NH_4 -N. The reagents were added to them as was used for the samples.

3.3.8.4 : Determination of NO_3 -N in flood water/soil solution/ leachate :

About 1 to 2 ml of soil solution/ flood water/ leachate was used to determine NO_3 -N Colorimetrically by 2,4-phenol disulfonic acid method (Jackson 1973).

3.3.9 Nitrogen use efficiency parameters :

Three nitrogen use efficiency parameters were used in this study :

(1) Agronomic efficiency (NUE)/grain yield response.

$$A.E.\% = \frac{Y_T - Y_O}{N_F}$$

Where Y_T = Yield in treatment (kg/ha)

Y_O = Yield in Control (kg/ha)

N_F = N supplied by fertilizer (kg/ha)

(2) Relative efficiency :

$$R.E.(%) = \frac{Y_T - Y_O}{Y_S - Y_O} \times 100$$

Where Y_S = Yield in Standard source (kg/ha)

$$(3) \text{ Apparent N recovery (ANR) \%} = \frac{U_T - U_O}{N_F} \times 100$$

Where U_T = N uptake in treatment (kg/ha)

U_O = N uptake in control (kg/ha)

N_F = N supplied by fertilizer (kg/ha).

CHAPTER IV

RESULTS AND DISCUSSION

RESULTS AND DISCUSSION

In order to meet the objectives spelt out in the previous chapter, a column study and a field study was carried out in the medium land soils of the central farm of Orissa University of Agriculture and Technology, Bhubaneswar. The climatological data like rainfall, evaporation, air temperature, relative humidity during the field experiment from July to November are presented in the appendices from II to VI.

During the crop growth, the rainfall was 1183mm and the evapotranspiration was about 498mm. Although the high rainfall was observed from July to September, the crop remained unaffected due to flooding, though the adjacent lowlying area remained submerged in water for one day at least. Due to high rainfall no irrigation water was applied to crop.

4.1 THE PHYSICO-CHEMICAL PROPERTIES OF THE SOIL :

The physico-chemical properties of the soil profile in which the present experiment was carried out were determined. The salient features of the soil properties are presented in Table 1. The texture of the soil was sandy loam upto soil depth of 30 cm, sandy clay loam from 30 to 75 cm and

Table 1 PHYSICAL AND CHEMICAL PROPERTIES OF THE SOIL AT THE EXPERIMENTAL SITE.

Properties	Soil Depth (cm)						
	0-15	15-30	30-45	45-60	60-75	75-90	90-105
Sand (%)	73.8	71.8	63.8	68.4	47.8	55.8	55.8
Silt (%)	14.0	14.0	12.0	5.2	18.0	8.0	8.0
Clay (%)	12.2	14.2	24.2	26.4	34.2	36.2	36.2
*Texture	Sl	Sl	Sc1	Sc1	Sc1	Sc	Sc
BD (g cm ⁻³)	1.67	1.81	-	-	-	-	-
*Steady State infiltration rate:	0.67 cm/h						
pH	6.8	7.2	7.3	7.4	7.5	-	-
EC (dsm-1)	0.10	0.18	0.25	-	0.12	-	-
OC (%)	0.31	0.27	0.20	0.16	-	-	-
*Total N (kg/ha)	855	817	899	932	-	-	-
*Available P ₂ O ₅ (kg/ha)	28	13	10	7	-	-	-
*Available K ₂ O (kg/ha)	212	-	-	-	-	-	-
*CEC (Cmol P+Kg-1)	5.0	5.0	7.1	11.8	14.4		

* Kalikinkar Bondyopadhyay MSc (Ag) Thesis 1992

sandy clay upto 105 cm soil depth. The bulk density of the soil varied from 1.6 to 1.8 gm/cm having the maximum value in the plough sole layer.

The soil reaction was about neutral throughout the profile. The soils were free from toxic ions. The organic carbon content was low and decreased with depth. The CEC of the soil ranged from 5 to 18 cmol p^+ /kg and increased with depth with increasing clay content. Based on available nutrient indices the soil was found to be very low with respect to N, high with respect to available P_2O_5 , and medium with respect to available K_2O .

Based on these characteristics and other morphological features of the profile the soil in the medium land site of the Central Research Station has been classified to be a member of fine loamy mixed hyperthermic family of haplaquept.

4.2 COLUMN STUDY :

The soil collected from 0-15 cm soil depth from the site in which the field experiment was to be conducted has been used to conduct the leaching of Urea super granule (USG) in a soil column.

The physical parameters describing ~~the~~ the leaching of the USG are presented in the table 2. The USG containing 395.784 mg of $\text{NH}_2\text{-N}$ was displaced with 0.02 N CaSO_4 solution at a flow rate of $7.7 \text{ cm}^3/\text{h}$. Leachates collected at different time intervals were analyzed for $\text{NH}_2\text{-N}$, $\text{HN}_4\text{-N}$ and $\text{NO}_3\text{-N}$.

4.2.1 Leaching of $\text{NH}_2\text{-N}$:

The Breakthrough curve (BTC) of $\text{NH}_2\text{-N}$ in the effluents is presented in Fig. 4 and Appendix VII. The solid line was drawn as per the HPG computer graphic method. It is observed that at a soil depth of 9 cm the $\text{NH}_2\text{-N}$ appeared at 11 h and reached at its maximum concentration of 2300 mg/L during 25-29 h. Thereafter the concentration of $\text{NH}_2\text{-N}$ in the leachate decreased and appeared to be negligible at 42 h of leaching. This shows that the $\text{NH}_2\text{-N}$ took about 42 hours to leach down a soil depth of 9 cm. The amount of $\text{NH}_2\text{-N}$ in the leachate was computed by integrating the area under the $\text{NH}_2\text{-N}$ BTC (Fig. 4) by using the following equation.

$$N = \frac{J.A. \sum_{i=0}^T C_i t_i}{1000} \dots\dots(1)$$

Where N is the amount (mg) of Nitrogen leached down.
 J is the soil water flux (cm/h)
 A is the cross sectional area of the column. (cm^2)
 C_i is the concentration (mg/L) of $\text{NH}_2\text{-N}$ in the leachate in time, t_i and
 T is the total leaching period in hour.

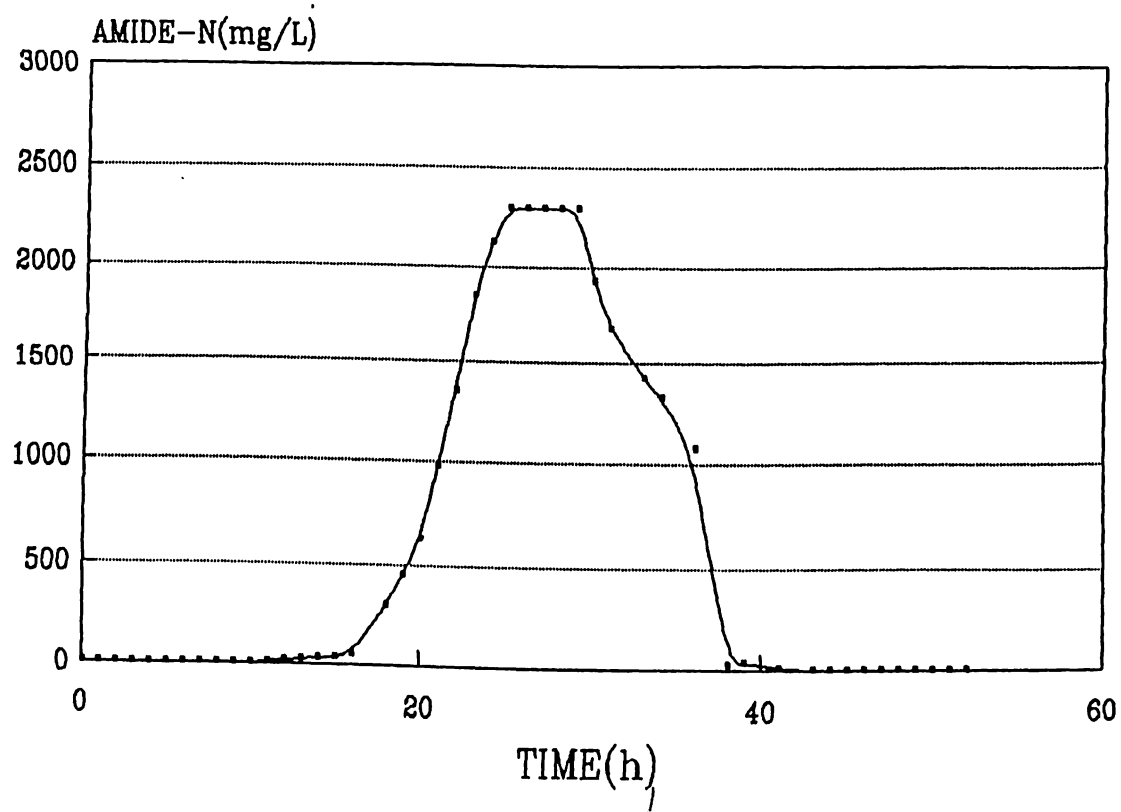


Fig4 BTC of Amide-N stemming
from USG placement in soil column

The term $\sum_{i=0}^T C_i t_i$ in the above equation (1) indicates the area under BTC curve in Fig. 4. By integrating the area under the BTC curve in Fig. 4, it was estimated that the amount of $\text{NH}_2\text{-N}$ leached down was 210.362 mg out of 395.784 mg of N applied in form of USG at soil surface. This shows that about 53.15% of the applied N from USG has been leached down during 42 h of leaching and the balance amount (46.85%) has been either retained in soil or transformed to some other form.

The velocity of $\text{NH}_2\text{-N}$ was computed by deviding the mean time at which the Urea-N attained the peak concentration with the soil depth as per the following equation.

$$V_u = \frac{Z}{t_m} \quad \dots\dots (2)$$

Where V_u is the velocity (cm h^{-1}) of $\text{NH}_2\text{-N}$
 Z is the soil depth (cm) and
 t_m is the mean resident time (h) at which the maximum concentration of $\text{NH}_2\text{-N}$ appeared in the leachate.

Since the BTC of $\text{NH}_2\text{-N}$ appeared to be bell shaped, the mean resident time was taken as the mean time at which the concentration of $\text{NH}_2\text{-N}$ appeared to be maximum in the effluent (Fig. 4). Thus the velocity of $\text{NH}_2\text{-N}$ was computed to be 0.328 cm/h. The velocity of soil water was computed by deviding the

soil water flux with average volumetric water content of the soil column and was found to be 0.404 cm/h. This shows that $\text{NH}_2\text{-N}$ was displaced at a slightly slower rate than the soil water. It may be presumed that during the transport, the $\text{NH}_2\text{-N}$ gets weakly adsorbed on the sorbed phase and thus delayed the appearance of BTC. Working with the Maahas clay Savant and De Datta (1979) also observed that the $\text{NH}_2\text{-N}$ gets weakly adsorbed while moving through the soil.

The rate of Urea hydrolysis was computed by using the following equation:

$$C_u/C_o = e^{-k_u t_m} \quad \text{..... (3)}$$

Where C_u/C_o indicates the fraction of $\text{HN}_2\text{-N}$ leached down in soil,

t_m the mean resident time and

k_u the rate constant for USG hydrolysis.

The value of the USG hydrolysis rate constant (k_u) was found to be 0.023/h at a temperature of 27.5 $\pm$ 1.5 C for a mean resident time of 27.44 h by assuming first order rate Kinetics. Houngrayoon et al. (1991) had determined the urea hydrolysis rate constants varying from 0.036/h to 0.288/h for Crowley silt loam soil when soil columns were incubated with an urea solution (750 mg N/L) at a temperature of 30 C under

flooded condition. Working with the soil in which present experiment is conducted, Khanda (1985) determined the urea hydrolysis rate constants to be 0.038, 0.068, 0.14/h at a temperature 24 C, 29 C and 35 C under incubation study. The urea hydrolysis rate constant was to be of the first order reaction. Further leaching a solution pulse of urea in the soil column, he has reported the values of urea hydrolysis rate constant to vary from 0.018/h to 0.086/h at 30.5 C. While the presence of sucrose increased the urea hydrolysis rate, neem cake and PMA solution along with urea solution appeared to depress the urea hydrolysis rate constant. From a laboratory incubation study Sahu (1993) observed that the urea hydrolysis rate had appeared to obey a first order rate constant for this soil. The rate constants of urea hydrolysis were 0.0023/h for the sterilised water, distilled water and flood water systems and 0.025/h for the aqueous phase of soil system at a temperature of 25 C.

The rate constant of USG hydrolysis (0.023/h) estimated in the present case during leaching appeared to be a little less than that reported by Houngrayoon et al. (1991) and Sahu (1993) under incubation study. Even the rate in the present study appeared to be less than value (0.079/h at a temperature of 30.5 C) determined by displacing a solution pulse of urea through soil column (Khanda 1985). This shows that urease activity is reduced to one third when USG is

applied in the form of granule even on the soil surface in place of urea.

4.2.2 Leaching of Ammonium-N ($\text{NH}_4\text{-N}$) :

The BTC of $\text{NH}_4\text{-N}$ for the leachate fractions collected at a depth of 9 cm soil column is presented in Fig.5 and Appendix VII. This solid lines are drawn by using the HPG computer graphic method. It has been observed that the $\text{NH}_4\text{-N}$ was found to be negligible upto 10 h and thereafter the concentration of $\text{NH}_4\text{-N}$ in the leachate has been increasing with time upto 126 h. It has been found to be much less than that of $\text{NH}_2\text{-N}$ at any time. However, the $\text{NH}_4\text{-N}$ was appeared in the leachate at the same time as it found in case of $\text{NH}_2\text{-N}$. This shows that USG hydrolysis was started soon after its dissolution in soil water. The recovery of $\text{NH}_4\text{-N}$ in the leachate fractions was calculated (equation - 1) by integrating the area under the BTC of $\text{NH}_4\text{-N}$ in Fig. 5 and was found to be 1.64% of the applied N (Table 6) for a period of 126 h. This shows that a small amount of $\text{NH}_4\text{-N}$ is found in the leachate fractions. Had the experiment been continued, the leaching of $\text{NH}_4\text{-N}$ on account of USG hydrolysis would have been more than this amount (1.648%).

The effluents collected were also analyzed for $\text{NO}_3\text{-N}$. It was observed that the concentration of $\text{NO}_3\text{-N}$ was negligible. So the BTC of $\text{NO}_3\text{-N}$ is not presented here. But

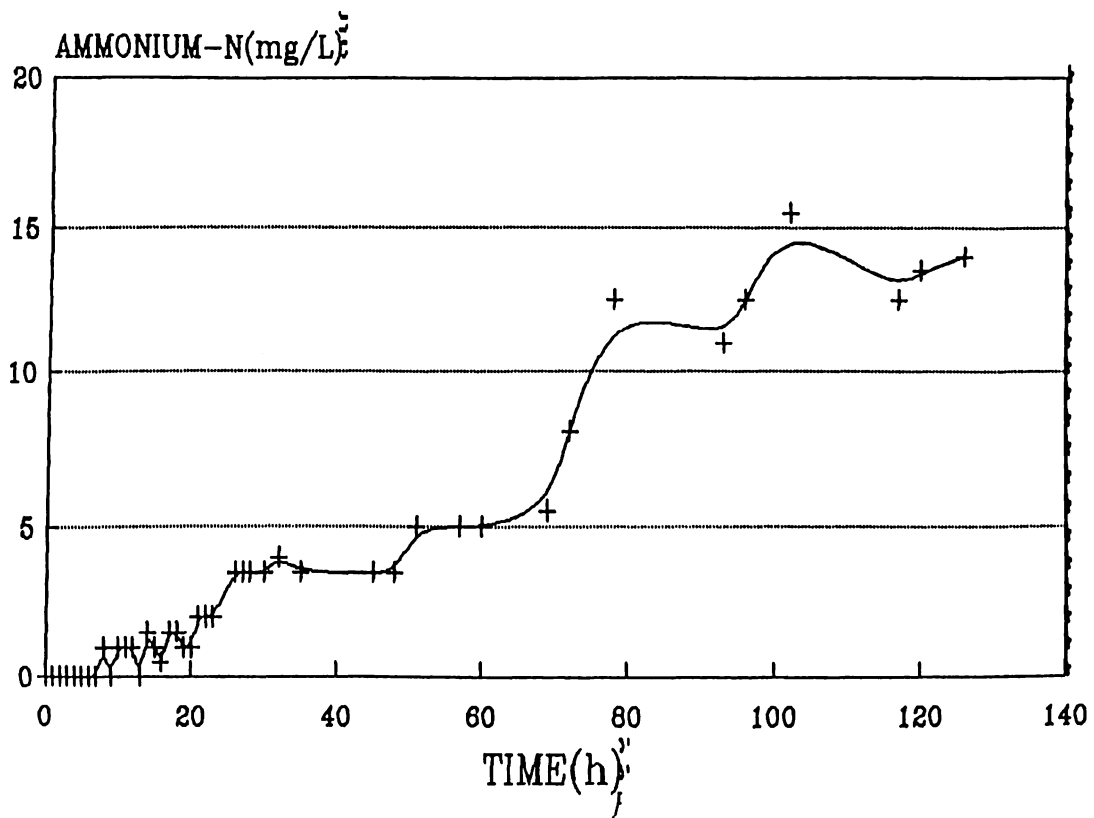


Fig 5 BTC of Ammonium-N stemming from USG placement in soil column

this shows that the rate of nitrification, if at all, is either very slow or the rate is less than that of the nitrate reduction. Working with the upland soil of central farm, (OUAT), Bhubaneswar, Misra and Mishra(1988) observed that no $\text{NO}_3\text{-N}$ was detected in the effluents of the column when different solution pulses of ammonium salts were leached through the soil columns because of low rate of nitrification. This may be true for leaching of USG in the soil.

4.2.3 Sorption of Nitrogen :

After leaching for 126 h the soil column was cut into different slices of 1.5 cm thick each. The water extract and KCL extract of $\text{NH}_2\text{-N}$, $\text{NH}_4\text{-N}$ and $\text{NO}_3\text{-N}$ were determined and presented in Table 3, 4 and 5.

The content of $\text{NH}_2\text{-N}$ in the soil solution varied from 1-5 mg/L (Table 3) whereas its content in the exchangeable phase was determined to be negligible. This shows that sorption of $\text{NH}_2\text{-N}$, if any, happened for a short period in this soil and therefore, $\text{NH}_2\text{-N}$ had moved more or less at the same rate as that of the soil solution (Water).

The amount of $\text{NH}_4\text{-N}$ (Table 4) in the soil solution after 126 h of leaching was found to vary from 0.486 to 0.849 mg/unit layer. The amount of soluble $\text{NH}_4\text{-N}$ was found to increase with column length upto 7.5 cm. (Fig. 6). The

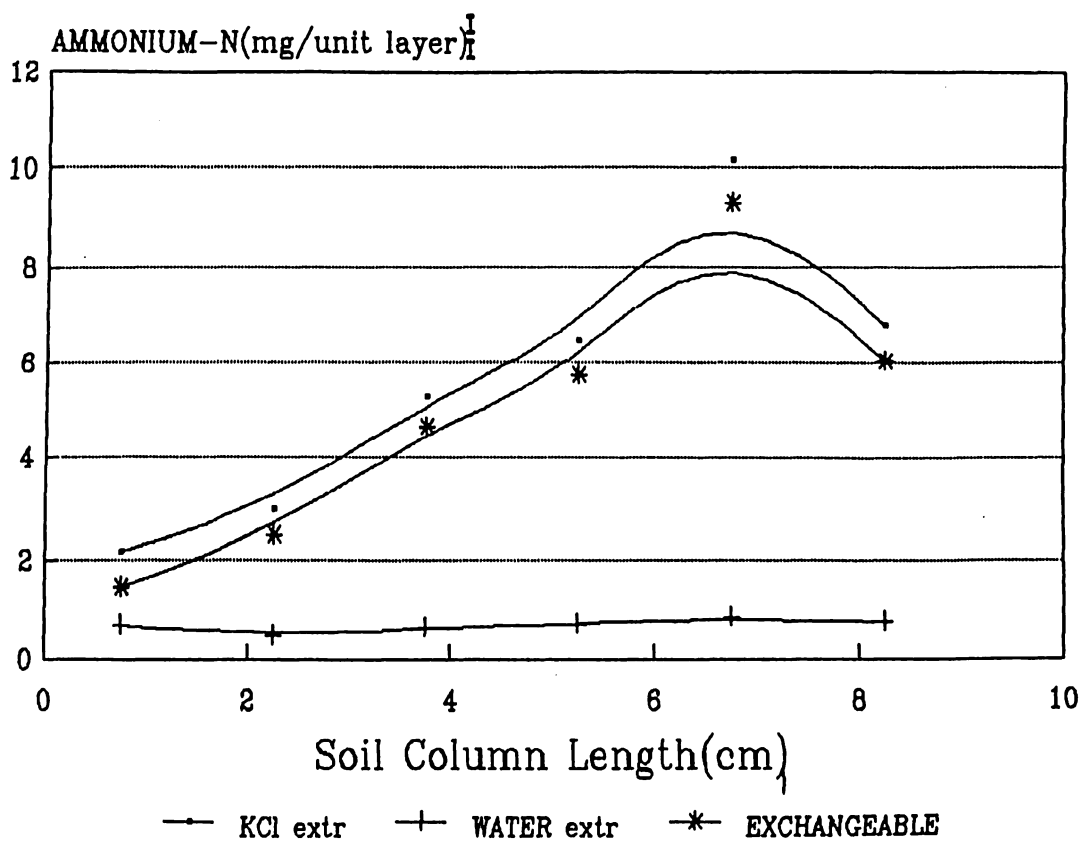


Fig6 Spatial distribution of
Ammonium-N during miscible
displacement of USG in soil column

exchangeable $\text{NH}_4\text{-N}$ was computed by deducting the soluble $\text{NH}_4\text{-N}$ from the 2M KCl-PMA extractable $\text{NH}_4\text{-N}$. It varied from 1.448 to 9.291 mg/unit layer throughout the soil column. Like that of soluble $\text{NH}_4\text{-N}$ the content of exchangeable $\text{NH}_4\text{-N}$ was found to increase with depth (Table 4). Again, the content of exchangeable $\text{NH}_4\text{-N}$ in each layer was found to be more than the soluble $\text{NH}_4\text{-N}$. By adding contents of $\text{NH}_4\text{-N}$ in each layer, it has been estimated that about 10.16% of applied $\text{NH}_2\text{-N}$ was retained as soluble and exchangeable $\text{NH}_4\text{-N}$ in soil even after leaching for 126 h.

The content of $\text{NO}_3\text{-N}$ in the water extract is presented in table 5. The concentration of $\text{NO}_3\text{-N}$ in the solution phase was found to be maximum in the top layer and below it the concentration of $\text{NO}_3\text{-N}$ was less. This shows that rate of nitrification, although slow, was confined in top layer. Quantitatively, the amount of $\text{NO}_3\text{-N}$ in the soil layer after leaching was estimated to be 1.044 mg (Table 5) and was 0.264% of added $\text{NH}_2\text{-N}$. Thus a very small fraction of the added $\text{NH}_2\text{-N}$ was found to remain as $\text{NO}_3\text{-N}$ in soil.

4.2.4 Nitrogen Balance :

The various component of Nitrogen in soil stemming from the leaching of USG surface placement for 126 h are presented in Table-6. Among the three forms, the $\text{NH}_2\text{-N}$ and $\text{NH}_4\text{-N}$ were leached down the soil to an extent of 54.79% of the

Table 2 PHYSICAL PARAMETERS FOR LEACHING OF USG IN SOIL COLUMN

Physical Parameters

Column length	9.0 cm
Cross Sectional area	50.24 cm ²
Bulk density	1.60 g/cm ³
Volumetric water content	37.94 cm ³ cm ⁻³
Depth of Standing water	1.0 cm
Discharge rate	7.7 cm ³ /h
Temperature	27.5 1.5 C
Amount of USG Nitrogen applied	395.784 mg
Velocity of water	0.404 cm/h
Velocity of NH ₂ -N	0.328 cm/h
Percentage of NH ₂ -N in the leachate	53.2
Percentage of NH ₄ -N in the leachate	1.6
NO ₃ -N in the leachate	nil
USG hydrolysis rate constant	0.023 h ⁻¹

TABLE 3 : SPATIAL DISTRIBUTION OF NH₂-N STEMMING FROM LEACHING OF USG (SURFACE PLACEMENT) IN SOIL COLUMN.

