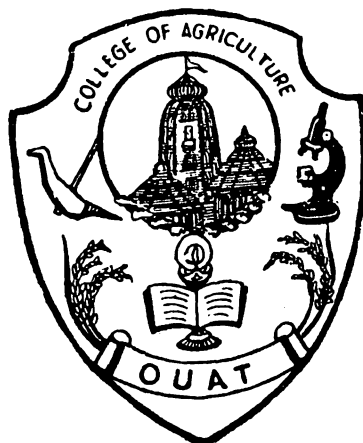


STUDY ON UREA HYDROLYSIS IN THE ROOT ZONES OF RICE, WHEAT AND GROUNDNUT

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 & Biochemistry)

By
Kalikinkar Bandyopadhyay



Department of Agricultural Chemistry, Soil Science & Biochemistry

COLLEGE OF AGRICULTURE

Orissa University of Agriculture and Technology

BHUBANESWAR

1992

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**DEDICATED TO
PARAM PUJYAPAD ACHARYADEB
SRI SRI BARDA**

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**By
KALIKINKAR BANDYOPADHYAY**

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Bhubaneswar
June 23, 1993

CERTIFICATE

Certified that the thesis entitled "**STUDY ON UREA HYDROLYSIS IN THE ROOT ZONES OF RICE, WHEAT AND GROUNDNUT**" 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 Kalikinkar Bandyopadhyay** under my guidance and supervision during the academic year, 1992. 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 him.


23.6.93
(Dr. C. Misra)

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Kalikinkar Bandyopadhyay
(Kalikinkar Bandyopadhyay)

**STUDY ON UREA HYDROLYSIS
IN THE ROOT ZONES OF RICE, WHEAT AND GROUNDNUT**

Student : K.K.Bandyopadhyay

Chairman : Dr. C.Misra

ABSTRACT

Field experiments were carried out in replicated microplots (1 m x 1 m) with rice (Pathara) as the test crop in order to study urea hydrolysis subsequent to application of several urea based N fertilizer sources, viz. GCU, UNP (19-19-0), UNP (27-9-0), USG, PU + ECC alongwith PU, FYM and no nitrogen control. Urea tagged with ^{15}N (10% a.e.) were also applied to wheat and groundnut grown in microplots with wooden and polythene enclosures in order to study urea hydrolysis and N transformation under unsaturated condition. The soil of the experimental site is classified as a member of fine loamy mixed hyperthermic family of an haplaquept. specially designed ammonia traps and solution samplers set up in the microplots for rice allowed the collection of data on volatilization loss of ammonia and $\text{NH}_2\text{-N}$ concentration distribution in the soil solution. Ammonia traps were also provided in wheat and groundnut plots together with tensiometer and neutron access pipes for collection of data on N transformation and water balance studies. The grain yield, N uptake, agronomic efficiency and apparent N recovery percentage data from rice experiment indicated highly significant grain yield response due to all urea based N fertilizers among which again USG and PU applied in two splits could be rated as the most efficient sources of nitrogen, GCU and PU+ECC of intermediate efficiency whereas the UNP sources are the least efficient. Based on measured ammonia volatilization loss values, $(\text{NH}_2\text{-N})$ concentration in flood water and that in soil solution following fertilizer application it was inferred that hydrolysis was faster in the case of PU, GCU and UNP (19-19-0) whereas it is rather sluggish in the case of UNP (27-9-0), PU + ECC and USG treatments. In the case of wheat and groundnut fertilizer urea application at sowing appear to induce an appreciable mineralisation of inherent soil organic matter whereas this was absent when the fertilizer was applied at maximum tillering of wheat. More information regarding N transformation in the root zone of wheat and groundnut would be available after the results of atomic ratio analysis of soil and plant samples for wheat and groundnut experiments are received.

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CHAPTER-I

INTRODUCTION

INTRODUCTION

1.2 IMPORTANCE OF NITROGENOUS FERTILIZERS

Efficient soil and fertilizer management has been recognised as the key to sustained prosperity of a country like India. With the introduction of high yielding and fertilizer responsive varieties which brought about the green revolution the demand for fertilizer has increased many fold. Consequently there is necessity for evolving efficient technology for enhancing crop production and yet avoid the degradation of the environment through unbalanced and excessive fertilization.

Among the chemical fertilizers the nitrogenous compounds are required in large quantities per unit land area for most food and fibre crops. The transformation and fate of the N-fertilizers in the soil have currently demanded the greatest attention of scientists.

The nitrogenous fertilizer manufacture is an energy intensive process. Estimates show that 1 kg of N fertilizer needs about 2 kg fossil fuel (8×10^4 J) for manufacture, packing, transport and application. Among the nitrogenous fertilizers, urea is more popular because of its low cost per unit of nutrient. In Asia, fertilizer nitrogen production has increased from 3.6×10^6 t

in 1970 to 18×10^6 t in 1982-83 of which 85% is urea (Strangel, 1979). By 1989-90 the production level of N fertilizers in India was around 6.8×10^6 tonnes and the consumption level, 8.0×10^6 tonnes.

1.2 N-FERTILIZERS AND THE ENVIRONMENT

Unfortunately the nitrogenous fertilizers are not efficiently utilised by crops like rice. Milsui (1954) has estimated that rice commonly recovers only 30-40 per cent of applied fertilizer N, whereas upland crops recover 50-60%. The rest 60-70% of nitrogen applied to rice are lost by way of gaseous losses through nitrification-denitrification and ammonia redatilization or through leaching and run off (Broadbent, 1978, 1979; Craswell and Vlek, 1979). Even some of the N absorbed by the rice plant might be lost as gas from plant foliage (Wetsehar and Farquhar, 1980). Nitrogen losses are not only extremely costly but also environmentally detrimental. The NO_3^- -N leached below the root zone pollutes the ground water. When the NO_3^- concentration in drinking water in excess of 45 ppm leads to health hazards. N_2O which is produced by denitrification may be a cause for ozone depletion.

1.3 METHODS FOR INCREASING N-USE EFFICIENCY

Hence to mitigate such losses and enhance the efficiency of nitrogenous fertilizer new technologies are being developed and tested. Urea has been granulated and currently marketed

in the form of urea super granule (USG). When buried in the root zone this new material would release $\text{NH}_2\text{-N}$ which hydrolyses to NH_4^+N that are absorbed on colloidal soil particles and get available to the crop for a longer period of time due to reduced leaching and gaseous (both volatilization and denitrification) losses. Likewise sulphur coated urea, rock phosphate coated urea, crotonolide diurea, isobutylidene diurea, ureaform and gypsum coated urea neem cake and karanj cake coated urea etc. are developed and tested. Recently nitrification inhibitors like encapsulated calcium carbide (ECC) is applied alongwith urea to increase N use efficiency. Efforts are underway to formulate other such efficient nitrogen sources through planned research work.

1.4 STUDIES ON N-TRANSFORMATION PROCESSES

In the past several studies have been made by Rolsten et al. (1978), Mangaraj and Misra (1978) and others for determining the kinetics of nitrate reduction as influenced by several environmental factors in open soil systems. Pattnaik (1982) has studied the effect of solution flow rate on the denitrification process. Jena (1985) studied soil water and nitrogenous fertilizer movement and balance in the root zones of different rainfed wheat and legume intercropping systems employing tensiometers, neutron moisture meter and ^{15}N tagged urea. Khanda (1985) studied the kinetics of urea hydrolysis in the laboratory, both under static and dynamic conditions. Misra et al. (1991) have studied kinetics of urea hydrolysis

in oxidised and reduced zone as well as the attendant ammonia volatilisation loss in the rice fields. However, few studies have been devoted in order to quantify the urea hydrolysis process consequent upon using different urea-based fertilizer for rice grown under submergence and for other crops grown under irrigated conditions.

1.5 OBJECTIVES

The objectives of the present investigation have, therefore been

- * to study the relative efficiency of different urea based fertilizers applied to submerged rice.
- * to determine the temporal variation of concentration of $\text{NH}_2\text{-N}$ in flood water and soil solution resulting from the application of different urea-based fertilizers.
- * to determine and compare the ammonia volatilization loss amounts from rice field following application of different urea based fertilizers.
- * to measure ammonia volatilization loss and $\text{NH}_2\text{-N}$ transformation in wheat and groundnut plots following application of urea.
- * to estimate components of water balance of wheat using neutron hydroprobe and $\text{Hg-H}_2\text{O}$ tensiometers.

CHAPTER-II

REVIEW OF LITERATURE

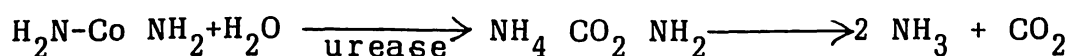
REVIEW OF LITERATURE

2.1 HYDROLYSIS OF UREA (CLOSED SYSTEM) UNDER STATIC CONDITION

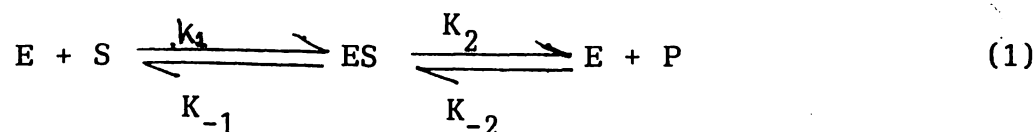
When urea is applied to soil it undergoes hydrolysis to ammonium by the action of an extracellular soil enzyme called 'urease'. This enzyme is believed to be released by dead and ruptured cells of ureolytic microorganisms and plant organs and found adsorbed on soil colloids (Connad, 1942) or present in the soil solution. In soil the urease activity appears to be correlated in general with the microbial population and it increases with the increase in organic matter content. Its concentration is the greatest in the rhizosphere and dependent on particular plant species and is subjected to seasonal variation. McCarty et al. (1991) reported that microbial production of urease in carbon amended soils is not directly repressed by NH_4^+ or NO_3^- but by products formed by microbial assimilation of these forms of N. This conclusion is supported by the finding that biologically active isomers of alanine, arginine, asparagine, aspartate and glutamine repressed urease production in carbon amended soil, whereas the D-isomers of these amino acids had little or no influence

on urease production. Thus they concluded that urease synthesis by soil micro-organisms is controlled by global N regulon. Legume seeds also contain urease (Finar, 1964). The hydrolysing activity of urease has been recognised to be brought about owing both to microbial association and activity as well as to the free enzyme which remains adsorbed on colloid surface. The values of Michaelis Menton coefficient, K_m (Vide supra) for adsorbed urease has been reported to be higher than that for microbial urease (Paulsen and Kurtz, 1969).

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_2 , k_{-1} and k_{-2} are the relevant rate constants.

The reaction rate can be shown, based on Michaelis-Menton treatment, to be

$$v = -\frac{ds}{dt} = k_2 \frac{E_0 + [S]}{K_m + [S]} \quad (2)$$

The following treatment of Eq (2) is essentially given by Misra (1973). If the concentration of the enzyme is nearly

independent of substrate concentration, Eq (2) may be integrated to,

$$-K_2 E_0 t = K_m \ln (S/S_0) + (S-S_0) \quad (3)$$

where S_0 is the concentration of substrate at $t = 0$. If the value of the initial concentration of substrate S_0 is small which is also the condition for a nearly constant enzyme concentration and the value of K_m is relatively large, the second term on the right side of equation (3) may be neglected to yield,

$$\ln(S/S_0) = -K_2/K_m E_0 t = -kt$$

or $S = S_0 \exp (-kt) \quad (4)$

where $k = K_2 E_0/K_m$ and may be regarded as the first order reaction rate constant. Equation (4) is identical to an enzyme catalysed reaction derived on the basis of first order kinetics

Vinod Kumar and Waganet (1984) studied the kinetics of urea transformation as a function of temperature on two soils, Panoche and Wellsville. The experimental procedure involved taking 10 g soil in 150 ml polyethylene bottles to which 0.2 mg N/g soil was added with required amount of water to establish field capacity. The experiment was carried out 10° C, 20° C and 30° C. At intervals of 2, 4, 5, 8, 10, 12 and 24 hours, triplicate sub-samples from the incubated soil were employed for the determination of urea N.

First order rate constant (k) energy of activation (E_a), the entropy of activation (S^*) and standard Gibb's free energy change for the process (G^*) were calculated based on well known equations of chemical kinetics.

For constant temperature,

$$K = \frac{1}{t} \ln (C_o/C_t) \quad (5)$$

where K = first order rate constant (h^{-1})

t = time (h)

C_o = initial urea concentration

C_t = Urea concentration at time , t

E_a , was calculated based on Arrhenius equation.

$$d \ln k / d T = \frac{E_a}{R T^2} \quad (6)$$

where E_a = Activation energy (K cal/mol)

R = Gass constant (1.99×10^{-3} K cal/deg/mol)

T = Temperature ($^{\circ}K$)

On integrating eq (6) yields

$$\ln (k_{T_2}/k_{T_1}) = \frac{E_a(T_2 - T_1)}{R(T_2 T_1)} \quad (7)$$

where k_{T_2} and k_{T_1} are rate constants at T_2 and T_1 respectively.

Measurement of $K(T)$ therefore, provides data necessary to calculate several thermodynamic parameters.

The values of first order rate constant K were found as $0.2518 h^{-1}$ and $0.0842 h^{-1}$ at $10^{\circ} C$ for walsville and Panoche soil, respectively. Similarly K at $20^{\circ} C$ were 0.4375 and 0.1194 and $K_{30^{\circ}C}$ were 0.5222 and 0.1919 for these two soils, respectively. Also, E_a (K cal/ mol) values were found to be 9.15 and 5.78 , G° (K cal/mol) values, 17.42 and 18.04 and S° (cal/deg/mol) -29.21 and -43.31 , respectively, for these two soils.

Khanda (1985) reported the thermodynamic parameters $K_{24^\circ\text{C}}$, K_{29° and $K_{35^\circ\text{C}}$ to be 0.038 h^{-1} , 0.068 h^{-1} and 0.14 h^{-1} . for urea hydrolysis in Bhubaneswar medium-land rice soil. He reported that as the incubation period is increased above 18 h the linearity of concentration vs time curve is affected. He measured the energy of activation for the urea hydrolysis reaction as 21,7 K cal/mol .

Rachpal Singh and P.H. Nye (1984) examined the route of hydrolysis of urea in soil over a wide range of concentration upto 10 moles of N per dm^3 of soil solution, found in fertilizer practice in Begbroke Sandyloam adjusted to different pH values. They observed that on rewetting air dry soil, urease activity increased rapidly, reached maximum within the first 24 hours and then decreased and slowly level off after around 4 days. Pre-treatment of soil with urea or NH_4^+ had no effect on the urease activity. Urease activity increased with substrate concentration, reached an optimum value and then decreased with rising urea concentration. The authors developed a model for predicting concentration profiles of urea, ammonium and soil pH in a soil column following diffusion of surface applied urea using independently derived parameters and experimentally tested the model and found it to be satisfactory.

2.2 HYDROLYSIS OF UREA-N IN SOIL UNDER DYNAMIC CONDITION (OPEN SYSTEM)

Ardakani et al. (1975) examined previously developed mathematical models based on first and zero-order sequential transformations of urea-N by soil urease and other

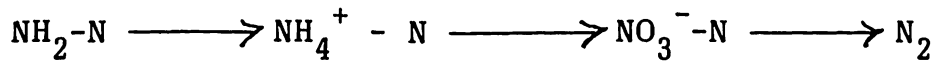
micro-organisms based on Michaelis-Merton type kinetics in a laboratory soil column with continuous flow. Analysis of the data showed that the model could adequately describe the concentration profiles of urea, NH_4^+ , NO_2^- and NO_3^- . Apparent rate constants for urea hydrolysis and for NH_4^+ and NO_2^- oxidation increased with duration of flow. The apparent rate constants for urea hydrolysis after 17, 22, 30, 36 and 44 days were found to be 0.25, 0.80, 2.50, 1.10 and 1.50 h^{-1} , respectively. This increase in rate constant is attributable to microbial growth. The microbial profile developed in the column was characterised by a decrease in population density with depth.

If a solution containing urea is percolated down a soil profile inhabited by micro-organisms, its composition will change with depth. The theory governing the solution transport with concomitant nitrogen transformation in this situation has been presented (Mc Laren, 1978, Cho, 1971 and Misra et al., 1974). These theoretical models provide means for calculating rate constants of nitrogen during continuous flow.

Wagenet et al. (1977) described the fate of applied ^{15}N -urea (95% a.e.) leached through the soil columns. They quantitatively measured the spatial and temporal distribution of $\text{NH}_2\text{-N}$, $\text{NH}_4\text{-N}$ and $\text{NO}_3\text{-N}$ to estimate the magnitude of the first order microbial transformation coefficients of nitrogen

moving in soil columns. The rate constants for enzymic hydrolysis of urea, K_1 , oxidation of ammonium, K_2 and reduction of nitrate, K_3 , were observed to be 0.016, 0.010 and 0.001 h^{-1} , respectively at the ambient temperature of 19.4° C.

Jena et al. (1988) studied the fate of applied ^{15}N urea in rice, pigeonpea and rice + pigeonpea system. They assumed the sequential transformation of applied fertilizer N in the soil to obey the first order kinetics:



The mean rate coefficients of K_u, K_1 and K_2 for urea hydrolysis oxidation of $\text{NH}_4^+ \text{-N}$ and reduction of $\text{NO}_3^- \text{-N}$, respectively were estimated based on the following equations.

$$C/C_0 = e^{-k_u t} \quad (8)$$

$$C_1/C_0 = \frac{K_u}{K_1 - K_u} (e^{-k_u t} - e^{-k_1 t}) \quad (9)$$

$$C_2/C_0 = \frac{K_u K_1}{(K_1 - K_u)(K_2 - K_u)} e^{-k_u t} + \frac{K_u K_1}{(K_u - K_1)(K_2 - K_1)} e^{-K_1 t} + \frac{K_u K_1}{(K_u - K_2)(K_1 - K_2)} \quad (10)$$

where C_0 is the initial concentration of $\text{NH}_2\text{-N}$ added C_1 , C_2 are the concentrations of $\text{NH}_4^+ \text{-N}$ and $\text{NO}_3^- \text{-N}$, respectively at any time t , following the transformation reactions.

Using the relationship described above for the 60 day old crop root zone, Jena et al. (1988) worked out the rate constants K_u, K_1 and K_2 as 0.03, 0.05 and 0.02 h^{-1}

for rice, 0.035, 0.035 and 0.035 h^{-1} for pigeon pea 0.035, 0.027 and 0.034 h^{-1} for Rice + pigeon pea and 0.041, 0.038 and 0.027 h^{-1} for the bare ultisol profile at Bhubaneswar, respectively.

Khanda (1985) leached 15 ml of a solution pulses in 15 cm columns of sandy loam soil packed to a B.D. of 1.5 g/cm^3 . He got a series of break through curves for leaching prilled urea solution (400 ppm $\text{NH}_2\text{-N}$ and neem cake extract (3 kg Neem cake per 10 kg urea), prilled urea solution (400 ppm $\text{NH}_2\text{-N}$) and KCl-PMA (2 M solution), prilled urea solution containing sucrose and prilled urea solution alone.

The recovery fraction for urea, urea + sucrose, urea + neem extract and urea + KCL PMA was found out to be 0.42, 0.39, 0.39 and 0.79 respectively using the relation, $C/c_0 = \exp(-KT)$, Khanda computed the first order rate constants for these systems as 0.079, 0.086, 0.077 and 0.018 h^{-1} respectively.

Beri et al., (1978) studied the movement of surface applied urea in a soil column in laboratory condition with or without addition of commercial urea. Leaching was done with 8 cm water maintaining 1 cm water head on the soil surface immediately after 24 hours of urea application. They found that most of the urea leached down with the water front in the initially dry soil. In the soils maintained at 50 % field capacity urea peak lagged behind the wetting

front. A part of the applied N remained close to the surface when water was applied 20 h after urea application which was probably adsorbed as hydrolysed urea (i.e. NH_4). Application of commercial urease prevented the urea from moving down the wet soil but had little effect on initially dry soil.

Sadeghi et al., (1988) studied the temperature effect on urea diffusion coefficient in soil. They observed that diffusion coefficient of urea in soil is related to diffusion coefficient of urea in water, which increases with temperature. They determined the diffusion coefficient in water using Philips and Ellis capillary tube method. They found the values as 0.89×10^{-9} , 1.27×10^{-9} , 1.92×10^{-9} , 2.16×10^{-9} , 3.04×10^{-9} and $3.25 \times 10^{-9} \text{ m}^2/\text{s}$ for 0, 10, 20, 30, 40 and 50°C , respectively. From these values the urea diffusion coefficient in soil can be found out following Papendick and Campbell (1980) as,

$$D_u = D_w \times K \times \theta^a \quad (11)$$

where $K = \text{Tortuosity} = 2.8$

$a = \text{Constant} = 3.0$

and $\theta = \text{Volumetric water content}$

2.3. FACTORS INFLUENCING HYDROLYSIS OF UREA

The rate of urea hydrolysis in soil depends on several factors like temperature, substrate concentration, organic matter content, moisture-regime calcium carbonate, salt concentration and pH.

2.3.1 Effect of Temperature on Urea Hydrolysis

With the increase in temperature the urea hydrolysis generally increases. Vinod Kumar and Wagnet (1984) found that urease activity increased linearly with temperature from 5 to 35°C in all soils, though from 35 to 45°C the linear relationship did not hold. The percentage of increase from 5 to 35°C was 23, 32 and 23 in Kilburn, Dagore and Nibley soils, respectively. Gould et al. (1978) found that urease activity continued to increase even after 37°C. Recently Khanda (1985) studied the hydrolysis of urea in soil incubated at three temperatures i.e. 29°C, 35°C and 24°C and observed the urea hydrolysis rate constants to be 0.038, 0.068, 0.14 h⁻¹ at 24°C, 29°C and 35°C. The Q₅ and Q₁₀ values reported by him are 1.79 and 3.3, respectively.

2.3.2 Effect of substrate Concentration on Urea Hydrolysis

Kumar and Wagnet (1984) found that increasing the levels of urea-N from 250 to 1000 µg N/kg in the soil results in linear increase in urease activity in Kilburn, Dagore and Nibley soil.

2.3.3 Effect of organic matter on Hydrolysis of Urea

Kumar and Wagnet (1984) found that dried grass had no effect on urease activity of Kilburn, Dagore and Nibley soils. When decomposed organic matter and farm yard manure were added, however, the urease activity of all three soils

increased. Thus the increase might have been due to the presence of extra cellular urease adsorbed on finer and well decomposed organic matter particles, which has been suggested as the reason for such effect in other studies (Myers Mc. Garity, 1968).

Raynolds et al. (1985) reported that urea hydrolysis rate is greater in pasture samples than in soils collected from cultivated fields. For samples from cultivated fields urea hydrolysis is positively correlated with total nitrogen and organic carbon under field moist and air dry condition.

2.3.4 Effect of moisture regime on hydrolysis of urea

Kumar and Wagnet (1984) observed that increasing the moisture content from 25% of field capacity to full field capacity increased urease activity by 15, 29 and 46% in kilburn, Dogore and Nibley soils, respectively. As the moisture content was further increased to flooding, however, soil urease activity decreased. A similar relationship was observed by Myers and Mc. Garity (1968).

This reduction in urease activity on flooding may be attributed to reduction in aeration, Reddy and Chhonkar (1991).

Gill et al. (1991) from their incubation studies under aerobic and anaerobic conditions concluded that urea hydrolysis and FYM decomposition is five to six times more rapid under aerobic condition than under anaerobic condition.

2.3.5 Effect of soil pH on urea hydrolysis

Urea hydrolysis proceeds at slower rate in acid soils. For example in a Bihar soil with pH 5.4 to 5.9 ammonification of urea was complete in four weeks, but in soils of high pH (>7.2) urea hydrolysis was rapid and took only 3 to 7 days for completion depending upon the concentration of urea (Shankhyān Shukla, 1976). Increasing the rate of urea N application slowed down the ammonification rate of urea, more in acid soils than in alkaline soil. The higher rate of urea hydrolysis at higher soil pH may be attributed to NH_3 volatilization and hence provision of an outlet for the NH_4^+ that is formed due to urea hydrolysis. Similar results were obtained by Shahrawat (1992). Taking three soils of different pH values in vertisol (pH = 8.35), Alfisol I (pH = 6.2) and Alfisol II (pH = 4.5) he found that hydrolysis of added urea (100 ppm) was complete in one day only in vertisol, 2 days in Alfisol I and not complete even, after 10 days in Alfisol II.

2.3.6 Effect of CaCO_3 on hydrolysis of urea

Zantua et al. (1977) observed a negative relationship between CaCO_3 content on natural soils and soil urease activity. Kumar and Wagnet (1984) observed that addition of 2.4 and 8% amorphous CaCO_3 decreased the urease activity in all the three soils (i.e. Kilburn, Dagore and Nibley) they studied.