Soil Column Length (cm)	Gravimetric water content (%)	KCl-Extractable NH ₂ -N (mg/100 dry Soil)	Water Extractable NH ₂ -N (mg/L)	KCl-Extractable NH ₂ -N (mg/Unit layer)	Soluble NH ₂ -N (mg/Unit layer)
0-1.5	27.35	Nil	2.25	Nil	0.074
1.5-3.0	25.23	Nil	1.25	Nil	0.038
3.0-4.5	22.37	Nil	2.25	Nil	0.061
4.5-6.0	21.57	Nil	1.00	Nil	0.026
6.0-7.5	22.36	Nil	2.00	Nil	0.054
7.5-9.0	23.40	Nil	5.50	Nil	0.155
TOTAL					0.408

Table 4 Spatial distribution of Ammonium-N stemming from leaching of USG surface placement in soil column.

Soil Column Sength (cm)	Gravi- metric water content %	KCl Extract- able $\text{NH}_4\text{-N}$ mg/100g dry soil	KCl Extract- able $\text{NH}_4\text{-N}$ (mg/l)	Water Extrout $\text{NH}_4\text{-N}$ mg/l	Exchange- able $\text{NH}_4\text{-N}$ (mg/l)	KCl Extract-able $\text{NH}_4\text{-N}$ mg/ Unit layer	Soluble $\text{NH}_4\text{-N}$ mg/Unit layer	Exchavge- able $\text{NH}_4\text{-N}$ mg/Unit layery
0-1.5	27.35	1.776	64.94	21.0	43.94	2.141	0.693	1.448
1.5-3.0	25.23	2.460	97.50	16.00	81.50	2.966	0.486	2.480
3.-4.5	22.37	4.356	194.73	24.0	170.73	5.253	0.647	4.606
4.5-60.	21.57	5.350	248.03	28.0	220.03	6.451	0.728	5.723
6.0-7.5	22.36	8.409	376.07	31.5	334.54	10.140	0.849	9.291
7.5-9.0	23.40	5.620	240.17	27.0	213.17	6.777	0.762	6.015
TOTAL						33.728	4.165	29.5

TABLE 5 SPATIAL DISTRIBUTION OF NITRATE-N STEMMING FROM LEACHING OF
USG (SURFACE PLACEMENT) IN SOIL COLUMN.

Soil Column Length (Cm)	Gravimetric Water Content(%)	Water Extract NO ₃ -N (mg/L)	Soluble NO ₃ -N (mg/unit layer)
0-1.5	27.35	14.29	0.471
1.5-3.0	25.23	4.00	0.122
3.0-4.5	22.37	4.0	0.122
4.5-6.0	21.57	4.8	0.128
6.0-7.5	22.36	2.1	0.060
7.5-9.0	23.40	5.0	0.141
TOTAL			1.044

TABLE 6 VARIOUS FORMS OF NITROGEN (%) STEMMING FROM LECHING OF USG
SURFACE PLACEMENT.

Components of Nitrogen	Leachate (%)	Exchangeable form (%)	Solution phase leaching (%)	TOTAL
NH ₂ -N	53.15	Nil	0.103	53.253
NH ₄ -N	1.64	7.47	1.050	10.160
NO ₃ -N	Nil	Nil	0.264	0.264
TOTAL	54.79	7.47	1.417	63.677

applied nitrogen and the dominant ion was found to be $\text{NH}_2\text{-N}$. Since the $\text{NH}_2\text{-N}$ content in the soluble phase as well as in the exchangeable phase was found to be very small, it is presumed that a major fraction (47%) of applied USG was hydrolyzed to $\text{NH}_4\text{-N}$ during leaching. The contents of $\text{NH}_4\text{-N}$ in the solution as well as in the sorbed phase were found to be 1 and 7%, respectively. This amounts to 10% of the applied nitrogen including the $\text{NH}_4\text{-N}$ leached down through the leachate. It is also seen that the $\text{NO}_3\text{-N}$ in the leachate as well as in the soil after leaching was very small. This shows that the nitrification has occurred to a small extent and major fraction (37%) of the hydrolyzed $\text{NH}_4\text{-N}$ has remained unaccounted in the soil. It has been reported by Sahu (1993) that about 5% of the applied $\text{NH}_2\text{-N}$ from urea was lost from this soil by way of ammonia volatilisation. Since major fraction of the hydrolyzed ammonium remains in the exchangeable form in the soil column it is presumed that a part of the $\text{NH}_4\text{-N}$ which is not accounted for, was fixed in the interlayers of the soil. Further work is warranted to determine the fraction of $\text{NH}_4\text{-N}$ fixed in the soil during displacement of USG.

4.2.5 Ammonium Equilibrium :

The relationship between the concentrations of $\text{NH}_4\text{-N}$ in soil solution with that present in the adsorbed form during leaching of USG in soil column is presented in Fig. 7 and

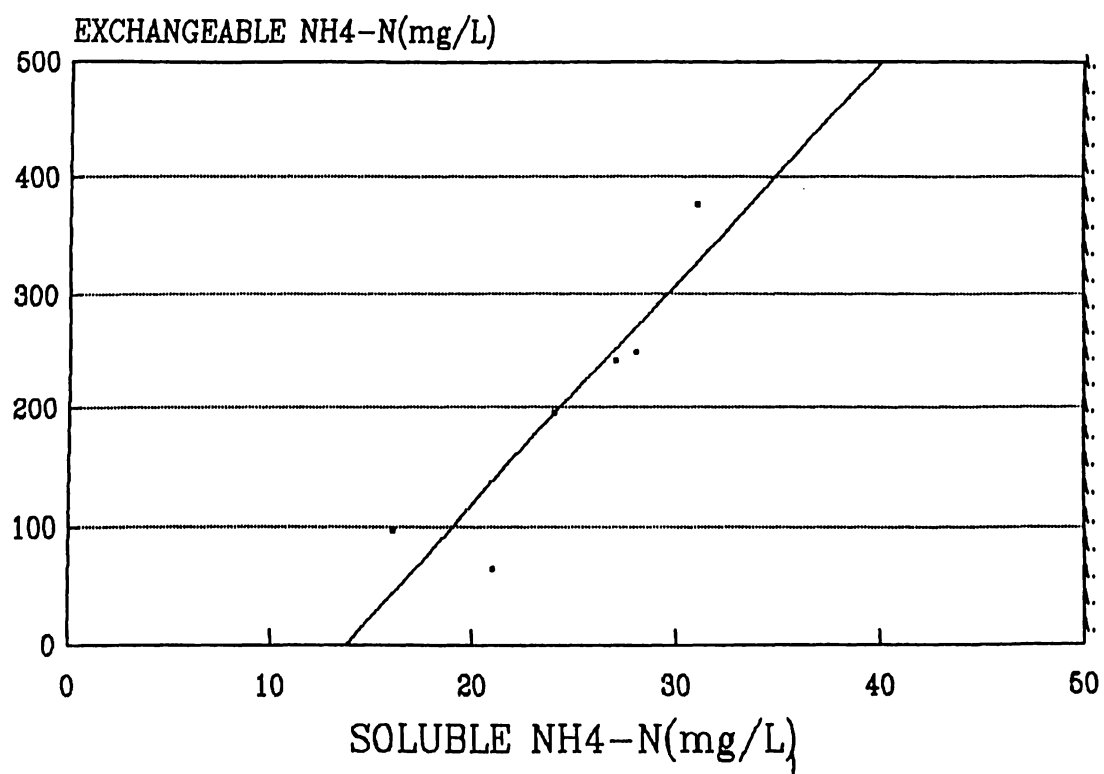


Fig 7 Ammonium sorption during
miscible displacement of USG
in soil column

Table 4. The relationship between the two phases appears to be linear with co-relation coefficient (r^2) of 0.825. In order to describe the relation a modified form of freundilich model is proposed by using the following equation.

$$S = S' + R C^{1/m} \quad \text{.....(4)}$$

Where S is the $\text{NH}_4\text{-N}$ (mg/unit volume) in the sorbed phase,
 S' is the intercept of adsorption equilibrium line,
 R represents the NH_4 distribution coefficient and
 C is the concentrastion of $\text{NH}_4\text{-N}$ (mg/unit soil layer)
 in soil solution. In eq. (4) m is a constant.

Assuming the value of $m=1$, the value of R was estimated to be 17.5 (Fig. 7). Using the Bhubaneswar upland soils, Mishra and Misra (1988) determined the value of $\text{NH}_4\text{-N}$ distribution coefficient to be 2.0 under incubation study. Further, Mishra and Misra (loc cited) while leaching a solution pulse of ammonium nitrate under limed condition, determined the value of R to be 0.5 by Curve-fitting the ammonium BTC. The value of R (17.5) determined in the present study appears to be more than the value of R ($=0.5$) of Mishra and Misra (1988). Since the displacement of USG was carried out at a slower rate, the probability of $\text{NH}_4\text{-N}$ sorption was expected to be high in the present case. Further, the value of S' was estimated to be -246.5. It shows that a high concentration of $\text{NH}_4\text{-N}$ is maintained in soil solution before

being adsorbed in initially ca-saturated soil. Once calcium is displaced, the rate of sorption of $\text{NH}_4\text{-N}$ appears to be high in medium land soil.

4.3 FIELD EXPERIMENT

4.3.1 Time of USG placement :

During kharif 1994 a field experiment was laid out (Fig. 1) in the medium land of the central farm, OUAT so as to evaluate the time of USG placement for kharif rice. It was a randomised block design with four replications and six treatments including control.

4.3.1.1 Grain and straw yield of kharif rice :

The grain yields (on the basis sun drying for 2-3 days) of rice (cv. Lalat) are presented in table 7, Photo plate 3,4 & 5 presents the photograph of the grain production under different treatments. The mean grain yield of rice varied from 31.73 q/ha without application of N to 43.88 q/ha with USG placement at 14 DAT. The computed CD value of the grain at the 5% level of probability for treatments was found to be 4.28 q/ha with a coefficient of variation of 7.44%. Replication was computed to be significant. Thus the heterogeneity of soil has been properly taken care of while planning the field experiment. The mean grain yield of rice treated either with PU or with USG had significant difference over the control (Without fertiliser application). Again there



Photo Plate 3. Standing rice crop.



Photo Plate 4. Standing rice crop.



Photo Plate 5. Standing rice crop. ;

was not much difference in the yields of rice for application of PU in splits (T₁) and the placement of USG at 21 DAT (T₅). This shows that placement of USG at 21 DAT was as good as split application of PU. But when USG was applied earlier, the yields of rice grain (T₂, T₃, and T₄) were increased ~~in~~ incomparison to that due to application of PU. The maximum as well as significant yield of rice was obtained when USG was applied at 14 DAT (T₄). This shows that placement of USG at 14 DAT appears to be the best time for increasing the productivity of the crop when it is deep placed @ 76 kg N/ha. Since this is the first year of the experiment, the findings of this trial need further investigation. Working with alluvial silty loam soil Rao et al. (1989) observed that the USG could be applied at any time upto 21 DAT without any sacrifice in yield for a long duration variety of Kharif Rice and a short duration variety of Rabi Rice. A similar finding has also been observed in the present case.

The mean straw yield listed in table 8 presents almost a comparable picture with that obtainable in grain yield data. Application of fertilizers has increased straw yield from 33.9 g/ha (without applying fertiliser) to 47.48 q/ha. This shows that the application of N fertilizer has increased the straw yield besides increasing the grain yield. Sahu (1993) has also recorded a similar observation for this soil.

TABLE 7 GRAIN YIELD OF KHARIF RICE C.V LALAT (REPLICATED TRAIL).

Treatmente	R1	R2	R3	R4	Mean
T1 76 Kg N/ha an PU Split application (1:2:1)	40.54	41.92	32.20	37.07	37.93
T2 76 kg N/ha an USG application at 0 DAT	41.20	35.24	40.13	36.32	38.22
T3 76 Kg N/ha as USG application at 7 DAT	45.80	39.94	35.01	37.67	39.60
T4 76 Kg N/ha as USG application at 14 DAT	49.47	43.67	40.37	42.02	43.88
T5 76 Kg N/ha as USG application at 21 DAT	43.42	34.88	34.92	37.52	37.68
T6 Control (No N was applied)	35.59	30.50	34.41	26.43	31.73

ANOVA

Source	Degree of freedom	Sum of Squares	Mean Sum of squares	F test	
				Calcu- lated	Table value
Treatment	5	305.71	61.142	7.573	2.90
Replication	3	170.752	56.91	7.049	3.29
Error	15	121.107	8.073		

CD (0.05) = 4.277 (q/ha)

C.V (%) = 7.44

S.E (M) = 1.42

TABLE 8 STRAW YIELD OF KHARIF RICE C.V. LALAT (REPLICATED TRIAL).

Treatments	R1	R2	R3	R4	Mean
T1 76 Kg N/ha as PU split application 1:2:1	41.96	49.50	40.21	46.00	44.41
T2 76 Kg N/ha as USG application at 0 DAT	48.41	44.08	43.33	46.33	45.53
T3 76 Kg N/ha as USG application 7 DAT	49.87	44.79	37.00	43.08	43.68
T4 76 Kg N/ha as USG application at 14 DAT	48.04	48.87	47.87	45.16	47.48
T5 76 Kg N/ha as USG application at 21 DAT	46.16	43.71	43.04	41.75	43.66
T6 Control (No N was applied)	41.00	30.79	34.25	29.71	33.93

ANOVA

Source	Degree of freedom	Sum of Squares	Mean sum of squares	F values	
				Calculated	table value
Treatment	5	446.062	89.21	8.13	2.90
Replication	3	83.826	27.942	2.55	3.29
Error	15	164.480	10.965		

CD (0.05) = 4.98

CV (o/r) =7.67

SE (m) = 1.65

Table 9 STRAW - GRAIN RATIOS FOR KHARIF RICE CV. LALAT (REPLICATED TRIAL).

Treatment		Straw-Grain ratio
T1	76 kg N/ha as P.U. split application (1:2:1)	1.17
T2	76 kg N/ha as USG application at 0 DAT	1.19
T3	76 kg N/ha as USG application at 7 DAT	1.10
T4	76 kg N/ha as USG application at 14 DAT	1.08
T5	76 kg N/ha as USG application at 21 DAT	1.16
T6	Control (No N was applied)	1.07

TABLE 10 : BIOMETRIC OBSERVATION OF KHARIF RICE (1994) (REPLICATED TRIAL)

Treatment		Mean plant height (cm)	Mean Panicle length (cm)	Mean no. of tillers
T1	76 kg N as PU/ha Split application (1:2:1)	89.66	22.85	8.22
T2	76 kg N as USG Application at 0 DAT	98.27	24.31	10.7
T3	76 kg N as USG Application at 7 DAT	93.85	24.36	10.3
T4	76 Kg N as USG Application at 14 DAT	95.17	24.50	11.02
T5	76 kg N as USG Application at 21 DAT	91.42	23.86	10.52
T6	Control (No Nitrogen applied)	81.41	22.84	7.75
C.D. (5%)		2.176	0.964	1.71
C.D. (1%)		3.015	1.33	2.37

The straw-grain ratios of Kharif rice is presented in Table 9. The straw to grain ratio of rice varied from 1.07 (T6, without fertilizer application) to 1.19 incase of the treatment (T2) receiving USG at the time of transplanting. However there is no difference in straw-grain ratio between the treatment in which USG was applied at 14 DAT (T4) and that without fertilizer application (T6). Probably, the application of N fertilizer has increased the straw yield of the crop when not applied in time. But the application of N fertilizer in right time may have mobilised the nitrogen towards more grain production (T4) than straw.

4.3.1.2 Yield attributing characteristics of kharif rice :

Table 10 represents the mean plant height, panicle length and mean number of tillers for Kharif Rice. The height of rice plant at harvest stage ranged from 81.4 to 95.2 cm when N-fertilizers were applied in different forms and at different times. The maximum plant height was observed in treatment (T4) receiving USG at 14 DAT and resulting the highest yield. Similarly a significant difference in mean panicle length was recorded when USG was applied at different times but difference in the mean panicle length between the control (T6) and the treatment T1 receiving PU splits appeared to be negligible. Thus USG is found to be a better form of N fertilizer in increasing the mean panicle length than PU splits. The number of effective tillers at harvest stage

varied from 8-11 among the treatments. There was no difference in increasing the number of effective tillers when PU was applied, but, like in case of the panicle length, USG appeared to increase significantly the number of effective tillers that would contribute to grain yield of the rice. This shows that among the yield attributing characteristics, although PU happens to increase only the plant height, the placement of USG, particularly at the time of 14 DAT appears to contribute to the other yield attributing characters like panicle length, effective tillers besides plant height. Thus the placement of USG has resulted a more grain production than PU splits.

4.3.1.3 Nitrogen concentration at different growth stages of rice :

The nitrogen concentration of kharif rice at tillering, PI, and harvest is presented in Table 11. It is found that the concentration of N in plant decreased with advancement in the age of the crop which might be due to increase in the dry matter production. The same trend in nitrogen concentration was also observed by Sahu (1993). On the other hand at any stage of the growth, application of N fertilizers appeared to increase the N concentration in the plant. The increase in N concentration is recorded more in case of USG placement than the PU split application because of immobilization of N by the growth of green algae in the later case (Roger et al. 1980). At harvest stage the concentration

of N in plant was found to be the highest in case of PU split (T1), this shows that top dressing of PU at the PI stage has contributed towards higher plant uptake of nitrogen. Further it is observed (Table 11) that the increase in N concentration was the highest when USG was applied at 14 DAT. This indicates that the timely application of USG has not only significantly increased the yield attributing characters of the plant but also increased the N concentration in plant at any stage of its growth and thus has contributed to increase the yield of rice.

4.3.1.4 Nitrogen Uptake :

The result on nitrogen uptake by rice plant based on the concentration and the yield (both grain and straw dried at 60 C) recorded in Table 12. The nitrogen uptake by rice per hectare of land ranged from 33.8 to 51.7 kg incase of grain and from 18.9 to 26.01 kg incase of straw. The total uptake of N varied from 52.7 kg/ha without application of N to 77.7 kg/ha with the application of N fertilizer. The highest N uptake value by grain was obtained when USG was applied at 14 DAT, but incase of straw the highest N uptake value was determined when PU was split applied. This shows that when PU was applied at PI stage, most of the N remained in vegetative stage and could not be mobilized unlike that of the USG placement at 14 DAT. Therefore USG when applied at 14 DAT appeared to be the better form of fertilizer than PU in efficient utilisation of applied N.

4.3.1.5 Nitrogen use efficiencies :

The three Nitrogen use efficiencies i.e. Agronomic efficiency (NUE), relative efficiency, and Apparent nitrogen recovery of rice are presented in table 13. The NUE varied from 8 to 16 with the application of various forms of N. However NUE was more or less same when PU was applied in splits or the placement of USG was carried out at 0 DAT or 21 DAT. On the other hand agronomic efficiency of the crop was doubled when USG placed at 14 DAT in comparison to PU splits.

This shows that the time of application of USG has tremendous effect on efficient utilisation of USG N in the plant. The relative efficiency (RE) of the rice yield were computed by assuming the yield of rice under the PU split at 100%. Like that of the agronomic efficiency the RE of USG was about 104% and 95.97% when USG was applied at 0 DAT or 21 DAT, respectively. However efficiency was increased to 126.94% when USG was applied at 7 DAT, but the RE was doubled for USG placement at 14 DAT. This shows that placement of USG at proper time appears to be superior to the PU split for medium land rice.

The apparent N recovery which indicates the N uptake, was more or less same with PU split and USG applied at 14 DAT. Application of USG at any other time has reduced the N recovery of the plant from the applied source.

Table 11 N-CONCENTRATION (%) OF KHARIF RICE, C.V. LALAT (REPLICATED TRIAL) AT DIFFERENT STAGES OF ITS GROWTH.

Treatment	N Concentration (%)			
	Tillering Stage	P.I. Stage	Harvest Grain	stage Straw
T1 76 kg N/ha as PU split application (1:2:1)	1.31	1.16	1.30	0.85
T2 76 kg N/ha as USG application at 0 DAT	1.47	1.14	1.19	0.64
T3 76 kg N/ha as USG application at 7 DAT	1.44	1.00	1.16	0.66
T4 76 Kg N/ha as USG application at 14 DAT	1.61	1.59	1.30	0.66
T5 76 Kg N/ha as USG application at 21 DAT	1.49	1.37	1.18	0.68
T6 Control (No N was applied)	1.14	1.10	1.17	0.67

Table 12 NITROGEN UPTAKE BY KHARIF RICE (REPLICATED TRIAL.)

Treatment	N uptake (kg/ha)			kg N uptake/ q. grain
	Grain	Straw	Total	
T1 76 kg N/ha as PU Split application (1:2:1)	44.87	31.33	76.20	2.00
T2 76 kg N/ha as USG application at 0 DAT	41.39	24.19	65.58	1.72
T3 76 kg N/ha as USG application at 7 DAT	41.88	23.93	65.81	1.66
T4 76 kg N/ha as USG application at 14 DAT	51.71	26.01	77.72	1.77
T5 76 kg N/ha as USG application at 21 DAT	40.33	24.64	64.97	1.72
T6 Control (No N was applied)	33.79	18.87	52.66	1.66

Table 13 EFFICIENCY OF NITROGEN APPLICATION ON KHARIF RICE
(REPLICATED TRIAL).

Treatment	Agronomic efficiency (%) (NUE)	Relative efficiency (RE) (%)	Apparent N recovery (%)
T1 76kg N/ha as PU split application (1:2:1)	8.15	100.00	30.97
T2 76kg N/ha as USG application at 0 DAT	8.54	104.68	17.00
T3 76kg N/ha as USG application at 7 DAT	10.34	126.94	17.30
T4 76kg N/ha as USG application at 14 DAT	16.00	195.97	32.97
T5 76kg N/ha as USG application at 21 DAT	7.83	95..97	16.19
T6 Control (No N was applied)	-	-	-

Keeping in view of efficiency factors it may be stated that application of USG at 14 DAT appears to be the best combination not only in increasing the yield but also in increasing the N uptake of rice.

4.3.2 Dose and placement depth of USG

4.3.2.1 Yield and yield attributing characteristics of kharif rice :

In an adjacent site of the main experiment an observation trial having a plot size of 2 X 2 m was prepared for studying the dose and placement depth of USG on Kharif rice C.V. Lalat. The grain and straw yields as well as the yield attributing characters are presented in Table 14. The USG was placed at 2.5 cm depth representing the oxidised soil layer in the first three treatments. In the second three treatments USG was placed at 5.0 cm depth by hand placement and this zone represented the reduced soil layer. In each placement depth, the USG was applied @ one, two and three granules per placement point so as to maintain the doses of 38 kg N/ha, 76 kg N/ha and 96 kg N/ha, respectively as per the IFDC recommendations. It has been observed that both the grain and straw yields increased with the increase in fertilizer dose. This shows that the yield of rice could be increased if USG is applied at a rate more than 76 kg N/ha which has been recommended for the main plot experiment. Further it is observed (Table 14) that the grain yield of rice is more when

USG was placed at a depth of 5 cm than that applied at 2.5 cm depth. This shows that the efficiency of USG could be increased if it could be applied as deep as 5 cm depth. A similar observation was noted by Rao et al. (1989) who reported that the yield of rice could be increased to a maximum value when the placement depth of USG is increased to 8 cm.

The straw to grain ratio presented in Table 14 appears to increase with increasing the N dose but decreased when USG was placed at 5 cm depth in comparison to its shallow placement. This shows that although application of N in form of USG increases the straw yield but a higher grain yield is associated when USG was deep placed. Since this is an observation trial, further work is needed to understand the actual depth of placement since deeper placement involves more labour cost as well as leaching of nitrogen below the recall of plant roots.

The effect of the dose and the depth of placement on yield attributing characters of the plant is presented in Table 15. The increase in the rate of application of N in the form of USG has increased the plant height as well as the number of tillers per hill, but at higher dose the panicle length is found to be reduced slightly. On the other hand in comparison to shallow placement, the deep placement of USG at

Table 14 EFFECT OF DOSE AND DEPTH OF POINT PLACEMENT OF USG ON GRAIN YIELD AND STRAW YIELD OF KHARIF RICE C.V. LALAT (OBSERVATION TRIAL).