2.3.7 Effect of concentration of different salts and HCl on the hydrolysis of urea by pigeon PEA extract

Panda and Pattaniak (1985) studied the hydrolysis of urea by the urease (contained in the pigeon pea extract) when added to 0.0, 0.04, 0.1, 0.2, 0.4, 1.0 or 2.0 N KCl solution containing urea-N and found the percentages of urea-N hydrolysed as 98.5, 100, 100, 99.9, 91.2, 83.5, and 68.4, respectively. They also studied the hydrolysis of urea brought about by pigeonpea extract added to 0.0, 0.10, 0.25, 0.50, 1.0 and 2.0 N HCl containing urea-N and found the percentages of urea-N hydrolysed as 98.5, 58.8, 11.8, 6.9, 11.8, 2.9 and 4.4, respectively.

In another set of experiments the effect of 0.2 N NaCl, 0.2 N KCl, 0.2 N Na_2SO_4 , 0.2 N KCl + 0.1 N HCl or 0.2 N NaCl + 0.1 N HCl on urea hydrolysis brought about by pigeon pea extract was studied. The percentages of urea-N hydrolysed were observed to be 96.3, 97.3, 97.0, 8.8 and 5.9, respectively.

The authors reported that salt concentration higher than 0.2 N inhibited the hydrolysis of urea by pigeon pea extract to varying degrees. There was not much difference among KCl, NaCl on Na_2SO_4 in their effect on the hydrolysis. Concentration of HCl even at 0.02 N inhibited the hydrolysis process.

2.4 MODELLING OF HYDROLYSIS OF UREA IN FLOODED RICE SOIL

Fertilizer urea hydrolysis in the flood water, oxidised and reduced zones of rice soils is not completely understood (Savant et al., 1985) and therefore quantitative information on insitu hydrolysis of added urea fertilizer in such soils is almost non existent.

Misra et al. 1991 developed a model to quantify hydrolysis of urea in flooded rice soil.

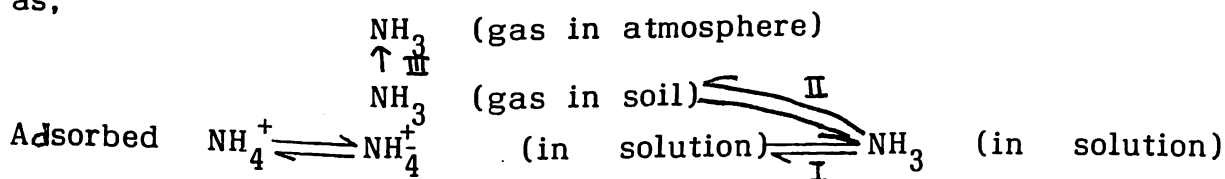
The basic concept behind this model is that when urea is top dressed on a rice field with standing water the concentration of urea suddenly increases at the soil surface. While top dressing urea an unknown fraction of it remains in the standing flood water or diffuses into it from lower layers of standing water as well as from the soil surface. The urea deposited on the soil surface migrates to lower soil layers as well. While remaining in soil and on its way to lower soil layers and to the standing flood water it undergoes hydrolysis by the action of urease enzyme. So the hydrolysis rate constants for urea will vary in flood water as well as in soil. Even in the soil in the vicinity of rice rhizosphere there remains a partially oxidised and below it a reduced zone. So in the soil the hydrolysis rate constants will also vary in the oxidised and reduced zone depending on urease activity in these zones.

A field study was conducted to test this model in which 37.5 kg N/ha as urea was top-dressed in a winter rice field with standing water. Three break through curves (BTC) were drawn for temporal variation of $\text{NH}_2\text{-N}$ in flood water, in soil solution at depth 0-5 cm (oxidised zone) and at depth 0-10 cm (reduced zone). From these BTC the hydrolysis constants were computed and reported as K (Oxidised zone) (0.09 h^{-1}) K (reduced zone) (0.05 h^{-1}) K (flood water) (0.015 h^{-1}). These results are in general agreement with that reported by Savant et al. (1985). Again the hydrolysis rate constant found for the oxidised zone in the temperature range of 22.5 to 35.5°C are in close agreement with the urea hydrolysis rate constant value obtained by Khanda (1985) under static and dynamic condition under the same temperature range for the same soil.

2.5 VOLATILISATION LOSS OF AMMONIA

When urea undergoes hydrolysis it gives rise to NH_4^+ ion which forms NH_3 that ultimately volatilises to the atmosphere at normal temperature and pressure. Ammonia is a basic gas so it has affinity for acidic compounds and for water. So its reaction with water are the fundamental determinants of the rate of volatilisation.

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



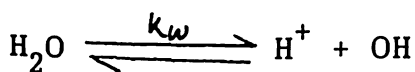
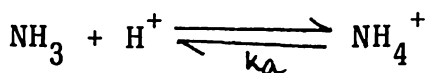
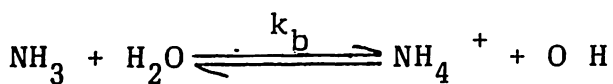
Thus the rate of ammonia volatilisation is controlled by three steps.

- I) Conversion of NH_4^+ (in solution) to NH_3 (in solution)
- II) Conversion of NH_3 (in solution) to NH_3 (gas in soil)
- III) Transfer of NH_3 (gas in soil) to NH_3 (gas in atmosphere)

The driving force for NH_3 volatilisation from a moist soil (or solution) is normally considered to be the difference between the partial pressure of NH_3 in equilibrium with the liquid phase and that in the ambient atmosphere Denmead et al. (1982). The equilibrium vapour pressure of NH_3 is controlled by the NH_3 concentration in the adjacent solution which in the absence of other ionic species is affected by the NH_4^+ ion concentration and pH.

I. AMMONIA - AMMONIUM EQUILIBRIA

This equilibria is represented by



The dissociation parameters K_a , K_b and k_w are related by,

$$\text{p}K_a = \text{p}K_w - \text{p}K_b \quad (12)$$

$$\text{and based on } \text{p}K_a - \text{pH} = \log \frac{[\text{NH}_4^+]}{[\text{NH}_3]} \quad (13)$$

$$\text{and } \text{p}K_a = \text{p}K_w - \text{p}K_b \quad (14)$$

$$\text{one gets } (\text{p}K_w - \text{p}K_b) - \text{pH} = \log \frac{[\text{NH}_4^+]}{[\text{NH}_3]}$$

Accurate values for K_b have been obtained by Bates and Pinching (1950) from EMF measurements. It is evident from eq(14) that when pH rises there is more tendency towards formation of NH_3 in solution.

The dissociation constants K_w , K_a and K_b varies markedly with temperature. Emerson et al. (1975) provided the following expression for calculating the values of K_a at a particular temperature.

$$\log_{10} K_a = -0.09018 - \frac{2729.92}{T} \quad (15)$$

where T is the absolute temperature.

II. AMMONIA (SOLUTION) - AMMONIA (GAS) EQUILIBRIA

The ammonia in solution and gaseous phase are related by the Henry's law,

$$\frac{\text{Concentration of } \text{NH}_3 \text{ in solution phase}}{\text{Concentration of } \text{NH}_3 \text{ in gaseous phase}} = H \quad (16)$$

where H is Henry's constant which varies with temperature Hales and Drewes (1979) and the sub-committee on Ammonia (1979) provided an expression for the variation of H with temperature viz,

$$\log_{10} H = 14.77.7/T - 1.6937 \quad (17)$$

where H (M/M), the Henry's constant.

Many workers find it more convenient to consider the partial pressure of NH_3 , $P(\text{NH}_3)$ in equilibrium with the concentration of NH_3 in solution and derive the relation

$$p(\text{NH}_3) = RT \left(10^{1.60352 - 4207.62/T} \right) \frac{[\text{NH}_4^+]_{\text{solution}}}{[\text{H}^+]} \quad (18)$$

Thus temperature, ammonium concentration and pH markedly affect the partial pressure of NH_3 in equilibrium in solution.

Denmead et al. (1962) used a reparameterisation of the relationship given by the sub committee on Ammonia (1979) to calculate the equilibrium partial pressure $p(\text{NH}_3)$ based on the ammonia-cal N concentration (i.e. the sum of NH_4^+ -N and NH_3 -N in solution), pH and temperature.

The relationships are,

$$[\text{NH}_3]_{\text{solution}} = \frac{[\text{NH}_3 + \text{NH}_4^+]_{\text{solution}}}{1 + 10^{(0.09018 + 2729.92/T - \text{pH})}} \quad (19)$$

$$\text{and } p(\text{NH}_3) = \frac{0.00488 [\text{NH}_3]_{\text{solution}}}{10^{(1477.8/T - 1.6937)}} \quad (20)$$

where the concentration of NH_3 is in g/m³, pressure are in mb and temperature in °K. Equation(20) shows that the equilibrium partial pressure of NH_3 increase linearly with the concentration of NH_3 in solution and exponentially as the temperature.

It is apparent that the presence of CO_2 , other forms of alkalinity, acidity and ion pair formation will affect the equilibrium between NH_3 and NH_4^+ and thus influence NH_3 loss Vlek and Stumpe (1978).

III. TRANSPORT OF NH_3 GAS THROUGH SOIL INTO THE ATMOSPHERE

Ammonia must be transported to the soil surface before it gets lost to the atmosphere and a number of workers have shown that the rate of loss is related to the depth of NH_3 below the soil surface. Transport can be accomplished by the movement in liquid or gaseous phases, and the relative importance of these two phases will depend on the water content of the soil (Gardner, 1965). Distribution of NH_3 between the two phases will be related by Henry's law and affected by the temperature of the solution. Movement in the gaseous phase will usually be by molecular diffusion but in liquid phase it may be by diffusion of NH_3 molecule through the water or by convection if water is moving with respect to the soil.

Diffusion in liquid phase is affected by the tortuous nature of the diffusion path in soils, the soil water content, the higher viscosity of the water near the surfaces of the clay minerals, the concentration of NH_3 in solution, the temperature and the fact that diffusion can only occur in that fraction of the pore space that is filled with water.

Diffusion in gaseous phase is determined by the porosity and tortuosity of the soil and the concentration of NH_3 in

pore space (Gardner, 1965). The relative importance of convection and diffusion in the transport of NH_3 has been assessed by Gardner (1965) who concluded that considerably more NH_3 could be lost by convection than diffusion ($\sim 9:1$). However, when the NH_3 is located near the soil surface diffusion alone could account for appreciable losses.

Ammonium can also be transported to the soil surface by convection and diffusion and be converted to NH_3 which can be lost from the soil. This is more likely in flooded rice soil. Reddy et al. (1980) have shown that ammonium diffuses from the anaerobic soil layer of flooded soils to the overlying aerobic soil layer. This finding was confirmed by Tusneem and Patrik, 1971 using ^{15}N . Broad band and Tusueem, 1971, Ready et al. (1980) determined the diffusion coefficient for ammonium in different flooded soils and found that it ranged between 0.059 to 0.061 cm^2/day . The diffusion coefficient increased with the increasing soil moisture content and ammonium concentration.

Volatilisation loss of NH_3 from solution occurs in response to a difference in vapour pressure between the solution and the ambient air (Denmead, 1982). The volatilisation loss increases with the increase in the wind speed as it promotes more rapid transport of NH_3 away from the water surface.

This phenomenon is also found under dry situations as observed by Freney et al. (1981) and Denmead et al. (1982)

incorporate these separate influence on volatilisation rate into a bulk aerodynamic formula of the type.

$$F = K (P_o - P_g) \quad (21)$$

where F is flux density of NH_3 away from the surface K is an exchange coefficient which is a function of wind speed at the reference height Z , P_z is the partial pressure of NH_3 at the that height and P_o is the equilibrium NH_3 vapour pressure of the solution.

There is no universal relationship between K and the wind speed as there is both liquid phase and air phase resistance to NH_3 volatilisation. Liss and Slter 1974 expected that K is linearly related to wind speed assuming no liquid phase resistance. Deanmand (1982) reported that K is related to $U^{2.3}$, ($r = 0.90$) where U is wind velocity.

2.6 FACTORS INFLUENCING AMMONIA VOLATILISATION

Ammonia volatilisation is regulated by many factors which may be broadly categorised under the follfowing 4 headings.

- (i) Inherent soil properties which includes CEC, pH, buffering capacity, CaCO_3 content.
- (ii) Interacting processes which includes urease activity, plant uptake and leaching.
- (iii) Environmental factors which includes water, temperature, wind speed, atmospheric ammonia concentration.
- (iv) Agronomic factors.

2.6.1 CATION EXCHANGE CAPACITY

As ammonium is positively charged ion it reacts with the cation exchange complex in soils. Thus many workers have observed a negative correlation between CEC of soils and volatilisation loss of NH_3 (Ryan et al., 1981). A minimum CEC of about 25 meq/100 g is required to reduce NH_3 volatilisation loss substantially (Lyster et al., 1980).

Fenn et al. (1981) reported that the relationship between CEC and NH_3 volatilization is disturbed in the presence of soluble Ca^{++} which occupies the exchange complex and the chances of NH_4^+ being adsorbed on exchange complex is minimised.

2.6.2 pH

An increase in pH of the soil accelerates the $\text{NH}_4^+ \rightarrow \text{NH}_3$ conversion. In low land rice soils the pH of flood water is more important than pH of soil in controlling NH_3 volatilization. Because the pH of soil may not change much; but the flood water pH is liable to change and the growth of biota such as algae may raise the pH of the flood water 1 or 2 units over that of the soil.

2.6.3 Buffer capacity

Dissociation of NH_4^+ ion releases H^+ in addition to NH_3 ; consequently the medium becomes acidic as the volatilization proceeds at a rate depending on the conversion of NH_4^+ to NH_3 and the buffering capacity (Avnimelech and Laher, 1977). Therefore, NH_3 volatilization is more in soils of high base status where the acidity produced by the $\text{NH}_4^+ \longrightarrow \text{NH}_3$

conversion is neutralized by carbonate and other forms of alkalinity. Many workers have found higher NH_3 volatilization from calcareous soil Fenn et al. (1981).

A strong positive correlation exists between NH_3 loss and calcium carbonate content of soil. Later studies showed that ammonia loss was more closely related to clay sized calcium carbonate than to total calcium carbonate (Ryan et al. 1981).

2.6.4 UREASE ACTIVITY

Urea gets converted to ammonium form by the action of urease enzyme present in soil. So, the ammonium concentration and hence volatilization loss of ammonia depend on the urease activity of the soil. Addition of organic matter results in an increase in the extracellular urease enzyme which causes greater hydrolysis of urea resulting in formation of more of NH_4^+ ion and hence more NH_3 .

2.6.5 PLANT UPTAKE

Assimilation of N by plants reduces the potential for NH_3 loss (Reddy and Patric 1980). This effect is of course governed by the time of fertilizer application relative to the stages of growth.

2.6.6 LEACHING

When the fertilizer after addition gets leached down which is likely in light textured soils with low CEC the chances of volatilization loss of NH_3 is reduced.

Ammonia volatilization from natural surfaces in the field follows a marked diurnal cycle resembling that of solar radiation but the cycle probably results from associated phenomena such as changes in temperature, wind velocity, the effect of water evaporation on solution chemistry (e.g. Denmead et al. 1978)

2.6.7 WATER

Fenn and Escarzaga (1977) found that when ammonium salts are applied to initially wet soil and initially dry soil followed in each case by addition of water, NH_3 loss was greater from the initially wet soil. They suggested that this might have occurred because during infiltration of the initially dry soil the ammonium solution would penetrate both the large and small pores whereas in the initially wet soil, most of the NH_4^+ would remain in larger pores. When evaporation occurred subsequently, capillary movement to the surface would occur preferentially through the larger pores so that in the initially wet soil, the ammonium would be replaced and moved to the surface more efficiently than in dry soil.

Ferguson and Kissel (1986) from their laboratory study concluded that rapid drying of soil was found to rapidly decrease the rate of NH_3 loss from soil. This may be attributed to the reduction in hydrolysis of urea applied to soil due to drying.

2.6.8 TEMPERATURE

With the increase in temperature the relative proportion of NH_3 to NH_4^+ present at a given pH increases, the solubility of NH_3 in water decreases and the diffusion of NH_3 through

soil increases. Therefore, higher the temperature greater the potential for NH_3 loss. Temperature also affects the solubility of the fertilizers added to soil the urease activity and the rate of microbial transformation of soil organic matter (Bremner and Mulvaney, 1978).

2.6.4 Wind speed

Bouwmeester and Vlek (1981) incorporated the effects of wind speed into a model predicting NH_3 volatilisation loss from flooded soils from knowledge of flood water chemistry and meteorological conditions. Their model predicts that increasing the wind speed will increase the volatilisation rate but the effect diminishes at higher wind speeds.

The effects of wind speed are confounded by certain other factors. Bouwmeester and Vlek (1981) suggest that at high pH_s volatilization rates become insensitive to further increase in wind speed due to depletion of NH_3 in the surface layer of flood water. The replenishment of NH_3 in the liquid phase then controls the transfer process. Their model assumes that this would be by molecular diffusion only.

2.6.10. Crop canopy

Denmead et al. (1976) found that even though, there was a substantial release of NH_3 from the ground in a grass-clover pasture almost none of it escaped to the atmosphere above the canopy. The effect of NH_3 absorption was to reduce the NH_3 concentration of air from 16 ug m^{-3} near the soil surface to 1 ug m^{-3} at the top of the canopy. Lemon and

Van Houtte (1980) reported a similar account in a quack grass field but in that case the plant reduced the NH_3 concentration from $40 \mu\text{g m}^{-3}$ above the plant canopy to $3 \mu\text{g m}^{-3}$ within it. Denmead et al. (1982) found that an increase in leaf area index from 1 to 1.9 reduced volatilization by a factor of 7.

2.6.1). AGRONOMIC FACTORS

Ammonia volatilization can be influenced by farming operations. The effects can be categorised into (i) source strength (i.e. quantity of addition), (ii) equilibria (e.g. addition of urea which produces micro-environment of high pH, (iii) transport processes.

Volatilization loss of NH_3 is not only influenced by the rate of fertilizer addition and chemical nature of the fertilizer but by the physical nature of fertilizer and its mode of application. Matocha (1976) and Prasad (1976a) demonstrated that volatilization loss of NH_3 from sulphur coated urea to be considerably reduced compared with that in the conventional method of urea application. Others have shown that NH_3 volatilization can be reduced by placing ammonium based fertilizer below the soil surface e.g. Fenn and Kissel (1976) or by incorporation of the fertilizer into soil by cultivation (Matocha 1976).

Panda et al. (1988) reported (5.8%) of applied nitrogen to be lost through ammonia volatilization when urea was broadcast on the surface of saturated soil, whereas the minimum loss (0.4%) occurred with the placement of urea super granule under continuous flooding.

Misra et al. (1991) reported around 12.8% volatilization loss of NH_3 following topdressing of urea to an acidic rice soil.

More and Varade (1978) reported that addition of organic matter to the soil tended to minimise the volatilized NH_3 . This might be attributed to exchange reaction and biological immobilization of NH_4^+ -N. Organic matter increase the exchange capacity and favour increased biological activity giving faster nitrification.

Fenn et al. (1981 b) showed that addition of calcium along with surface applied urea reduced volatilization loss of ammonia. This may be attributed to reduction in the rate of urea hydrolysis due to the formation of calcium urea complex, Fenn et al. (1981 a,b) studied the effect of Ca/N ratios on NH_3 volatilization with the expectation that the inclusion of soluble calcium or magnesium salts with N fertilizers could be economical if Ca/N ratios of <1 inhibited NH_3 loss. Ammonia loss progressively decreased with increasing Ca/urea-N ratios; addition of 25% and 50% reduced NH_3 losses in the green house from 69% of the applied N to 11 and 6% respectively.

Sannigrahi and Mandal (1988) from their laboratory incubation study on slow release urea based fertilizers reported that highest loss (13.1%) was observed from urea and the lowest (0.9%) from crotonylidene diurea. Lack coated urea closely followed urea in respect of the pattern of loss but

the magnitude of loss was always lower than that from urea (10%) volatilisation from urea form and isobutylidene diurea were markedly lower than those from urea and lack coated urea but there differences narrowed down during the latter period of incubation.

2.7 CROP NITROGEN RECOVERY

Rice plant can use ammonium, nitrate and even urea-N (Mitsui and Kurihara, 1962) but the timing of fertilizer N availability is a factor influencing plant uptake since the rice plant does not have a well developed root system until later in its growth period (Tanaka et al. 1959). Unfortunately N taken up late in the growing season is not very efficiently utilised to increase grain yield.

Venkateswarlu and Matim Singh (1982) reported that rice variety sona contained consistently higher N among all other varieties tested at all stages of growth : 1.39% at tillering, 0.42% at flowering, 1.243% in grain and 0.614% in straw. The nitrogen uptake by grain and straw were 52.55 kg/ha and 20.47 kg/ha, respectively. The N content in all the three rice varieties tested was less at flowering than at tillering. Both at tillering and in grain at harvest N content increased with increase in spacing and fertility level.

Apparent recovery of applied nitrogen by rice happened to be 34.3% in experiments conducted in IARI (Fertilizer News, Feb. 1982) and 39-56% (mean value 43.4%) in experiments conducted under the PL 480 project at OUAT, Bhubaneswar. However, the apparent N recovery through the application of USG point placed in the root zone of rice grown in the dry season was recorded as 54% (Anonymous, 1989).

Van et al. (1981) studied the uptake of labelled nitrate by wheat in a sandy loam soil. Only 3% of the added nitrate was found in the grain, 13% in the straw plus chaff and 2% in harvested roots. Six per cent of N in plant came from fertilizer and the rest 94% from soil. Plants of the first row outside the fertilized plot took up 1.4% of the added fertilizer and those of 2nd row only 0.4%. Total recovery of added fertilizer in soil and plant was 93.1% indicating that 6.9% was lost in conventional cultivation practice.

Singh and De (1978) reported based on field experiments that nitrogen concentration of wheat plants supplied with 100 kg N/ha at 55 DAS, 85 DAS and 105 DAS was 3.42%, 1.81% and 1.23%, respectively and after harvest the grain and straw contained 1.69% and 0.34% N, respectively. The nitrogen uptake values for the above three growth stages and at harvest was 46.85, 102.63, 153.99 and 128.30 kg/ha, respectively.

Patel and Patel (1988) reported that N content in groundnut haulms at flowering stage, pegging stage and at harvest varies between 2.95-3.18%, 1.80-2.08% and 1.88-2.00%, respectively and at harvest the N content of kernel varies between 3.82-4.45% and that of shell varies between 1.02-1.05% under different management practices.

2.8 SOIL HYDROLOGICAL BASIS OF SUB SOIL WATER AVAILABILITY (OR SOIL WATER BALANCES)

A series of field studies have been conducted during 1978-1991 by Patra and Misra (1985), Jena and Misra (1987), Misra (1984), in the upland lateritic soil of the Central Research Station at Bhubaneswar so as to evolve, quantify sub-soil water availability based on the hydraulic properties of the soil monitored chiefly by Hg-H₂O tensiometry and also neutron hydroprobe.

Jena and Misra (1987) studied the water balance component of the root zone of pigeonpea intercropped with short duration rice varieties. They computed the soil water depletion (D, cm) from soil water content profiles $\theta(Z, t)$ by using the relationship.

$$D = \Delta S = \int_{Z_1}^{Z_2} \int_{\theta_1(Z)}^{\theta_2(Z)} d\theta \, dZ \quad (22)$$

where $S = (S_{\text{final}} - S_{\text{initial}})$ is the storage change and Z_1 and Z_2 are two soil depths. Soil water flux below the root zone (q cm d⁻¹) was computed using Darcy's law. $q = -K(\theta) \frac{\partial H}{\partial Z}$

Where $K(\theta)$ is hydraulic conductivity, $\partial H / \partial z$, the hydraulic gradient.

The (mean) $\bar{K}(\theta)$ for this internally draining profile is,

$$K(\theta) = 1.30 \exp 35.12 (\theta - 0.326) \dots\dots (23)$$

where $K(\theta)$ is the hydraulic conductivity in cm/h. The hydraulic head gradient was calculated based on measured soil water pressure head values using tensiometer readings

at 90 cm and 105 cm soil depths. The mean hydraulic conductivity was calculated for a dry spell period t (with θ varying between θ_i and θ_f) as

$$K(\bar{\theta}) = K \left(\frac{\theta_i + \theta_f}{2} \right) \quad (24)$$

The amount of up/down-ward percolation, P , was calculated using.

$$P = t \frac{(q_i + q_f)}{2} \quad (25)$$

Where q_i and q_f are, respectively, the initial and final flux values across a given soil layer.

Evapo-transpiration (ET) was computed from the water balance relationship.

$$D = S = S_f - S_i = (R + IR) - (ET - P + RF) \quad (26)$$

using zero rainfall period (R) and no irrigation water (IR) such that $ET = -S + P = P - D$ (27)

Based on their study Jena and Misra (1987) concluded that among the rice varieties intercropped with pigeon pea, Pigeon pea + Parijat gave the highest LER value (1.34) followed by pigeon pea + Kalakeri (1.24). The magnitude of soil water depletion in rice + pigeonpea intercropping system remained in between those for the component crops. The mean evapotranspiration (ET) value (68 days old crops) was 0.89 cm/day for pigeon pea, and 0.49 cm/day for Kalakeri grown as sole crops. But the ET values for the intercrop fell in-between just as did the depletion amounts.

Patra and Misra (1985) studied the water depletion pattern by different crops and observed that the deep rooted legumes, like black grams and groundnut, registered much greater mean ET values, eg, 1.28 and 1.86 cm/day, respectively, during 30 to 70 days of crop growth period and part of the ET demand was met by recharge from layers below 120 cm. On the other hand, the cereals were observed to ~~evapo-~~transpire only 50 % of that of the legumes and happened to lose most of the water received through (rainfall/irrigation) by deep percolation below the root zone.

Jena (1985) studied the water utilisation pattern by different mono and intercropping systems. Among different crops studied, pigeon pea was observed to utilise soil water from all the depths (0-105 cm) of the profile, whereas the rice roots being confined to 0-30 cm. the highest amount of depletion occurred in that zone. Finger millet and maize roots seemed to be quite active in 0-60 cm soil layer. Blackgram depleted more water from 0-60 cm depths whereas groundnut roots were more active even below 60 cm depth in as much as greater amount of depletion occurred in 60-105 cm soil layer in this case. During the dryspells, the ET values tended to be higher for the legumes (pigeon pea, 0.97 cm/day groundnut, 1.39 cm/day and blackgram 0.84 cm/day) than those for cereal + legume intercropping system (Rice + pigeonpea, 0.38 cm/day and fingermillet + pigeon pea, 0.56 cm/day).

Misra and Patro (1984) studied the root characteristics of different rice varieties and concluded that the yield of short duration rice varieties, in general, increased with an increase in root length and decrease in the root volume. Higher water content in the surface (0-30 cm) soil layer was associated with long rooted varieties. These two observations were correlated by the additional finding that higher yields were associated with higher soil water content in the 0-30 cm soil zone. Root volume was negatively correlated with soil water content.

CHAPTER-III

MATERIALS AND METHODS

MATERIALS, EXPERIMENTAL AND COMPUTATIONAL METHODS

3.1 MATERIALS

3.1.1 Experimental site and soil characteristics

The experimental site was located in the Regional Research Station, Orissa University of Agriculture and Technology, Bhubaneswar (Latitude 20° 5' N, Longitude 85° 50' E altitude 100 m above mean sea level). Soil samples were collected layerwise from the experimental site during October, 1992, before the start of the experiment, processed and utilised for the determination of basic physical and chemical properties.

3.1.2 Neutron moisture meter

Neutron hydroprobe supplied by Campbell Pacific Nuclear Agency with Am and Be neutron source and BF₃ slow neutron detector was used for water balance studies during the crop growth period.

3.1.3 Tensiometer

Mercury water tensiometers were prepared with hard PVC (polyvenyl chloride) pipes (15 cm I.D. and 0.2 cm wall thickness) and porous ceramic cups (5 cm long, 1.5 cm I.D.)

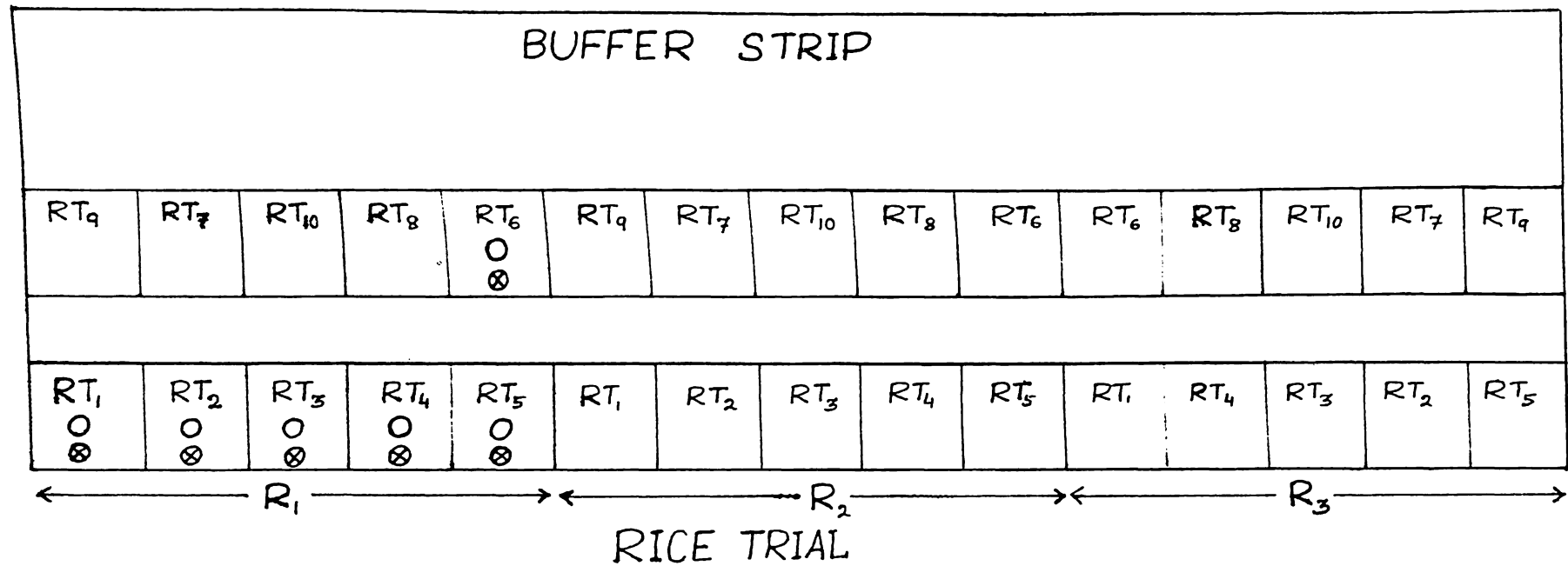
and installed at 60 cm and 75 cm depths in order to monitor the rate and direction of flow of soil water.

3.1.4 Soil solution sampler

Soil solution samplers with hard PVC pipes (I.D. : 5.0 cm) glued to a porous ceramic cup at one end and the other end fitted to a rubber cap were installed at a soil depth of 7.5 cm in the microplots growing rice in order to monitor the change in concentration of $\text{NH}_2\text{-N}$ in the crop root zone.

3.1.5 Preparation of microplots

In the experimental sites small microplots (closed system) were constructed by installing wooden border cum polythene enclosures of dimension; 91.5 x 91.5 cm in which the former extended upto 15 cm soil depth whereas the polythene extended upto 75 cm. The wooden border with polythene remained 15 cm above the ground-surface in order to check lateral seepage while receiving irrigation water. Adequate precaution was taken during the installation of the polythene sheet enclosures so as not to disturb the top soil and the soil inside the enclosed area. There were three microplots for wheat (two closed and one free system) and one for groundnut. Thirty microplots (1 x 1 m) with earthen bunding were prepared. The layout alignment of the microplots for rice experiment is shown in Fig. 1 and for wheat and groundnut experiment in Fig. 2.



RT₁ = PU 50%+50%

RT₆ = PU + ECC

EXPERIMENTAL DESIGN : RBD

RT₂ = GCU

RT₇ = FYM + ECC

PLOT SIZE : 1m x 1m

RT₃ = UNP (19-19-0)

RT₈ = FYM

VARIETY : PATHARA

RT₄ = UNP (27-9-0)

RT₉ = ECC

O : SOLUTION SAMPLER

RT₅ = USG

RT₁₀ = CONTROL

⊗ : AMMONIA TRAP

FIG 1 : RICE EXPERIMENT

3.1.6 ^{15}N tagged urea

Tagged urea containing 10% atomic excess of ^{15}N supplied by Rastriya Chemical Ltd., Bombay, was used in the experiments. However, results of atomic ratio analysis could not be had on time for inclusion in this thesis.

3.1.7 Ammonia trap

This consists of circular plastic discs (17.5 cm in diameter) fixed by nailing them down on solid wooden sticks of 1 cm² rectangular crosssection. Whatman No.1 filter paper cut to equivalent size and shape with a suitable hole in its centre was inserted through the bottom end of the stick and allowed to closely cover the lower side of the plastic disc snugly enough. These were fixed to the plastic plate with the help of paper clips. The filter paper was moistened with sulphuric acid (1N) and the traps were set up like microumbrellas between the plant rows by inserting the sticks into the top soil. The NH_3 volatilized got absorbed in the acid soaked filter paper. After fixed time interval these filter papers were replaced by fresh (acid soaked filter) papers. The $\text{NH}_4\text{-N}$ content of these (acid soaked) filter papers thus removed were determined by macro-Kjeldhal method (Jackson, 1973).

3.1.8 Infiltrameter

This is a rectangular box of size 0.5 x 0.5 m x 0.3 m made up of wooden planks open at both the ends. This is inserted

into the soil with 10 cm portion of it remaining above soil surface.

3.2 FIELD EXPERIMENTS

The present investigation was planned to study chiefly the hydrolysis of urea form applied urea-based fertilizers in the root zones of three crops i.e. rice, wheat and groundnut. Hydrolysis of urea under saturated conditions was studied in the root zone of rice whereas that under unsaturated condition was studied in the root zone of wheat and groundnut.

3.2.1 Rice experiment

This winter (dry) season (1992-93) experiment was laid out in order to evaluate the efficiency of some urea-based nitrogen fertilizers. The experiment was laid out in randomised blocks of 1 x 1 m microplots with three replications and the following treatments :

- RT₁ - Prilled urea (50% + 50%)
- RT₂ - Gypsum coated urea (Received from RCF with 5 % coating)
- RT₃ - Urea nitrophosphosphate (19-19-0) (Received from RCF)
- RT₄ - Urea nitrophosphate (27-9-0) (Received from RCF)
- RT₅ - Urea super granule (IFFCO)
- RT₆ - Prilled urea + ECC (Encapsulated calcium carbide) (Received from Dr. N.K. Banarjee, IARI)
- RT₇ - FYM + ECC
- RT₈ - FYM
- RT₉ - ECC
- RT₁₀ - Control (No nitrogen)



PP. 1. MICROPLOTS WITH STANDING RICE CROP

The treatments RT_1 to RT_6 provided 76 kg N/ha each all as a single basal dose except in the case of RT_1 in which case nitrogen was applied in two equal splits, one at transplanting and the other at maximum tillering stage.

Twentyeight days old rice seedlings (cultivar : Pathara) was transplanted at 20 x 15 cm spacing in 1 x 1 m field plots. Solution samplers were installed at 7.5 cm soil depth between two crop rows in one of the replications (Fig. 1, PPl). Uniform doses of P_2O_5 @ 50 kg/ha and K_2O @ 60 kg/ha were applied to all the plots at puddling. Well decomposed FYM (N content 1.06%) @ 10 t/ha was applied to RT_7 and RT_8 plots before transplanting. Encapsulated calcium carbide (ECC) was applied @ 30 kg/ha to RT_6 , RT_7 and RT_9 plots at transplanting. Urea Super Granules were point placed at 5 cm soil depth (approx.) within 4 rice hills, alternately, so as to supply 76 kg N/ha in RT_5 .

All fertilizer materials were mixed with dry soil and uniformly spread on the ponded water in the microplots with the standing crop.

All other intercultural operations, irrigation and plant protection measures were taken as and when necessary (Appendix-I).

3.2.1.1 Collection of volatilised ammonia

Volatile NH_3 was collected using ammonia traps placed at 22.5 cm height from the soil surface in one of the replications

at 7 am 1 pm and 5 pm daily upto 8-9 days after application of nitrogen fertilizers at transplanting. In RT_1 , volatile NH_3 was also collected with the help of ammonia traps placed at 15 cm and 22.5 cm above soil surface at 7 am, 1 pm and 5 pm daily upto 8-9 days following application of 38 kg N/ha (prilled urea) at maximum tillering. The samples were kept in the refrigerator, if required, before estimating NH_4 -N content by macro-Kjeldhal distillation method. (Jackson, 1973).

3.2.1.2 Collection of Flood Water samples and Soil Solution from the root zone of Rice

Water samples were collected from at least 3 spots at a depth of 1.5 cm from the ponded water surface from each of the nitrogen treated plots at 1 h, 4 h, 7 h, 10 h, 13 h, 16 h, 19 h, 22 h, 25 h, 49 h, 73 h, 97 h, 121 h, 145 h, and 169 h after N application with the help of a 20 ml pipette. Treatment wise the samples were homogenised each time and were kept in plastic bottles. One millilitre of 50 ppm phenyl mercuric acetate (PMA) solution was added to each sample to inhibit microbial growth. These samples were kept in the refrigerator, if necessary, and were employed for determination of NH_2 -N.

Soil solution samples were collected using soil solution samplers placed (and loosely capped) at 7.5 cm soil depth within two rice crop rows (Fig. 1, PPl). The samples were collected with the help of a 20 ml pipette at the sample time as in the case of flood water sampling following N application

at transplanting. The samples were mixed with 1 ml of 50 ppm PMA solution and stored in the refrigerator, if required, and were employed for the determination of $\text{NH}_2\text{-N}$ content.

In RT_1 , 38 kg N/ha as prilled urea was top dressed at the maximum tillering stage. Flood water samples and soil solution samples from 7.5 cm soil depth were collected as already described at 1 h, 4 h, 7 h, 10 h, 13 h, 16 h, 19 h, 22 h, 25 h, 49 h, 73 h, and 98 h following N application. These samples were mixed with 1 ml of 50 ppm PMA solution and kept in refrigerator, if necessary, and then employed for the estimation of $\text{NH}_2\text{-N}$ content.

3.2.1.3 Collection of Soil and Plant Samples

Surface soil samples collected from the experimental site before the start of the experiments and after harvesting of the crop, were processed in the laboratory and the $\text{NH}_4\text{-N}$ and $\text{NO}_3\text{-N}$ content determined in 2 M KCl extract (Black, 1965). Water content of these samples were estimated separately by gravimetric method.

Plant samples were collected before top dressing of fertilizer at the active tillering stage by chipping 5 tillers from each plot from ground level. Grain, straw, and root samples from each treatment were collected after harvest.

Water content of the plant samples was determined after drying at 60°C for 4 h in a hot air oven. Then the samples were oven-dried at 80°C , ground by Wiley mill before

their nitrogen content was determined by micro Kjeldhal method (AOAC, 1970).

3.2.2 Wheat and Groundnut Experiment

During the dry season, 1992-93, an unreplicated experiment in field microplots was laid out in order to study the hydrolysis of urea and water balance in the root zone of wheat and groundnut. The treatments allocated for wheat were :

- WT₁ - Free system (prilled urea was applied both at sowing and tillering) in a plot (2.5x2.5 m) which had no border.
- WT₂ - Closed system with border (3.1.5) (¹⁵N tagged urea applied at sowing & ¹⁴N prilled urea was applied at tillering).
- WT₃ - Closed system (¹⁴N prilled urea applied at sowing and ¹⁵N tagged urea was applied at tillering).
- WT₄ - Control (No nitrogen). The crop sown in the area surrounding the microplots served as the control which did not receive any N-fertilizer.

The treatment allocated to groundnut was :

- GT₁ - Closed system (¹⁵N tagged prilled urea applied at sowing).
- GT₂ - Control (No nitrogen) (Plants grown in the area surrounding the microplots).

There were some closed system microplots for wheat and groundnut which were equally treated with respect to irrigation and fertilizer application but supplied with ordinary

urea and were harvested at different growth stages to estimate the dry matter accumulation. The purpose of this was not to disturb the treated microplots.

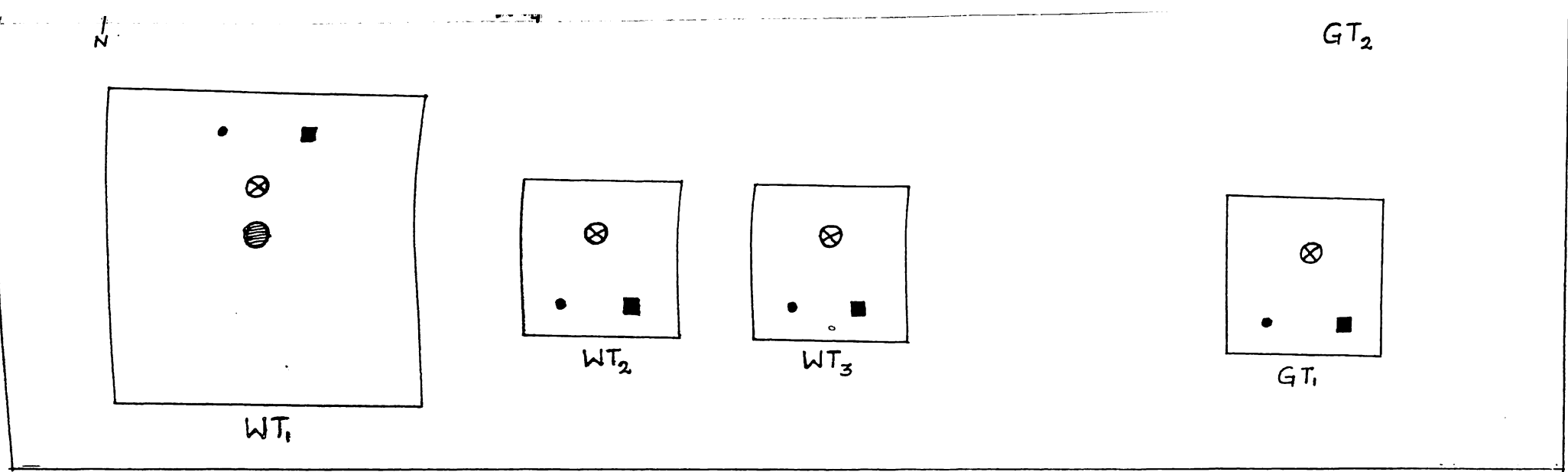
3.2.2.1 Sowing

Wheat seed (cultivar : Sagarika) and groundnut seed (cultivar : OG 52-1) were sown in the microplots on 13.12.92. P_2O_5 and K_2O @ 50 kg/ha and 50 kg/ha for wheat and 40 kg/ha and 40 kg/ha for groundnut respectively, were applied at the time of sowing. Each microplot was equipped with mercury water tensiometers the cups of which reached the depths of 60 and 75 cm. One aluminium access pipe was installed so as to have it reach the depth of 1 m in the "free system" microplot (WT_1) in which wheat was sown, (Fig.2, pp 2).

3.2.2.2 Application of nitrogen fertilizer at sowing

On 14.12.92, 50 kg of N/ha in the form of ^{14}N or ^{15}N urea was dissolved in pond water so as to provide 1.5 cm of surface irrigation and applied to the wheat microplots according to the treatment design (3.2.2) with the help of a flower can. Equivalent amount of irrigation water without dissolved urea was applied to the control plants.

Tagged (^{15}N) urea fertilizer @ 20 kg/ha was applied to groundnut microplot as an aqueous solution so as to provide 1.5 cm of surface sprinkle irrigation using a flower can.



WHEAT TRIAL

$T_1 : 14_N + 14_N$ FREE SYSTEM
 $T_2 : 15_N + 14_N$ CLOSED SYSTEM
 $T_3 : 14_N + 15_N$ CLOSED SYSTEM
 $T_4 : N\&l$ CONTROL

VARIETY : SAGARIKA

DOSE : 100 - 50 - 50

• : TENSIMETER (60 cm SOIL DEPTH)
 ■ : TENSIMETER (75 cm SOIL DEPTH)
 ● } NEUTRONMETER ACCESS PIPE
 ⊗ : AMMONIA TRAP

GROUNDNUT TRIAL

$T_1 : 15_N$ CLOSED SYSTEM G_1
 $T_2 : N\&l$ CONTROL

VARIETY : OG 52-1

DOSE : 20-40-40

FIG2: WHEAT AND GROUNDNUT EXPERIMENT



PP. 2.1 MICROPLOT WITH STANDING WHEAT CROP



PP. 2.2 MICROPLOT WITH STANDING GROUND NUT CROP



PP. 2.1 MICROPLOT WITH STANDING WHEAT CROP



PP. 2.2 MICROPLOT WITH STANDING GROUND NUT CROP

The control plants were also irrigated like wise but without adding any nitrogenous fertilizers. (The irrigation water used in these experiments contained 4 ppm $\text{NH}_4\text{-N}$ and 6.9 ppm $\text{NO}_3\text{-N}$).

3.2.2.4 Application of nitrogen fertilizer at tillering

Prilled urea (14_{N} or 15_{N}) each @ 50 kg N/ha was applied in the form of aqueous solution so as to provide 3 cm of irrigation at the active tillering stage of wheat.

3.2.2.3 Interculture

All intercultural operations including irrigation and plant protection measures were provided as and when necessary (Appendix 1).

3.2.2.4 Collection of volatilised ammonia

Attempts were made to collect NH_3 escaping into air by volatilisation (following application of nitrogenous fertilizers) using special ammonia traps devised and set up for this purpose (3.1.7 and 3.2..1.1).

The ammonia traps were fixed at a height of 20 cm (approx.) above the soil surface. The filter papers were changed thrice during day i.e. at 7 am, 12 noon and 5 pm so as to avoid drying of acid soaked filter papers due to day time heating and evaporation. The filter papers after



PP. 3 MICRO PLOT WITH STANDING WHEAT CROP WITH
NEUTRON HYDROPROBE ACCESS PIPE, TENSIO-
METERS AND AMMONIA TRAP.

3.2.2.7 Collection of plant samples

Above ground plant samples from the wheat and groundnut plots were collected before top dressing (26 DAS) and again at 71 (DAS).

Grain and straw yield data of crops as well as grain/pod and straw/haulm samples were collected at harvest. All the samples were employed for the estimation of nitrogen. Water content of all samples were recorded by oven drying subsamples at 60° C for 4 h and the values employed to express the results on dry basis. Total nitrogen content of all finely ground (Wiely mill) plant samples was determined by micro Kjeldhal distillation (AOAC, 1976) based on which the uptake values at harvest were computed.

3.2.3 Biometric observation at harvest

Biometric observations like plant height, effective tiller, panicle length, number of filled grains, spikelet sterility percentage, thousand grain weight as well as straw, grain yield data were recorded for different treatments of rice and wheat as the case may be. Biometric observations like plant height, number of branches, hundred kernel weight, shelling percentage as well as pod&haulm yield were recorded for groundnut.

3.2.4 Root studies

Ten clumps were earmarked in all treatments of rice (one replication) wheat and groundnut plots and uprooted

with the help of a spade. The root samples were then thoroughly washed to remove the adhering soil and oven-dried at 80° C. Finally these were ground to powder form by means of a Wiley mill and their total nitrogen content determined by micro-Kjeldhal distillation method (AOAC, 1970).

3.3 EXPERIMENTAL METHODS (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 Systronic make 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 make 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's rapid titration method following Jackson (1973).

3.3.5 Available phosphorus

The available P content of the soil was determined following Olsens' method employing NaHCO_3 extractant buffered at pH 8.2 (Jackson, 1973).

3.3.6 Total nitrogen of soil

Total nitrogen content of soil was determined following Bremner's method as described in Black (1965).

3.3.7 Nitrogen content of plant samples

Nitrogen concentration in plant samples was determined following AOAC (1970). The results were expressed on dry basis (60°C).

3.3.8 Estimation of $\text{NH}_2\text{-N}$, $\text{NH}_4^+\text{-N}$ and $\text{NO}_3^-\text{-N}$ content of soil/flood water/soil solution

Immediately after collection from the field soil samples weighing 20 g were taken in 250 ml conical flasks contain 200 ml of 2 M KCl PMA. 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 and the filtrate collected in another conical flask with proper label. These filtrate samples were utilised for the estimation of $\text{NH}_2\text{-N}$, $\text{NH}_4^+\text{-N}$ and $\text{NO}_3^-\text{-N}$. These as well as flood water samples and soil solution samples were stored in refrigerator before analysis, if required

The estimation of NH_4 and $\text{NO}_3\text{-N}$ was carried out in the KCl extract following the methods described in Black (1965).

The $\text{NH}_2\text{-N}$ content of soil extract flood water and soil solution was determined colorimetrically following Modified Diacetyl Monoxime method (Mulvany and Bremner, 1979). The standard graph prepared based on this method is presented in Fig.3.

3.3.9 Estimation of volatilised ammonia

The filter papers collected from the ammonia trap described in 3.2.1.1 and 3.2.2.4 were carefully transferred to macro Kjeldhal distillation flasks with around 50 ml distilled water added for washing the polythene bag that contained the filter paper. The $\text{NH}_4^+\text{-N}$ trapped in the acidified filter paper was thus determined following the macro Kjeldhal distillation method (Jackson, 1973).

The amount of $\text{NH}_3\text{-N}$ lost due to volatilisation was expressed with reference to the known area of filter paper and finally reported as kg of $\text{NH}_3\text{-N}$ lost per hectare of soil surface.