Treatment	Grain yield (q/ha)	Straw yield (q/ha)	Straw to Grain Ratio
T1 38kg N/ha as USG placement at 2.5cm depth at 7 DAT	34.81	32.125	0.92
T2 76kg N/ha as USG placement at 2.5cm depth at 7 DAT	43.42	43.75	1.01
T3 96kg N/ha as USG placement at 2.5cm depth at 7 DAT	51.48	59.75	1.16
T4 38kg N/ha as USG placement at 5.0cm depth at 7 DAT	46.65	39.75	0.85
T5 76kg N/ha as USG placement at 5.0cm depth at 7 DAT	45.06	44.00	0.98
T5 96kg N/ha as USG placement at 5.0cm depth at 7 DAT	50.83	55.00	1.08

Table 15 BIOMETRIC OBSERVATION IN KHARIF RICE C.V LALAT (OBSERVATION TRIAL)

Treatment	Mean Plant height(CM)	Mean Panicle length(CM)	Mean number of tillers
T1 38kg N/ha as USG placement at 2.5cm depth at 7 DAT	88.1	22.90	8.5
T2 76kg N/ha as USG placement at 2.5cm depth at 7 DAT	95.30	25.35	9.3
T3 97kg N/ha as USG placement at 2.5cm depth at 7 DAT	97.90	23.88	9.9
T4 38kg N/ha as USG placement at 5.00cm depth at 7 DAT	90.35	23.90	9.5
T5 76kg N/ha as USG placement at 5.0cm depth at 7 DAT	96.95	26.15	10.0
T6 966kg N/ha as USG placement at 5.0cm depth at 7 DAT	93.30	24.70	14.0

Table 16 EFFECT OF DOSE AND PLACEMENT DEPTH OF USG ON NITROGEN CONCENTRATION OF KHARIF RICE(CV-LALAT)*.

Treatment	N-concentrationn (%) Harvest	
	Grain	Straw
T1 38 kg N/ha as USG placement at 2.5cm depth at 7 DAT	1.07	0.61
T2 76 kg N/ha as USG placement at 2.5cm depth at 7 DAT	1.00	0.77
T3 96 kg N/ha as USG placement at 2.5cm depth at 7 DAT	1.07	0.77
T4 38 kg N/ha as USG placement at 5.0cm depth at 7 DAT	1.06	0.54
T5 76 kg N/ha as USG placement at 5.0cm depth at 7 DAT	1.16	0.82
T6 96 kg N/ha as USG placement at 5.0cm depth at 7 DAT	1.30	0.81

* OBSERVATION STRIP

Table 17 EFFECT OF DOSE AND PLACEMENT DEPTH OF USG ON NITROGEN UPTAKE OF KHARIF RICE*.

Treatment	N uptake (kg/ha)			kg N uptake/q grain
	Grain	Straw	Total	
T1 38 kg N/ha as USG placement at 2.5cm depth at 7 DAT	33.88	16.26	50.14	1.44
T2 76 kg N/ha as USG placement at 2.5cm depth at 7 DAT	39.51	27.96	67.47	1.55
T3 96 kg N/ha as USG placement at 2.5cm depth at 7 DAT	50.13	38.18	88.31	1.72
T4 38 kg N/ha as USG placement at 5.0cm depth at 7 DAT	45.17	17.81	62.98	1.35
T5 76 kg N/ha as USG placement at 5.0cm depth at 7 DAT	47.64	29.95	77.59	1.72
T6 96 kg N/ha as USG placement at 5.0cm depth at 7 DAT	60.14	36.98	97.12	1.91

* OBSERVATION STRIP

5.0 cm has been found to increase the yield attributing characteristics of the plant which ultimately contributed to increased the grain production.

4.3.3.2 N content and N uptake in plant :

The data on Nitrogen concentration and N uptake at harvest as affected by the dose and placement depth of USG are presented in table 16 and 17. It is observed that increasing the dose of application in form of USG increased the N concentration in the straw at both depths of placement. But incase of grain deep placement of USG contributed to more nitrogen content in plant than shallow placement. Perhaps when USG is placed at shallow depth, besides hydrolysis, the aerobic micro-organisms may have oxidised $\text{NH}_4\text{-N}$ to $\text{NO}_3\text{-N}$. Since $\text{NO}_3\text{-N}$, once formed, is subjected to leaching loss the long term effect of USG at increased dose could not be observed in increasing the nitrogen concentration in plant unlike the deep placement in which oxidation of $\text{NH}_4\text{-N}$ was suppressed and plant uptake of nitrogen was increased with increase in dose of fertilizer. Thus deep placement of USG appears to increase the nitrogen concentration in grain than the shallow placement.

4.4 TRANSPORT AND TRANSFORMATION OF NITROGEN IN SOIL AT DIFFERENT TIMES OF USG PLACEMENT :

In replication R1, one soil water sampler was installed at a soil depth of 5cm prior to the broadcasting of

P.U @ 19 kg N/ha (T1). In the same replication also, the soil water samplers were installed in three plots in which USG was deep placed at 0, 7, 14 DAT. In each such plot, three soil water samplers were installed at soil depths of 5.0 and 10.0 cm each, representing the lateral distances of 5, 10 and 15 cm from the point of USG placement. The soil water samples collected periodically from various soil depths and overlying floodwater, were analysed for $\text{NH}_2\text{-N}$, $\text{NH}_4\text{-N}$ and $\text{NO}_3\text{-N}$. The concentrations of N over time at various soil depths and in floodwater are represented in graphical forms. The BTCs of N was drawn by using a HPG computer graphic model to curve fit the observed concentrations of N in all the cases.

4.4.1 Transport and transformation of $\text{NH}_2\text{-N}$ in soil:

The BTCs of $\text{NH}_2\text{-N}$ at soil depths of 5cm was presented in Fig. 8 (Appendix - VIII) for different times of USG placement. The BTCs appeared to be bell shaped upto 50h in all the cases. The BTC of $\text{NH}_2\text{-N}$ also appeared earlier when the USG was placed at 7 DAT (T3) than that applied at 0 and 14 DAT (T2 and T4). The early appearance of BTC of $\text{NH}_2\text{-N}$ may be due to high rainfall soon after placement of USG in T3. It is also observed that the amount of $\text{NH}_2\text{-N}$ recovered at soil depth of 5 cm was maximum for USG placement at 0 DAT, intermediate for USG placement at 7 DAT and the lowest for USG placement at 14 DAT. This shows that the maximum amount of applied USG has been hydrolyzed when it was applied at 0 DAT in comparison to

that applied at a latter stage. Perhaps the soil was in an oxidized state at the time of transplanting and during the course of soil submergency the oxidative condition of the soil was reduced.

Fig. 9 (Appendix IX) depicts BTCs of $\text{NH}_2\text{-N}$ at a soil depth of 10cm. It has been observed that the concentration of $\text{NH}_2\text{-N}$ at any time was lower than that observed at soil depth of 5cm and a tailing of the BTCs of $\text{NH}_2\text{-N}$ was observed upto 144 hours. This shows that while the $\text{NH}_2\text{-N}$ moved past the 5cm soil depth, a part of the applied $\text{NH}_2\text{-N}$ was hydrolyzed even in the reduced zone. The tailing of the each BTC further indicates that during transport, the sorption of $\text{NH}_2\text{-N}$ was taking place temporarily on the exchange complex of soil system. It has been observed (Fig. 9) that while the maximum concentration of $\text{NH}_2\text{-N}$ was observed at 12h and 32h, In cases of T2 and T4, the appearance of the peak concentration of $\text{NH}_2\text{-N}$ was delayed upto 36h in T3. This indicates that perhaps $\text{NH}_2\text{-N}$ had moved through some preferential pore channels while moving through the soil layer of 5-10cm at the time of trasnplanting.

Diffusion of $\text{NH}_2\text{-N}$ in flood water.

The BTCs of $\text{NH}_2\text{-N}$ in flood water stemming from application of PU at transplanting on the soil surface and point placement of USG at 0,7,14 DAT are presented in Fig. 10

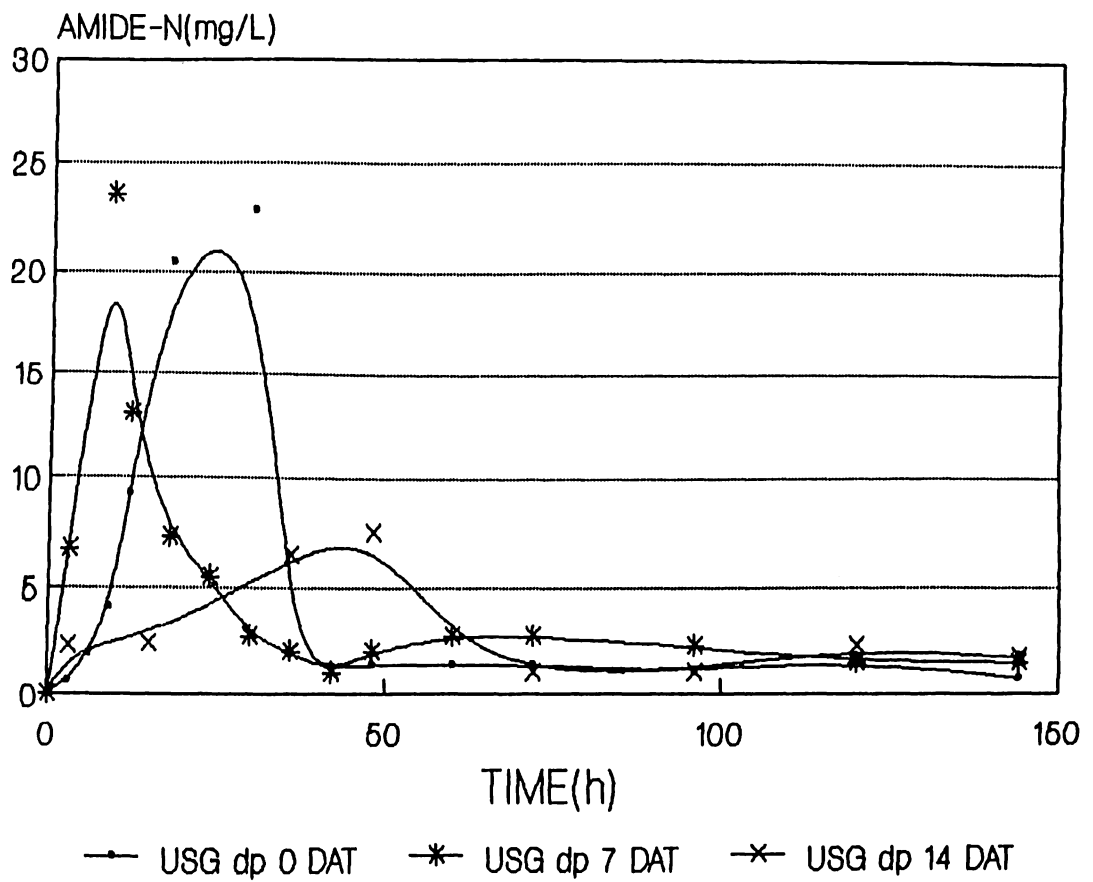


Fig 8 BTC of Amide-N at 5cm soil depth
and 5cm distance from USG placement

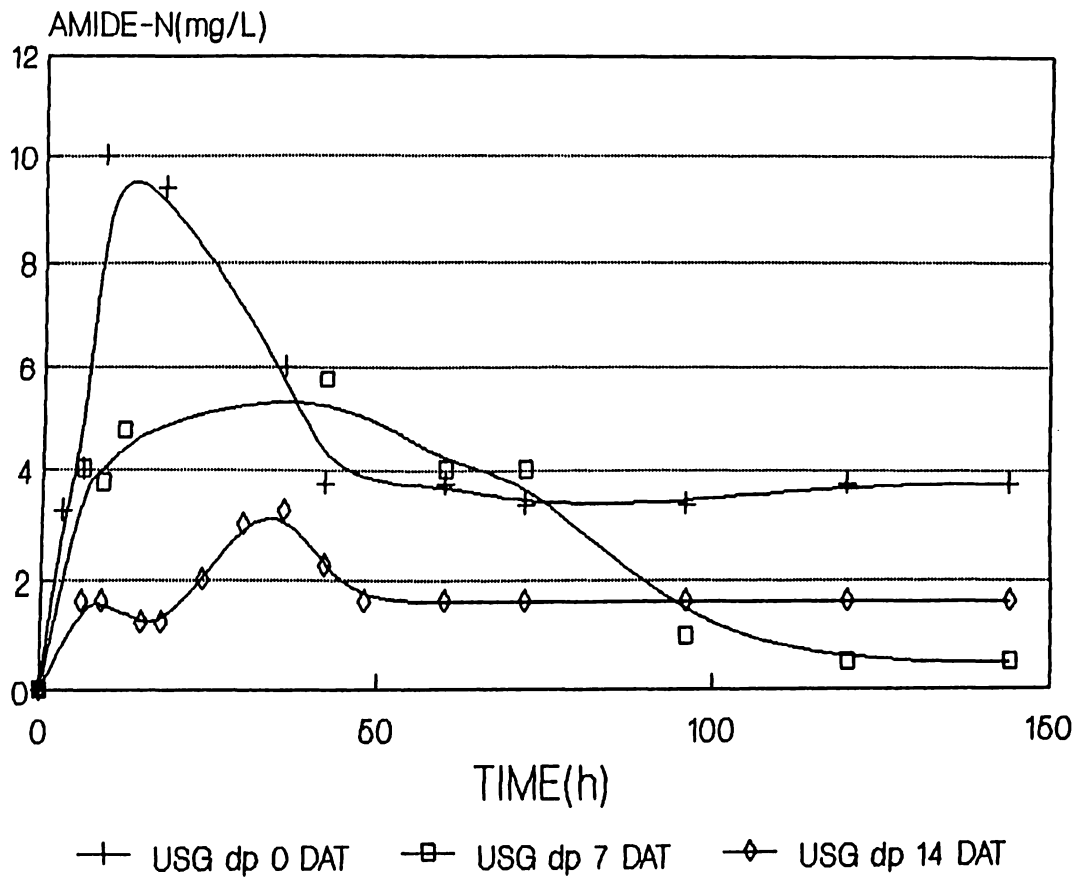


Fig 9 BTC of Amide-N at 10cm soil depth
and 5cm distance from USG placement

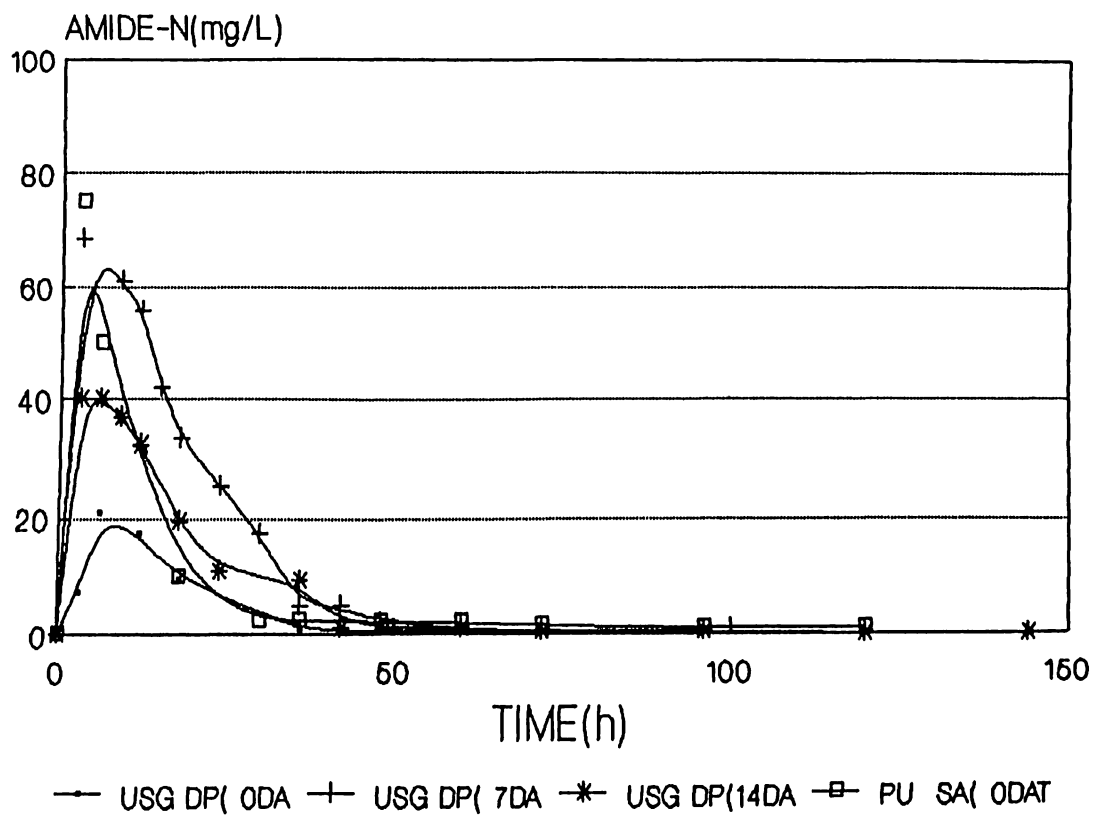


Fig.10BTC of Amide-N in floodwater
stemming from PU and USG application
in medium land rice soil

and Appendix - X. The concentration of $\text{NH}_2\text{-N}$ appeared in the floodwater within 1-2 h of application, attained its maximum value by 4-8 h and there after decreased to negligible amount at 50 h of placement/application. This shows that appreciable amount of applied $\text{NH}_2\text{-N}$ has moved upward by way of diffusion. The amount of $\text{NH}_2\text{-N}$ in floodwater was different at different times of USG placement. In case of USG placement at 0 DAT (T2) small amount of $\text{NH}_2\text{-N}$ was found in floodwater in comparison to that found in floodwater for other treatments (T1, T3 and T4). At the time of transplanting of rice the floodwater had a lot of suspended soil particles and undecomposed organic matter that served as the sites of urea hydrolysis. So a high rate of urea hydrolysis resulting low concentration of $\text{NH}_2\text{-N}$ was observed in floodwater at the time of transplanting in comparison to other times of placement despite a high concentration of $\text{NH}_2\text{-N}$ built up at soil depth of 5cm. As the time progressed the suspended particles in the floodwater settled down, the urease activity was reduced and a high concentration of $\text{NH}_2\text{-N}$ was observed in floodwater when USG was point placed at 7 DAT. It is also observed in Fig. 10 that the concentration of $\text{NH}_2\text{-N}$ in floodwater at any time at 14 DAT (T4) was less than that observed at 7 DAT. This is expected since the $\text{NH}_2\text{-N}$ in soil water at 5cm soil depth (Fig. 8) from USG placement at 14 DAT was less than that present at 7 DAT. It is observed that the concentration of $\text{NH}_2\text{-N}$ (Fig. 10) in flood water stemming from broadcasting of P U @ 19kg/ha(T1)

was more or less same as that of the $\text{NH}_2\text{-N}$ stemming from point placement of USG @ 76 kg N/ha at 7 DAT. This shows that the diffusion of $\text{NH}_2\text{-N}$ to flood water from deep placement of USG even at higher dose was less than surface broadcasting of PU at lower dose.

4.4.2. Transport and transformation of $\text{NH}_4\text{-N}$ in soil :

The BTCs of $\text{NH}_4\text{-N}$ at soil depth of 5 cm stemming from deep placement of USG at 0, 7 and 14 DAT are presented in Fig 11 (Appendix XI). It shows that the $\text{NH}_4\text{-N}$ appeared at the placement site of USG within 8-10 h. As the time passed, the concentration of $\text{NH}_4\text{-N}$ in the soil water increased and attained a peak value of (106.6 mg/L) at 34.5 h in the case of USG Placement at 0 DAT, 55 mg/L at 55 hour for USG placement at 7 DAT and 124 mg/L at 88 h for USG Placement at 14 DAT. With a slight decrease, the concentration of $\text{NH}_4\text{-N}$ remained unchanged with progress of time. Further the concentration of $\text{NH}_4\text{-N}$ in the soil water was found to be more than that of the $\text{NH}_2\text{-N}$ (Fig. 8) at the same soil depth. This indicates that the $\text{NH}_2\text{-N}$ from applied USG was hydrolysed to $\text{NH}_4\text{-N}$ to a large extent at soil depth of 5 cm after overcoming a lag period of 6-8 h.

Again the concentration of $\text{NH}_4\text{-N}$ over time in the soil water was different for different times of USG placement. It was more when USG was point placed at 0 DAT than that at 7

DAT. Since the redox potential of the top soil layer was higher at transplanting than that at 7 DAT (due to soil submergency), the high rate of Urease activity was expected in the former case. This might have resulted a high concentration of $\text{NH}_4\text{-N}$ in the soil solution at the begining. Further, with progress of time, the initial high concentration of $\text{NH}_4\text{-N}$ in soil water resulted the inhibition of urease activity. The hydrolysis of USG depression took place at slower, but at constant rate. Thus the appearance of $\text{NH}_4\text{-N}$ in soil water continued for a long time.

Again at 7 DAT the suspended soil particles in floodwater were settled down and the urease activities in floodwater was reduced and this resulted in release of low concentration of $\text{NH}_4\text{-N}$ in the soil water.

At 14 DAT, due to prolonged soil submergence, the redox potential was further reduced and the urease activities were also reduced. This has resulted a delaying and retardation of urea hydrolysis in soil. So the concentration of $\text{NH}_4\text{-N}$ in soil water was minimum for USG placement at 14 DAT in comparison to other times of USG placement. Savant et al. (1985) have observed that when the period of submergence increases, the redox potential, is reduced which reduces the urease activity. In the present case, since the soil was subjected to submergence for a period of 14 days prior to the

point placement of USG (T4) perhaps the soil has attained a reduced state and thus delayed the urea hydrolysis. On the other hand, after the placement of USG the root activity of rice was increased and the rhizosphere was enriched with oxygen. The rhizosphere of plant served an oxidized zone, which resulted to increase the urea hydrolysis rate in soil with progress of time. Thus the combined effects of soil submergences and the presence of oxidized zone resulted a slow rate of ammonium formation in soil for USG placement at 14 DAT.

In Fig. 12, the BTCs of the $\text{NH}_4\text{-N}$ at soil depth of 10 cm are presented for the placement of USG at 0, 7 and 14 DAT (Appendix XII). While the maximum concentration of $\text{NH}_4\text{-N}$ in soil water due to placement of USG was about 8-14 mg/L in case of the USG placement at 7 DAT and 14 DAT, the concentration of $\text{NH}_4\text{-N}$ in soil water was very high (96 mg/L) in case of USG placement at transplanting. This shows that while a lot of $\text{NH}_4\text{-N}$ was subjected to leaching through diffusion and/or mass flow in case of USG placement at transplanting, a very small amount of $\text{NH}_4\text{-N}$ was leached down to a depth of 10 cm in case of USG placed at 7 DAT and 14 DAT. At transplanting due to puddlings the top soil (Sandy loam) was loose and the percolation rate was very high. So a lot of $\text{NH}_4\text{-N}$ formed at a soil depth of 5 cm at transplanting was leached down by mass flow to 10 cm depth and a little was left

for plant uptake. As the period of soil submergence proceeded there was a structural built-up of soil particles in top soil layer and the percolation of water was reduced. As a result $\text{NH}_4\text{-N}$ formed at a soil depth of 5 cm could not be leached down by mass flow and remained within 5-10 cm soil layer on account of sorption at low velocity. The $\text{NH}_4\text{-N}$ so formed thus was a source of nitrogen for plant uptake in course of time. It may be referred (Fig. 11) that at soil depth of 5 cm the area under the BTC of $\text{NH}_4\text{-N}$ at 14 DAT was more than that 7 DAT, and the corresponding values under BTC of $\text{NH}_4\text{-N}$ (Fig. 12) at soil depth of 10 cm were less. This shows that much of $\text{NH}_4\text{-N}$ retained in soil layer of 5 to 10 cm in case of USG placement at 14 DAT than that at 7 DAT. Since the rhizosphere activity of rice was more in case of USG placement at 14 DAT than at 7 DAT. The nitrogen uptake by plant was more in the former case (14 DAT) than the later case.