3.3.10 Estimation of $^{15}\text{N}/^{14}\text{N}$ in plant/pod/grain/straw samples

Oven dried finely ground pod/grain/straw/root samples from treatments including those which received tagged urea

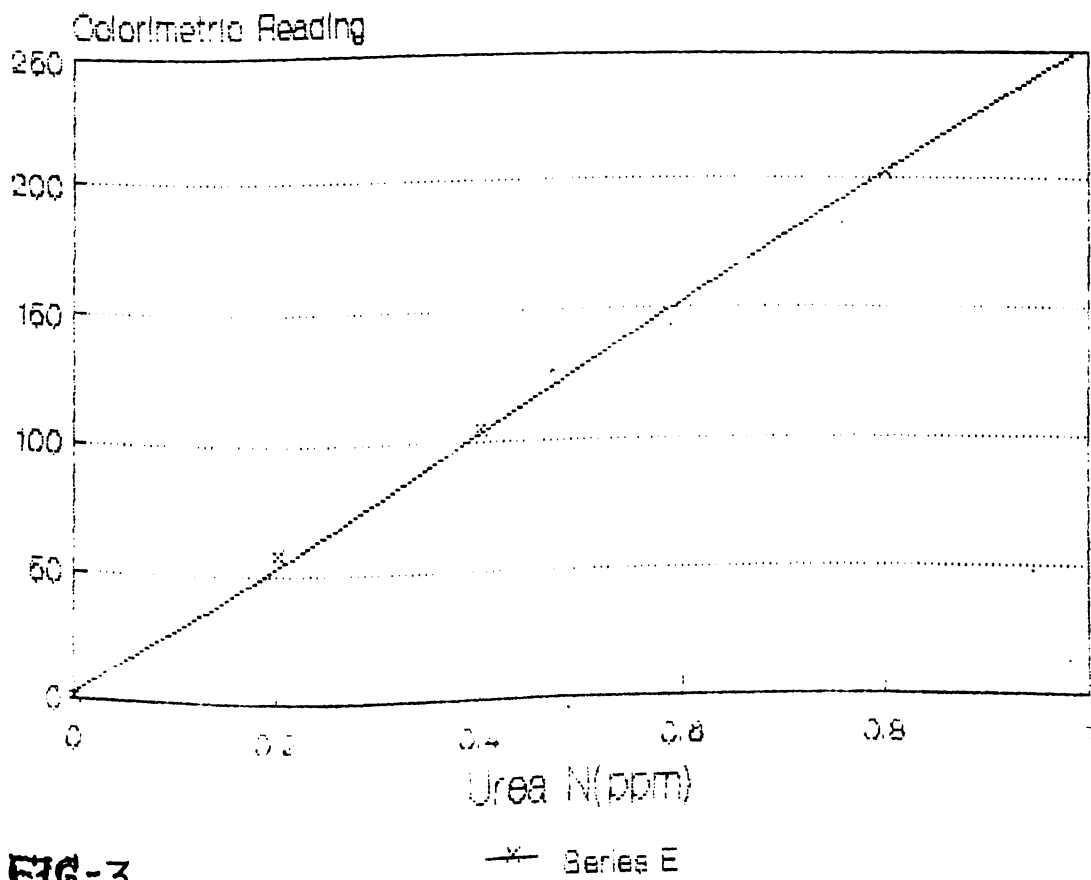


FIG-3

Urea Standard Graph

were employed for the determination of total $\text{NH}_4^+\text{-N}$. (^{15}N + ^{14}N in the laboratory by micro Kjeldhal distillation method (AOAC, 1970) using standard H_2SO_4 to collect the distillate. After titration, the contents were reacidified and evaporated before being sent to RCF laboratories for $^{15}\text{N}/^{14}\text{N}$ analysis. Because by the time this thesis manuscript was prepared the results were not available, only the total $\text{NH}_4^+\text{-N}$ content of the plant parts are reported herein.

3.3.11 Estimation of total $^{15}\text{N}/^{14}\text{N}$ in soil.

In 2 M KCl-PMA extract of soil samples $\text{NH}_2\text{-N}$, $\text{NH}_4^+\text{-N}$, $\text{NO}_3^-\text{-N}$ were estimated as described in 3.3.8. The distillates were collected and treated as has been described in 3.3.10 and only the total value ($^{15}\text{N} + ^{14}\text{N}$) would be reported herein in as much as the results of $^{15}\text{N}/^{14}\text{N}$ atomic ratio data could not be had on time. Similarly, the results of total ($\text{NH}_4^+ + \text{NO}_3^- \text{-N}$) values of soil N content ($^{15}\text{N} + ^{14}\text{N}$) stemming from macro Kjeldhal distillation (Black, 1965) of soil digests could be reported in this dissertation.

3.3.12 N-contents of urea based fertilizers

$\text{NH}_2\text{-N}$ content of nitrophosphates (27-9-0 and 19-19-0) was estimated by macro Kjeldhal distillation method following digestion according to method prescribed by AOAC, 1970.

3.3.13 N-content of farm-yard manure

Total N ($\text{NH}_4^+\text{-N} + \text{NO}_3^-\text{-N}$) content of farm-yard manure

sample used in this study was determined by standard H_2SO_4 + salicylic acid digestion and macro Kjeldhal distillation method (Black, 1965).

3.3.14 Nitrogen content of irrigation (pond) water

$\text{NH}_2\text{-N}$, $\text{NH}_4^+\text{-N}$ and $\text{NO}_3^-\text{-N}$ contents of irrigation water used from a near - by pond were determined by colorimetric and distillation methods described in 3.3.8.

3.4 EXPERIMENTAL METHODS (PHYSICAL)

3.4.1 Bulk density (B.D.)

Field bulk density of the experimental soil was determined in each 15 cm layer up-to a depth of 90 cm by core method. Brass cores of 5 cm ID and 3 cm length were employed. (Black, 1965).

3.4.2 Particle size analysis

Particle size analysis was carried out using the hydrometer method (Piper, 1950).

3.4.3 Estimation of soil water content

Soil water content for different soil layers was determined using gravimetric method CPN/neutron hydroprobe.

3.4.4 In-situ steady state infiltration rate

The infiltrameter (3.1.8) was buried in soil up to 20 cm such that 10 cm of it remained above the surface of

the soil. The soil inside the infiltrometer was puddled after pouring water. Sufficient water was added time to time in the infiltrometer so as to maintain a head of 5 cm. while reading the time for 1 cm of water to enter into the soil till steady state was attained. The final value was reported as steady state infiltration rate.

3.4.5 Soil water relationships

For the purpose of inferring the soil water content (θ) based on the measured count ratio (CR) by means of the CPN hydroprobe, the following relationship already formulated by Jena (1985) as

$$CR = 0.104 + 0.048\theta(\%) \quad (28)$$

was used. Tensiometer readings (Z_1) were converted to pressure head (h) values based on the known relationship.

$$h = -(12.55 Z_1 - Z_2 - Z_3) \quad (29)$$

Where Z_2 height to Hg in the cup from the soil surface and Z_3 is height of the soil surface from the tensiometer cup embedded in the soil. The $h(\theta)$ function

$$\theta = 0.323 \exp(-0.004 h) \quad (30)$$

(Where h is the suction head) was adopted from Jena, (1985) for converting computed h values (based on tensiometer readings) to θ . Finally a world average function (Nielsen et al. 1983).

$$K(\theta) \text{ (cm/h) } = 1.45 \exp [75.6(\theta - 0.32)] \quad (31)$$

was chosen for the present study to calculate soil water flux values at given θ .

3.4.6 Soil water balance (E.T.)

The well known water balance relationship (Misra and Jena, 1989)

$$D = S = S_f - S_i = (R+IR) - (ET - P + RF) \quad (26)$$

(Where S_i and S_f are the initial and final soil moisture storage, respectively, R is rain fall, IR , irrigation; ET evapotranspiration P , percolation and RF , run off amounts) was adopted for computing ET .

For periods of zero rainfall and no irrigation,

$$ET = -S + P = P - D \quad (27)$$

Deep percolation (P) is calculated as $P = t (q_i + q_f)/2$ where t is time and q_i and q_f are the initial and final fluxes, respectively.

q is calculated from the Dancy's law, (32)

$$q = -K(\theta) \frac{dh}{dz} = -K(\theta) \left(\frac{h_2 - h_1}{z_2 - z_1} + 1 \right)$$

where h_1 and h_2 are the mean soil moisture pressure heads at two different heights i.e. z_1 and z_2 , respectively, For this present study the world average $K(\theta)$ value was used (3.4.5).

This relationship was used to estimate the ET of wheat in the free system plot (WT_1) between two irrigation events coinciding with 40 DAG and 47 DAG.

3.4.7 Moisture free basis of expression of results

Moisture % oven dry basis ($M\%$) is calculated as,

$$(M \%) = \frac{ADW - ODW}{ODW} \times 100 \quad (33)$$

Where ADW = air dry weight (fresh weight) and ODW = oven dry weight.

From the moisture % of a sub sample (soil/plant material) the oven dry weight of the main sample is calculated as

$$ODW = ADW \times \frac{100}{100 + M\%} \quad (34)$$

Using air dry weight (ADW_1) of a given moisture level ($M_1\%$) air dry weight (ADW_2) at a desired moisture level ($M_2\%$) can

$$\text{be calculated by the formula } ADW_2 = ADW_1 \times \frac{100 + M_2\%}{100 + M_1\%} \quad (35)$$

3.5 NITROGEN USE EFFICIENCY PARAMETERS

Three nitrogen use efficiency parameters were used in this study.

1. Agronomic efficiency (NUE)/grain yield response

$$AE = \frac{Y_T - Y_0}{N_F} \quad (36)$$

Where Y_T = Yield in treatment (kg/ha)

Y_0 = Yield in control (kg/ha)

N_F = N supplied by fertilizer (kg/ha)

2. Relative efficiency :

$$RE = \frac{Y_T - Y_0}{Y_S - Y_0} \times 100 \quad (37)$$

Where Y_S = Yield in standard source.

$$3. \text{ Apparent N recovery (\%)} : = \frac{U_T - U_0}{N_F} \times 100 \quad (38)$$

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

U_0 = N uptake in control (kg/ha)

CHAPTER-IV

RESULTS AND DISCUSSION

RESULTS AND DISCUSSION

The major objective of the present investigation has been to evaluate and compare the transformation pattern of urea based fertilizers/urea in the root zones of rice, wheat and groundnut grown in microplots in the dry season (December, 1992 to April, 1993). The trials were laid out in a medium land situation of the Central Research Station of OUAT, Bhubaneswar, Orissa.

4.1 PHYSICAL AND CHEMICAL PROPERTIES OF THE EXPERIMENTAL SOIL

The physical and chemical properties of the soil at the experimental site are listed in Table 1. As may be seen from the table, the texture of the soil, in the surface layers upto 30 cm depth is sandy loam, between 30-75 cm, it is a sandy clay loam and in the lower layers between 75-105 cm it is a sandy clay.

The bulk density of the surface layer (0-15 cm) is 1.7 g/cm³ but in the lower 15-30 cm layer it increased to 1.8 g/cm³ due apparently to plough sole compression. The bulk density values in the lower layers is invariant remain at 1.6 g/cm³. This is expected as much as the clay content of the soil layers

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
1. Sand(%)	73.8	71.8	63.8	68.4	47.8	55.8	55.8
2. Silt (%)	14.0	14.0	12.0	5.2	18.0	8.0	8.0
3. Clay (%)	12.2	14.2	24.2	26.4	34.2	36.2	36.2
4. Texture	Sl	Sl	SCl	SCl	SCl	SC	SC
5. B.D. * (g cm ⁻³)	1.7	1.8	1.6	1.6	1.6	1.6	-
6. Steady state infiltration rate : 0.67 cm/h							
7. pH	6.5	7.4	7.1	7.2	7.1	6.6	6.5
8. EC(dS m ⁻¹)	0.14	0.09	0.12	0.19	0.16	0.19	0.19
9. OC (%)	0.42	0.19	0.11	0.08	0.06	0.08	0.05
10. Total N (Kg/ha)	855	817	899	932	-	-	-
11. Available P ₂ O ₅ (kg/ha)	28	13	10	7	-	-	-
12. Available K ₂ O (kg/ha)	212	-	-	-	-	-	-
13. CEC (cmol (p ⁺ kg ⁻¹))	5.0	5.0	7.1	11.8	14.4	15.0	18.0

* Mean of three determinations employing undisturbed core samples.

below 30 cm increases and ranges between 24-36.2%, whereas the clay content of the surface layers ranges between 12-14%.

The steady state infiltration rate of the soil as measured in the field has been observed to be 0.67 cm/h. which is almost one-half that observed by Jena (1985). for this soil in a nearby upland site.

The pH of the surface layer being 6.5 is close to neutrality. This as well as the values ranging between 6.5-7.4 for the lower layers appear to be typical of medium land lateritic submerged rice soil around Bhubaneswar unlike that in an upland situation (Jena 1985) in the Central Research Station of OUAT where the soil has been observed to be strongly acidic. This should be expected. Because the soil the upland sites are depleted of the basic cations due to leaching (mean annual rainfall in Bhubaneswar is recorded to be around 1500 mm). and are associated with lower pH and cation exchange capacity values down the soil profile as compared to that for the soil of the medium land situation.

Interestingly whereas Jena (1985) reports the CEC values for an upland soil profile to range between 3.8 to 4.3 C mol (p+)/kg with the clay content varying between 8 and 23%, the soil profile in the present experimental site is observed to possess CEC values ranging between 5 and 18 C mol (p+)/kg with clay content varying between 12 and 36%.

On the otherhand, there is a very striking difference in the picture of organic carbon distribution of the profile in the upland site as cited above (Jena, 1985) as compared to that in the present experimental site. The organic carbon percentage ranges between 0.54 to 0.38 in the upland soil profile down to a depth of 105 cm whereas in the medium land situation where the present experiment was laid out the organic carbon content of the 0-15 cm layer is 0.42% but the percentage decreases drastically down the profile to values as low as 0.05%. The observed contrast is hard to explain especially because the higher degree of water saturation in the medium land site should normally encourage organic matter retention leading to higher values than that observed in the upland site.

The total ($\text{NH}_4^+ + \text{NO}_3^-$) nitrogen content of the soil layers upto 60 cm showed very little variation and ranges between 855 to 930 kg/ha which should fall in low category. The C/N ratio of the surface layer, however, is around 10:1 which should be considered as normal.

The available P_2O_5 by Olsen's method for the surface is observed to be high whereas available K_2O by the ammonium acetate method falls in the medium category.

The Electrical conductivity values of the soil layers ranging between 0.14 to 0.19 ds/m indicate non-saline nature of the soil profile.

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 RICE EXPERIMENT

4.2.1 Grain and straw yield data

Table 2, lists the mean grain and straw yield data stemming from the rice experiment as recorded in threshing floor after sundrying and that expressed in oven dry basis after drying subsamples of grain and straw at 60° for 4 hours in a hot air oven. The corresponding straw grain ratio have also been presented in this table. The replicationwise data of grain and straw yield expressed on dry basis together with the respective ANOVA are presented in table 3 and 4 for the rice experiment. The results show that the treatment effects in respect of both grain and straw have been highly significant. Although the accepted basis of oven dry expression is by determining the moisture content by heating the sample at $80 \pm 5^{\circ}\text{C}$ upto a constant weight this could not be done for this present experiment. However, heating at 60°C for 4 hours is expected to drive out most of the moisture from the grain and straw samples and indeed for grinding in an Wiely mill the samples were dried further at 80°C for indefinite periods without recording the percentage of water lost at that temperature. In any case the data should be treated as good and reduced

TABLE 2 : RICE EXPERIMENT: GRAIN AND STRAW YIELD (q/ha)

Treatment	SUN DRIED			OVEN DRIED		
	Grain	Straw	Straw/ Grain	Grain	Straw	Straw/ Grain
RT ₁ (PU,50%+50%)	56.85	55.5	0.98	51.27	50.04	0.98
RT ₂ (GCU)	53.68	51.59	0.96	48.73	45.72	0.94
RT ₃ (UNP,19:19:0)	50.06	51.84	1.04	45.16	43.66	0.97
RT ₄ (UNP,27:9:0)	51.03	48.59	0.95	46.22	40.04	0.87
RT ₅ (USG)	56.96	55.53	0.97	52.07	49.08	0.94
RT ₆ (PU+ECC)	53.94	54.66	1.01	48.91	46.21	0.94
RT ₇ (FYM+ECC)	37.67	36.60	0.99	34.32	28.56	0.83
RT ₈ (FYM)	39.20	35.43	0.90	35.03	29.36	0.84
RT ₉ (+ECC)	37.17	34.59	0.93	35.38	29.95	0.85
RT ₁₀ (CONTROL)	34.61	31.51	0.91	31.67	27.11	0.86
SE(m) ±	4.31	2.99	-	3.87	3.59	
CD(5%)	9.05	6.29	-	8.14	7.55	

TABLE 3 : RICE EXPERIMENT:GRAIN YIELD (DRY BASIS)

Treatment	Grain Yield (q/ha)			
	R ₁	R ₂	R ₃	Mean
RT ₁ (PU,50%+50%)	58.54	50.37	44.91	51.27
RT ₂ (GCU)	44.75	47.60	53.85	48.73
RT ₃ (UNP,19:19:0)	45.74	38.85	50.90	45.16
RT ₄ (UNP,27:9:0)	49.48	43.15	46.03	46.22
RT ₅ (USG)	52.37	55.01	48.83	52.07
RT ₆ (PU+ECC)	42.11	51.75	52.87	48.91
RT ₇ (FYM+ECC)	31.08	35.28	36.61	34.32
RT ₈ (FYM)	32.07	31.03	42.01	35.03
RT ₉ (ECC)	34.74	36.69	34.71	35.38
RT ₁₀ (CONTROL)	27.14	31.54	36.32	31.67

A N O V A

Source	Degree of Freedom	Sum of Square	Mean sum of Square	Calculated F
Replication	2	50.56	25.28	1.124
Treatment	9	1675.16	186.13	8.274 ^{**}
Error	18	404.87	22.49	-

SE (m) + = 3.872
 CD (5%) = 8.135
 CV (%) =11.06

* Dried

** at 1% level

TABLE 4 : RICE EXPERIMENT: STRAW YIELD (DRY BASIS)

Treatment	Straw Yield (g/ha)			
	R ₁	R ₂	R ₃	Mean
RT ₁ (PU, 50%+50%)	58.57	46.16	45.39	50.04
RT ₂ (GCU)	43.44	43.07	50.64	45.72
RT ₃ (UNP19-19-0)	40.46	37.37	53.14	43.66
RT ₄ (UNP, 27-9-0)	41.04	37.19	41.88	40.04
RT ₅ (USG)	40.69	51.58	45.97	59.08
RT ₆ (PU+ECC)	46.01	45.46	47.16	46.21
RT ₇ (FYM+ECC)	25.76	28.10	31.82	28.56
RT ₈ (FYM)	29.14	23.84	35.10	29.36
RT ₉ (C+ECC)	27.10	30.65	32.10	29.95
RT ₁₀ (CONTROL)	22.93	25.63	32.77	27.11

A N O V A

Source	Degrees of Freedom	Sum of Square	Mean sum of Square	Calculated F Value
Replication	2	114.75	57.38	2.97
Treatment	9	2305.6	256.18	13.246 **
Error	18	348.18	19.34	-

SE (m) ± = 3.591
CD(5%) = 7.515
CV (%) = 11.28%

to a common water content basis for comparing the effects due to different fertilizer treatments to which the rice crop was subjected. As a matter of fact most investigators assume a 14% moisture content on sundrying and statistically treat their data so as to evaluate the treatment effect. In the present study the moisture content on heating for 4 hours at 60°C in the hot air oven yielded water content of grain around 10% and that of straw around 20%. It is further observed in Table 2 that the straw: grain ratio for the sun dried data are very close to that expressed on oven dry basis and happen to range between 0.87 to 1.04 for treatments including the urea based fertilisers and the ratio ranged between 0.83 to 0.94 for the control and FYM treatments. Obviously therefore the fertiliser treatments lead to higher amounts of straw compared to the grain yield that under the FYM/control treatments (not receiving any in-organic nitrogen). Such a trend indicates that inorganic fertilizer treatments lead relatively to higher straw production as compared to that in the treatments with organic manure and no nitrogen.

It should be recognised that inorganic fertilizer treatments RT_1 - RT_6 differed in the forms of nitrogen they supplied. The urea nitrophosphate in RT_3 and RT_4 although provided 76 kg total N/ha the amide fraction in these two treatments happened to be 45.5% and 47.3% (Appendix 4), respectively, there by supplying 34.66 and 35.95 kg NH_2 -N/ha, the balance being supplied in the form of NO_3 -N. Despite this the computed

C.D. of 8.15 q/ha (Table 3) at 5% level of probability rendered the mean grain yield data stemming from RT₁ to RT₆ statistically at par. All the same the mean grain yield due to USG in RT₅ is observed to be the highest (52.07 q/ha) (Table 3), Closely followed by that (51.27 q/ha) from RT₁ (PU applied in 2 equal splits). The grain yields from RT₃ and RT₄ have been of the lowest magnitude viz., 45.16 and 46.22 q/ha apparently due to the inefficiency of the NO₃ source for rice, which these fertilizers provided to a considerable extent viz., 54.4% and 52.7% respectively. The results stemming from field experiment conducted under PL 480 project during 1986 dry season in this research station established the significant superiority of USG (point placed) to supply 76 kg N/ha over three standard split prilled urea application at equivalent N dose (Jena and Misra, 1987). The highest grain yield recorded under the USG treatment at that time happened to 55 q/ha & that for PU was 45 q/ha. The trials conducted by the IFFCO agronomists on farmers fields during kharif 1981 in 9 states of country showed point placement of USG to have recorded 17.9% higher yield over split applied urea at 60 kg N dose/ha, Kumar and Mishra (1988). Again the results of trials conducted by IFFCO agronomists in farmers' fields during kharif 1982-84 revealed point placed USG to have brought about higher yields as compared to nitrogen application through urea in standard splits (Kumar and Misra, 1988). It should also be noted that the effect of ECC together with PU applied in one dose (76 kg/ha) has not been as promising as was claimed by Dr. N.K. Banarjee. The lower grain yield

of GCU as compared to that in RT_1 receives support from the results of field experiments conducted under AICARP during 1984-85 (Anonymous, 1986). It should however, be noted that in certain cases of residual study with wheat grown as the succeeding crop to rice in deep black soils of Navsari and mixed red and black soils of Kathulia GCU treatment led to better residual effect than the standard PU treatment.

The mean grain yield data from RT_7 and RT_9 involving farm yard manure and control with or without ECC proved to be statistically at par and significantly lower than the inorganic fertiliser treatments under this study. It should be recognised that as much as 106 kg N/ha were provided through the FYM under RT_8 and yield proved to be only 10% higher (35.03 q/ha) than that from control (31.67 q/ha). Apparently most of the nitrogen in the organic farm remained unavailable and did not help in enhancing the grain and straw yield (Table 4) appreciably. Likewise the effect of ECC was not realised at all when it was used in combination with FYM but surprisingly under RT_9 ECC alone without any nitrogen results in 10% additional yield.

The mean straw yield listed in Table 4 presents almost a comparable picture with that observed in the grain yield data and hence do not merit any special comments.

4.2.2 NITROGEN CONCENTRATION IN RICE PLANT PARTS AND UPTAKE BY THE CROP

Table 5 lists the nitrogen concentration (%) in tiller, grain, straw and root samples of rice plant grown under this

TABLE 5 : RICE EXPERIMENT: NITROGEN CONCENTRATION (DRY BASIS) IN TILLER, GRAIN, STRAW AND ROOT

Treatment	Nitrogen concentration(%)			
	Tiller	Grain	Straw	Root
RT ₁ (PU, 50%+50%)	1.36	1.31	0.43	0.76
RT ₂₂ (GCU)	1.33	1.14	0.43	0.35
RT ₃ (UNP, 19-19-0)	1.70	1.31	0.33	0.80
RT ₄ (UNP, 27:9:0)	1.49	1.22	0.48	0.63
RT ₅ (USG)	2.10	1.29	0.48	0.34
RT ₆ (PU +ECC)	1.36	1.09	0.48	0.42
RT ₇ (FYM+ECC)	1.46	1.10	0.37	0.49
RT ₈ (FYM)	1.79	1.24	0.32	0.63
RT ₉ (ECC)	1.33	1.21	0.32	0.49
RT ₁₀ (CONTROL)	1.15	1.25	0.30	0.69

study. The corresponding uptake data are presented in Table 6. It may be observed from these data whereas in the tillers and grain the concentration of nitrogen in respect of treatments with inorganic nitrogen, the organic manure and control do not differ appreciably. The concentration values in rice straw are generally higher in the case of the former treatments than that in the latter. No consistent conclusion can be drawn, however, for the rice roots stemming from different treatments. It is interesting to note that the roots due to the USG treatment are the poorest in respect of nitrogen concentration.