Ammonium in Floodwater :

Fig. 13 depicts the BTCs of $\text{NH}_4\text{-N}$ in Floodwater stemming from broadcasting of PU on soil surface and deep placement of USG at 0 DAT, 7 DAT and 14 DAT (Appendix XIII). The BTCs appear to be bell shaped and appear to be more or less same as that of $\text{NH}_2\text{-N}$ in floodwater (Fig. 10), except that the long tailings were observed in case of $\text{NH}_4\text{-N}$ BTCs for USG placement at 7 DAT and at 14 DAT. In case of PU application, the concentration of $\text{NH}_4\text{-N}$ was less than the

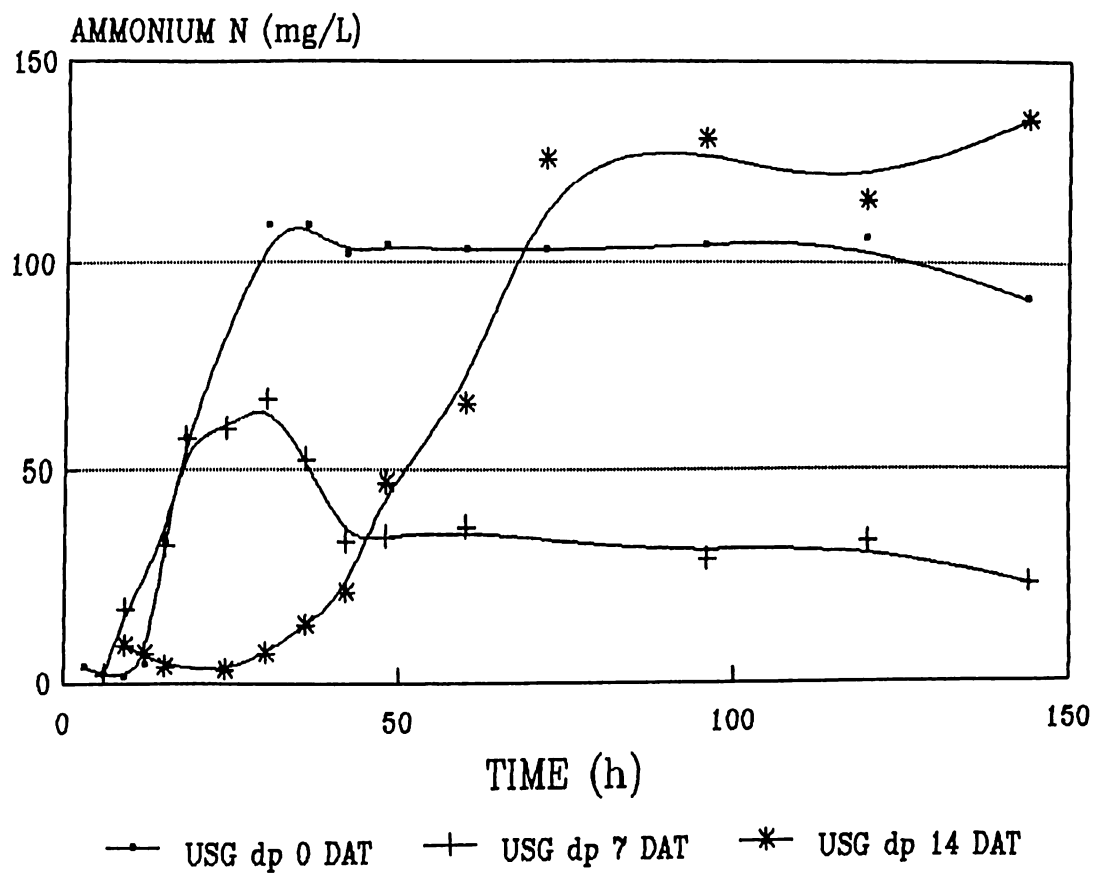


Fig11BTC of Ammonium-N at 5cm soil depth
and 5cm distance from USG placement

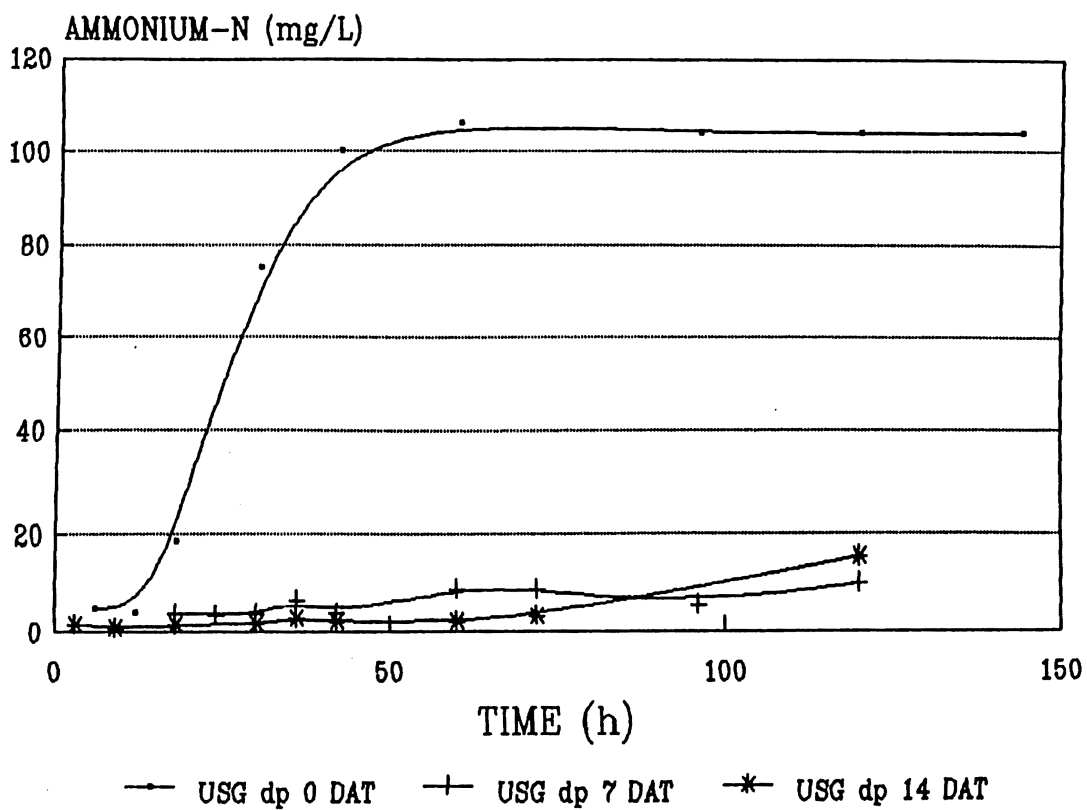


Fig12BTC of Ammonium-N at 10cm
soil depth and 5cm distance
from USG placement

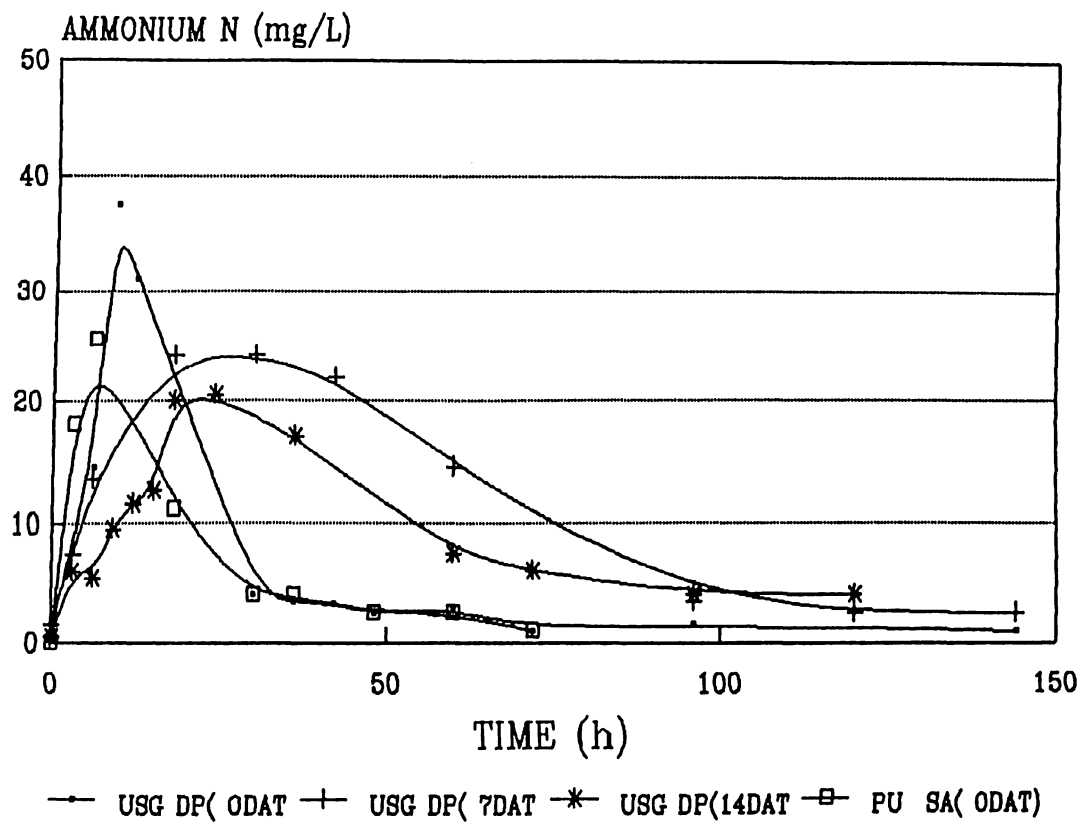


Fig13BTC of Ammonium-N in floodwater
stemming from PU and USG application
in medium land rice soil

$\text{NH}_2\text{-N}$ concentration in floodwater. On the otherhand the concentration of $\text{NH}_4\text{-N}$ was more than the concentration of $\text{NH}_2\text{-N}$ stemming from USG placement at 0 DAT. This shows that while the $\text{NH}_2\text{-N}$ was moving upward by diffusion a part of it was hydrolyzed into $\text{NH}_4\text{-N}$ in soil floodwater system. Thus the $\text{NH}_4\text{-N}$ in floodwater appeared more in amount incase of USG deep placement at transplanting than that which was transformed from PU in floodwater system only. Similarly the $\text{NH}_4\text{-N}$ present in floodwater stemming from deep placement of USG at 7 and 14 DAT represented a part of $\text{NH}_2\text{-N}$ that has moved upward through soil floodwater system. Since the concentration of $\text{NH}_4\text{-N}$ was found more in floodwater in which USG was deep placed at 7 DAT than that at 14 DAT, it indicates that the hydrolysis rate of USG was decreased with the progress of soil submergence.

A sharp decrease in the shape of BTC of $\text{NH}_4\text{-N}$ after the peak concentration was observed in case of BTCs of $\text{NH}_4\text{-N}$ stemming from broadcasting of PU and USG at 7 DAT. Since the floodwater was highly concentrated with dissolved $\text{NH}_4\text{-N}$ at this time, the sharp decrease in BTCs of $\text{NH}_4\text{-N}$ may due to $\text{NH}_3\text{-N}$ volatilisation. The evidence of NH_3 volatilisation was observed by Sahu (1993) who estimated NH_3 loss to an extent of 2 to 5% of applied USG in this soil.

Further in cases of USG deep placement at 7 and 14 DAT, the tailing of BTCs of $\text{NH}_4\text{-N}$, was observed for a long

period. This may have been due to low rate of USG hydrolysis at prolonged period of soil submergence and less NH_3 volatilization loss as compared to USG placement at 0 DAT.

4.4.3 Nitrification :

The soil water samples collected at 5 and 10 cm soil depths were also analysed for $\text{NO}_3\text{-N}$. No $\text{NO}_3\text{-N}$ was detected in the soil water samples. So the BTC of $\text{NO}_3\text{-N}$ is not presented here. This shows that the nitrification of $\text{NH}_4\text{-N}$ stemming from USG placement appears to be either negligible or less than the rate of nitrate reduction in soil. It may be referred (Table 6) that when USG was applied on soil surface in a soil column, a little $\text{NO}_3\text{-N}$ was only detected in the top soil layer for this soil. Working with Bhubaneswar upland soils, Misra and Mishra (1977) had observed that nitrification is practically ceased from applied ammonium salts under saturated condition.

4.4.4 Vertical movement of $\text{NH}_2\text{-N}$:

The BTCs of $\text{NH}_2\text{-N}$ in floodwater and at the soil depths of 5 and 10 cm stemming from placement of USG at 0 DAT, 7 DAT, 14 DAT are presented in Fig. 14, 15, 16 and Appendices XIV, XV, XVI, respectively. The mobility of $\text{NH}_2\text{-N}$ was considered from the time that the concentration of the solute was found to be maximum. In case of USG placement at 0 DAT (Fig. 14, T2), it is observed that the $\text{NH}_2\text{-N}$ appeared in floodwater at an earlier period than that observed at its

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placement site (5 cm soil depth). This shows that $\text{NH}_2\text{-N}$ moved vertically upward to floodwater by way of diffusion soon at a fast rate. It has also been observed that the concentration of $\text{NH}_2\text{-N}$ although low had appeared at a longer period at soil depth of 10 cm than that observed at placement site (5 cm soil depth). This shows that the solute is moving through 5 to 10 cm soil depth both by diffusion and mass flow. Further by comparing the BTCs of $\text{NH}_2\text{-N}$ of floodwater and that at soil depth of 10 cm, it is shown that $\text{NH}_2\text{-N}$ in its downward movement from 5 to 10 cm soil depth had taken longer period than that reaching the same distance in upward direction. So the diffusion of $\text{NH}_2\text{-N}$ in a vertical upward direction was presumed to be quicker than the convective diffusion in a vertical downward direction.

While the USG was placed at 7 DAT (Fig. 15, T3), the $\text{NH}_2\text{-N}$ concentration was found to be more in floodwater, intermediate at 5 cm soil depth and the least at 10 cm soil depth. Further the peak concentration of $\text{NH}_2\text{-N}$ was found to appear a little earlier in floodwater than at 5 cm soil depth like the previous case (Fig. 14). A tailing of BTC of $\text{NH}_2\text{-N}$ was also observed at soil depth of 5 cm. This shows that with progress of soil submergence a lot of $\text{NH}_2\text{-N}$ was diffused to floodwater like the previous case. On the other hand convective diffusion of $\text{NH}_2\text{-N}$ in a vertical downward direction was greatly reduced when USG placed at 7 DAT in comparison to

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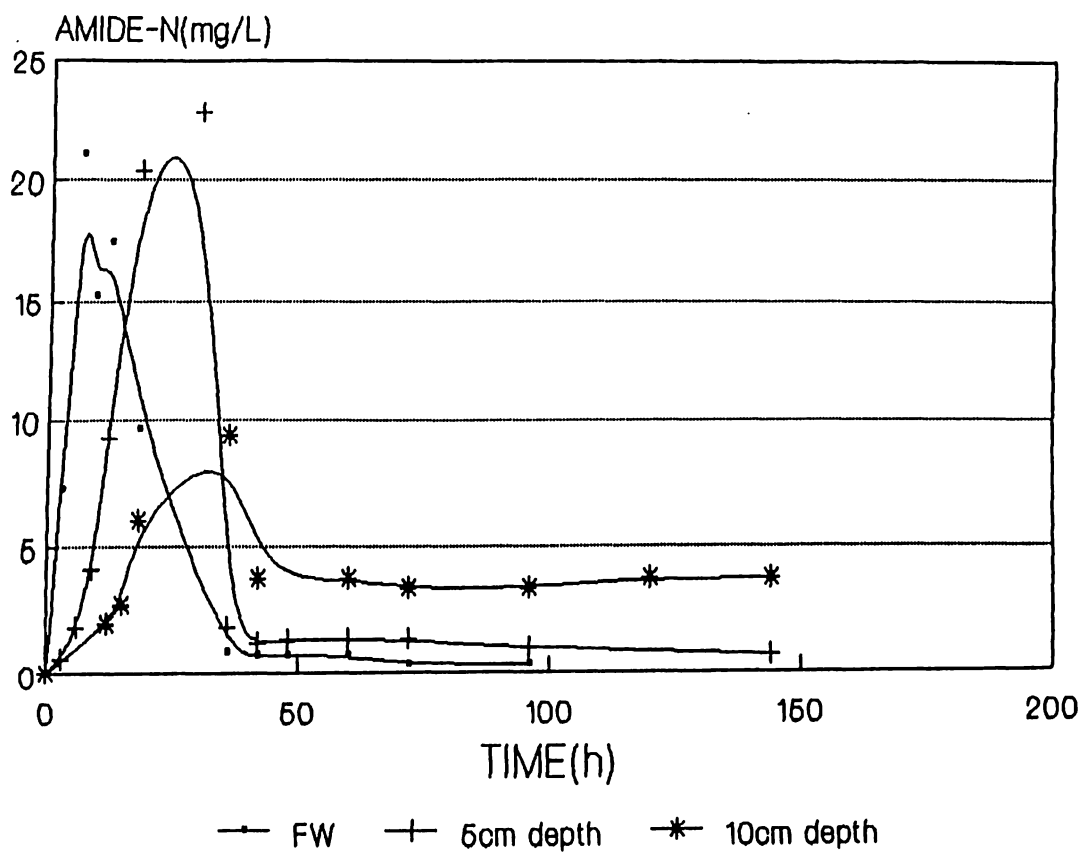


Fig14 BTC of Amide-N stemming from
USG placement at 0 DAT

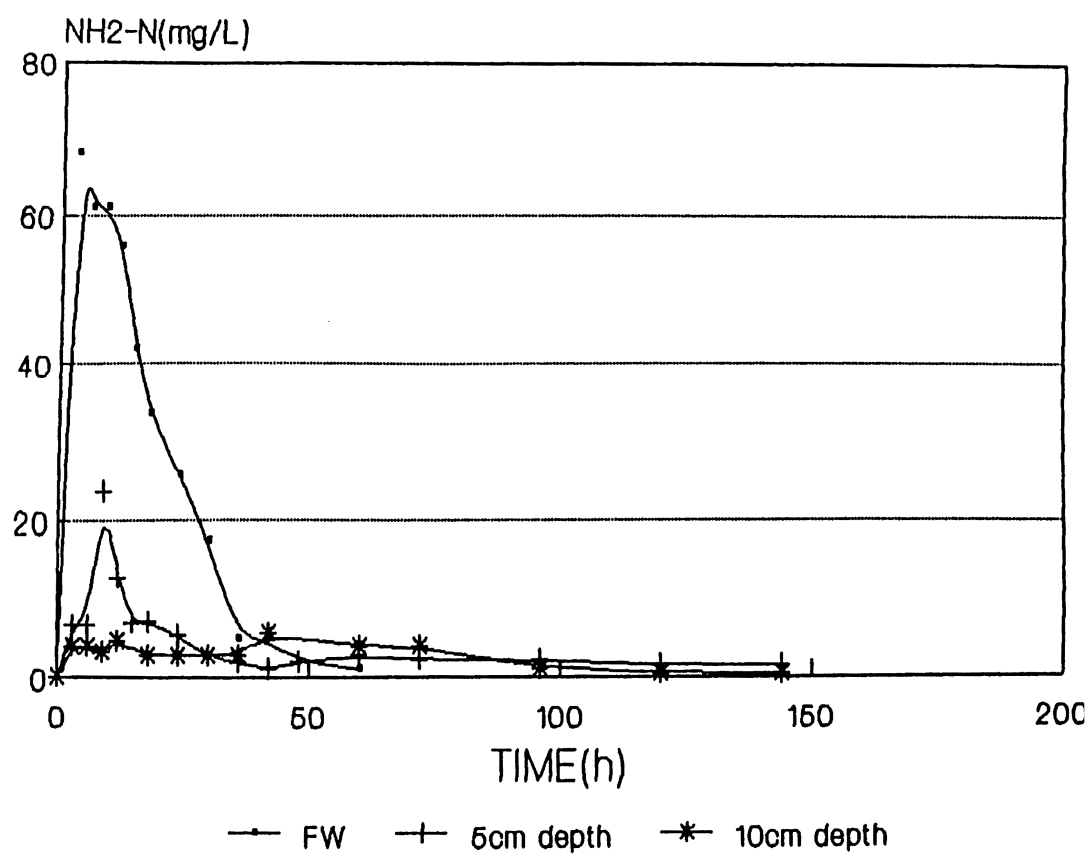


Fig15 BTC of Amide-N stemming
from USG placement at 7 DAT

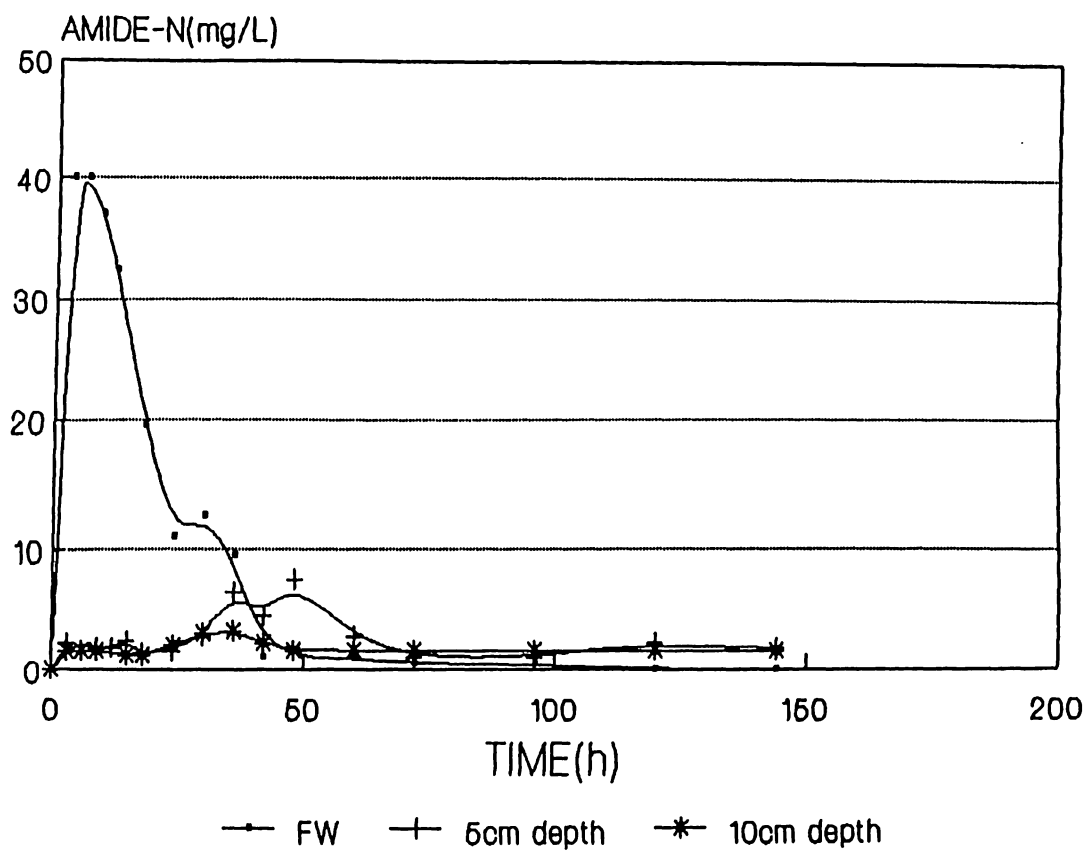


Fig 16 BTC of Amide-N stemming from USG placement at 14 DAT

0 DAT. The low rate of diffusion may be due to the low-rate of percolation which had been associated with the progress of soil submergence.

In Fig. 16 (T4) like that of the previous cases (Fig 14 and 15) a lot of $\text{NH}_2\text{-N}$ was found in floodwater and the peak concentration of $\text{NH}_2\text{-N}$ was observed earlier than that at placement site. At soil depth of 10cm the concentration of $\text{NH}_2\text{-N}$ in soil water was minimum and a tailing of BTC of $\text{NH}_2\text{-N}$ was observed. This shows that while increasing the period of soil submergence upward diffusion of $\text{NH}_2\text{-N}$ into floodwater remained unaffected, but the convective diffusion of $\text{NH}_2\text{-N}$ in a vertical downward direction was further reduced due to sedimentation of suspended particles moving through the soil layer of 5 to 10cm depth.

4.4.5 Lateral movement of $\text{NH}_2\text{-N}$.

The BTCs of $\text{NH}_2\text{-N}$ at 5cm soil depth for lateral distances of 5, 10 and 15cm are presented in Fig. 17 ,18 and 19 for USG placement at 0 DAT, 7 DAT and 14 DAT, respectively. It has been observed in Fig. 17 (T2) that at 5cm horizontal distance the concentration of $\text{NH}_2\text{-N}$ attained its maximum value at h. Thus the $\text{NH}_2\text{-N}$ moved laterally at a velocity of 0.2 cm/h while moving through a horizontal distance of 0-5 cm. On the other hand the change in $\text{NH}_2\text{-N}$ concentration over time was negligible at a distance of 10 cm and 15 cm (Fig.