Nitrogen uptake data (Table 6) which are based on the concentration (%) (Table 5) have been appreciably higher for the inorganic fertilizer treatment both in respect of grain and straw as well as in respect of kg N uptake/q of grain produced. The highest value in the case of the latter having been 1.74 kg/q of grain, under RT₅ (USG). This is an indicator of superior efficiency of USG compared with that of all other inorganic nitrogen treatments and certainly with the ones under the organic treatments and the no nitrogen control.

4.2.3 NITROGEN USE EFFICIENCY

Nitrogen use efficiency parameters based on three different criteria, viz. agronomic efficiency, relative efficiency and apparent N recovery in respect of inorganic N treatment and control have been presented in Table 7. These data indicate that USG is the most efficient fertilizer among the lot closely followed

TABLE 6 : RICE EXPERIMENT:NITROGEN UPTAKE (DRY BASIS)

Treatment	N Uptake (kg/ha)			Kg N Uptake, qGrain
	Grain	Straw	Total	
RT ₁ (PU,50%+50%)	67.16	21.52	88.68	1.73
RT ₂ (GCU)	55.55	19.66	75.21	1.54
RT ₃ (UNP,19:19:0)	59.16	14.41	73.56	1.63
RT ₄ (UNP,27:9:0)	56.39	19.22	75.61	1.64
RT ₅ (USG)	67.17	23.56	90.73	1.74
RT ₆ (PU+ECC)	53.31	22.18	75.49	1.54
RT ₇ (FYM+ECC)	37.75	10.57	48.32	1.41
RT ₈ (FYM)	43.44	9.40	52.84	1.51
RT ₉ (ECC)	42.81	9.58	52.39	1.48
RT ₁₀ (CONTROL)	39.59	8.13	47.72	1.51

TABLE 7 : RICE EXPERIMENT: NITROGEN USE EFFICIENCY (3.4)

Treatment	Agronomic Efficiency (Kg grain/ Kg N applied	Relative Efficiency (%)	Apparent N Recovery (%)
RT ₁ (PU, 50%+50%)	26	100	54
RT ₂ (GCU)	23	87	36
RT ₃ (UNP, 19:19:0)	18	66	34
RT ₄ (UNP, 27:9:0)	19	74	37
RT ₅ (USG)	27	104	57
RT ₆ (PU+ECC)	23	88	37
RT ₁₀ (CONTROL)	-	0	-

by two split dose of PU (RT_1) GCU, and PU+ECC being third in order as far as agronomic efficiency is concerned. However, judged in light of apparent N recovery per cent the treatments may be rated in the descending order $RT_5 > RT_1 > RT_4=RT_6 > RT_2 > RT_3$. In an equivalent study by Jena and Misra (1987) the USG has been rated as the most efficient source with an apparent N recovery percentage of 54.2 as compared to 44.7 due to prilled urea. The efficiency of USG both based on Agronomic efficiency as well as apparent N recovery value has been reported in many instances (Anonymous, 1986; Panda and Pattaniak, 1989 and Mitra et al., 1989) and especially in the case of soils with heavier texture, higher CEC or lower steady state infiltration rate (Mohanty, 1991). Based on results of experiments conducted earlier (Rabi, 1986-87) in this research station. Mitra et al. (1989) reported that the values (for 60 and 90 kg N/ha treatments) of apparent N recovery and agronomic efficiency values to be 51% and 29 kg/kg respectively for which values are close to those recorded under the present study.

4.2.4 VOLATILISATION LOSS OF AMMONIA

Cumulative volatilisation loss values of ammonia following application of urea based nitrogen fertilizers for treatment RT_1 - RT_6 are listed in Table 8 together with the loss values pertaining to both basal and top dressing applications for PU under RT_1 . The corresponding detailed data pertaining to daily ammonia volatilisation are illustrated in Fig. 4 to

TABLE 8 : **RICE EXPERIMENT: CUMULATIVE VOLATILIZATION LOSS OF NH₃-N FOLLOWING APPLICATION OF UREA BASED FERTILIZERS.**

Treatment	Nitrogen applied(kg/ha)		Nitrogen Volatilized (kg/ha) (Cumulative)		
	Basal	Top Dressed	Following Basal Application	Following Top Dressing	Total
RT ₁ (PU, 50%+50%)	38	38	1.9(5%)*	2.2(5.8%)	4.1(5.4%)
RT ₂ (GCU)	76		1.8(2.4%)		1.8(2.4%)
RT ₃ (UNP, 19-19-0)	76		2.9(3.8%)		2.9(3.8%)
RT ₄ (UNP, 27-9-0)	76		1.4(1.8%)		1.4(1.8%)
RT ₅ (USG)	76		2.2(2.9%)		2.2(2.9%)
RT ₆ (PU+ECC)	76		2.0(2.6%)		2.0(2.6%)

* Numbers in parenthesis are percentages of N applied.

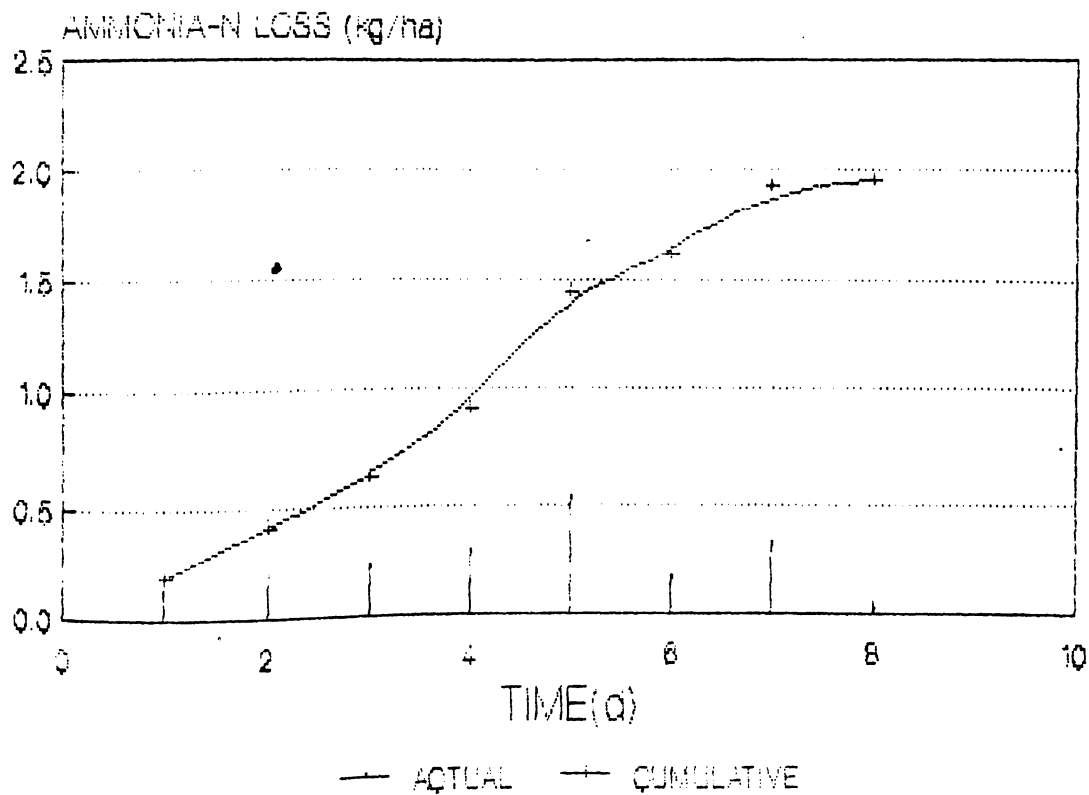


Fig.4 Volatilisation Loss of ammonia-N following basal application of 38kgN/ha (PU) to Rice.

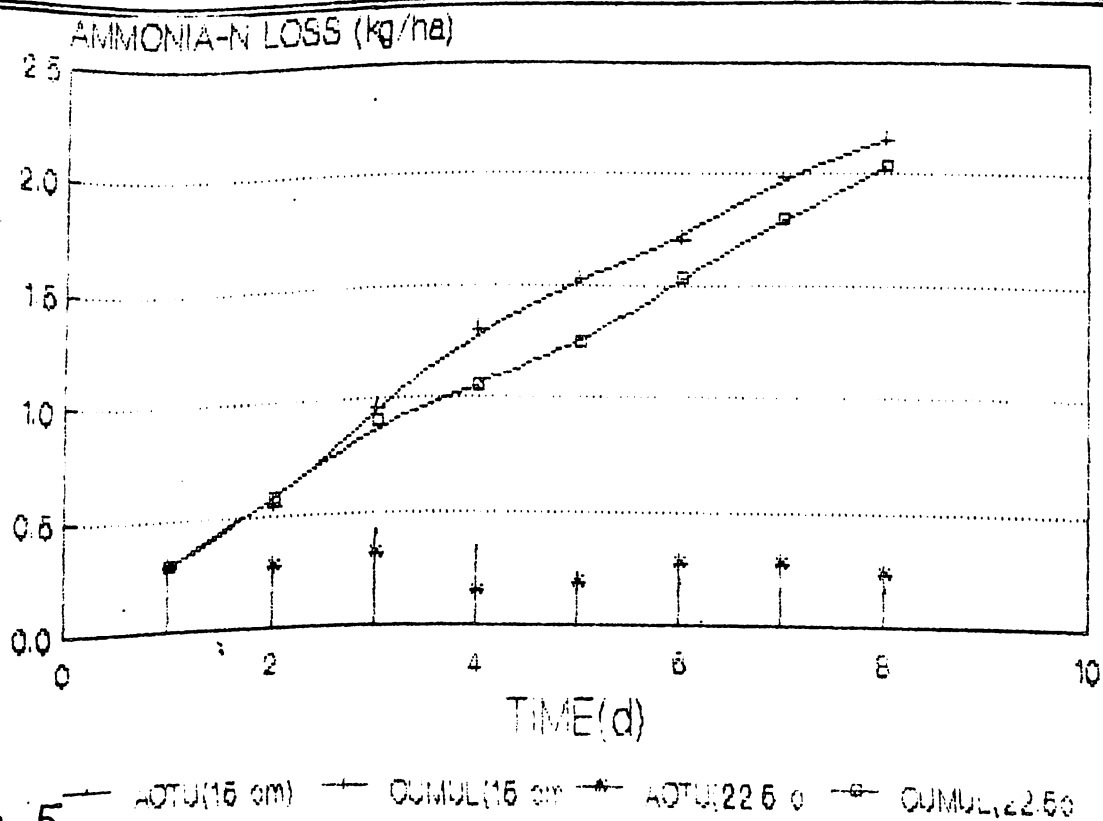


FIG. 5 Volatilisation Loss of ammonia-N following Topdressing of 38kgN/ha (PU) to Rice at 15 cm & 22.5 cm height

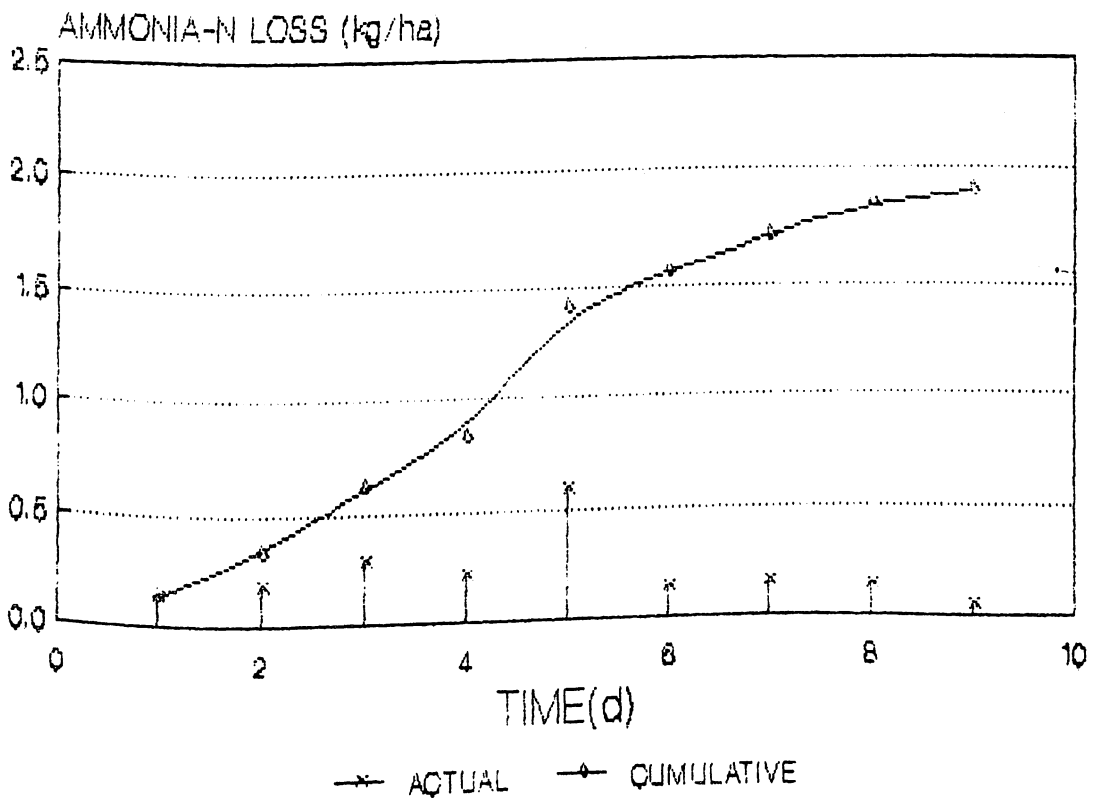


Fig 6. Volatilisation Loss of ammonia-N
 following basal application of ~~16~~ 76 KgN/ha
 (CU) to Rice

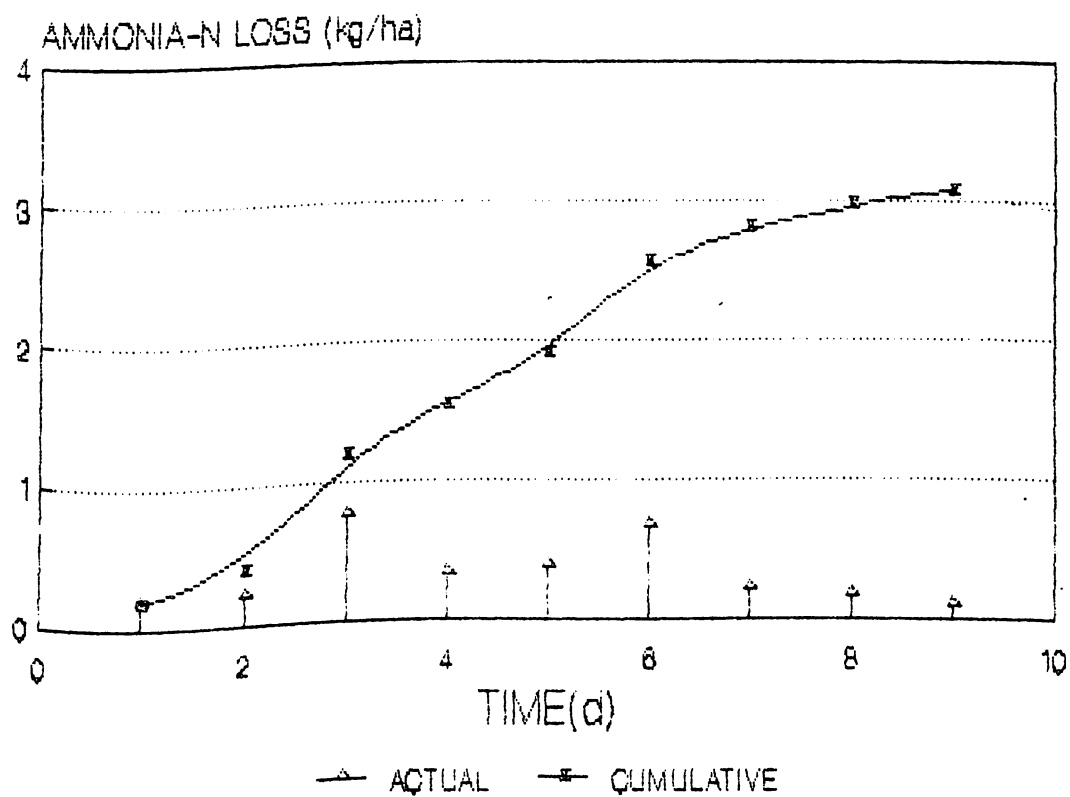


Fig7. Volatilisation Loss of ammonia-N following basal application of 76KgN/ha (UNP 19-19-0) to Rice

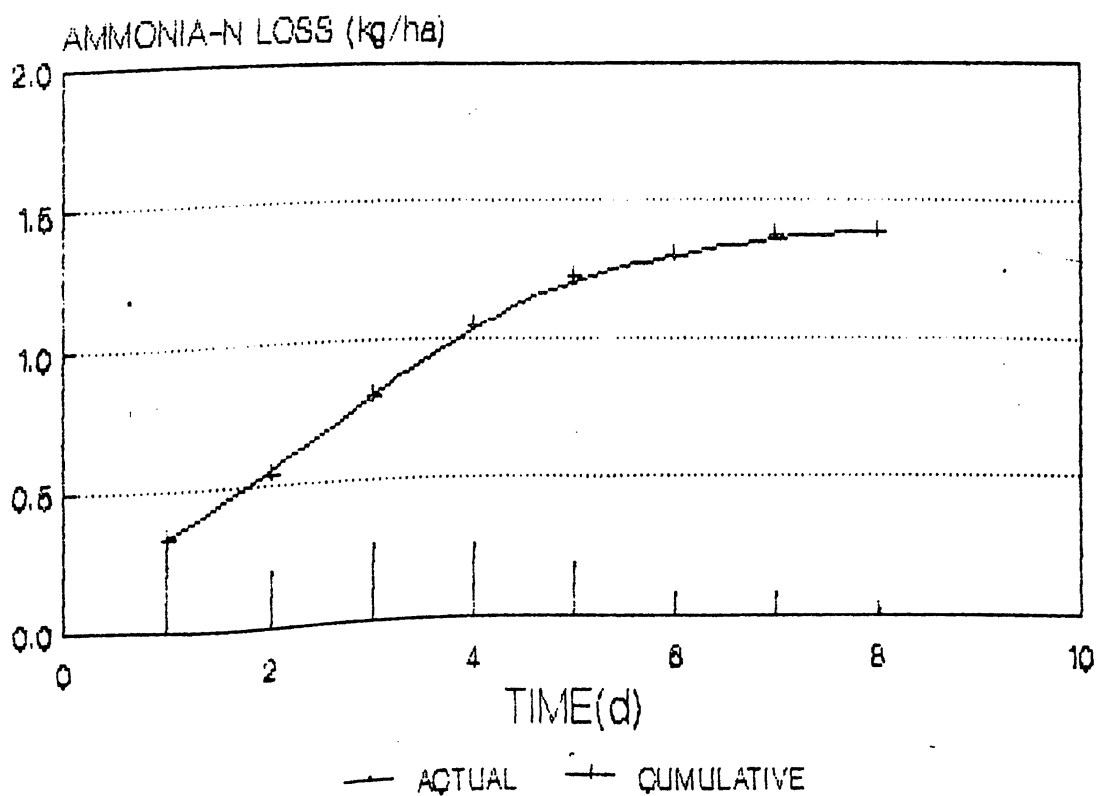
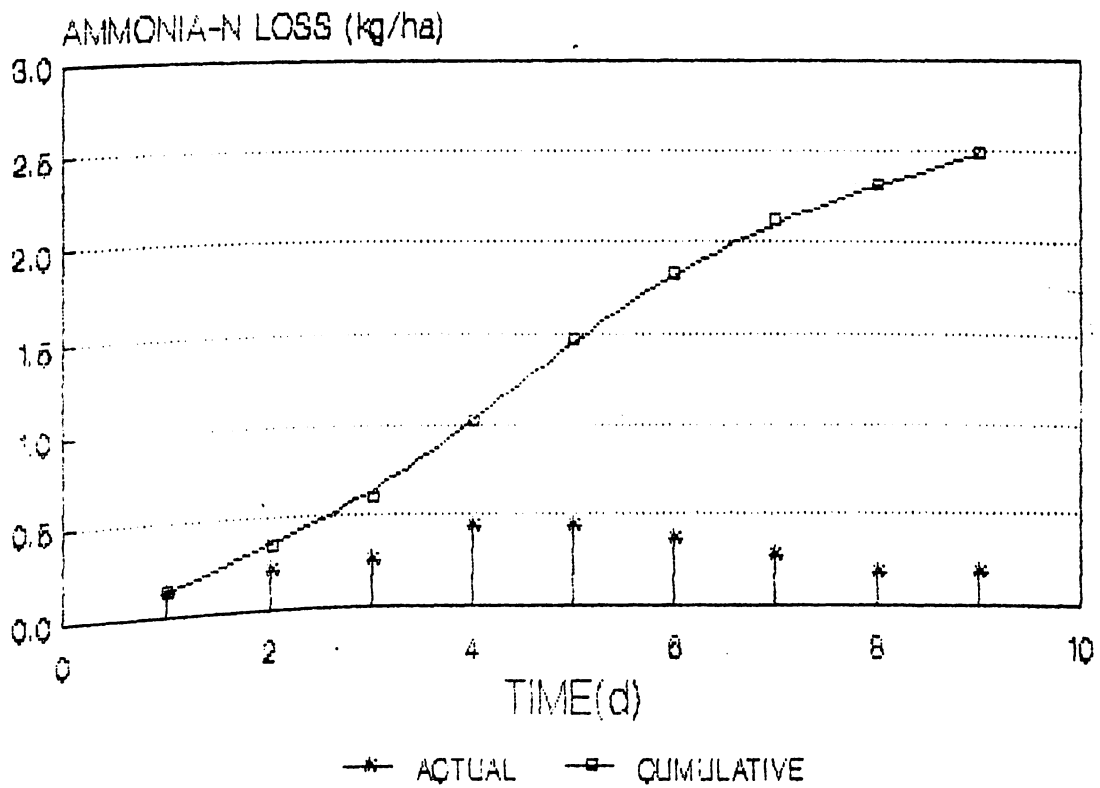


Fig8. Volatilisation Loss of ammonia-N
following basal application of 76KgN/ha
(UNP 27-9-0) to Rice

**FIG 4**

Volatilisation Loss of ammonia-N
following basal application of 76 kg N/ha
(USG) to Rice

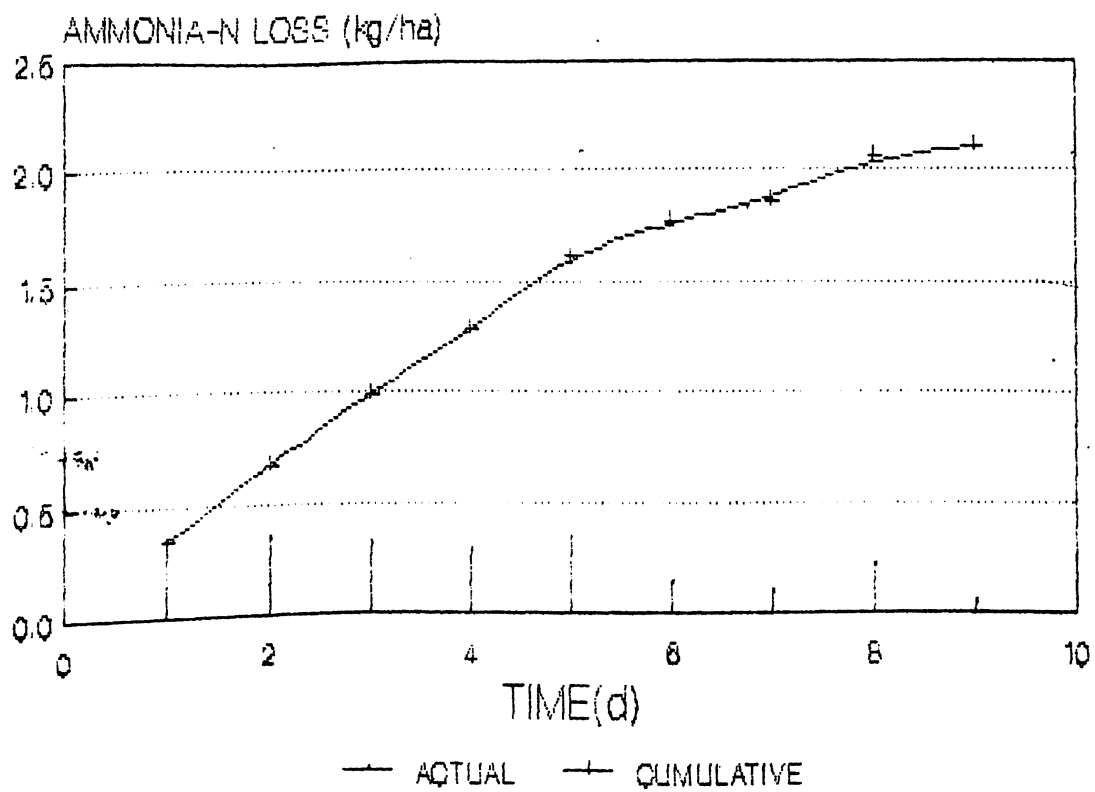


Fig.10 Volatilisation of ammonia-N
from flood water following basal
application of 76KgN/ha(PU)&EOC to Rice

10. Table 2.1.1 under the appendix lists the actual periodically determined NH_3 loss amounts based on which the daily loss values have been computed for use in the figures. Opportunity was not available in the present study to set up ammonia traps in the control plots so as to assess the ammonia loss. As such the volatilisation loss values of ammonia recorded in the present study would have included a small fraction stemming from the soil source. Data presented in Table 8 indicate that the cumulative loss of nitrogen have been the highest under RT_3 and amounts to 2.9 kg/ha. Expressed as percentage of the added fertilizer nitrogen, PU (RT_1) registers the highest value i.e. (5%) following basal application and 5.8% following top dressing.

The percentage loss amounts of volatilised ammonia due to UNP 19-19-0 (RT_3) happened to be next (3.8%) in order. The percentage loss values under GCU, USG and PU single split with ECC under RT_2 , RT_5 and RT_6 should be considered at par and that under RT_4 is the lowest (1.8%). This trend of results should be expected because USG is placed deeper in the soil which results in a restricted migration of NH_3 into the flood water. In the case of RT_6 ECC appears to retard hydrolysis process presumably on account of the poisonous effect of the carbide (which releases C_2H_2) on the hydrolysing enzymes although no plausible explanation can be put forth for GCU under RT_2 . On the other hand Mohanty and Mosier (1990) have reported higher loss values of ammonia with PU

+ ECC treatment as compared to that with single split PU treatment. The results under the present study are not comparable with those of Mohanty et al in as much as the opportunity was not available to evaluate the fraction of volatile $\text{NH}_3\text{-N}$ emerging from the fertilizer source alone and that coming from the soil source through the use of tagged urea. Moreover the estimation of volatilisation loss of ammonia was not continued beyond 9 days following fertilizer application under the present study. However, as may be seen in Fig (4) to (10) ammonia volatilisation apparently slowed down by the 9th day under most of the treatments. The actual ammonia loss data in these figures also show that a peak in ammonia volatilisation loss amount was reached between 4th to 6th day and usually decreased for earlier and later times. It is, however, interesting that despite 50 % of the full dose of amide nitrogen was added at the first split as basal application under treatment RT_1 the cumulative loss is comparable to that under RT_6 in which full dose of urea i.e. 76 kg N/ha was applied as single basal dose with ECC. Apparently this is proof that use of ECC tends to bring about a reduction in ammonia volatilisation loss amount as compared to that in prilled urea treatment. This observation could have possibly been further corroborated had there been an additional treatment with full dose of urea applied as basal without ECC.

However, in contrast to these results an entirely novel hypothesis has been advanced by Fenn (1981) in order to explain

the effect of calcium salts in general on the reduction of volatilisation loss of ammonia in the paddy situation. These authors claim that volatilisation loss of NH_3 could be reduced by the application of soluble calcium and magnesium salt due to the precipitation of CaCO_3 under alkaline conditions by way of preventing the formation of ammonium carbonate and bicarbonate salts which lead to volatilisation subsequent to urea hydrolysis. Under acidic condition the initial pH in the presence of Ca or Mg may be too low for CaCO_3 precipitation. Precipitation will only occur if sufficient ammonium carbonate is produced to raise the pH above 7 and NH_3 loss should not be appreciable until this pH value is exceeded. This mechanism was confirmed by the later work of Fenn et al (1981) who also showed that added Ca has an additional effect, viz, it reduces the rate of urea hydrolysis by the formation of calcium-urea complex.

It is significant to note that in the present study conducted on a soil the pH in flood water of which remained around 6.5 - 7.5. The addition of calcium salts in the form of ECC (30 kg CaC_2 /ha) and GCU (8 kg CaSO_4 /ha) may have led to the formation of Ca-urea complex as has been suggested by Fenn et al (1981) and reduced the nitrogen loss amounts by volatilisation as may indeed be observed in data presented in Table 8.

Infigure 5 volatilisation loss amounts of $\text{NH}_3\text{-N}$ stemming from top dressing of prilled urea under treatment RT_1 are presented on actual and commulative basis. The corresponding values are presented in Appendix 2.1.2. It may be noted that ammonia traps were set up with its umbrella at height of 22.5 cm. above the soil surface following the basal application of nitrogen fertilizers. However, following top dressing in RT_1 , the traps were set up both at 15 and 22.5 cm above the soil surface. This really amounted to heights of 8 and 15.5 cm above flood water level. The graphs representing the comulative loss amount in Figure 5 stemming from 15 cm and 22.5 cm traps show that the amount of volatilised NH_3 collected by the former trap is somewhat higher than the later. The results reported by Misra et al. (1991), however, indicate that the ammonia loss amounts estimated over a period of 6 days following top dressing of 37.5 kg N/ha as PU for these two different heights were almost identical and happened to be 100% higher than that estimated in the present study. The temperature prevailing in the flood water during the period when Misra et al. (loc-cit) collected the NH_3 loss amounts happened to range between 22.5 to 35.5°C whereas it may be seen from Appendix table 2.6.1 that the flood water temperature ranged between 22 to 31°C during this study. This may have been one of the reasons for the higher amount of NH_3 loss detected by these authors. However, further work is required to explain the differential observations. The increase in the amount of ammonia volatilisation loss for higher temperature as has been observed by Misra et al. (1991) is supported by a Bremner and Mulvany (1978) among a number of others.

4.2.5 Temporal variation of amide nitrogen concentration in flood water and soil solution

Variations of amide nitrogen content in the flood water and soil solution at 7.5 cm depth with time following the basal application and top dressing of PU @ 38 kg N/ha (RT_1) is graphically illustrated in figure 11 and 12 respectively. Similar data for the application of other urea based fertilizers at transplanting in treatments RT_2 , RT_3 , RT_4 , RT_5 and RT_6 are presented in figures 13 to 17. Appendices 2.2, 2.3 and 2.4 list the detailed observations pertaining to these figures. The basal dose of PU and other urea based fertilizers were applied between the rows of rice plants after they were transplanted with around 5 cm of standing flood water. The level of flood water decreased 1.9 cm/day (0.9 - 3.3 cm) on an average during days following basal application and 1.5 cm/day (0.7-2.0 cm/day) on an average during the days following top dressing.

After every 24 hours beginning the application of fertilizers, part of the water infiltrated was replenished for facilitating sample collection 1.5 cm below the water surface using a pipette. The soil solution sampling at the depth of 7.5 cm was done with the help of solution samplers (3.2, 1.2). [The concentration of amide, ammonium and nitrate of the water used for irrigation in these experiments happened to be 0, 4 and 6.9 mg/l, respectively (Appendix 4).]

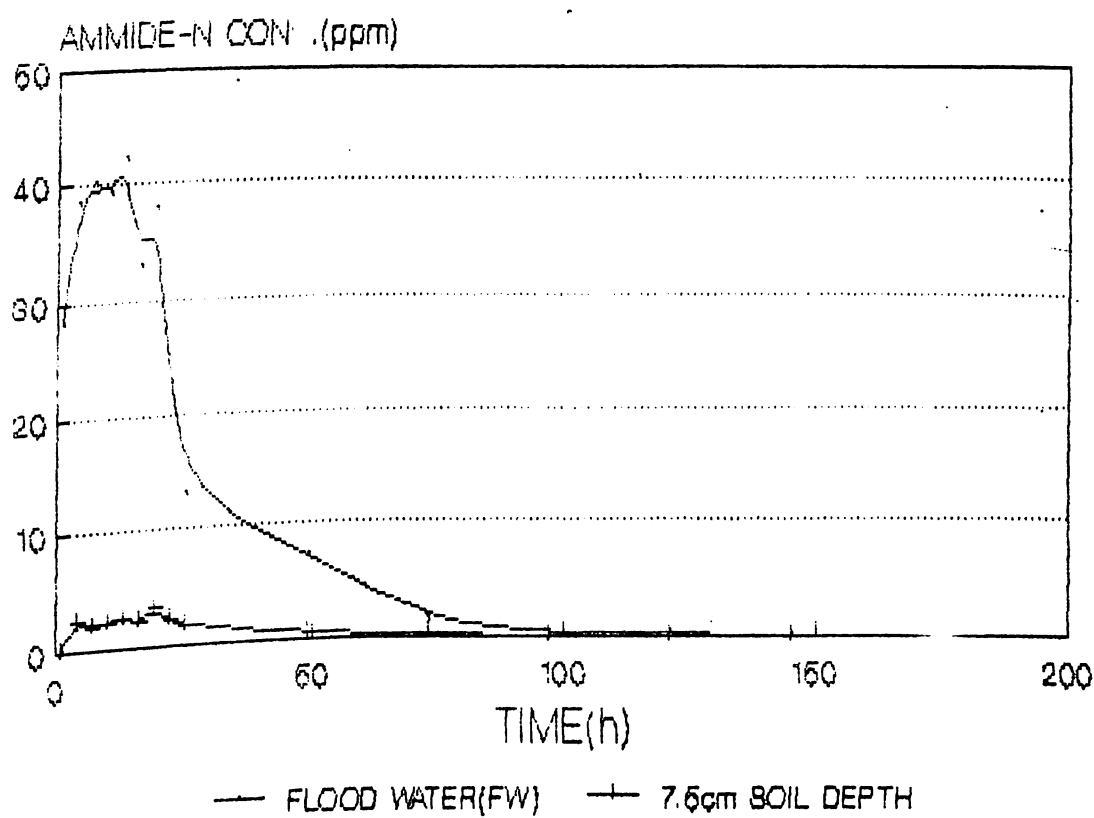


FIG II: CON. OF AMMIDE-N IN FW & SOIL SOLUTION
FOLLOWING BASAL APPLICATION OF
36KgN/ha(PU) TO RICE

In Fig.11 and 12 the observed concentration distribution appear as points which have been connected by means of Havards graphics software to form smooth graphs. The features of these graphs in both figures appear to be in general similar in that the amide nitrogen concentration in both flood water and soil solution increased from near 0 level to a peak vlue and then decreased to zero. In the case of basal application (Fig. 11), the peak value of 40 ppm of $\text{NH}_2\text{-N}$ in flood water is boserved to have been attained in around 12 hours the concentration reaching zero near 100 hours. However, in the case of soil solution the peak is not clearly defined and the solution concentration drops to zero near 75 hours, attaining the maximum value around 19 hours. In Fig. 12, however, the peaks both for flood water and the soil solution are clearly defined and are attained at 7 hours and 10 hours with the concentration dropping to zero around 80 hours and 25 hours, respectively. The results depicted in Fig. 11 suggest that the urea hydrolysis process was continued atleast for 100 hours in the flood water following basal application of PU whereas this process took only 80 hours following top dressing presumably due to higher temperature (Appendix 2.6.1) and increased biological activity. It should be noted here that decrease/ⁱⁿ $\text{NH}_2\text{-N}$ concentration after 24 hours in the flood water is both due to hydrolysis and dilution caused by partial replenishment of the water that infiltrated/evaporated that may have been the possible cause why Misra ^{et al} (1991) observed a long tail despite somewhat higher ambient temperature prevailing at the time of their study as compared to that prevailed in

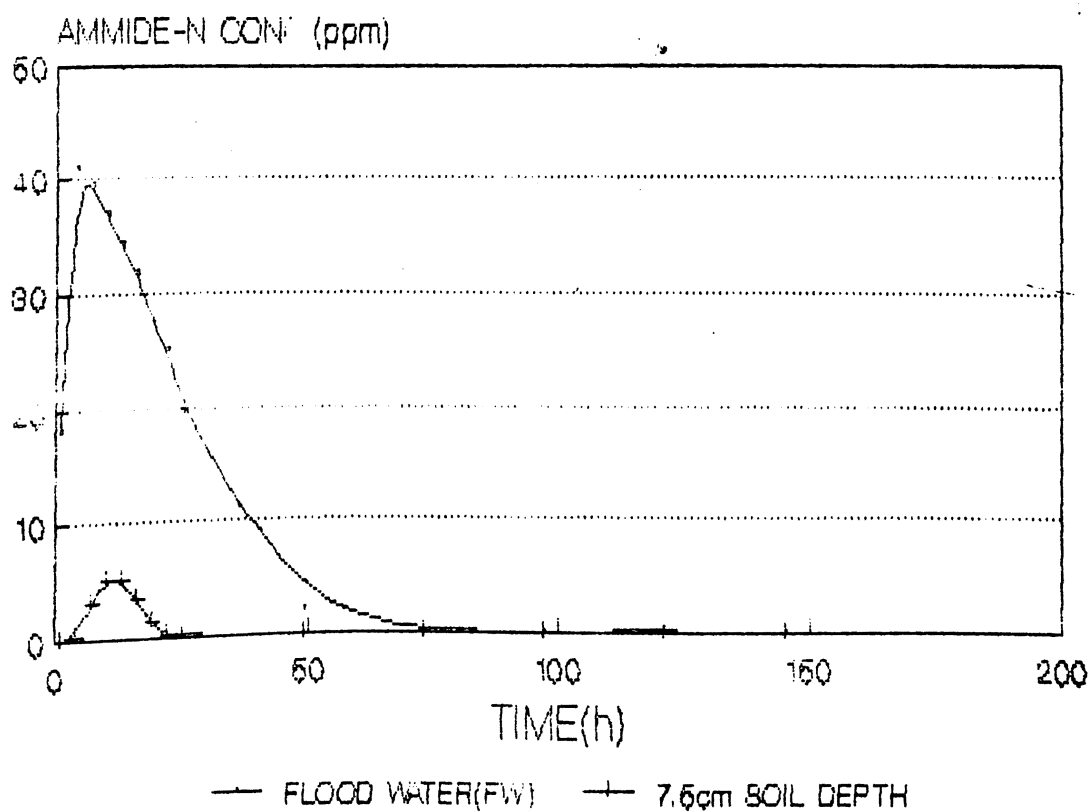


FIG 12: CON. OF AMMIDE-N IN FW & SOIL SOLUTION
FOLLOWING TOPDRESSING OF
38KgN/ha(PU) TO RICE

the present study (Appendix 2.6.1 and 2.6.2). The results of temporal variation of $\text{NH}_2\text{-N}$ in flood water and soil solution were analysed by Mishra et al. (1991) based on the solution of a convective diffusion model subject to Dirac delta function boundary condition and reported 0.015 h^{-1} , 0.05 h^{-1} and 0.09 h^{-1} as the values for the urea hydrolysis, rate constants for flood water, reduced zone and oxidised zone of the soils respectively. Efforts could be made to utilise the data recorded under the present study for computing the urea hydrolysis rate constants incorporating even the dilution effect into a new model. However, opportunity was not available to accomplish that before preparation of this thesis.

Panda et al. (1988 a, b) carried out a series of investigations in order to measure nitrogen distribution in flooded rice soil following application of PU and USG. Panda et al (1989) reported ammonia volatilisation loss of $< 1\%$ of applied nitrogen with USG and 2-6% with surface broadcast prilled urea. While the loss values due to PU are in agreement with that in the present study that from the application of USG is appreciably higher owing possibly to difference soil conditions etc. These authors observed that surface broadcast nitrogen in the form of PU was found mostly in the top 0-5 cm layer and there was only small vertical movement of applied nitrogen to 5-10 cm depth. Under the soil conditions (CRRI, Cuttack) in which these authors worked the leaching loss in the form of NH_4^+ and NO_3^- was only 0.2-0.4% of nitrogen applied.

No loss occurred as $\text{NH}_2\text{-N}$. These results are attributable to low water percolation rate in the experimental site.

Although these results of Panda et al (loc.cit) appear to be in general agreement with that obtained in the present study in respect of treatments, RT_1 , RT_2 and RT_3 (as illustrated in Fig. 13, 14), the amounts of $\text{NH}_2\text{-N}$ migrating to 7.5 cm soil depth stemming from UNP (27-9-0) treatment (RT_4) and PU + ECC treatment (RT_6) are appreciably higher as may be seen in Fig. 15 and 17. On the other hand, the distribution of $\text{NH}_2\text{-N}$ due to point placed USG illustrated in Fig. 16 is unique in the sense that most of $\text{NH}_2\text{-N}$ remains in soil solution at 7.5 cm depth and traceable until 150 hours following application. The other distinguishing features of temporal variation of $\text{NH}_2\text{-N}$ concentration in Fig. 13 to 17 are that the $\text{NH}_2\text{-N}$ concentration distribution of flood water presents a long tail upto 150 hours except in the case of PU+ECC treatment in RT_6 where the zero concentration in flood water is reached in around 100 hours. The peaks in the flood water $\text{NH}_2\text{-N}$ concentration are reached between 15 to 20 hours in RT_2 to RT_5 treatments with the peak values around 60, 40, 50 and 6 ppm, respectively. The lower peak concentration in RT_5 is suggestive of the slower rate of migration of $\text{NH}_2\text{-N}$ upwards into the flood water from 5 cm soil layer. On the other hand, the $\text{NH}_2\text{-N}$ distribution pattern both in flood water and soil solution appears to be quite distinct in as much as the peaks (Fig. 17) in the flood water $\text{NH}_2\text{-N}$ distribution curve and that pertaining to soil solution are reached

CON. AMIDE-N (PPM)

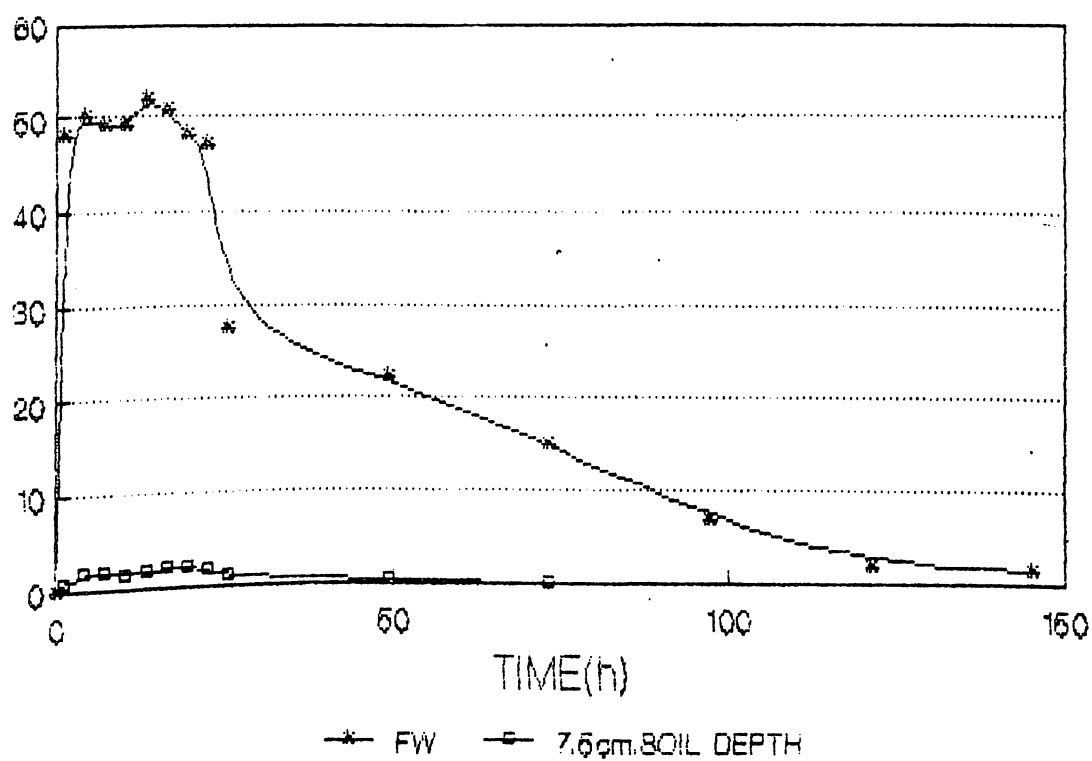
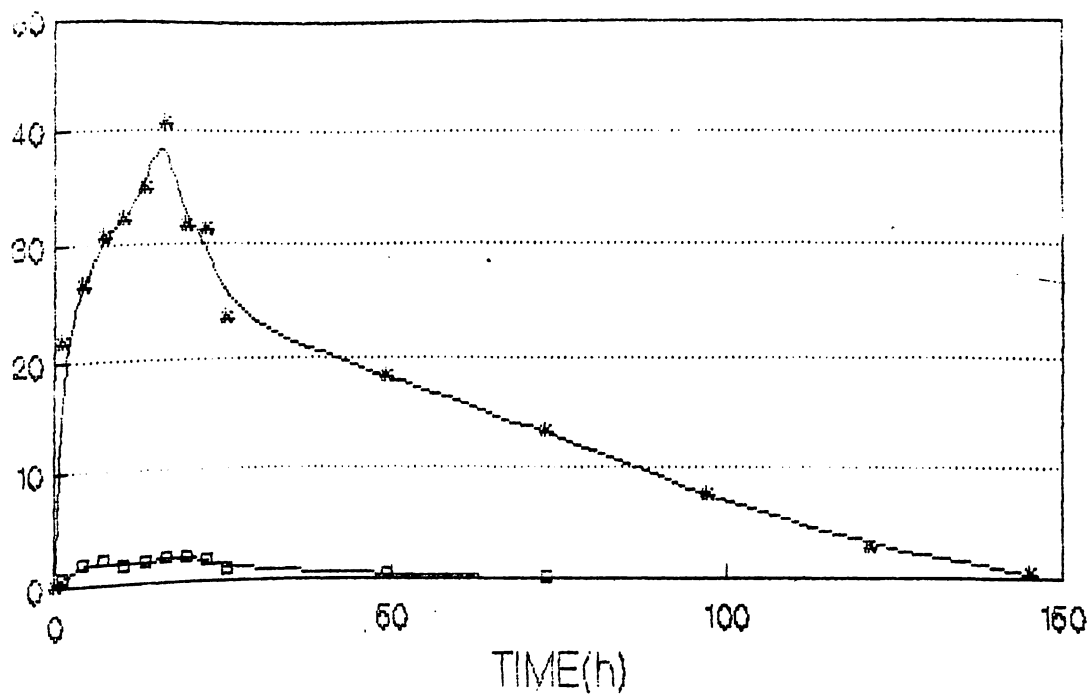


FIG 13: CON. OF AMIDE-N
AFTER 70kgN/ha (GOU)
APPLIED TO RICE AT TRANSPLANTING

CON. AMIDE-N (PPM)



* FW □ 7.5 cm. SOIL DEPTH

FIG 14: CON. OF AMIDE-N
AFTER 70kgN/ha(UNP, 19-19-0)
APPLIED TO RICE AT TRANSPLANTING

CON. AMIDE-N (PPM)

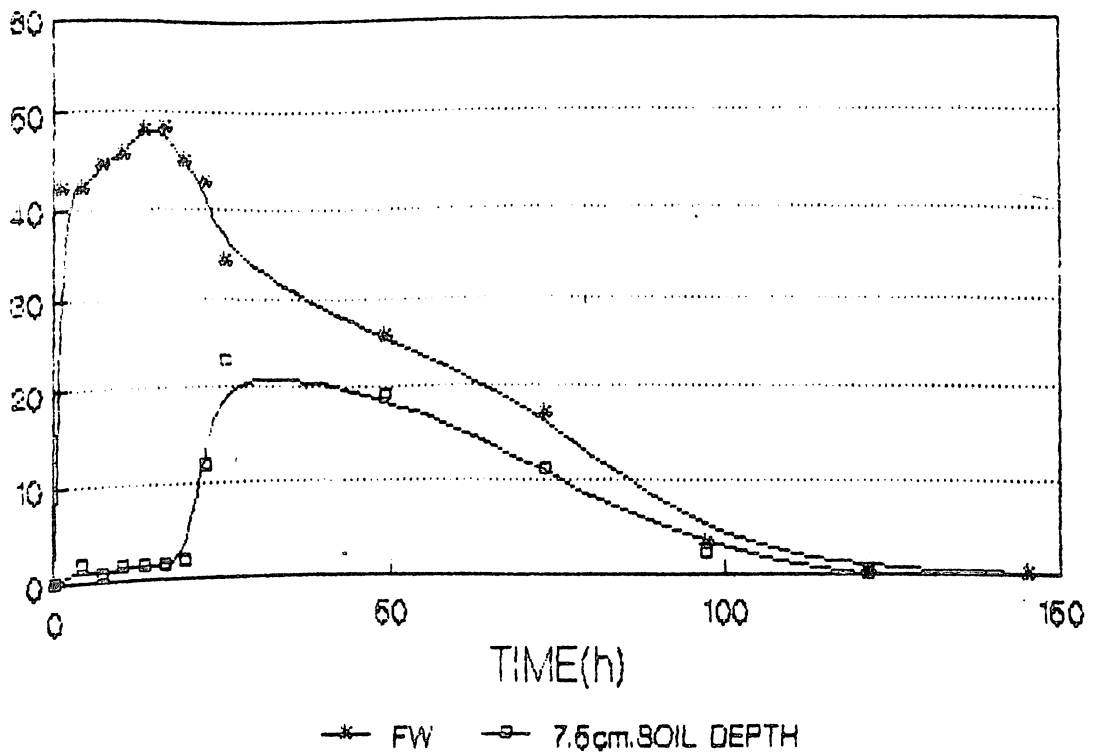


FIG 15: CON. OF AMIDE-N
AFTER 70kgN/ha (UNP, 27-9-0)
APPLIED TO RICE AT TRANSPLANTING

CON. AMIDE-N (PPM)