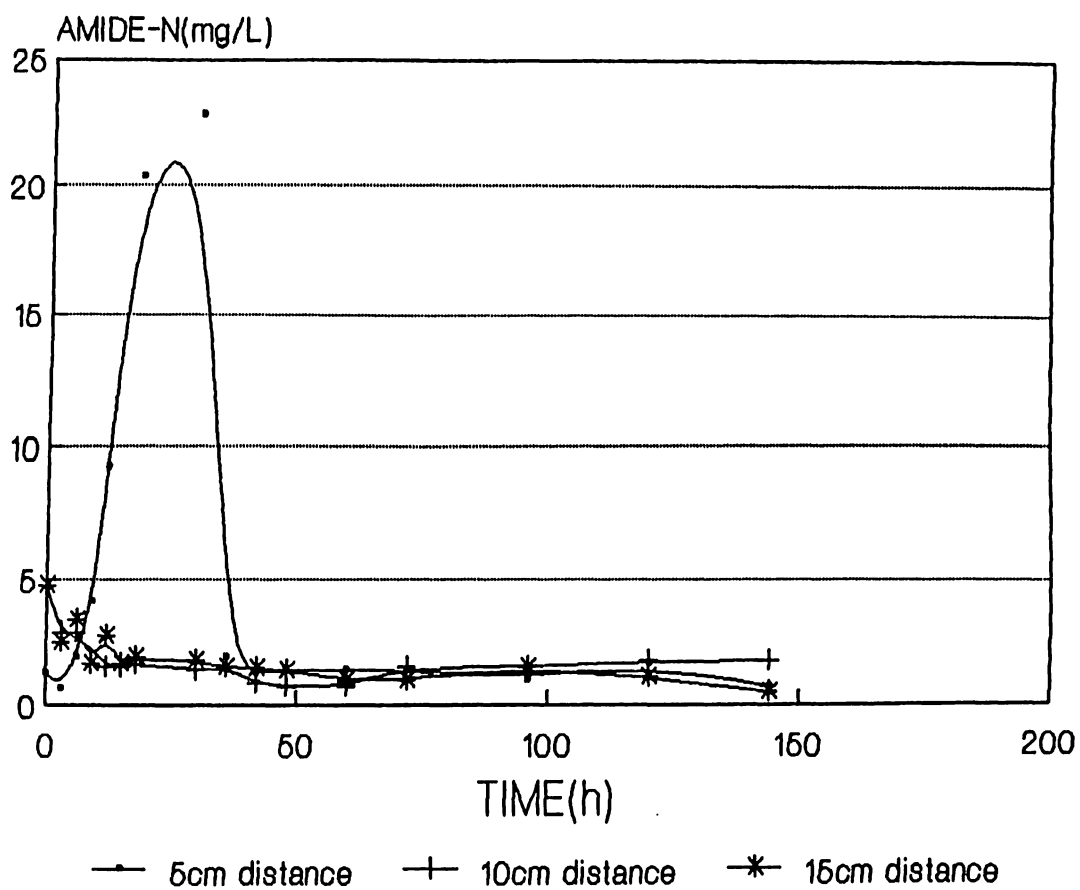


Fig17BTC of Amide-N at soil depth 5cm
stemming from USG placement at 0 DAT

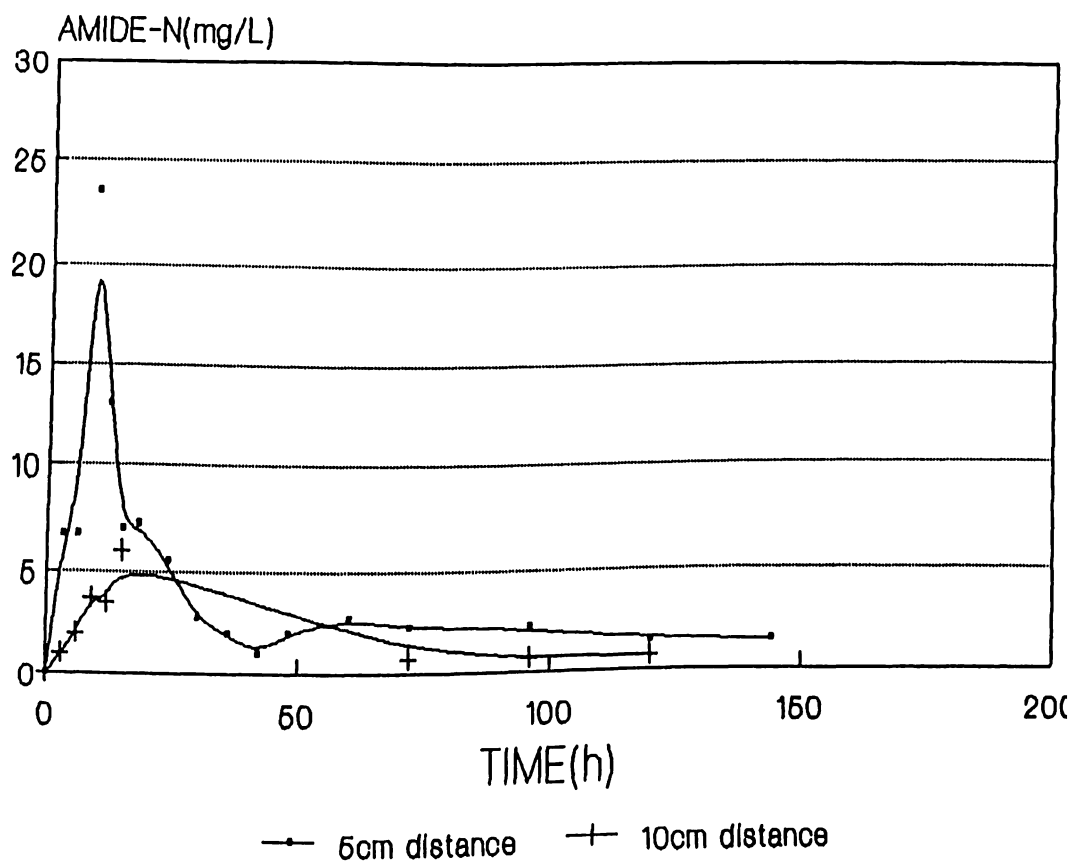


Fig18BTC of Amide-N at soil depth 5cm
stemming from USG placement at 7 DAT

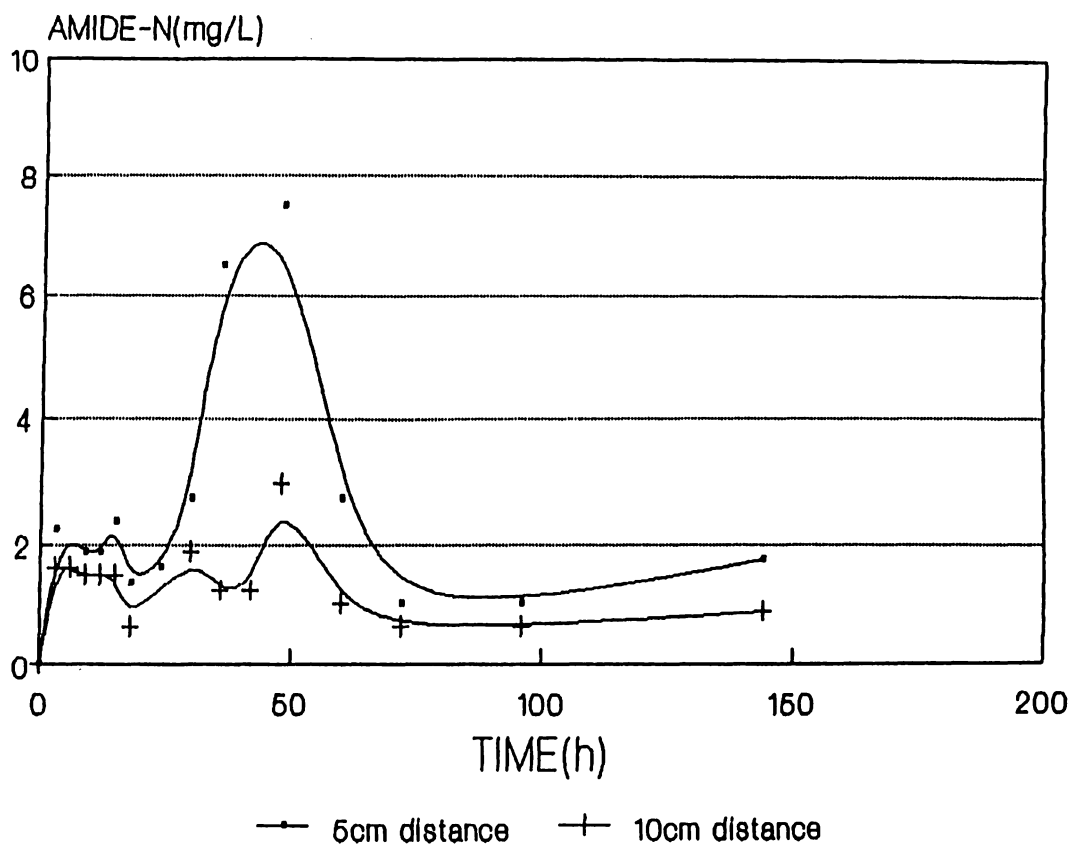


Fig19BTC of Amide-N at soil depth 5cm
stemming from USG placement at 14 DAT

17). Thus the lateral movement of $\text{NH}_2\text{-N}$ was to 5-10 cm horizontal distance at best and no $\text{NH}_2\text{-N}$ moved beyond 10 cm. In Fig. 18 only the BTCs of $\text{NH}_2\text{-N}$ at lateral distances of 5 cm and 10 cm are presented for USG placement at 7 DAT. The variation in peak concentration of $\text{NH}_2\text{-N}$ was observed over time for both the distances. This shows that at 7 DAT of USG placement, the $\text{NH}_2\text{-N}$ moved past the 10 cm distance unlike the earlier period of USG placement. Further it is observed from peak concentration, that the rate of lateral movement of $\text{NH}_2\text{-N}$ appeared to be quicker at 5cm distance than that observed at 10cm distance, presumably with the progress of soil submergence, the rate of lateral movement of $\text{NH}_2\text{-N}$ was increased. A similar trend in the lateral movement of $\text{NH}_2\text{-N}$ was also observed when the USG placement was delayed to 14 DAT (Fig. 19). Perhaps delaying the placement time of USG in soil appears to encourage lateral movement of $\text{NH}_2\text{-N}$ as a result of which the distance between the solute and the rhizosphere of rice plant was decreased and the uptake of N by the plant was increased in comparison to earlier placement of USG.

4.4.6 Vertical movement of $\text{NH}_4\text{-N}$

The BTC of $\text{NH}_4\text{-N}$ stemming from USG point placement at 0 DAT, 7 DAT and 14 DAT are presented in Fig. 20, 21 and 22 respectively appendices 20, 21, 22. In each figure the BTC of $\text{NH}_4\text{-N}$ indicates the $\text{NH}_4\text{-N}$ concentration in floodwater and in soil water collected at a soil depths of 5 and 10cm over time.

In Fig. 20 (T2) the $\text{NH}_4\text{-N}$ concentration in floodwater appeared to be less than the $\text{NH}_4\text{-N}$ concentration in the soil water collected at a soil depth of 5 and 10 cm. Further, the shape of BTC of $\text{NH}_4\text{-N}$ in floodwater was more or less similar to that of $\text{NH}_2\text{-N}$ in floodwater but different from BTC of $\text{NH}_4\text{-N}$ at soil depth of 5 cm. This indicates that possibly the $\text{NH}_4\text{-N}$ has been transformed from USG hydrolysis in floodwater and unlike $\text{NH}_2\text{-N}$, the upward diffusion of $\text{NH}_4\text{-N}$ from soil appears to little affect the concentration of $\text{NH}_4\text{-N}$ in floodwater. In Fig. 20 it also indicates that the BTCs of $\text{NH}_4\text{-N}$ at soil depths of 5 and 10 cm were observed to be more or less same and the BTC of $\text{NH}_4\text{-N}$ appeared a little earlier than that observed at 5cm depth. This shows that USG placement at transplanting increased the downward movement of $\text{NH}_4\text{-N}$ by way of convective diffusion to a great extent in comparison to its upward movement by way of diffusion.

The BTCs of $\text{NH}_4\text{-N}$ in floodwater and in soil water collected at 5 and 10 cm soil depths are presented in Fig. 21. for USG Placement at 7 DAT. The peak concentration of $\text{NH}_4\text{-N}$ in floodwater was observed at the same time as that of the $\text{NH}_4\text{-N}$ at soil depth of 5 cm. On the other hand the $\text{NH}_4\text{-N}$ concentration in the soil water was found to be less at 10 cm soil depth than that at 5 cm soil depth. Further the peak concentration of $\text{NH}_4\text{-N}$ was shown to be at 70 h. of USG application. This shows that $\text{NH}_4\text{-N}$ moved past a soil depth of

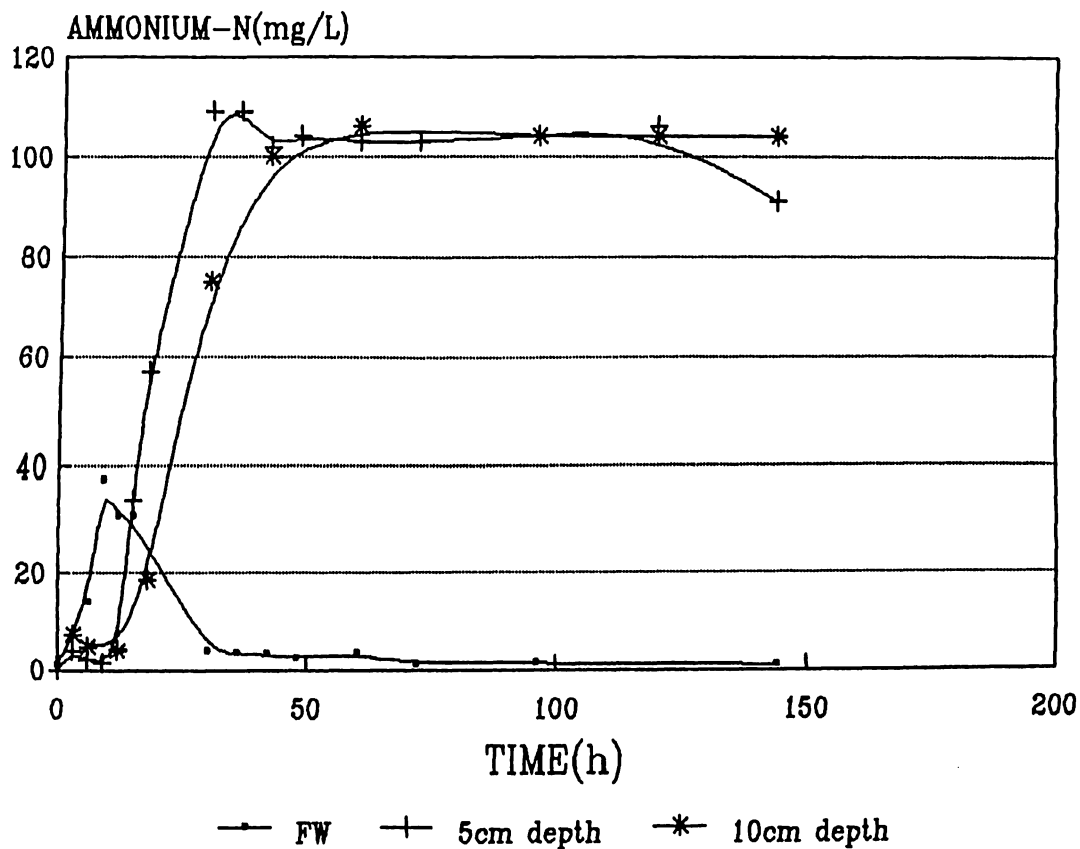


Fig2aBTC of Ammonium-N stemming from
USG placement at 0 DAT

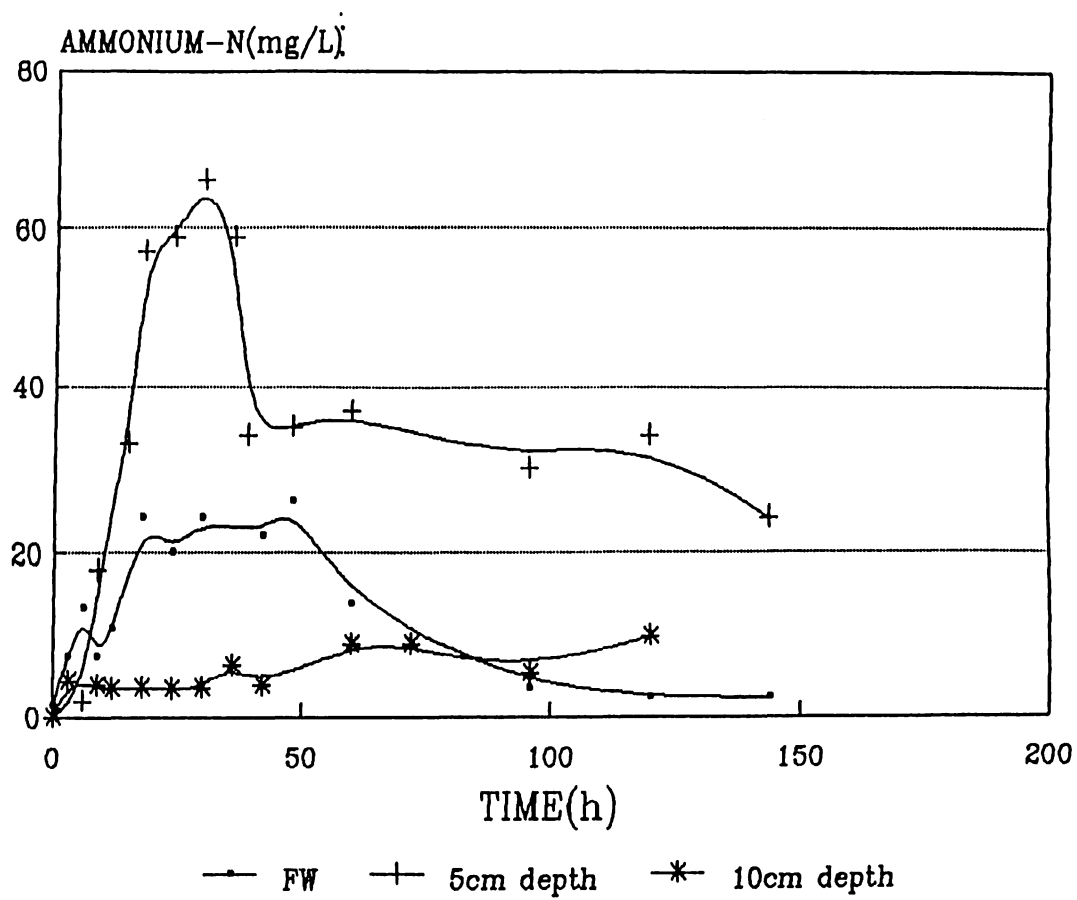


Fig2:BTC of Ammonium-N stemming from
USG placement at 7 DAT

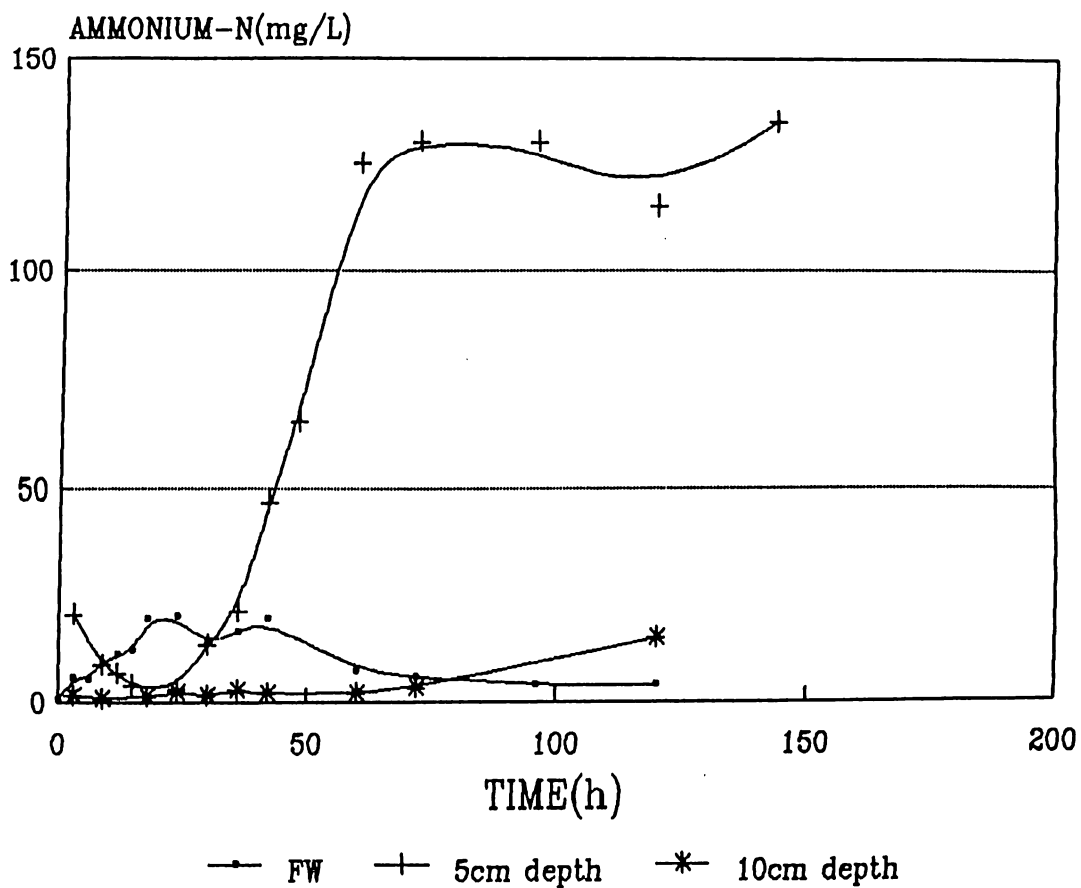


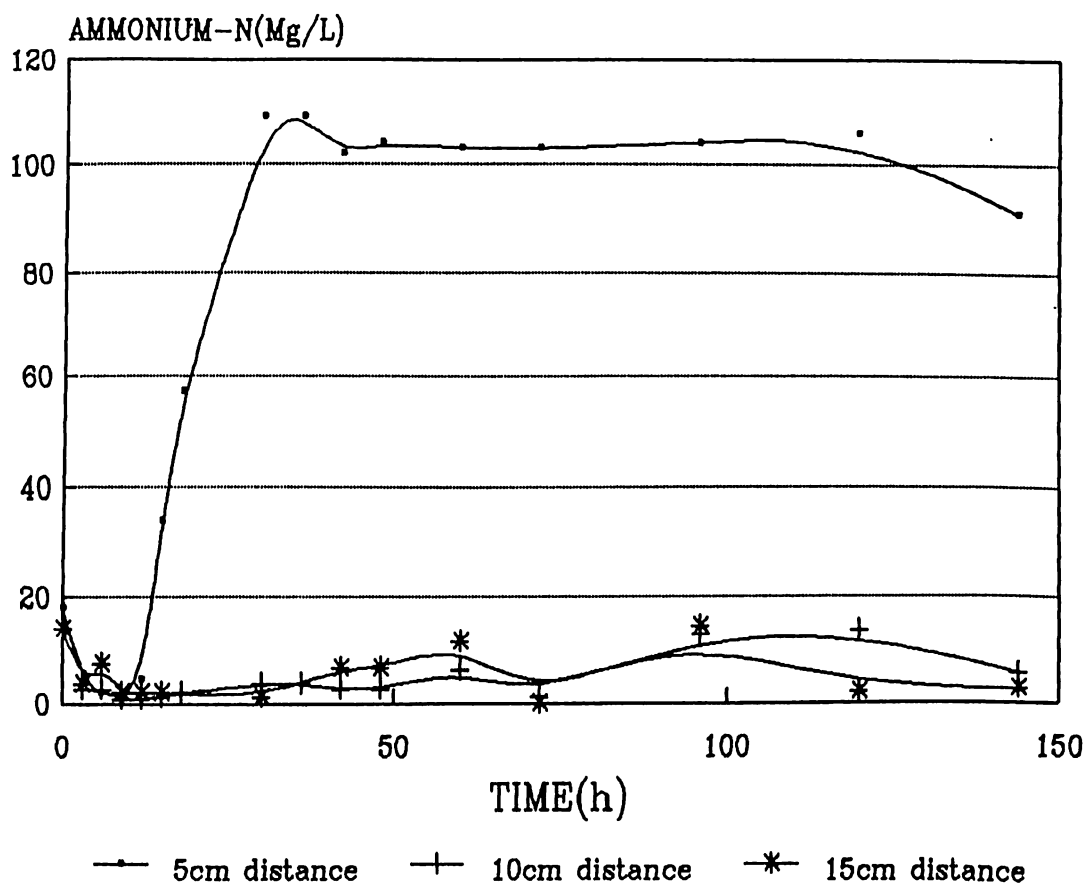
Fig22BTC of Ammonium-N stemming from
USG placement at 14 DAT

5 to 10 cm at a velocity of 0.07 cm/h and a large fraction of the $\text{NH}_4\text{-N}$ was adsorbed and/or taken up by the plant during its transport in soil. At this soil layer the velocity of $\text{NH}_4\text{-N}$ was greatly reduced on account of sedimentation of suspended particles in soil pores.

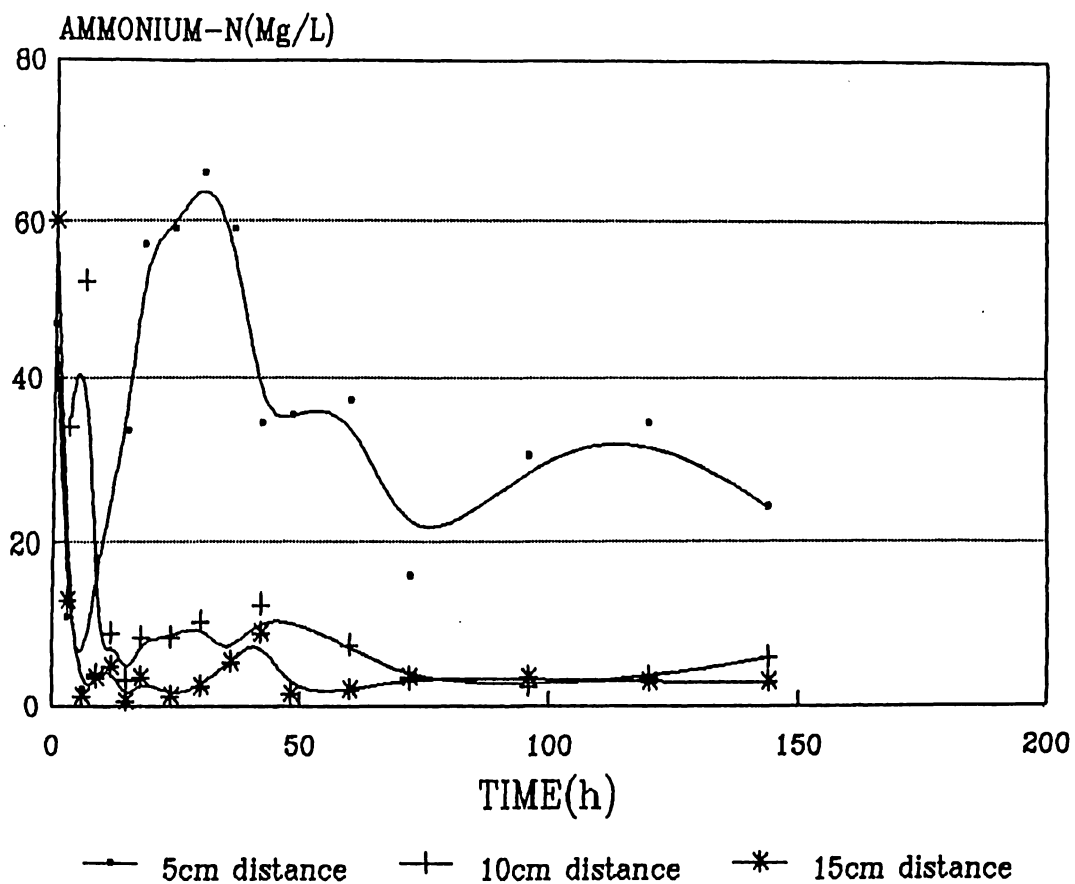
The BTC of $\text{NH}_4\text{-N}$ in floodwater and at soil depths 5 and 10 cm are presented in Fig. 22 for USG deep placement at 14 DAT. Since urea hydrolysis in floodwater was decreased with the progress of soil submergence, the concentration of $\text{NH}_4\text{-N}$ in floodwater was found to be less than that present for USG placement at 7 DAT. Further the concentration of $\text{NH}_4\text{-N}$ in soil water at a soil depth of 5 cm was found to be initially low and subsequently increased to a high value with progress of time. On the otherhand the concentration of $\text{NH}_4\text{-N}$ was found to be minimum at a soil depth of 10 cm. This shows that with increasing period of submergence, the downward movement of $\text{NH}_4\text{-N}$ was further reduced and due to slow velocity of $\text{NH}_4\text{-N}$ most of $\text{NH}_4\text{-N}$ remained within 5-10cm soil depth during its transport. Thus the retention of $\text{NH}_4\text{-N}$ in the soil layer of 5 to 10 cm was more for USG applied at 14 DAT than that applied at 7 DAT.

4.4.7 Lateral movement of $\text{NH}_4\text{-N}$:

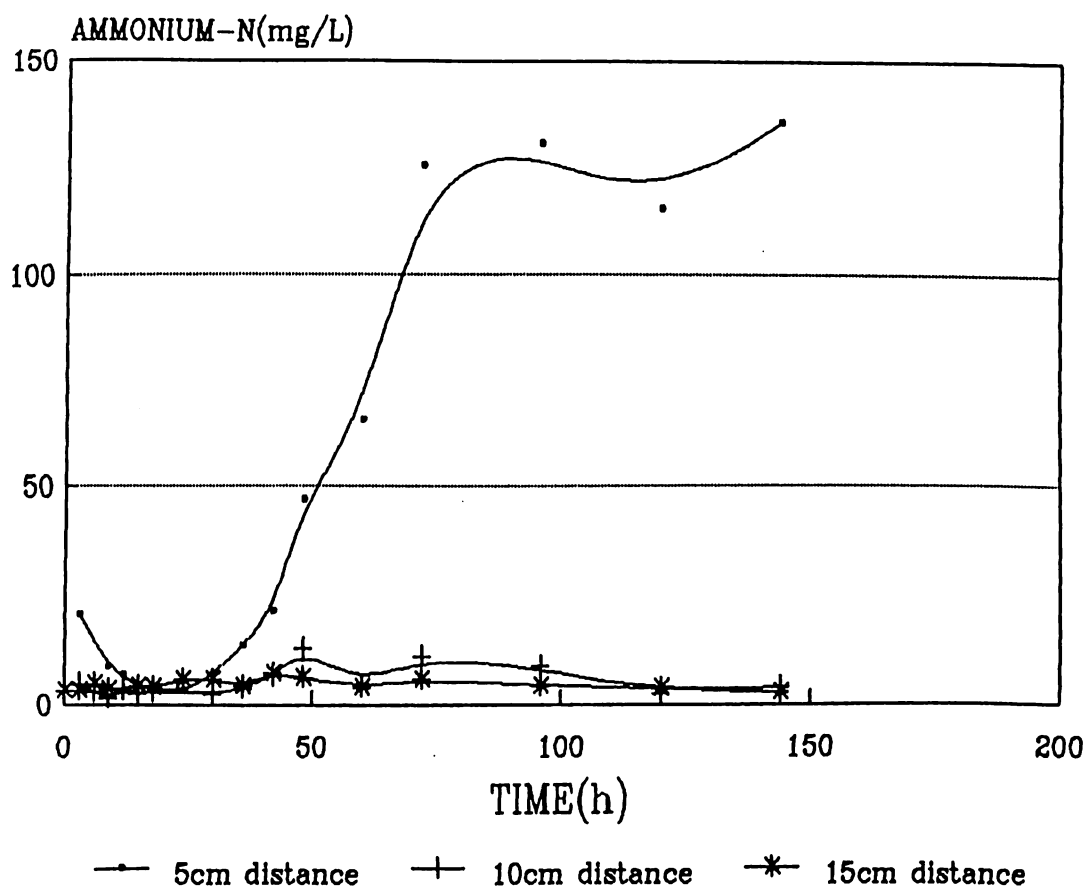
The BTC of NH_4 at a soil depth of 5 cm stemming from USG placement at 0, 7, and 14 DAT are presented in Fig. 23, 24



²³
Fig BTC of Ammonium-N at soil depth of
5cm stemming from USG placement at 0 DAT



24
Fig BTC of Ammonium-N at soil depth 5cm
stemming from USG placement at 7 DAT



²⁵
 Fig BTC of Ammonium-N at soil depth 5cm
 stemming from USG placement at 14 DAT

and 25 and appendices 23,24 and 25 respectively. In each figure the BTCs of $\text{NH}_4\text{-N}$ represent concentration of $\text{NH}_4\text{-N}$ for lateral distances of 5, 10, 15 cm from the point of USG placement. It has been observed that the concentration of $\text{NH}_4\text{-N}$ is much more at a lateral distance of 5 cm than that observed at the lateral distances of 10 and 15 cm. Further the variation in the concentration of $\text{NH}_4\text{-N}$ was observed negligible at the distance of 10 to 15 cm. This shows that the lateral movement of $\text{NH}_4\text{-N}$ was negligible beyond 10 cm of USG placement. Further $\text{NH}_4\text{-N}$ was found to appear later than the appearance of $\text{NH}_2\text{-N}$ for the corresponding times of USG placement (Fig. 17,18 and 19). Therefore it is presumed that the site at which $\text{NH}_4\text{-N}$ appeared represents the point of hydrolysis of USG without lateral movement or has been transported laterally to a distance of 5 cm at best.

4.5. Transport and transformation of Nitrogen in soil as affected by dose and the placement of USG :

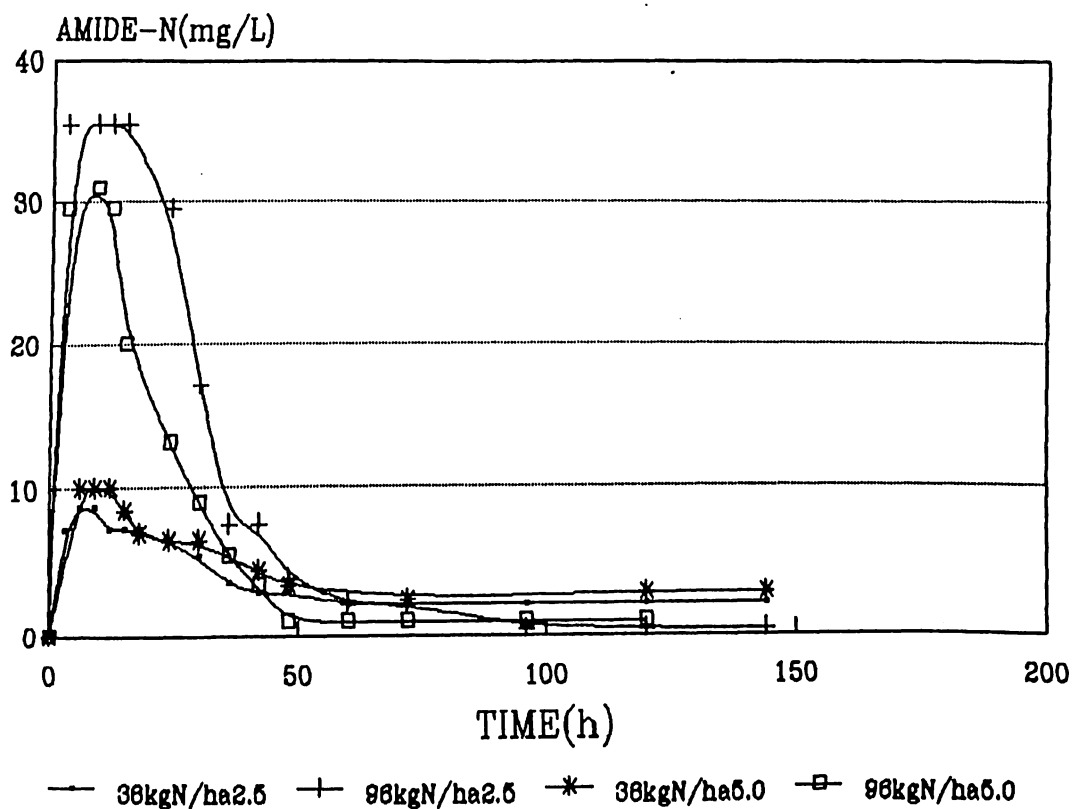
In an observation strip consisting of four rice plots (T1, T3, T4, T6) soil water samplers were installed at soil depths of 5 and 10 cm prior to placement of USG. The soil water samples collected over time were analyzed for $\text{NH}_4\text{-N}$. The floodwater samples collected over time were also analysed for $\text{NH}_2\text{-N}$ and $\text{NH}_4\text{-N}$. The BTCs of both $\text{NH}_2\text{-N}$ and $\text{NH}_4\text{-N}$ were drawn by curve-fitting the observed concentration with the help of the HPG computer graphic model.

4.5.1 Transformation of Amide-N in floodwater

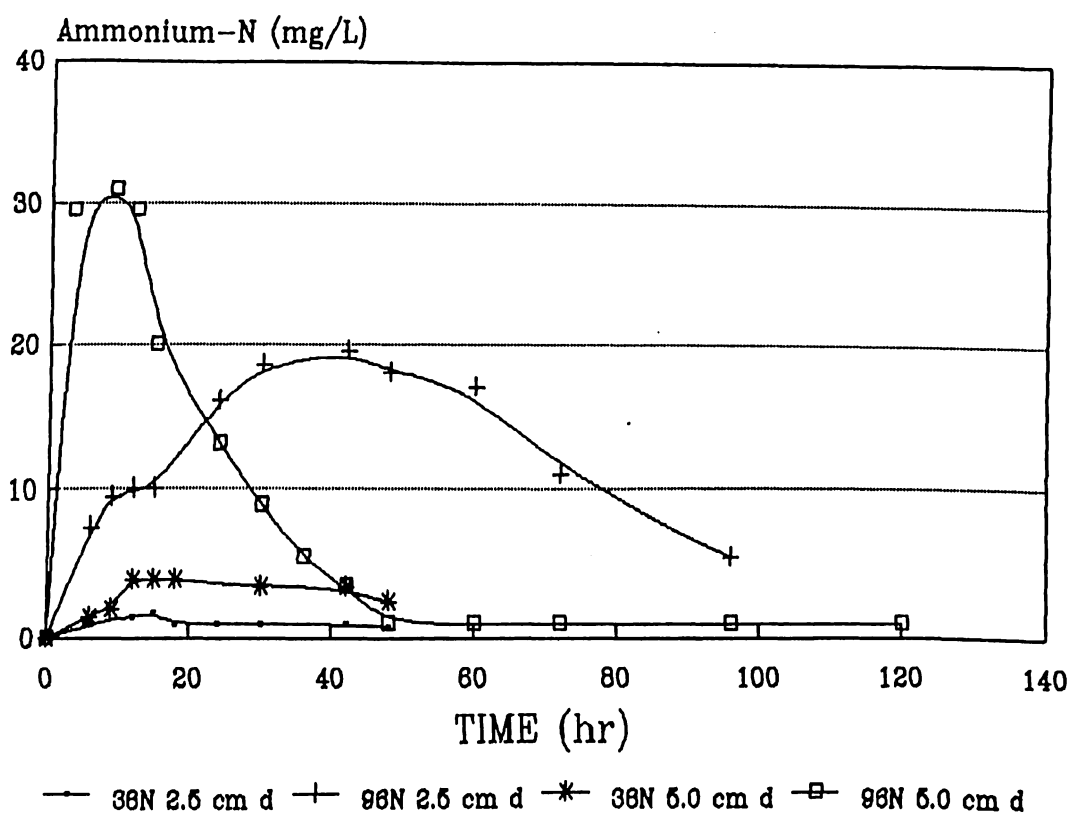
The BTCs of $\text{NH}_2\text{-N}$ in floodwater stemming from placement of USG @ 38 kg N/ha at 2.5 cm soil depth (T1), 96 kg N/ha at 2.5 cm soil depth (T3), 38 kg N/ha at 5.0 cm soil depth (T4), and 96 kg N/ha at 5.0 cm soil depth (t6) are presented in Fig. 26 (Appendix - 26). Like the previous case BTCs of $\text{NH}_2\text{-N}$ in floodwater appeared soon after application of USG at different soil depths. The time that the peak concentration of $\text{NH}_2\text{-N}$ attained was more or less same for all the treatments irrespective of depth and dose of USG application. It is also observed that the BTCs of $\text{NH}_2\text{-N}$ for all the treatments appear to be bell shaped and the $\text{NH}_2\text{-N}$ disappeared in flood water at about 50 h of application like the previous case. (Fig. 10). Perhaps the upward diffusion of urea appears to be least affected when USG was placed within 2.5 to 5 cm soil depth. However increasing the dose of USG-N the rate of diffusion of $\text{NH}_2\text{-N}$ into floodwater was increased. So far diffusion of $\text{NH}_2\text{-N}$ was concerned the placement of USG at 5 cm soil depth was as good as the placement of the same at 2.5 cm depth at lower dose of N application. But at a high diffusion of USG-N the rate of diffusion of $\text{NH}_2\text{-N}$ was slightly reduced when the USG was placed in the deeper layer (5 cm depth) in comparison to a shallow placement (2.5 cm).

4.5.2 Transformation of $\text{NH}_4\text{-N}$ in floodwater :

The BTCs of $\text{NH}_4\text{-N}$ in floodwater stemming from placement of USG @ 38 kg N/ha and 96 kg N/ha at two soil



26
Fig BTCs of Amide-N in floodwater
stemming from USG placement in soil
(Observation strip)

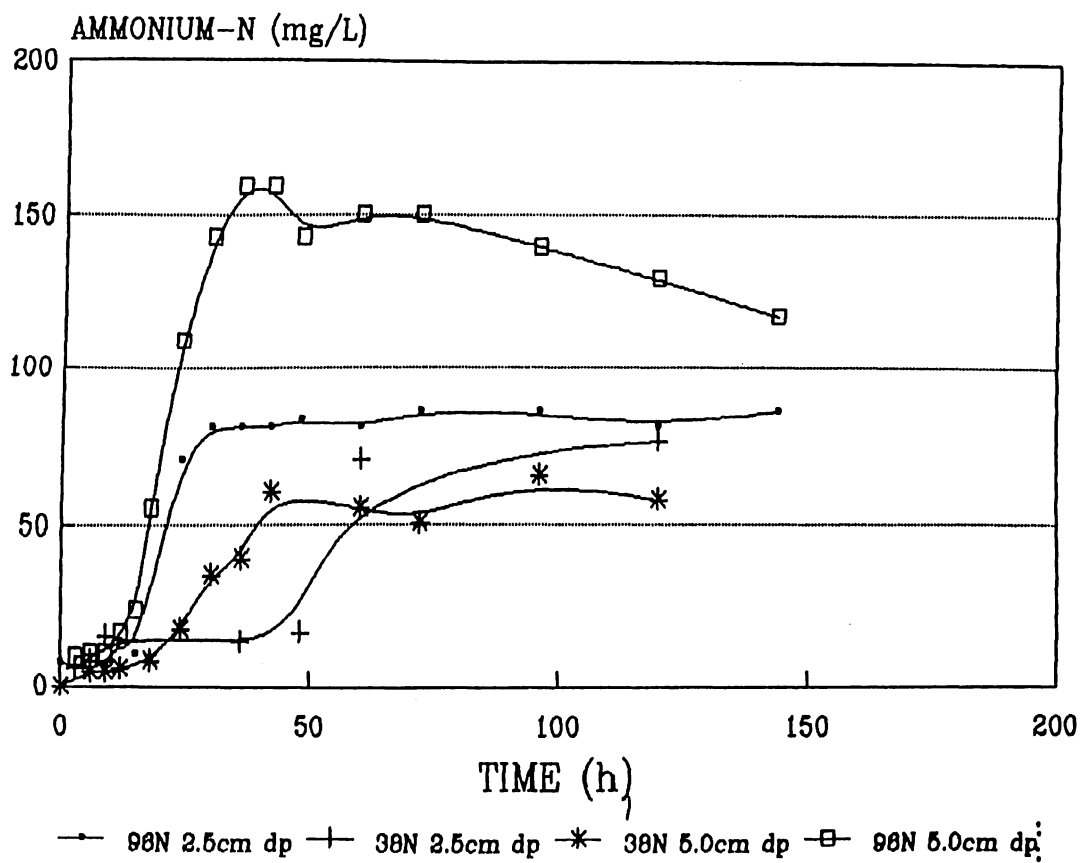


Fig²⁷ BTC of Ammonium-N in floodwater
stemming from USG placement in soil
(observation trial)

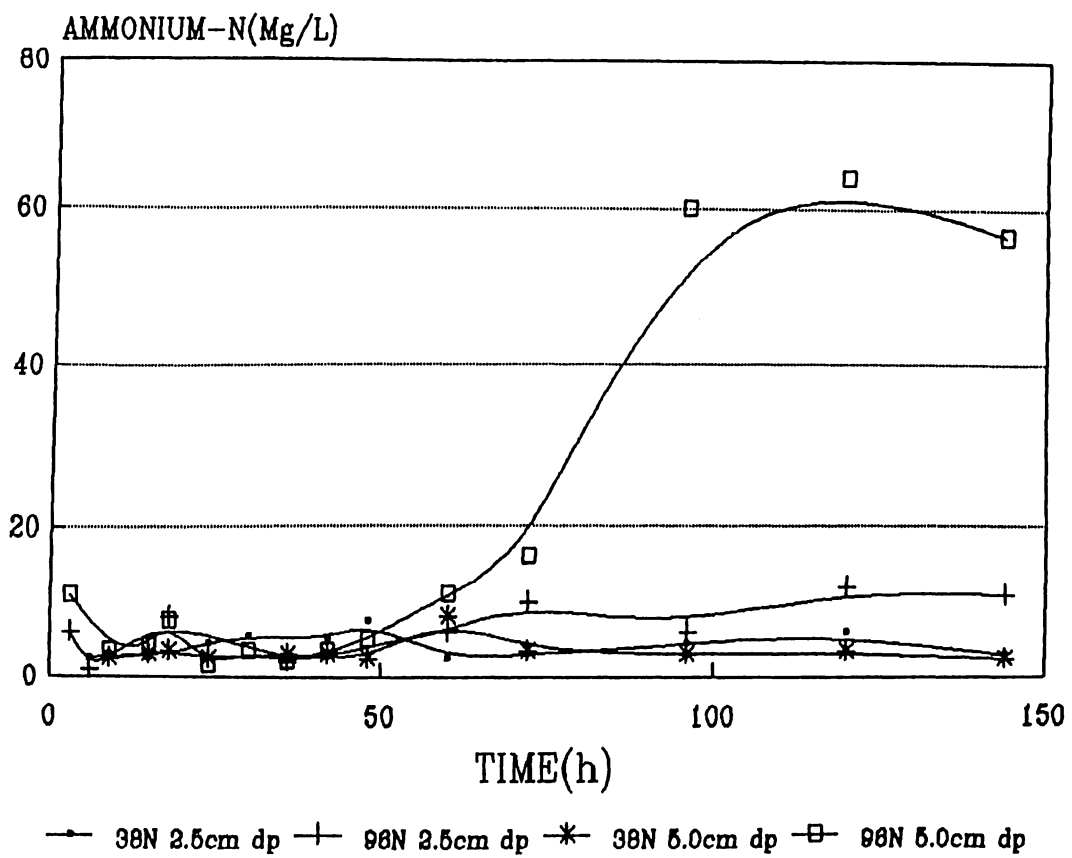
depths of 2.5 and 5.0 cm are presented in Fig. 27 and appendix 27. In floodwater the concentration of $\text{NH}_4\text{-N}$ at anytime was less than that of $\text{NH}_2\text{-N}$. Further the concentration of $\text{NH}_4\text{-N}$ was also lower at low dose than at high dose of N application. This shows that perhaps the rate of USG hydrolysis was related to the $\text{NH}_2\text{-N}$ concentration in the floodwater.

4.5.3 Transformation of $\text{NH}_4\text{-N}$ in soil layer of 2.5 to 5cm

The BTCs of $\text{NH}_4\text{-N}$ at soil depth of 5 cm stemming from application of USG @ 38 kg N/ha and 96 kg N/ha and at two soil depths of placement are presented in Fig. 28 and appendix 28. The soil water samplers were installed at a lateral distance of 5 cm from the point of placement in each case. It is observed that like the previous case a lag phase in the appearance of $\text{NH}_4\text{-N}$ in soil water was observed upto 10 h and thereafter the concentration of $\text{NH}_4\text{-N}$ in soil water was increased. The increase in $\text{NH}_4\text{-N}$ concentration was the largest in case of USG placement at 5cm soil depth @ 96 kg N/ha, intermediate when the USG was placed @ 96 kg N/ha at 2.5 cm soil depth and the lowest when USG was placed at a lower dose (38 kg N/ha) in both the depths. The $\text{NH}_4\text{-N}$ present at soil depth of 5 cm in this case (Fig. 28) stems from the transformation of USG at the respective depths. The higher the dose of the N application, the more was the concentration of $\text{NH}_4\text{-N}$ at that depth. By comparing the BTCs of $\text{NH}_4\text{-N}$ at the same dose (96 kg N/ha) it is observed that the concentration of $\text{NH}_4\text{-N}$ in soil water was more in case of USG placement at 5



28
Fig BTC of Ammonium-N at 5.0cm soil
depth Stemming from USG placement



Fig²⁹ BTC of Ammonium-N at 10cm soil depth stemming from USG placement

cm depth than that at 2.5 cm deep placement. In spite of high rate of USG hydrolysis at 2.5 cm soil depth, the low recovery of $\text{NH}_4\text{-N}$ was observed at 5 cm soil depth. Perhaps a substantial amount of $\text{NH}_4\text{-N}$ had been adsorbed in the exchange complex of soil during its transformation and transport from 2.5 to 5 cm soil depth.