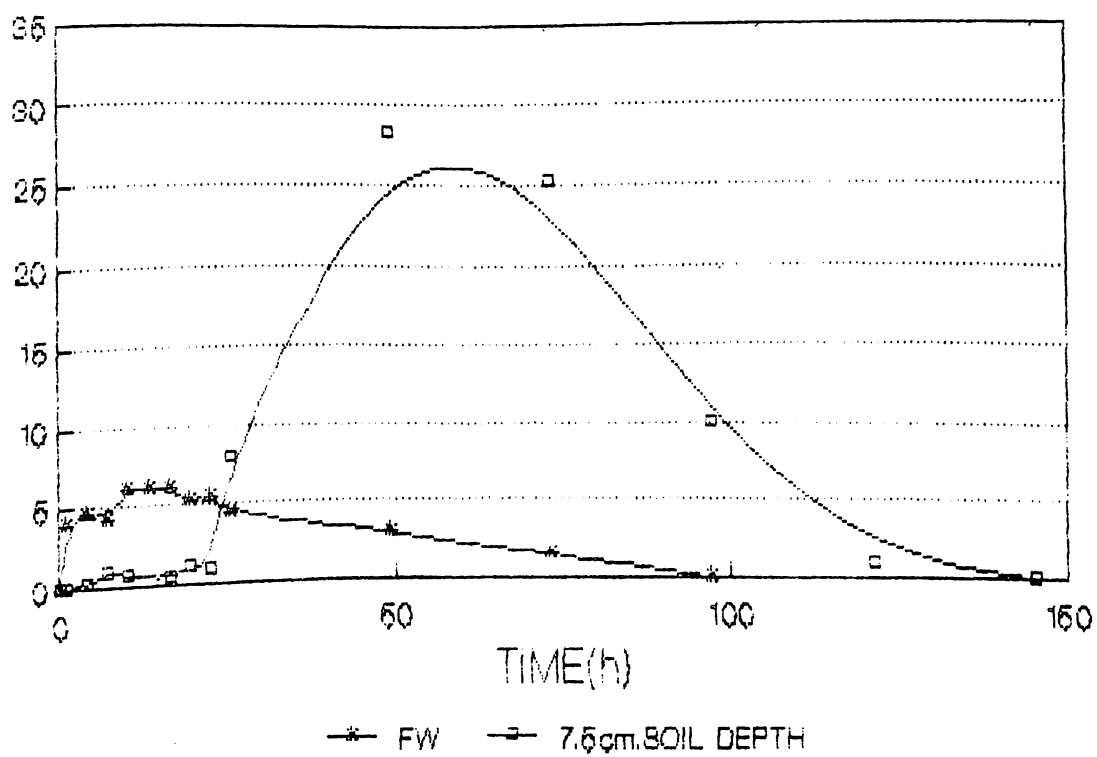


FIG 16: CON. OF AMIDE-N
AFTER 75 kgN/ha (USG)
APPLIED TO RICE AT TRANSPLANTING

CON. AMIDE-N (PPM)

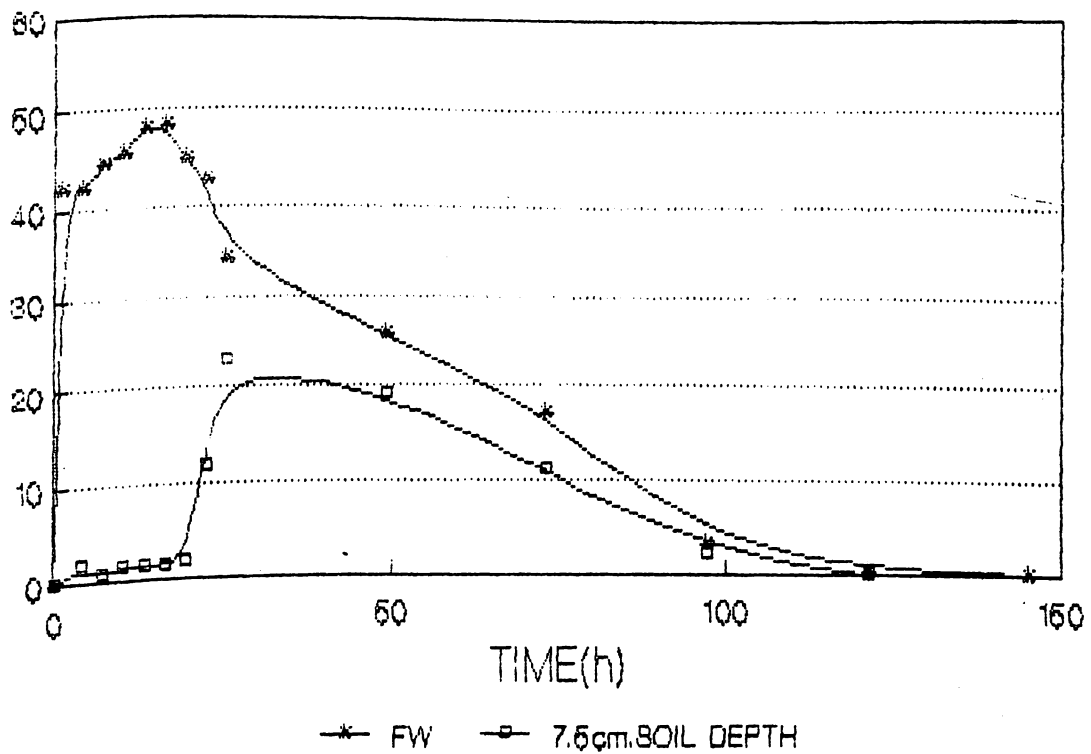


FIG 15: CON. OF AMIDE-N
AFTER 70kgN/ha (UNP, 27-9-0)
APPLIED TO RICE AT TRANSPLANTING

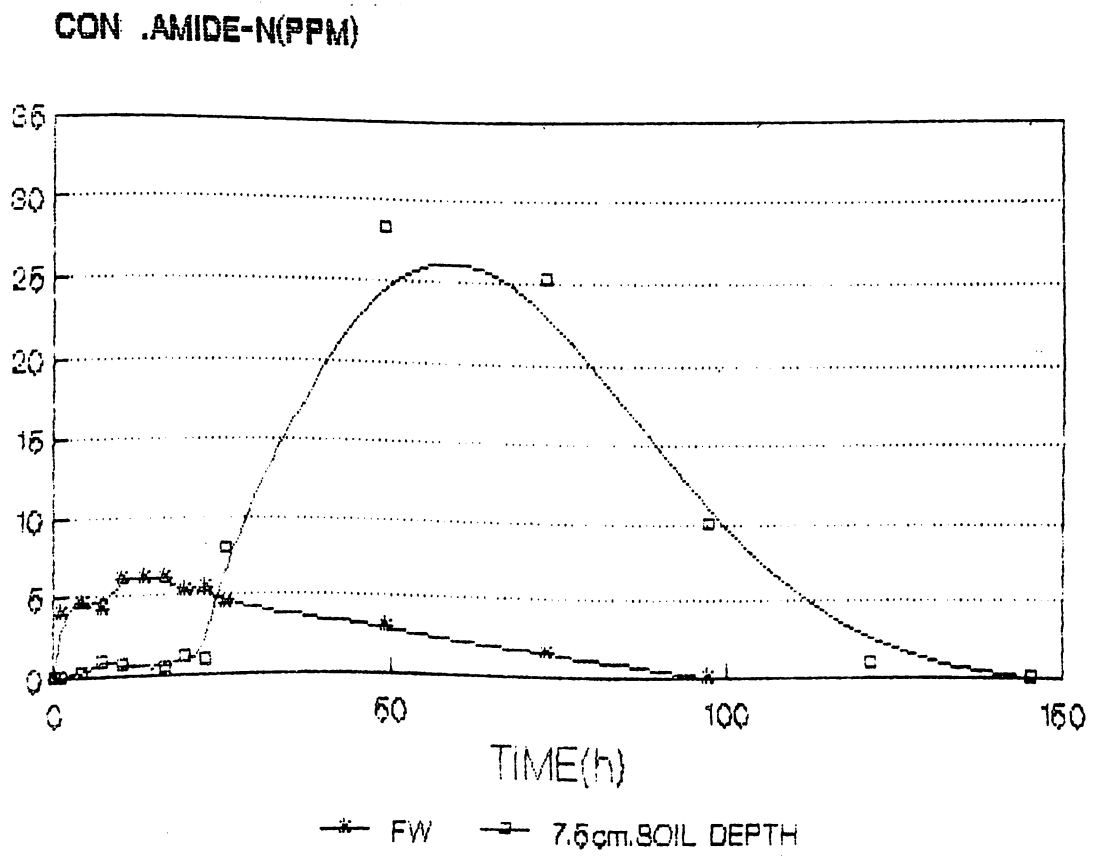
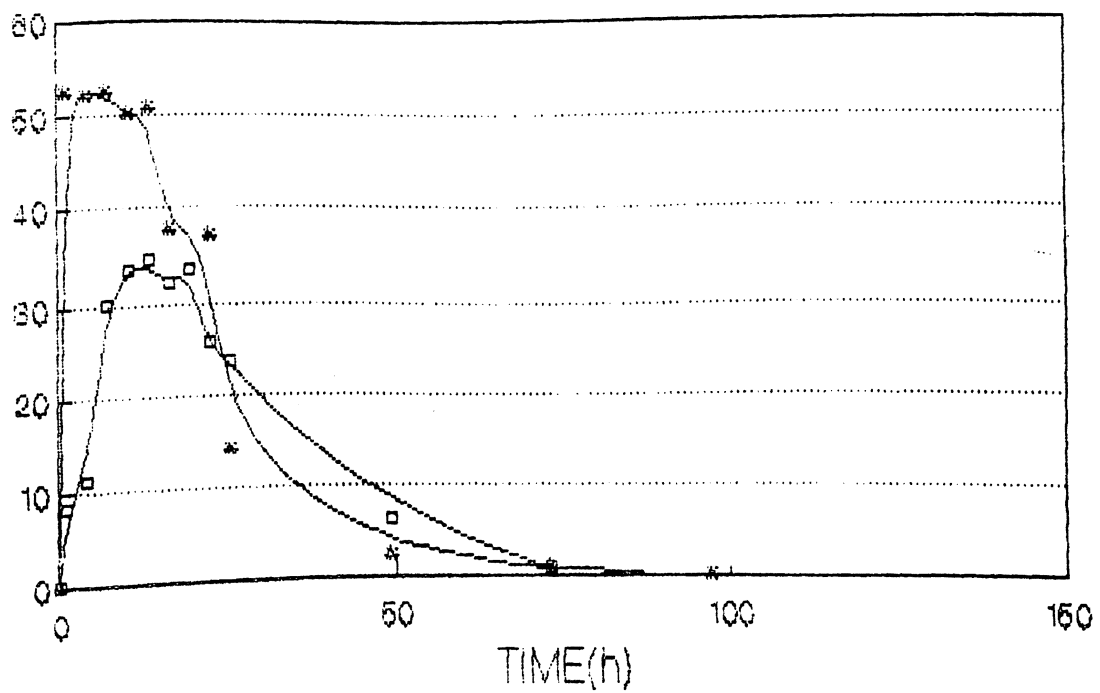


FIG. 16: CON. OF AMIDE-N
AFTER 75 kgN/ha (USG)
APPLIED TO RICE AT TRANSPLANTING

CON. AMIDE-N (PPM)



—*— FW —□— 7.5cm. SOIL DEPTH

FIG 17: CON. OF AMIDE-N
 AFTER 70kgN/ha (PU)+ECO
 APPLIED TO RICE AT TRANSPLANTING

much earlier than in any of the other treatments supplying equivalent dose of nitrogen. The peak values in this case are around 52 and 35 ppm in the flood water and soil solution, respectively which are attained around 5 and 10 hours in these two cases. This indicates that somehow the added $\text{NH}_2\text{-N}$ moves faster into the lower soil layer thereby depleting its concentration in the flood water quicker than in the other equivalent treatments. The areas under concentration distribution curves in soil solution under RT_4 and RT_6 appear to be comparable and are of appreciable magnitude next in size only to that in RT_5 . However, the concentration in soil solution in RT_4 present a long tail upto 125 hours whereas in the case of the latter the tail extends upto nearly 80 hours. Both these patterns are suggestive of retarded urea hydrolysis rates that lead to a reduced nitrogen volatilisation loss of $\text{NH}_3\text{-N}$ under these two treatments as has been already noted in the previous section and in table 8. An exceptional case that does not present an obvious clue to infer the urea hydrolysis rate is the $\text{NH}_2\text{-N}$ distribution patterns in flood water and soil solution under treatment RT_2 that received GCU. The $\text{NH}_3\text{-N}$ volatilisation loss percentage in this treatment which was comparable to RT_6 should have prompted one to expect greater migration of $\text{NH}_2\text{-N}$ into the soil from flood water thereby suggesting a sluggish rate of hydrolysis. Apparently in this treatment formation of Urea-calcium complex as has been suggested by Fenn (1981) prevented the volatilisation loss of NH_3 as well as the migration of urea to lower soil layer

from flood water. The strong possibility of formation of calcium-urea complex in RT_6 can not be ruled out, however, together with a suspected poisonous effect of carbide factor contributing to greater rate of retardation of hydrolysis in RT_6 as compared to that in RT_2 .

These absorptions appear to be plausible in as much as the rate of percolation of water has been observed to be somewhat lower (1.5 cm/d) in RT_6 as against 2.2 cm/d under RT_2 treatment.

On the otherhand the (differential) behaviour of retarded hydrolysis and migration as inferred based on NH_2 -N distribution in RT_3 and RT_4 (Figs 14 and 15) is hard to explain especially considering the lower dose of NH_2 -N (~ 35 kg/ha) added under these treatments. Further work surely warranted in order to resolve the mystery.

The NH_4^+ -N and NO_3^- -N content stemming from urea hydrolysis in flood water or soil solution could not be measured under the present study. The exceptional features under some of these treatments as has been referred to in the foregoing could possibly have been explained with such data which ought be collected in future investigations.

The present field experiment on rice was conducted in the dry season when the chance of loss of nitrogen due to lateral seepage of water over vast areas is completely ruled out unlike

that in the wet season where all the fields remain submerged and water moves from field to field both by surface and subsurface seepage in response to hydraulic gradient. The loss by leaching of soluble N compounds (e.g. $\text{NH}_2/\text{NH}_4^+/\text{NO}_3^-$) under the present study is therefore negligible. The NH_4^+ -N resulting from hydrolysis is not expected also to migrate much deeper in soil beyond the root zone of rice crop as also has been observed by Panda et al. (1988 a). Therefore the bulk of added nitrogen not absorbed into the plant system or lost by volatilization must have been dinitrified after nitrification of the resultant NH_4^+ in the root zone of rice crop where oxygen is known to be transported through the plant body or in the oxidised layer of the soil surface. Gaseous losses of nitrogen has also been suspected to occur through young plants (Mohanty and Mosier, 1990) and this could be an additional mechanism of loss of $\text{NH}_3/\text{N}_2/\text{N}_2\text{O}$ to ^{be}verified more extensively in future studies.

Krishnappa and Shinde (1980) attempted to trace the fate of ^{15}N urea under flooded rice culture over a sequence of three rice crops and reported around 31% as possible loss though denitrification and leaching to deeper layers beyond 55 cm. Under the present study the crop uptake component being 54% under the PU treatment and nearly 5% as volatilisation loss, accepting 31% as the loss due to denitrification as has been reported by Krishnappa and Shinde (1980) nearly 10% of the applied N is expected to remain immobilised in the soil biomass. Use of ^{15}N tagged urea in future studies would elucidate the N balance sheet with an acceptable reliability.

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4.2.6 Inorganic nitrogen content of surface soil at harvest

Inorganic nitrogen contents of the surface soil at harvest in the microplots under treatment RT_1 - RT_{10} are listed in Table 9 for the rice experiment. The interesting features of this data happen to be very high NH_4^+ and NO_3^- contents under the GCU treatment, hill amount under USG, FYM and the control treatments. The mineralisation cycle in the soil may result in variable amounts of NH_4^+ and NO_3^- at a given time under different situation. Under RT_1 treatment which received 50% PU during tillering has resulted in relatively rich root zone in present of the inorganic nitrogen contents.

The NH_4^+ and NO_3^- -N content in amounts in excess of 100 kg/ha under RT_2 treatment (GCU) appears to be puzzling. It is interesting to note that application of GCU to the rice crop served to bring about a significant residual effect in succeeding wheat crop in kathulia (mixed red and black soil) and Bansuara (deep black soil). Soil test data to explain these results (Anonymous 1987) are not available. However it is expected that as observed under the present study the higher amounts of inorganic nitrogen contained in the soil under the GCU treatment may have been responsible for such high residual effect. However, the causes as to why the GCU treatment should have led to such a nitrogen-rich rhizosphere at the harvest of the rice crop should have to be investigated further. It should be noted in passing also that the three treatments, RT_9 , RT_6 and RT_7 in which ECC alone was added

TABLE 9 : RICE EXPERIMENT: INORGANIC NITROGEN PRESENT IN THE SURFACE SOIL AT HARVEST

Treatment	Inorganic Nitrogen content (kg/ha)	
	$\text{NH}_4^+ - \text{N}$	$\text{NO}_3^- - \text{N}$
RT ₁ (PU50%+50%)	54	> 100
RT ₂ (GCU)	> 100	> 100
RT ₃ (UNP 19:19:0)	54	26
RT ₄ (UNP 27:9:0)	26	0
RT ₅ (USG)	0	0
RT ₆ (PU + ECC)	54	0
RT ₇ (FYM+ECC)	26	54
RT ₈ (FYM)	0	0
RT ₉ (ECC)	54	54
RT ₁₀ (CONTROL)	0	0

in addition to PU and FYM respectively led to respectable amounts of NH_4^+ and NO_3^- content of the soil of the root zone at the harvest time of the rice crop. The moderate nitrogen content of rhizosphere under RT_3 and RT_4 are also worth-noting. Is it possible that the observed richness of the rice rhizosphere under the treatments RT_2 , RT_3 , RT_4 as well as RT_6 , RT_7 and RT_9 would have all been due to the addition of calcium compounds to these treatments in one form or the other? It is premature enough to even to hypothesise that a calcium rich rootzone promotes mineralisation as in the present case following soil drying after harvest although effect of Ca^{++} through liming has been known to boost mineralisation (Goswami and Sahrawat, 1982).

4.2.7 Yield N concentration uptake of wheat

The grain yield, nitrogen concentration and uptake data for the wheat experiment are presented in Table 10 with the corresponding yield parameters listed in Appendix 3.3. In separately laid out microplots enclosed with polythene sheets wheat was planted and treated alike as in the case of the main microplots so as to periodically harvest the crop for recording dry matter accumulation. These data have also been listed in Table 10. Because there was no replication in this experiment the data could not be statistically analysed nor it was possible to present the fertilizer nitrogen recovery in the crop although the crop was treated with ^{15}N tagged urea owing to non-availability of the atomic ratio analysis results on time. All the same, comparison of the yield data stemming from the four treatments WT_1 to WT_4 shows that fertilizer

TABLE 10 : WHEAT EXPERIMENT : YIELD (DRY BASIS), NITROGEN CONCENTRATION, AND UPTAKE AT DIFFERENT STAGES OF GROWTH.

A. YIELD

Treatment	Dry matter 27 DAS	Accumulation Yield (Kg/ha)	
		71 DAS GRAIN	STRAW
WT ₁ (14 _N +15 _{N'} Free system		13.36	25.09
WT ₂ (15 _N +14 _{N'} Closed system		8.11	12.0
	Mean	Mean	
WT ₃ (14 _N +15 _{N'} Closed system	4.23	74.3	11.51
			13.29
WT ₄ Control, Free system		6.40	7.97

B N CONCENTRATION OF DIFFERENT PLANT PARTS

Treatment	27 DAS	71 DAS	GRAIN	STRAW	ROOT
WT ₁ (14 _N +14 _{N'} Free system	-	-	2.82	0.41	-
WT ₂ (15 _N +14 _{N'} Closed system)	2.95	1.12	2.92	0.61	-
	Mean 2.97	Mean 1.31			
WT ₃ (14 _N +15 _{N'} Closed system)	2.99	1.49	2.78	0.44	0.81
WT ₄ (Control, Free system)			2.31	0.27	0.41

C. N UPTAKE (kg/ha)

Treatment	Vegetative Stage		Harvest			KgN/q. grain
	27 DAS	71 DAS	Grain	Straw	Total	
WT ₁ (14 _N +14 _{N'} Free system)			37.68	10.53	48.21	3.6
WT ₂ (15 _N +14 _{N'} Closed system)	12.48	83.22	23.68	7.32	31.0	3.0
	MEAN 12.56	MEAN 96.97				
WT ₃ (14 _N +15 _{N'} Closed system)	12.65	110.71	32.00	5.85	37.85	3.3
WT ₄ (Control, Free system)			14.78	2.15	16.93	2.6

treatment effect in WT_1 and WT_3 are considerably higher than that in the control plot (WT_4) both in respect of grain and straw yields. The yield under WT_2 treatment was however, very much depressed, the reasons for which may be seen in Appendix 3.3 that lists the yield parameters of wheat. It is seen from this table that the number of clumps per square meter as well as the number of tillers/clump and the number of effective tillers/clump have been lower under WT_2 as compared to that in WT_1 and WT_3 . There was also evidence of bunt incidence in the grains under this treatment.

Concentration of nitrogen in the plant as may be observed in Table 10 decreases with time from 27 to 71 DAS as may be expected because the nitrogen absorbed in the earlier 27 DAS apparently got diluted owing to nearly 18 fold increase in dry matter despite absorption during the interim period. The nitrogen concentration in grain ranging between 2.3 - 2.92% in the four treatments appear to be quite high. It is not known whether the reported 1.69% N in wheat grain (Singh and De, 1978) is based on 14% or zero moisture content.

However, Schepers and Fox (1989) have reported the N content of harvested wheat grain as 2.18% on fresh basis for per hectare yields of a much higher magnitude than that was recorded under the present experiment. The nitrogen content value of straw appear to be reasonable and that for the roots for treatments WT_3 and WT_4 also appear possibly to be on the higher side.

The N uptake data listed in this table appear to be reasonable in light of lower magnitude of grain yield data as compared to that obtained in the wheat fields of the colder regions of the country. However the nitrogen uptake expressed as kg per quintal of grain again appear to be higher than the value of around 2 kg/q commonly reported for wheat under normal conditions. (Ramamoorthy and Velayutham, 1976).

However Misra and Jena (1978) reported nitrogen uptake per quintal of wheat grain in the range of 1.56 - 3.89 kg/q in treatments supplying 0-60 kg N/ha for wheat grown in medium land situations in this research station.

4.2.8 Yield , N concentration and uptake of groundnut

Table 11 lists the dry matter accumulation yield data in respect of kernel, shell, pods and haulm of groundnut together with the corresponding N concentration and uptake values. As in the case of wheat drymatter accumulation by 71 DAS was recorded based on the crop grown in separate microplots equivalently treated as in the main experiment. The data show that there is a considerable response (to 20 kg fertilizer as tagged urea) in the shape of pod yield over the control as also in respect of uptake of nitrogen. The pod yield figures have been much higher than 18 q/ha the mean groundnut pod yield reported for the dry season crop in the state of Orissa and the highest in the Country. However, because of the unavailability of atomic ratio analysis data it is not possible to assess the fraction of this uptake obtained from fertilizer/

Treatment	Dry Matter accumulation(q/ha) 71 DAS	Yield (q/ha)			
		Kernel	Shell	pod	Haulm
GT ₁ (15 _N , Closed system)	37.47	19.74	11.08	30.82	45.35
GT ₂ (Control, Free system)	-	6.65	5.03	11.68	39.19

B. NITROGEN CONCENTRATION (%)

Treatment	71 DAS	Kernel	Shell	Pod	Haulm	Root
GT ₁ (15 _N , Closed system)	2.14	4.82	1.69	3.69	2.8	1.61
GT ₂ (Control, Free system)	-	1.24	0.90	1.09	1.90	2.07

C. NITROGEN UPTAKE (kg/kg)

Treatment	71 DAS	Kernal	Shell	Pod	Haulm	Total	Kg N Uptake/ q Pod
GT ₁ (15 _N , Closed system)	80.19	95.15	18.73	138.88	126.98	265.86	8.63
GT ₂ (Control, Free system)	-	8.25	4.53	12.78	74.46	87.24	7.47

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atmospheric sources through nitrogen fixation. The nitrogen content in the groundnut pods under GT_1 is observed to be 3.69%. The N content value in the kernel has been reported by Patel and Patel (1988) to be in the range of 3.82-4.45% (the basis of expression being unknown) whereas that reported by Scheper and Fox, 1989 is 3.52% on fresh basis for the groundnut pods. The data reported in Table 11 are thus in close agreement with that reported elsewhere. The yield parameters of groundnut are listed in Appendix 3.3 and it is seen from these data that the treated crop is superior in almost all the yield parameters. However, the analysis of oil content for the kernel could not be carried out under the present study but is expected to be higher in the treated plants.