4.5.4 Transport and transformation of $\text{NH}_4\text{-N}$ in soil layer of 5-10 cm :

The BTCs of $\text{NH}_4\text{-N}$ at soil depth of 10 cm stemming from USG placement at soil depths of 2.5 and 5 cm and @ 38 kg N/ha and 96 kg N/ha are presented in Fig. 29 and appendix 29. The concentration of $\text{NH}_4\text{-N}$ in soil water at low dose of application (38 kg N/ha) appeared to be negligible when the $\text{NH}_4\text{-N}$ moved past a distance of 5-10 cm. This shows that at low dose of N application, the vertical downward movement of $\text{NH}_4\text{-N}$ was restricted to 10 cm. But at higher dose, BTCs of $\text{NH}_4\text{-N}$ appeared at 50 h of application and the concentration of $\text{NH}_4\text{-N}$ in the soil water was increased with increasing the depth of USG placement. Therefore it appeared that the downward movement of $\text{NH}_4\text{-N}$ was increased with the increase in the dose and depth of USG placement.

4.6 SPATIAL DISTRIBUTION OF $\text{NH}_4\text{-N}$ IN SOIL :

At about 144 h of USG placement in soil, one soil core of 10 cm length was collected at the placement point of USG from each of the six observation plots. Each soil core was

immediately sectioned into slices of 2 cm thick. The slices were treated with 2M KCl-PMA solution for determination of $\text{NH}_2\text{-N}$ and $\text{NH}_4\text{-N}$. The $\text{NH}_2\text{-N}$ and $\text{NH}_4\text{-N}$ concentration profiles are presented in Table 18. It is observed that no $\text{NH}_2\text{-N}$ was detected in the soil at about 144 h of USG application irrespective of dose and depth of application. This is expected since the $\text{NH}_2\text{-N}$ in soil was hydrolyzed by 50 h of its application. The spatial distribution of $\text{NH}_4\text{-N}$ is only presented in Fig. 30. It is observed that as the N dose was increased the KCl extractable $\text{NH}_4\text{-N}$ content in the soil was increased. This shows that higher the N dose, the more was the amount of N in soil in form of $\text{NH}_4\text{-N}$. It is also observed (Table 18) that at the shallow placement of USG (2.5 cm soil depth), the retention of $\text{NH}_4\text{-N}$ in soil was increased from surface upto 5 cm depth, and there after it was decreased. On the other hand when USG was deep placed (5 cm depth), the depth of accumulation of KCl-extractable $\text{NH}_4\text{-N}$ was lowered 6-8 cm in the soil. Further for the same dose of N application the retention of KCl- $\text{NH}_4\text{-N}$ was found to be more in the soil profile in which USG was placed at a shallow depth (2.5 cm) in comparison to its placement at 5 cm soil depth. Since the soil samples were collected at 144 h after USG placement, a part of the $\text{NH}_4\text{-N}$ during transformation of USG had been leached down from both depths of application. Perhaps the downward movement of $\text{NH}_4\text{-N}$ was more in case of deep placement of USG than shallow placement. Panda et al. (1989) also observed the

Table 18 EFFECT OF DOSE AND PLACEMENT DEPTH OF USG ON SPATIAL DISTRIBUTION OF AMIDE-N AND AMMONIUM-N IN SOIL.

Layer range in cm of core sample	Treatment	Amide-N mg/100gm dry soil	Ammonium-N mg/100gm dry soil	Treatment	Amide-N mg/100 gm dry soil	Ammonium- N mg/100 gm dry soil
0-2	T1 38 kg N/ha as USG	0	20.3	T4 38 kg N/ha as USG	0	2.8
2-4	2.5 cm depth	0	26.5	5.0 cm depth	0	8.1
4-6	placement	0	28.5	placement	0	10.97
6-8		0	22.4		0	-
8-10		0	0.6		0	0.85
0-2	T2 76kg N/ha as USG	0	38.1	T5 76kg N/ha 5cm depth	0	7.63
2-4	2.5cm depth of	0	47.3	of placement	0	15.10
4-6	placement	0	-		0	43.55
6-8		0	22.8		0	49.89
8-10		0	9.8		0	34.27
0-2	T3 96kg N/ha as USG	0	62.7	T6 96kg N/ha as USG 5cm	0	5.43
2-4	2.5cm depth of	0	99.2	depth of placement	0	23.84
4-6	placement	0	130.1		0	14.60
6-8		0	68.8		0	35.43
8-10		0	45.9		0	42.96

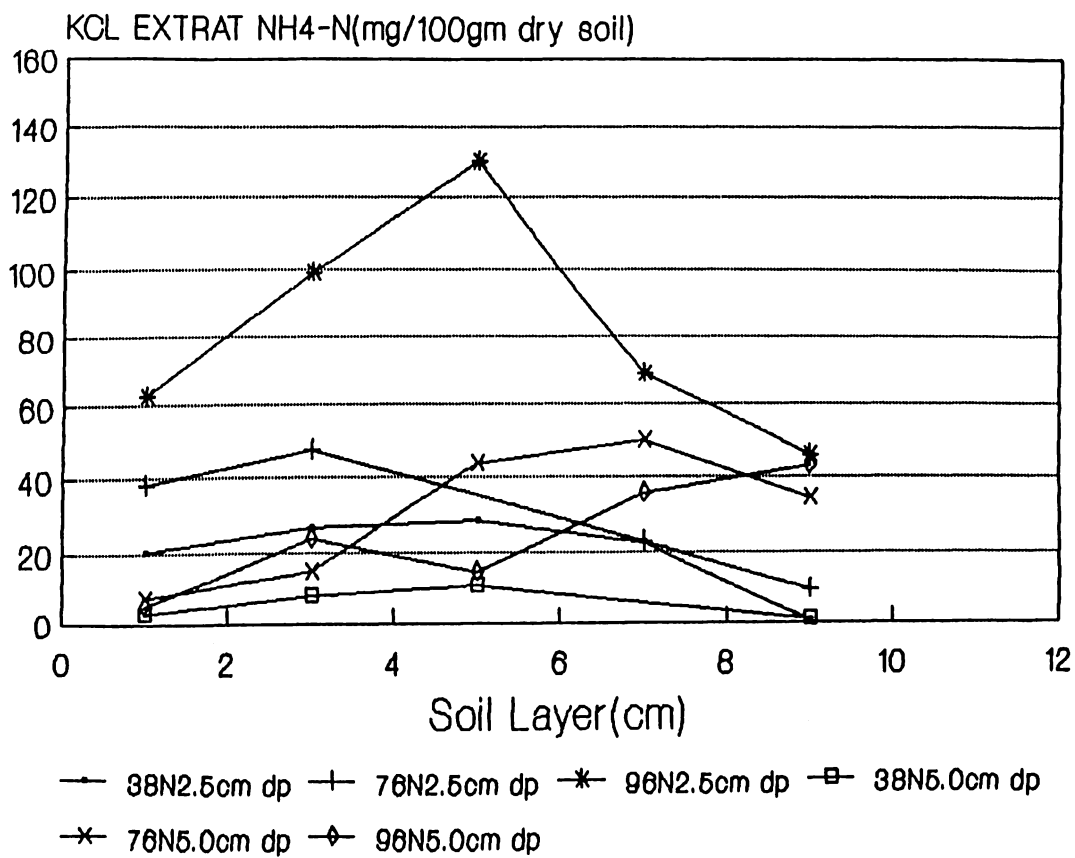


Fig 30 Spatial distribution of Ammonium-N
 at 144 h of USG placement in soil

upward and downward distribution of KCl-Extract $\text{NH}_4\text{-N}$ in soil from the placement of USG at different depths. The downward movement of $\text{NH}_4\text{-N}$ was more than that in upward direction. The same trend of upward and the downward distribution of $\text{NH}_4\text{-N}$ stemming from USG placement was also observed in the present case.

CHAPTER V

SUMMARY AND CONCLUSION

SUMMARY AND CONCLUSION

In order to study transport and transformation of nitrogen stemming from placement of USG at different times in rice soil, a field experiment was laid out in the medium land of central farm Orissa University of Agriculture and Technology, Bhubaneswar. The effect of placement depth and USG nitrogen dose on its transformation and transport were studied in observation strip of rice.

A laboratory experiment was also conducted in the same soil to study the kinetics of USG hydrolysis in soil column.

Laboratory Study

The surface 15 cm soil having silty loam in texture was collected from the medium land in central farm of OUAT. The spot represented the site where the field experiment was to be conducted. The air dry soil was packed to a bulk density of 1.6g/cm^3 in a column of 9 cm length and of 8.0 cm i.d. An USG containing 395.784 mg N was placed on the CaSO_4 solution saturated soil surface and was leached by displacing the CaSO_4 solution at a velocity of 0.4 cm/h. The leachates were collected for determination of $\text{NH}_2\text{-N}$, $\text{NH}_4\text{-N}$ and $\text{NO}_3\text{-N}$. From the BTCs of $\text{NH}_2\text{-N}$, it was observed that the $\text{NH}_2\text{-N}$ was leached

down to a soil depth of 9 cm. at a velocity of 0.33 cm/h in 42h. This shows that the $\text{NH}_2\text{-N}$ was displaced at a slightly slower rate than soil water presumably due to weak adsorption on the exchange complex of the soil. The recovery of $\text{NH}_2\text{-N}$ was computed by integrating the area under BTC of $\text{NH}_2\text{-N}$ and was estimated to be 53.15% of applied USG-N. By assuming a first order reaction, the rate constant for USG hydrolysis was computed to be 0.023/h at 27 C. The leachate fractions of the soil column were also analyzed for $\text{NH}_4\text{-N}$. It was observed the $\text{NH}_4\text{-N}$ appeared at the same time as that of the $\text{NH}_2\text{-N}$ in the leachate. The concentration of $\text{NH}_4\text{-N}$ at anytime was lower than that of the $\text{NH}_2\text{-N}$ and was increased with time up to 126 h. This shows that during the displacement, USG was slowly hydrolyzed to $\text{NH}_4\text{-N}$. The recovery of $\text{NH}_4\text{-N}$ in the leachate fractions was found to be of 1.64% of the applied USG-N. Thus a small fraction of applied N was leached down as $\text{NH}_4\text{-N}$ during the displacement. Since no NO_3 was detected in the effluents, it was presumed that the rate of nitrification in soil, if any, was either very low or the rate was less than that of nitrate reduction.

After leaching the soil column was dismantled and was analyzed for determination of the water extract and Kcl extract $\text{NH}_2\text{-N}$, $\text{NH}_4\text{-N}$ and $\text{NO}_3\text{-N}$. While $\text{NH}_2\text{-N}$ content in the soil was negligible in exchange phase it varied from 1 to 5 mg/L in solution phase. Thus the sorption of $\text{NH}_2\text{-N}$ was very

low and temporary during the displacement of USG in soil. Unlike $\text{NH}_2\text{-N}$ most of applied N remained as $\text{NH}_4\text{-N}$ in soil after leaching. It was observed that the $\text{NH}_4\text{-N}$ content both in solution and exchange phase increased with column length and the maximum amount was observed at soil depth of 6-7.5 cm from the surface. It has also been observed that the increase in the exchangeable $\text{NH}_4\text{-N}$ was associated with the increase in $\text{NH}_4\text{-N}$ content in the solution phase. A linear sorption model like that of a freundlich one was used to findout the relationship between the exchangeable and soluble $\text{NH}_4\text{-N}$ in soil. The nitrate-N content was less than $\text{NH}_4\text{-N}$ in soil water. It was found to be maximum in the top layer and was decreased with column length. This showed that during the displacement of USG a small amount of $\text{NH}_4\text{-N}$ was nitrified in the top soil layer. The unaccountable nitrogen not detected either in the leachate fractions or in KCl extract was about 37% of the applied N. This N was presumably fixed in soil either by immobilization or interlayer fixation or was lost through NH_3 volatilization.

The field experiment on rice was conducted in Kharif 1994 with a randomized block design having four replications and six treatments as detailed below :

- T_1 = 76 kg N/ha as P.U. (Split application 1:2:1)
 T_2 = 76 kg N/ha as USG at transplanting (0 DAT)

- T_3 = 76 kg N/ha as USG 7 days after transplanting
(7 DAT)
- T_4 = 76 kg N/ha as USG 14 days after transplanting
(14 DAT)
- T_5 = 76 kg N/ha as USG 21 days after transplanting
(21 DAT)
- T_6 = Control (No nitrogen fertilizer was applied).

Rice seedlings of 30 day old were transplanted. The Phosphatic and Potassium fertilizers were added @ 50 kg/ha each as a common dose. The PU was broadcast^{ed} in ratio of 1:2:1 at the time of transplanting, maximum tillering and the PI stage. The USG (1 gm size approximately) was point placed at soil depth of 5 cm at the centre of four hills of alternate rows. Prior to the application of N fertilizers, the soil water samplers were installed at soil depths of 5 and 10 cm and at a lateral distance of 5, 10 and 15 cm from the placement point of USG. The floodwater and the soil water samplers were collected periodically for determination of $\text{NH}_2\text{-N}$ and $\text{NH}_4\text{-N}$. Plant samples collected at tillering, PI and at harvest were used for estimation of N content. Some of the yield attributing characters were also recorded before harvesting of the crop.

The grain and straw yield data from the above mentioned experiment were subjected to statistical analysis.

It was, observed that application of nitrogen either in form of PU or USG increased significantly the grain and straw yields of rice. Even in comparison to PU split, the significant yields of grain and straw were recorded by placement of USG at 14 DAT. The yield differences among the treatments were observed in the following order.

$$T_4 > T_3 = T_2 = T_1 = T_5 > T_6$$

The slight variation in straw to grain ratio was found by the application of nitrogen fertilizer. Application of nitrogen fertilizer appeared to contribute to the vegetative growth of the crop. Further the application of USG at 14 DAT was found to produce more grain than straw. Perhaps the increase in yield was associated with the increase in yield attributing characters of plant. The beneficial effects in tillering, panicle length and plant height were found by increasing nitrogen dose as well as by the placement of USG at 14 DAT.

The N content at any stage of the plant was increase with the application of N fertilizers. Further N content in plant was more at tillering and was reduced to a minimum level at P.I stage. At the time of harvest of the crop, while the N concentration in grain was increased, that in straw was decreased. At tillering application of USG increased N concentration of plant more than the P.U. With progress in

growth the nitrogen content was found to increase by delaying in USG placement. Considering the three growth stages, the nitrogen content in plant was found to be maximum when USG was applied at 14 DAT.

The agronomic efficiency and the apparent N recovery of rice were found to be more in case of USG placement at 14 DAT than other treatments. Similarly the relative efficiency of USG placement at 14 DAT was doubled in increasing the rice yield in comparison to the P.U splits.

An observation strip consisting of six plots of rice was taken by the side of the main experiment so as to evaluate the effect of N dose and placement depth of USG. It is recorded that the grain and straw yields were increased up to 50.8 q/ha with increase in dose up to 96kgN/ha. The grain yield of rice was more for deep placement (5.0cm) than for shallow placement (2.5cm) of USG. This shows that reduced zone of soil served as the better site for USG placement with respect to grain yield. The placement of USG at 5cm soil depth was also observed to increase the yield attributing characters to a greater extent than the shallow placement at 2.5cm.

The placement of USG at 5cm soil depth was also found to increase the N uptake in plant at its higher dose of

application than the application of USG at lower dose for shallow or deep placement.

In order to study the transport and transformation of N in soil the soil water samplers were installed at 5 and 10 cm soil depths and with the lateral distances of 5, 10 and 15 cm from the placement point in each of three plots to which USG was applied at 0, 7 and 14 DAT. In case of application of PU, one soil water sampler was installed at 5 cm soil depth. The soil water at both the depths and the floodwater samples were collected periodically upto 144 h of the application of fertilizers. The BTCs of $\text{NH}_2\text{-N}$ and $\text{NH}_4\text{-N}$ were drawn by curve fitting the observed concentration of respective N over time with the help of HPG computer graphic method.

The concentration of $\text{NH}_2\text{-N}$ was found to attain its peak value by 4-6 h and was disappeared within 50 h floodwater irrespective of the time of PU or USG application. This indicated that the $\text{NH}_2\text{-N}$ moved to the floodwater by way of diffusion. Since the amount of $\text{NH}_2\text{-N}$ diffused to floodwater from PU broadcast @ 19 kg N/ha was more or less same as the USG placement at 5 cm soil depth @ ~~16~~⁹ kg N/ha, it was presumed that the rate of diffusion of $\text{NH}_2\text{-N}$ was less from the USG placement at 5 cm soil depth than the surface broadcast of PU. A part of the applied USG-N was also leached down as $\text{NH}_2\text{-N}$ below 10 cm depth due to convective diffusion before being

hydrolyzed into $\text{NH}_4\text{-N}$. The rate of downward flow of $\text{NH}_2\text{-N}$ was found to decrease by delaying the placement of USG.

The $\text{NH}_4\text{-N}$ stemming from USG placement and the basal application of P.U were observed in floodwater as well as in the soil water for a longer period than that observed in case of $\text{NH}_2\text{-N}$. The concentration of $\text{NH}_4\text{-N}$ in soilwater was found to be more than $\text{NH}_2\text{-N}$ at the same soil depth. While the $\text{NH}_4\text{-N}$ in floodwater appeared more or less at same time as that of the $\text{NH}_2\text{-N}$, the appearances of $\text{NH}_4\text{-N}$ in soil water was found to be delayed in comparison to that of $\text{NH}_2\text{-N}$. Further the concentration of $\text{NH}_4\text{-N}$ in soil water at 5cm soil depth was more than that of $\text{NH}_4\text{-N}$ in the floodwater for the corresponding time. This showed that the rate of hydrolysis of USG was more at soil depth of 5cm than that in the overlying floodwater. Further the concentration of $\text{NH}_4\text{-N}$ in floodwater was found to decrease in delaying the placement of USG. The concentration of $\text{NH}_4\text{-N}$ in soil water at soil depth of 5cm was increased for USG placement at 0 DAT, then decreased at 7 DAT, and with a lag phase, increased rapidly at 14 DAT. This showed that the rate of hydrolysis of USG in floodwater and soil water was presumably related to the appearance of $\text{NH}_2\text{-N}$ in the same phase as well as to the period of soil submersion. The period of submergence is shown to affect the convective diffusion of $\text{NH}_4\text{-N}$ below 5cm soil depth. The leaching loss of $\text{NH}_4\text{-N}$ by convective diffusion was maximum at transplanting and

subsequently reduced with increasing the period of soil submergence. This resulted in more retention of $\text{NH}_4\text{-N}$ in soil layer of 5-10cm incase of USG placement at 14 DAT than that in the same layer for USG placement at earlier period.

Since no $\text{NO}_3\text{-N}$ was detected in the leachate fractions at 5cm and 10cm soil depth, it was presumed that the rate of nitrification from placement of USG was very low or less than the nitrate reduction in the soil.

The lateral movement of $\text{NH}_2\text{-N}$ and $\text{NH}_4\text{-N}$ was studied from the soil water samples collected at lateral distances of 5, 10 and 15cm from the placement point of USG. Since the variation in $\text{NH}_2\text{-N}$ concentration was observed negligible from the soilwater samples at lateral distances of 10 and 15cm, the sphere of lateral movement of $\text{NH}_2\text{-N}$ was presumed to be restricted to 10cm of horizontal distance for USG placement at 0 DAT. However with progress of soil submergence while the downward movement of $\text{NH}_2\text{-N}$ was decreased, the movement of $\text{NH}_2\text{-N}$ was increased horizontally.

Like that of $\text{NH}_2\text{-N}$ the concentration of $\text{NH}_4\text{-N}$ overtime was observed maximum at 5cm distance from the point of placement of USG. However the concentration of $\text{NH}_4\text{-N}$ was decreased at lateral distance of 10 and 15cm for any time of USG placement. The variation in the concentration of $\text{NH}_4\text{-N}$ at

a lateral distance of 10cm was observed to be at same time as that found at 5cm. This showed that the horizontal movement of $\text{NH}_4\text{-N}$ was presumably caused due to concentration gradient of $\text{NH}_4\text{-N}$.

The concentration profile $\text{NH}_2\text{-N}$ in floodwater for USG placement at 2.5cm soil depth was found to be more or less same as that at 5cm depth at a particular dose of USG. This showed that the rate of diffusion of $\text{NH}_2\text{-N}$ into the floodwater may be least affected for USG placement at 2.5 and 5cm soil depths. However in increasing the dose of USG-N, the rate of diffusion of $\text{NH}_4\text{-N}$ in floodwater was increased. In floodwater the concentration of $\text{NH}_4\text{-N}$ at anytime was less than that of $\text{NH}_2\text{-N}$ for the USG placement at the same depth and at the same dose. Perhaps the rate of USG hydrolysis as well as the appearance of $\text{NH}_4\text{-N}$ was related to the $\text{NH}_2\text{-N}$ concentration in floodwater and diffusion of $\text{NH}_4\text{-N}$ from soil to floodwater was appeared to be negligible. It was also observed that the concentration of $\text{NH}_4\text{-N}$ at soil depth of 5 cm was maximum for USG placement @ 96 kg N/ha at 5.0 cm soil depth, intermediate for USG placement @ 96 kg N/ha at 2.5cm depth and the lowest when USG was placed at lower doses irrespective of placement depth. The higher the dose of USG, the more was also the concentration of $\text{NH}_4\text{-N}$ at the placement depth. At lower soil depth (10 cm), the downward movement of $\text{NH}_4\text{-N}$ was restricted for USG placement at shallow soil depth or at low dose. But at

higher dose of USG application, the leaching loss of $\text{NH}_4\text{-N}$ was increased with deeper placement of USG.

The spatial distribution of $\text{NH}_4\text{-N}$ in the top 10cm soil layer was appeared to increase with increasing the dose of USG-N. On the other hand for the same dose of N application the distribution of $\text{NH}_4\text{-N}$ was more for shallow placement of USG than the deep placement possibly because of increased downward movement of $\text{NH}_4\text{-N}$ in the later case.

CONCLUSIONS

Based on the foregoing studies and observations it is possible to conclude that,

- * During miscible displacement, rate constant for USG hydrolysis was computed to be 0.023/h in a soil column of 9cm length.
- * The velocity of $\text{NH}_2\text{-N}$ from applied USG was slower than the soil water.
- * The $\text{NH}_4\text{-N}$ moved still at a slower rate than the $\text{NH}_2\text{-N}$.
- * Ammonium sorption was computed to be linear during miscible displacement of USG in soil column.

- * Point placement of USG at 14 DAT increased significantly the straw and grain yields of rice in comparison to P.U splits in medium land soil.
- * The diffusion rate of $\text{NH}_2\text{-N}$ from soil to floodwater was lower for USG placement than P.U broadcast.
- * The rate of USG hydrolysis was more in field soil than in soil column.
- * The rate of diffusion of $\text{NH}_2\text{-N}$ in upward direction was more than its convective diffusion in downward direction.
- * The rate of USG hydrolysis was more at soil depth of 5cm than that in the floodwater.
- * $\text{NH}_2\text{-N}$ disappeared from the floodwater and the soil at 5cm depth by 50 h of USG placement.
- * The rate of hydrolysis of USG in floodwater decreased with the increasing period of soil submersion.
- * Leaching loss of $\text{NH}_2\text{-N}$ and $\text{NH}_4\text{-N}$ was decreased with increasing the period of soil submergence.

- * Placement of USG at 14 DAT reduced the leaching loss of $\text{NH}_2\text{-N}$, increased the $\text{NH}_4\text{-N}$ retention in the rooting zone and contributed to high uptake of nitrogen, growth and yield of the crop.
- * Lateral movement of $\text{NH}_2\text{-N}$ was restricted to 10cm distance from the placement point of USG.
- * The grain yield of rice was more from USG placement at 5cm depth than that at 2.5cm depth.
- * Increasing the N dose in form of USG increased the $\text{NH}_2\text{-N}$ and $\text{NH}_4\text{-N}$ concentration in floodwater as well as in soil water.
- * Lowering the placement depth of USG increases the downward displacement of $\text{NH}_4\text{-N}$ at high dose of N application.

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APPENDIX

Appendix 1 Calander of field operation

	Particulars	Replicated trial	Observation strip
1	Design	R.B.D.	-
2	Replications	4	-
3	Plot size	4 x 3m	2 x 2m
4	Crop	Rice	Rice
5	Variety	Ialat (120 days)	Ialat
6	Spacing (FU) (USG)	0.15 x 0.20m Modified IFDC design	- Modified IFDC design
7	Dose of N (kg/ha)	76	As per treatment
8	Dose of P_2O_5 (kg/ha)	50	50
9	Dose of K_2O (kg/ha)	50	50
10	Date of sowing	7th July 1994	7th July 1994
11	Date of transplanting	5th August 1994	5th August 1994
12	Plant protection measures	Demecron/Ekalux (Two times spraying	Demecron/Ekalux (Two times spraying
13	Weeding	Hand weeding once	Hand weeding once
14	Harvest	5th Nov. 1994	5th Nov. 1994

Appendix 2 Weather observations for the month of July 1994

Date	Temp °C*	R.H(%)**	Rain fall (mm)	Evapotranspiration (mm)
1	30.2	74	0.0	4.8
2	30.2	79	1.5	2.9
3	28.5	89	6.3	3.8
4	27.1	87	6.1	1.8
5	27.8	81	0.8	3.6
6	29.2	81	0.0	4.9
7	30.5	81	7.0	5.2
8	29.3	89	5.8	3.2
9	27.1	91	1.8	3.0
10	26.5	88	4.2	2.5
11	27.7	89	8.1	1.6
12	27.8	93	13.2	2.2
13	26.6	97	8.1	2.4
14	26.8	91	23.3	1.7
15	27.5	93	50.3	1.6
16	26.5	91	39.1	1.9
17	26.1	80	0.4	2.4
18	28.1	80	1.3	2.7
19	28.1	91	0.8	3.2
20	26.5	81	6.2	2.8
21	27.9	78	14.7	2.1
22	28.0	75	8.4	2.8
23	29.5	73	0.0	5.0
24	29.8	79	5.6	3.5
25	30.0	85	0.8	3.8
26	29.3	82	3.3	3.0
27	29.2	80	11.7	3.7
28	29.5	82	2.0	3.0
29	28.9	93	0.0	3.7
30	26.9	86	8.1	2.5
31	26.5	86	6.1	2.7
Total	-	-	238.0	93.9
Average	28.2	85		3.0

* Average of max and min

** Average of morning and After noon.

Appendix 3 Water observations for the month of Aug 1994

Date	Temp°C	R.H(%)**	Rain fall (mm)	Evaporation
1	27.5	84	12.8	2.3
2	28.0	76	0.0	3.1
3	29.0	91	7.9	1.8
4	27.6	80	0.0	2.9
5	28.5	76	7.9	3.1
6	29.6	78	2.5	3.1
7	28.0	88	78.0	Over flow
8	28.1	82	0.0	4.1
9	28.2	89	5.8	3.8
10	28.1	91	10.9	3.0
11	26.6	80	14.2	1.8
12	28.4	83	0.0	3.8
13	28.4	84	0.0	5.0
14	29.2	84	0.0	4.5
15	29.5	79	0.0	3.9
16	28.0	92	39.9	3.3
17	26.7	90	20.3	2.3
18	26.8	94	124.7	over flow
19	26.7	84	3.1	3.5
20	28.2	81	0.0	4.6
21	29.2	85	0.0	3.5
22	28.3	84	41.9	2.0
23	28.6	87	0.0	3.5
24	28.3	82	2.5	3.0
25	28.2	94	22.8	3.2
26	26.5	89	8.6	2.9
27	28.4	92	14.2	3.1
28	26.4	96	19.3	2.3
29	25.2	80	47.7	2.2
30	28.2	78	4.3	2.5
31	28.6	91	0.0	4.2
Total	-	-	489.3	91.9
Average	28.0	85	20	3.0

Appendix 4 Weather observations for the month of September 1994

Date	Temp°C	R.H (%)**	Rain fall (mm)	Evaporation (mm)
1	27.3	93	3.0	3.0
2	27.5	89	2.5	2.4
3	26.7	95	17.8	2.3
4	25.7	96	25.3	2.3
5	25.9	86	7.9	1.9
6	27.6	87	0.0	3.2
7	28.4	82	0.0	3.8
8	29.6	79	0.0	3.8
9	30.2	85	0.0	4.0
10	28.7	85	0.0	2.3
11	27.1	87	7.6	2.2
12	29.1	81	0.3	4.1
13	28.7	83	2.5	2.3
14	28.9	79	1.8	2.8
15	28.4	83	18.3	2.9
16	26.7	93	31.0	2.8
17	26.0	86	81.8	2.6
18	27.0	80	14.7	2.1
19	29.1	80	2.8	2.8
20	28.8	76	0.0	3.7
21	29.1	76	0.0	4.2
22	29.3	85	0.0	4.4
23	29.0	73	5.6	2.9
24	29.5	78	0.0	4.9
25	29.0	79	0.0	4.2
26	28.9	78	0.0	5.0
27	29.0	80	18.8	4.0
28	28.3	72	0.0	5.0
29	28.1	72	0.0	4.7
30	28.7	79	0.0	4.7
Total	-	-	251.7	101.3
Average	28.3	83	16.0	3.4

Appendix 5 Weather observations for the month of Oct 1994

Date	Temp °C**	R.H(%)**	Rain fall (mm)	Evaporation (mm)
1	28.4	81	0.0	3.7
2	28.1	86	0.0	3.8
3	28.0	81	15.7	3.3
4	28.4	91	0.0	4.2
5	27.2	94	31.2	3.0
6	26.3	95	63.3	2.3
7	24.5	86	12.9	1.9
8	26.7	84	8.4	3.5
9	27.4	83	0.0	3.8
10	27.5	77	9.4	3.4
11	28.7	76	0.0	4.2
12	28.5	69	0.0	4.1
13	28.1	73	0.0	4.6
14	27.6	74	0.0	4.2
15	27.5	66	0.0	4.3
16	28.2	70	0.0	4.0
17	27.0	63	0.0	3.7
18	26.0	74	0.0	4.2
19	25.0	87	0.0	4.0
20	26.1	79	1.8	2.2
21	27.0	79	0.0	4.0
22	27.5	80	0.0	3.5
23	26.7	78	0.0	3.9
24	27.0	79	2.0	2.5
25	27.0	90	0.0	3.9
26	26.9	79	3.1	2.9
27	27.3	80	0.0	3.8
28	27.8	71	1.5	4.4
29	27.1	74	0.0	3.8
30	27.9	75	0.0	3.9
31	27.7	73	0.0	3.8

Appendix 6 Weather observations for the month of Nov 1994

Date	Temp °C	R.H (%)	Rain fall (mm)	Evaporation
1	26.6	77	0.0	3.4
2	25.7	76	0.0	3.6
3	22.0	71	0.8	3.8
4	23.7	69	0.0	2.2
5	24.9	72	0.0	3.9
6	26.3	75	0.0	3.3
7	25.6	70	0.0	3.5
8	26.1	80	0.0	4.0
9	22.8	65	0.0	3.4
10	23.5	70	0.0	2.8
11	25.6	69	0.0	3.3
12	26.7	70	0.0	3.9
13	25.9	72	0.0	3.2
14	25.9	67	0.0	4.1
15	25.4	73	0.0	3.7
16	25.6	71	0.0	4.0
17	24.8	71	0.0	3.9
18	24.4	92	0.0	3.3
19	24.0	65	0.0	2.7
20	23.0	58	0.0	3.7
21	22.7	62	0.0	3.2
22	23.0	55	0.0	3.8
23	24.3	59	0.0	3.7
24	24.9	86	0.0	2.9
25	19.1	72	4.8	2.0
26	21.3	58	0.0	3.2
27	21.4	66	0.0	3.6
28	22.3	69	0.0	2.5
29	23.2	67	0.0	3.5
30	23.9	61	0.0	3.2
Total	-	-	-	101.3
Average	24.2	69	5.6	3.4

Appendix 7 Concentration of Amide-N and Ammonium-N in the leachates stemming from surface applied USG in a soil column.

Time	Amide-n Concentration (mg/l)	Ammonium-N Concentration (mg/l)	Time	Amide-n Concentration (mg/l)	Ammonium-N Concentration (mg/l)
0	0	0	27	2300.0	3.5
1	0	-	28	2300.0	3.5
2	0	0	29	2300.0	-
3	0	0	30	1925.0	3.5
4	0	0	31	1675.0	-
5	0	0	32	-	4.0
6	0	0	33	1425.0	-
7	0	0	34	1325.0	-
8	0	0	35	-	3.5
9	0	0	36	1075.0	-
10	0	1.0	45	-	3.5
11	7.5	1.0	48	24.0	3.5
12	17.0	1.0	51	38.0	5.0
13	24.0	0	54	-	-
14	31.0	1.5	57	10.0	5.0
15	35.0	1.0	60	-	5.0
16	50.0	0.5	69	1.0	5.5
17	-	1.5	72	0	8.0
18	300.0	1.5	78	0	12.5
19	450.0	1.0	84	0	-
20	625.0	1.0	93	0	11.0
21	975.0	2.0	96	0	12.5
22	1350.0	2.0	102	0	15.5
23	1850.0	-	117	0	12.5
24	21.25	-	120	0	13.5
25	2300.0	3.5	126	0	14.0
26	2300.0				

Appendix 8

Concentration of Amide-n (mg/L) overtime at 5cm soil depth and 5cm lateral distance from USG placement (76 kgN /ha) in a medium land rice soil.

Time (h)	USG dp 0 DAT 5 depth	USG dp 7 DAT	USG dp 14 DAT
0	0	0	0
3	0.625	6.75	2.25
6	1.875	-	-
9	4.125	23.5	-
12	9.25	13	-
15	-	-	2.375
18	20.375	7.25	-
24	-	5.5	-
30	22.75	2.75	-
36	1.875	2	6.5
42	1.25	1	-
48	1.375	2	7.5
48	1.375	2	7.5
60	1.375	2.75	2.75
72	1.375	2.75	1
96	1	2.25	1
120	1.625	1.5	2.25
144	0.75	1.5	1.75

Appendix 9

Concentration of Amide-N (mg/L) overtime at 10cm depth and 5cm lateral distance from USG 76 kg N/ha placement.

Time (h)	USG dp 0 DAT	USG dp 7 DAT	USG dp 14 DAT.
0	0	0	0
3	3.25	-	-
6	4	4	1.625
9	10	3.75	1.625
12	-	4.75	-
15	-	-	1.25
18	9.375	-	1.25
24	-	-	2
30	-	-	3
36	6	-	3.25
42	3.75	5.75	2.25
48	-	-	1.625
48	-	-	1.625
60	3.75	4	1.625
72	3.375	4	1.625
96	3.375	1	1.625
120	3.75	0.5	1.625
144	3.75	0.5	1.625

Appendix 10

Concentration of Anride-N (mh/L) in flood waterstenming from USG (76kgN/ha) placement and P. U(19kgN/ha) sorface application in a medium land rice soil.

Time (h)	USG DP(ODAT)	USG DP(7DAT)	USG DP(14DAT)	UP SA(ODAT)
0	0	0	0	0
3	7.25	68.5	40	75
6	21	-	40	50
9	-	61.1	37	-
12	17.5	55.9	32.5	-
15	-	42	-	-
18	9.625	33.5	19.5	10
24	-	25.5	11	-
30	-	17.5	-	2.5
36	0.875	5	9.5	2.5
42	0.75	5	1	-
48	0.75	2	-	2
60	0.75	1	1	2
72	0.375	-	0.5	1.5
96	0.375	-	0.5	1
120	-	-	0	1
144	-	-	0	-

Appendix 11

Concentration of Annonium-N (mg/L) over time at 5cm soil depth and 5cm latesat distances from USG placement @ 76 kg N/ha in a medium land rice soil.

Time (h)	USG dp 0 DAT	USG dp 7 DAT	USG dp 14 DAT
0	-	-	-
3	4	-	-
6	2	2	-
9	1.5	18	9
12	4.5	-	7
15	34	33	4
18	57	57	-
24	-	59	3
30	109	66	7
36	109	52	14
42	102	34	22
48	104	35	47
60	103	37	65
72	103	-	125
96	104	30	130
120	106	34	115
144	91	24	135

Appendix 12

Concentration of Ammonium-N (mg/L) over time at 10cm soil depth and 5cm laterals distance from USG placement @ 76kg N/ha in a medium land rice soil.

Time (h)	USG dp 0 DAT	USG dp 7 DAT	USG dp 14 DAT
0	-	-	-
3	-	-	1.5
6	5	-	-
9	-	-	0.75
12	4	-	-
15	-	-	-
18	18.5	3.75	1.375
24	-	3.5	-
30	75	3.75	1.625
36	-	6.50	2.75
42	100	4.0	2.175
48	-	-	-
60	106	9.0	2.125
72	-	9.0	2.25
96	104	5.5	-
120	104	10.0	15.5
144	104	-	-

Appendix 13

Concentration of Ammonium-N over time in flood water stemming from USG (76 kg/ha) placement in a medium land rice soil.

X Axis Numeric	USG DP (0 DAT)	USG DP (7 DAT)	USG DP (14 DAT)	PU SA (0 DAT)
0	1	1.5	0.5	0
3	8	7.5	6	18
6	14.5	13.5	5.5	25.6
9	37.5	-	9.5	-
12	31	-	11.5	-
15	-	-	12.5	-
18	-	24	20	11
24	-	-	20.5	-
30	4	24	-	4
36	3.5	-	17	4
42	3.3	22	-	-
48	2.5	-	-	2.5
60	3	14.5	7.5	2.5
72	1	-	6	1
96	1.5	3.5	4	-
120	-	2.5	4	-
144	1	2.5	-	-

Appendix 14

Concentration of Amide-N (mg/L) over time in floodwater 5cm soil depth and 10 cm soil depth stemming from USG placement (76 kg N/ha) at 0 DAT.

Time (h)	FW	5cm depth	10 cm depth
0	0	0	0
3	7.25	0.625	-
6	21	1.875	-
9	15.25	4.125	-
12	17.5	9.25	2
15	-	-	2.75
18	9.625	20.375	6
24	-	-	-
30	-	22.75	-
36	0.875	1.875	9.375
42	0.75	1.25	3.75
48	0.75	1.375	-
60	0.75	1.375	3.75
72	0.375	1.375	3.375
96	0.375	1.0	3.375
120	-	-	3.75
144	-	0.75	3.75

Appendix 15

Concentration of Amide-N (mg/L) overtime in floodwater, 5 cm soil depth and 10 cm soil depth stemming from USG placement (76 kg N/ha) at 7 DAT.

Time (h)	FW	5cm depth	10cm depth
0	0	0	0
3	68	6.75	4
6	61	6.75	4
9	61	23.5	3.25
12	55.9	13	4.75
15	42	7	-
18	33.5	7.25	2.88
24	25.5	5.5	2.88
30	17.5	2.75	2.88
36	5	2	2.88
42	5	1	5.75
48	2	2	-
60	1	2.75	4
72	-	2.25	-
96	-	2.25	-
120	-	1.5	0.5
144	-	1.5	0.5

Appendix 16

Concentration of Amide-N (mg/L) in floodwater, 5 cm soil depth and 10 cm soil depth stemming from USG placement (76 kg N/ha) at 14 DAT.

Time (h)	FW	5cm depth	10cm depth
0	0	0	0
3	40	2.25	1.625
6	40	-	1.625
9	37	1.875	1.625
12	32.5	1.875	-
15	-	2.375	1.25
18	19.5	1.375	1.25
24	11	1.625	2
30	12.5	2.75	3
36	9.5	6.5	3.25
42	1	4.5	2.25
48	-	7.5	1.625
60	1	2.75	1.625
72	0.5	1.0	1.625
96	0.5	1.0	1.625
120	0	2.25	1.625
144	0	1.75	1.625

Appendix 17

Concentration of Amide-N (mg/L) over time at soil depth of 5 cm and lateral distance of 5, 10, 15 cm from USG placement (76 kg N/ha) at 0 DAT.

Time (h)	5cm distance	10cm distance	15cm distance
0	1.25	-	4.75
3	0.625	2.875	2.5
6	1.875	2.875	3.375
9	4.125	-	1.625
12	9.25	1.5	2.75
15	-	1.5	1.625
18	20.357	1.625	1.875
24	-	-	-
30	22.75	1.375	1.75
36	1.875	1.5	1.5
42	1.25	0.875	1.45
48	1.375	0.75	1.375
60	1.375	0.75	1
72	1.375	1.5	1.0
96	1.0	1.5	1.5
120	1.625	1.75	1.125
144	0.75	1.75	0.5

Appendix 18

Concentration of Amide-N (mg/L) over time at soil depth of 5 cm and lateral distance of 5,10, 15 cm from USG placement (76 kg N/ha) at 7 DAT.

Time (h)	5cm distance	10cm distance
0	0	0
3	6.75	1
6	6.75	2
9	23.5	3.75
12	13	3.5
15	7	6
18	7.25	-
24	5.5	-
30	2.75	-
36	2	-
42	1	-
48	2	-
60	2.75	-
72	2.25	0.75
96	2.25	0.75
120	1.5	0.75
144	1.5	-

Appendix 19

Concentration of Amide-N (mg/L) over time at soil depth of 5 cm and lateral distance of 5,10, 15 cm from USG placement (76 kg N/ha) at 14 DAT.

Time (h)	5cm distance	10cm distance
0	0	0
3	2.5	1.625
6	-	1.625
9	1.875	1.5
12	1.875	1.5
15	2.375	1.5
18	1.375	0.625
24	1.625	-
30	2.75	1.875
36	6.5	1.25
42	-	1.25
48	7.5	3
60	2.75	1
72	1.0	0.625
96	1.0	0.625
120	-	-
144	1.75	0.875

Appendix 20

Concentration of Ammonium-N (mg/L) in floodwater,
5 cm soil depth and 10 cm soil of depth stemming
from USG placement (76 kg N/ha) at 0 DAT.

Time (h)	FW	5cm depth	10 depth
0	1	0	-
3	8	4	7.5
6	14	2	5
9	37.5	1.5	-
12	31	4.5	4
15	31	34	-
18	-	57	18.5
24	4	-	-
30	3.5	109	75
36	3.3	109	-
42	2.5	102	100
48	3.5	104	-
60	1.0	103	106
72	1.5	103	-
96	-	104	104
120	-	106	104
144		91	104

Appendix 21

Concentration of Ammonium-N (mg/L) in floodwater,
5 cm soil depth and 10 cm soil of depth stemming
from USG placement (76 kg N/ha) at 7 DAT.

Time (h)	FW	5cm depth	10cm depth
0	1.5	0	0
3	7.5	-	4.5
6	13.5	2	-
9	7.5	18	4
12	11	-	3.5
15	-	33	-
18	24	57	3.75
24	20	59	3.5
30	24	66	3.75
36	-	59	6.5
42	22	34	4
48	26	35	-
60	14	37	9
72	-	-	9.0
96	3.5	30	5
120	2.5	34	10
144	2.5	34	-

Appendix 22

Concentration of Ammonium-N (mg/L) in floodwater, 5 cm soil depth and 10 cm soil of depth stemming from USG placement (76 kg N/ha) at 14 DAT.

Time (h)	FW	5cm depth	10cm depth
0	0.5	-	-
3	6	21	1.5
6	5.5	-	-
9	9.5	9	0.75
12	11.5	7	-
15	12.5	4	-
18	20	-	1.37
24	20.5	3	2.25
30	14	14	1.65
36	17	22	2.75
42	20	47	2.125
48	-	65	-
60	7.5	125	2.125
72	6.0	130	3.25
96	4.0	130	-
120	4.0	115	15.5
144	-	135	-

Appendix 23

Concentration of Ammonium -N (mg/L) at soil depth of 5cm and lateral distance of 5, 10, 15 cm from USG placement (76 kg N/ha) at 0 DAT.

Time (h)	5cm distance	10cm distance	15cm distance
0	18	-	14
3	4	2.75	3.75
6	2	2.75	7.5
9	1.5	0.75	2
12	4.5	0.75	2
15	34	1.25	2
18	57	2	-
24	-	-	-
30	109	3.75	1.25
36	109	3.75	-
42	102	2.75	6.5
48	104	2.75	6.5
60	103	6.25	11.5
72	103	1.25	0
96	104	13	14.5
120	106	13.5	2.0
144	91	5.5	2.75

Appendix 24

Concentration of Ammonium -N (mg/L) at soil depth of 5cm and lateral distance of 5, 10, 15 cm from USG placement (76 kg N/ha) at 7 DAT.

Time (h)	5cm distance	10cm distance	15cm distance
0	47	-	60
3	11	33.5	13
6	2	52.5	1.25
9	18	4	3.5
12	-	9	5
15	33	3.25	0.5
18	57	8.5	3.5
24	59	8.5	1.25
30	66	10.5	2.5
36	59	5.5	5.5
42	34	12.5	9
48	35	-	1.5
60	37	7.5	2
72	16	3.25	3.5
96	30	2.5	3.5
120	34	3.5	3.0
144	24	6.0	3.0

Appendix 25

Concentration of Ammonium -N (mg/L) at soil depth of 5cm and lateral distance of 5, 10, 15 cm from USG placement (76 kg N/ha) at 14 DAT.

Time (h)	5cm distance	10cm distance	15cm distance
0	-	-	3.25
3	21	4.87	3.25
6	-	3	5
9	9	1.5	3.5
12	7	3.25	-
15	4	2.5	4.5
18	-	3	4.25
24	3	-	6
30	7	2.5	6
36	14	3.87	4.5
42	22	6.65	7.5
48	47	13.5	6.5
60	65	4.75	4.25
72	125	11.25	6.0
96	130	9.0	4.5
120	115	2.5	3.75
144	135	4.25	2.75

Appendix 26 Concentration of Amide-N(mg/L) overtime in floodwater stemming from USG placement (76 kg N/ha) in soil (observation trial).

Time (h)	38 N 2.5cm dp	96 N 2.5cm dp	38 N 5.0cm dp	96 N 5.0cm dp
0	0	0	0	0
3	7.25	35.5	-	29.5
6	8.75	-	10	-
9	8.75	35.5	10	31
12	7.25	35.5	10	29.5
15	7.25	35.5	8.5	20
18	7.25	-	7	-
24	6.5	29.5	6.5	13
30	5.5	17	6.5	9
36	3.75	7.5	-	5.5
42	3	7.5	4.5	3.5
48	3	4	3.5	1
60	2.25	2.25	-	1
72	2.25	2.25	2.5	1
96	2.25	0.5	-	1
120	2.25	0.5	3.0	1
144	2.25	0.5	3.0	-

Appendix 27 Concentration of Amminium -N (mg/L) in floodwater stemming from USG placement in soil (observation trial).

Time (h)	38 N 2.5cm dp	96 N 2.5cm dp	38 N 5.0cm dp	96 N 5.0cm dp
0	0	0	0	0
3	-	-	-	29.5
6	1	7.5	1.5	-
9	-	9.5	2	31
12	1.5	10	4	29.5
15	1.75	10	4	20
18	1	-	4	-
24	1	16	-	13
30	1	18.5	3.5	9
36	-	-	-	5.5
42	1	19.5	3.5	3.5
48	0.75	18	2.5	1
60	-	17	-	1
72	-	11	-	1
96	-	5.5	-	1
120	-	-	-	1
144	-	-	-	-

Appendix 28

Concentration of Ammonium-N (mg/L) at 5 cm soil depth from USG placement at 2.5 and 5.0 cm soil depths for 38 and 96 (kg N/ha).

Time (h)	96 N 2.5cm dp	38 N 2.5cm dp	38 N 5.0cm dp	96 N 5.0cm dp
0	7.5	-	0	-
3	-	6	-	9
6	5	8	4.5	10
9	6.5	16	4.5	10
12	14	-	5.5	17
15	10	-	-	24
18	-	-	8	55
24	70	-	18	109
30	80	-	35	143
36	80	14	40	159
42	80	-	60	159
48	82.5	17	-	143
60	80	70	55	150
72	85	-	50.25	150
96	85	-	65	140
120	80	75.5	57.5	130
144	85	-	-	117

Appendix 29

Concentration of Ammonium-N (mg/L) at 10 cm soil depth from USG placement at for 38 and 96 kg N/ha at 2.5 and 5.0 cm depth of placement.

Time (h)	38 N 2.5cm dp	96 N 2.5cm dp	38 N 5.0cm dp	96 N 5.0cm dp
0	-	-	-	-
3	-	6	-	11
6	2.5	1	-	-
9	3	2.5	2.5	3.5
12	-	-	-	-
15	2.5	-	3	4
18	-	-	3.5	7.5
24	4.5	8	2.5	1.5
30	5.5	-	-	3.5
36	-	2	3	2
42	5	3	3	3.5
48	7.5	-	2.5	5
60	2.5	6	8	11
72	3	10	3.5	16
96	4.5	6	3.0	60
120	6.0	12	3.5	64
144	3.0	11	2.5	56.5