4.2.9 Volatilisation loss of NH_3

Cumulative volatilisation loss data of NH_3 -N following urea application to wheat and groundnut are presented in Table 12. (It should be noted here that ammonia traps could not be set up during initial five days following basal application.) Some of these data have been graphically illustrated in Fig. (18, 19 and 20) with the detailed data listed in Appendix 3.1. The pertinent soil and air temperature during the period of collection of volatilised ammonia have been listed in Appendix 3.2 for wheat and groundnut experiments.

The cumulative volatilisation loss of ammonia following basal application (Table 12) is observed to be 2.99 kg/ha under WT_2

TABLE 12 : WHEAT AND GROUNDNUT EXPERIMENT : CUMULATIVE VOLATILISATION LOSS OF $\text{NH}_3\text{-N}$ (Kg/ha) FOLLOWING APPLICATION OF UREA TO WHEAT & GROUNDNUT.

Crop and Treatment	Nitrogen Applied (Kg/ha)		NH -N Volatilised (Kg/ha)		Total	Percentage of applied N Volatilised		
	Basal	TopDressed	Following* basal app- lication (over a pe- riod of 5 days)	Following app- lication at Maximum tille- ring(over a pe- riod of 9 days)		Following Basal application	Following Application at maximum tillering	Total
<hr/>								
<u>WHEAT</u>								
WT ₁	50	50	0.85	2.55	3.40	1.7	5.1	3.40
WT ₂	50	50	2.99	1.32	4.31	6.0	2.64	4.30
WT ₃	50	50	1.11	1.46	2.57	2.2	2.92	2.57
<u>GROUNDNUT</u>								
GT ₁	20	-	0.49	-	0.49	2.5	-	2.5

* Ammonia traps could not be set up during the initial five days following basal application of fertilizer urea. Cumulative $\text{NH}_3\text{-N}$ volatilization loss values reported here in therefore are that stemming from measurements during 6th to 10th day.

('closed systems') and 1.11 kg/ha under WT_3 ('closed system') and 0.85 kg/ha under WT_1 (free systems). Following application of urea at maximum tillering the cumulative volatilisation loss is seen to be appreciably higher under WT_1 (2.85 kg/ha) than that under WT_2 (1.32 kg/ha) and WT_3 (1.46 kg/ha).

Referring to illustrations in Fig. 18, 19 and 20 it may be observed that whereas the loss values following basal application under both wheat and groundnut almost remained unchanged in magnitude between 6th and 10th day, there is a clear reduction in the magnitude of the loss values during 4 to 9 day following top dressing in which under WT_1 . This may have been on account of crop stand at the time of top dressing as against the absence of the crop at the time of basal application. It should be recognised that following application and hydrolysis of urea in the soil the NH_4^+ -N that is formed is to get volatilised subject to environmental conditions and absorbed by the crop if standing at the time on the field while slowly migrating into the lower layer. Part of it may also get nitrified simultaneously especially in favourable oxygen rich environment such as that prevailing in the wheat and groundnut root zones. The actual NH_3 - volatilisation loss values measured over the days following application of prilled urea are thus expected to describe a bell shaped curve rising from near zero value to a peak and that indeed has been observed for experiments on both rice and wheat under the present study especially following top dressing of urea. But this is also true following basal

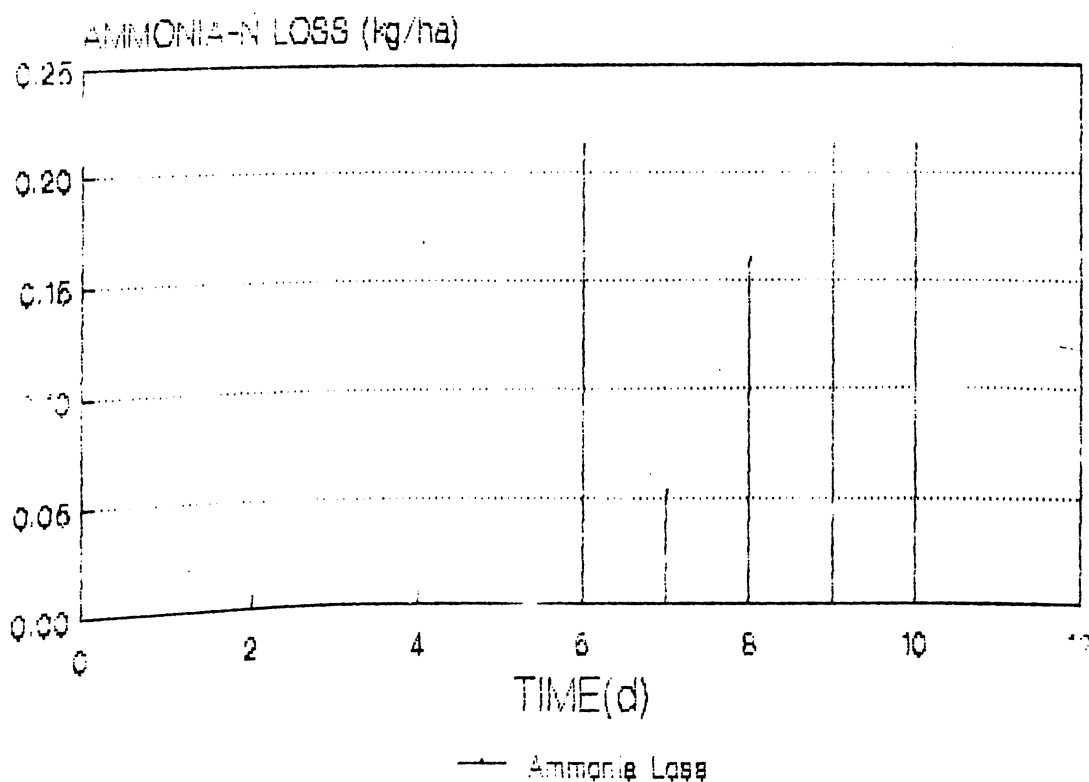


Fig:18: Volatilisation loss of Ammonia-N from Wheat plot(WT-1) following basal application of PU(50KgN/ha)

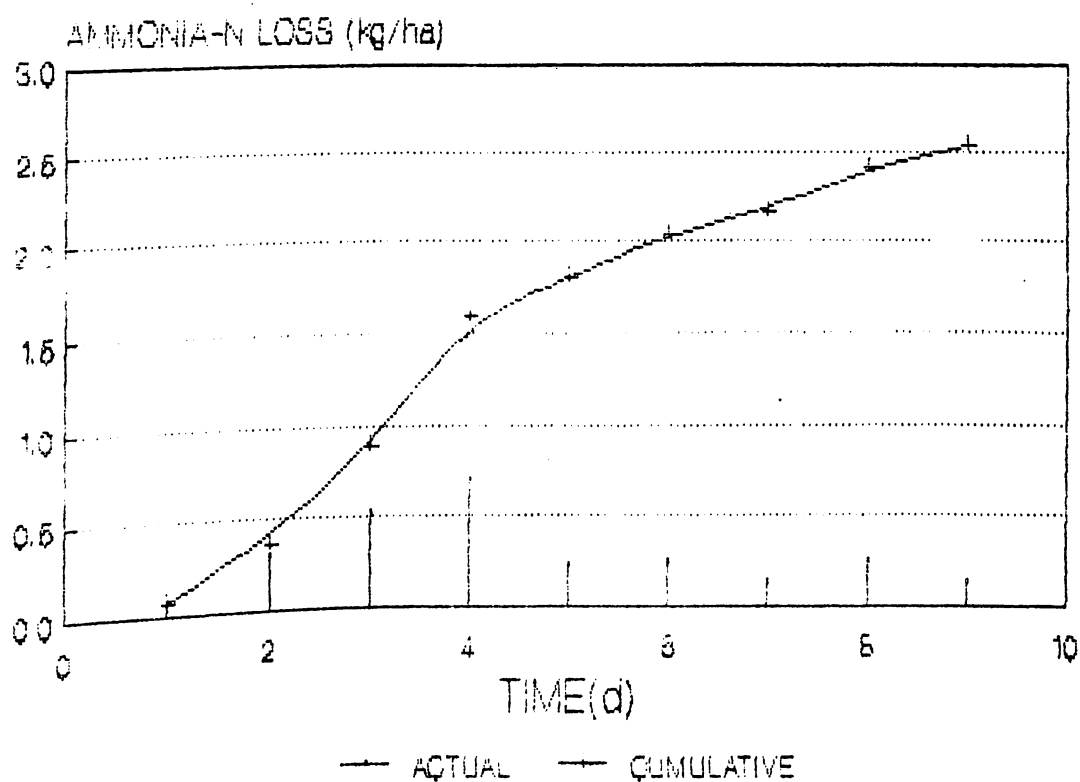


Fig.19 Volatilisation Loss of Ammonia-N
Following Topdressing of 50 Kg N/ha
(PU) to Wheat(T-1)

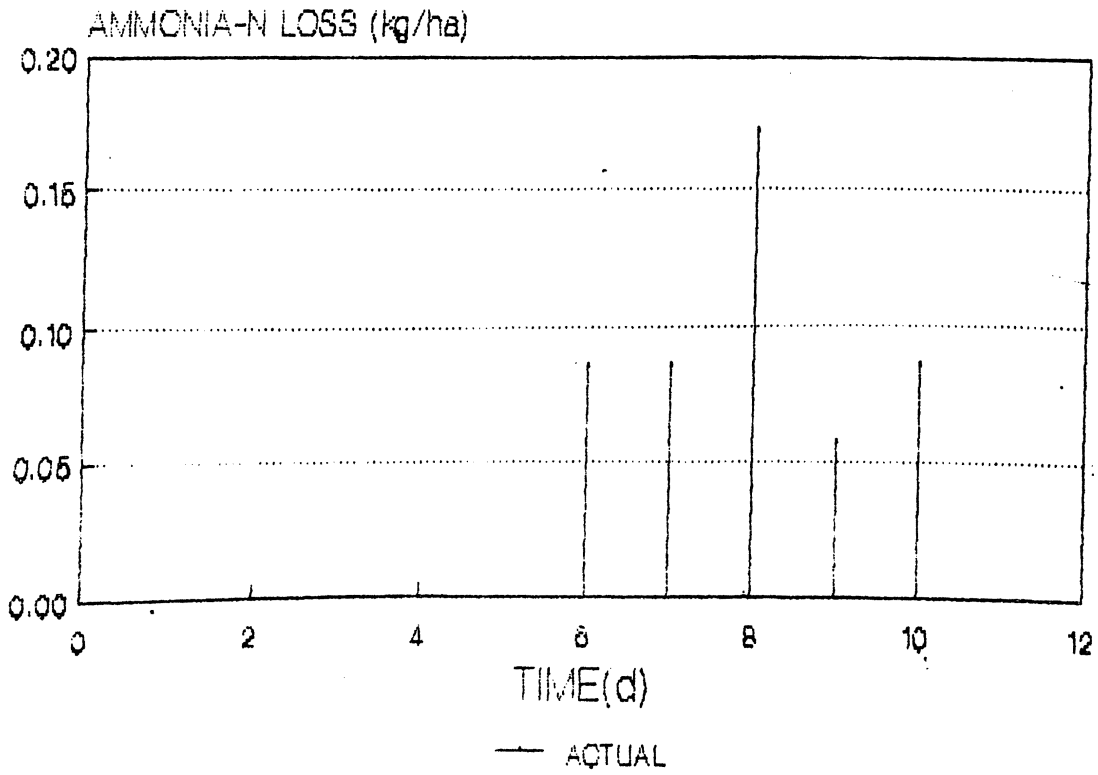


Fig.20 Volatilisation Loss of Ammonia-N
Following Basal application of 20Kg N/ha
(15N Urea) to Ground nut

application in the case of rice in which case freshly transplanted crop seedlings were standing in the field (4.2.4). The reason, thus, for the decreasing volatilisation loss value is the dwindling of NH_4^+ concentration with time on account of both crop uptake/nitrification or both ⁱⁿ appropriate situation.

4.2.10 Nitrogen transformation in the root zone of wheat following application of fertilizer urea

Table 13 lists the NH_2 , NH_4^+ and NO_3^- -N content of soil layers over time following application of tagged urea @ 50 kg N/ha at sowing of wheat under WT_2 (closed system). The fertilizer was applied as an aqueous solution amounting to 1.5 cm sprinkled over the microplot surface following sowing of wheat seeds (3.2.2.2). As the data in the table indicate, there was only traces of NH_2 -N in the profile but appreciable amount of NH_4^+ -N upto 30 cm depth and also that of NO_3^- -N up to 60 cm depth. But there was no NO_3^- -N in 30-45 cm layer. The applied urea appears to have fully hydrolysed within 24 hours of application having itself converted to NH_4^+ -N and also to NO_3^- -N as evidenced by the distribution of the concentration of the species over depth and time in the profile. Around 2.99 kg of NH_4^+ -N escaped into the atmosphere by volatilisation as has been noted in the preceeding section 4.2.8. However, the magnitude of the values of NH_4^+ -N obtained in 0-15 cm layer and that NO_3^- -N in all the 4 layers upto a depth of 60 cm suggest that on account of fertilization an appreciable fraction of soil nitrogen has mineralised even over 24 hours time and has moved down the depth. It is, however,

TABLE 13 : WHEAT EXPERIMENT: INORGANIC NITROGEN CONTENT OF THE SOIL IN THE MICROPLOT FOR WHEAT (WT₂) FOLLOWING APPLICATION OF 50kg N/ha (15_N UREA) AT SOWING.

Soil Depth (cm)	Before N Application	Time After N Application				
		24h	48h	72h	120h	360h
$\text{NH}_2^- \text{N}$ (Kg/ha)						
00-15	1.0	3.7	0			
15-30	1.1	2.8	0			
30-45	1.1	1.7	0			
45-60	1.1	1.1	0			
$\text{NH}_4^+ - \text{N}$ (Kg/ha)						
0 -15	35	154	175	258	44	31
15-30	20	19	13	3	3	6
30-45	0	0	4	0	6	6
45-60	0	3	4	0	0	6
$\text{NO}_3^- - \text{N}$ (Kg/ha)						
0 -15	127	174	32	130	141	0
15-30	25	139	104	108	133	0
30-45	0	164	49	107	121	0
45-60	57	165	34	108	95	0

very strange that at 360 hours the profile is devoid of any NO_3^- -N which may have been because of uptake of nitrogen by plants growing over a period of 15 days or by leaching/denitrification or by way of all the three mechanisms.

The accelerated mineralisation of the soil source nitrogen and its availability to the growing crop has been established through studies involving ^{15}N nitrogen (Oja and Subbiah, 1976). The total nitrogen content of the soil at the present experimental site ranges between 817 to 932 kg/ha upto a depth of 60 cm (Table 1). With the application of urea in the form of aqueous solution, the soil microflora become active and multiply. Not only do they act upon the fertilizer nitrogen, but also act on soil biomass and mineralise it. The mineralisation and immobilisation cycle however continues to proceed alternately and the NO_3^- -N resulting from oxidation in the surface soil migrates to the lower layers while it is appropriated by the plant or denitrified in the process. Misra *et al.* (1988) have worked out a complete balance sheet of tagged urea-N applied to upland cereal and legume crops and have computed the transformation coefficients based on their results. Such opportunity, however, was not available during the present study. However, these data could be treated similarly after the atomic ratio analysis of the soil/plant samples are carried out at a future point of time. It should be noted that accumulation of NH_4^+ -N / NO_3^- -N following basal application upto 120 hours has been possible on account of the absence of the crop in the microplots (WT_2 , GT_1).

Table 14 lists the nitrogen transformation data stemming from application of prilled urea @ 50 kg N/ha at tillering stage of wheat under RT₂. These data follow the same trend as observed in the preceeding Table for NH₂-N distribution although in this case traces of NH₂-N are present in soil even by 48 hours, which should be considered as extremely negligible. Before application of NH₂-N, the profile contained sufficient amount of NH₄⁺-N which appears to have got nitrified and absorbed to a large extent by the crop including that which resulted from hydrolysis of urea (less the amount that got volatilised: 1.32 kg NH₃-N/ha). It is very strange to observe that the profile had no NO₃⁻-N before application of urea nor the conditions are ready to have the NH₄⁺ nitrified until 48 hours following fertilization. Could it have happened that due to the application of nitrogen in the form of aqueous solution in the shape of 3 cm of irrigation water (3.2.2.4) the NO₃ formed from NH₄⁺ in the surface layer got quickly denitrified during its migration to the lower layer where reducing conditions prevail unlike the case of basal application which enhanced microbial activity of the rice follow and induced mineralisation of readily decomposable fraction of soil nitrogen itself at a fast pace. There is no evidence of such "priming effect" at tillering time owing possibly to a more resistant organic residue after the initial phase of mineralisation that already occurred following the basal application of fertilizer in these microplats as has been referred to above.

TABLE 14 : WHEAT EXPERIMENT: INORGANIC NITROGEN CONTENT OF SOIL IN THE ROOTZONE OF WHEAT (WT¹⁵N + ¹⁴N, CLOSED SYSTEM) FOLLOWING APPLICATION OF 50 ²Kg/ha (PRILLED UREA) AT TILLERING.

Soil Depth (cm)	Before N Application	Time After N 24h	Application 48 h
NH₂⁻N (Kg/ha)			
0 - 15	0	4.0	0
15-30	0	0.4	1.4
30-45	0	0.5	1.4
45-60	0	1.4	1.9
NH₄⁺ - N (Kg/ha)			
0 - 15	89	69	7
15-30	58	0	8
30-45	93	7	40
45-60	26	41	0
NO₃⁻ - N (Kg/ha)			
0 - 15	0	0	0
15-30	0	0	0
30-45	0	0	0
45-60	0	0	0

In Table 15 inorganic nitrogen distribution in the root zone of wheat under WT_3 (closed system) following application of tagged urea @ 50 kg N/ha at the maximum tillering stage. The NH_2 -N content distribution listed in this table is akin to that in the previous two instances of top dressing under WT_2 (Table 14). If out of the NH_4^+ hydrolysed from the added urea nearly 1.46 kg/ha was lost by volatilisation as has been noted earlier, the rest of the NH_4^+ -N must have suffered the same fate as has been noted and discussed in the case of WT_2 in Table 14. It is significant that the root zone does not contain any NO_3^- -N whatsoever as in the previous case of WT_2 at tillering.

Table 16 presents the inorganic nitrogen distribution data in the root zone of wheat under WT_1 (Free system) following application of 50 kg N/ha as PU at maximum tillering stage. These data are also akin to those presented in Table 14 and 15 except that the root zone in this case contains appreciable amount of NO_3^- -N before fertilizer application. The concentration of which decreases with time after 48 hours following fertilisation. It is hard to explain some of these variations in the NH_4^+ -N and NO_3^- -N Concentration in as much as the situation is complex involving many simultaneously occurring processes in this free system microplot through which water has been observed to move out at a fast rate and the profile gets recharged with water from lower layers in course of time (Table 18).

TABLE 15 : WHEAT EXPERIMENT: INORGANIC NITROGEN CONTENT OF THE SOIL AT "THE ROOT ZONE OF WHEAT (WT₃: 14^N+15^N, CLOSED SYSTEM) FOLLOWING APPLICATION OF 50 Kg^N/ha (15 N UREA) AT TILLERING

Soil Depth (cm)	Before N Application	Time After N Application	
		24h	48h

NH₂-N (Kg/ha)			
0 -15	0	1.4	0
15-30	0	1.8	1.8
30-45	0	2.0	0.9
45-60	0	3.7	1.9
NH₄⁺ - N (Kg/ha)			
0 -15	40	71	71
15-30	38	7	19
30-45	7	79	39
45-60	8	8	137
NO₃⁻ - N (Kg/ha)			
0 -15	0	0	0
15-30	0	0	0
30-45	0	0	0
45-60	0	0	0

TABLE 16 : WHEAT EXPERIMENT: INORGANIC NITROGEN CONTENT OF SOIL AT THE ROOT ZONE OF WHEAT (WT $^{14}\text{N}+^{14}\text{N}$ FREE SYSTEM) FOLLOWING APPLICATION OF $50\text{kg}^1\text{N/ha}$ (PRILLED UREA) AT TILLERING.

Soil Depth (cm)	Before N Application	Time After N Application	
		24h	48h
<hr/>			
$\text{NH}_2\text{-N}$ (Kg/ha)			
0 -15	0	1.4	1.9
15-30	0	0	0
30-45	0	9.2	1.0
45-60	0	1.0	0.5
$\text{NH}_4^+\text{-N}$ (Kg/ha)			
0 -15	55	88	30
15-30	0	62	0
30-45	57	31	0
45-60	0	31	62
$\text{NO}_3^-\text{-N}$ (Kg/ha)			
0 -15	> 100	175	151
15-30	> 100	0	143
30-45	> 100	31	0
45-60	> 100	65	0

4.2.11 Nitrogen transformation in the root zone of groundnut following application of fertilizer urea

Table 17 presents the inorganic nitrogen content of the soil in the microplot for groundnut (GT₁) following application of tagged urea @ 20 kg N/ha at sowing. The data presented in this Table appear to be exciting in that it has complete resemblance to that presented earlier in the soil of the microplot for wheat (WT₁) following tagged urea application at the sowing time (Table 13). Useful nitrogen transformation coefficients could be computed based on ¹⁵N atomic ratio analysis pertaining to these two cases when available albeit the absence of the standing crop in the microplots at this time. The values of NH₄⁺ and NO₃⁻-N contents of soil appear to be quite reasonable in respect of their magnitude and distribution over time and depth. The comments which have been made already for the data in Table 13 are hence applicable to those in this table with only minor variation keeping in view the difference in applied nitrogen dose in the two cases.

4.2.12 Soil water balance in wheat

Table 18 presents the components of root zone soil water balance during a 7 day period following 5 cm of irrigation applied to wheat under WT₁. Soil water depletion data recorded with the help of a neutron hydroprobe indicate that maximum depletion value is associated with 15-30 cm soil layer, depletion from 0-15 cm layer being next in order. This is expected because

TABLE 17 : GROUNDNUT EXPERIMENT : INORGANIC NITROGEN CONTENT OF THE SOIL OF THE MICROPLOT FOR GROUNDNUT (GT₁,¹⁵N, CLOSED SYSTEM FOLLOWING APPLICATION OF 20 Kg N/ha (¹⁵N UREA) AT SOWING

Soil Depth	Before N Application	Time After N Application				
		24h	48h	72h	120h	360h
NH₂-N (Kg/ha)						
0-15	1.0	0	0			
15-30	1.1	0	0			
30-45	1.1	0	0			
45-60	1.1	0	0			
NH₄⁺ -N (Kg/ha)						
0-15	35	25	103	27	58	19
15-30	20	0	0	0	0	12
30-45	0	0	3	6	12	12
45-60	0	0	0	0	0	9
NO₃⁻ - N (kg/ha)						
0-15	127	121	41	141	155	0
15-30	25	107	63	117	75	0
30-45	0	91	45	106	155	0
45-60	57	57	15	101	130	99

TABLE 18 :

WHEAT EXPERIMENT:COMPONENTS OF ROOT ZONE SOIL WATER BALANCE DURING A 7-DAY PERIOD FOLLOWING APPLICATION OF 5 CM IRRIGATION TO WHEAT (WT₁) AT 4 pm ON 25.1.93
(AGE OF THE CROP : 40 DAYS ON 25.1.93)

Soil Water Depletion (D) (During 8 am 26.1.93 to 1Pm 1.2.93)			Percolation/Recharge (P)			Evapotranspiration (ET = P-D)	Mean ET (cm/d)
Soil Depth (cm)	Depth Wise Depletion(cm)	Total Depletion (cm)	Day	Day Wise* percolation (cm)	Total percolation (cm)	(cm)	
0-15	-0.743	-2.948	1st	+1.12	+1.851	4.799	0.69
15-30	-1.710		2nd	+0.246			
30-45	-0.315		3rd	+0.240			
45-60	-0.180		4th	+0.230			
			5th	+0.011			
			6th	+0.004			
			7th	+0.005			

The values are based on 3 tensiometer readings on 26.1.93 and continued with readings recorded at 8 am, 1 pm and 5 pm on each day.

: In the first 15 hours following irrigation (5 pm on 25.1.93 to 8am 26.1.93) 4.4cm of water percolate down 67.5cm.

most of the functional roots of wheat should have been confined to 30 cm of soil which is supported by the findings of Misra and Jena (1980) who reported that wheat grown in rice fallows in this research station has its root system extended upto around 20 cm. Depletion from lower layers of the profile has been noted to be minimal in the present case suggesting that roots may have extended upto at most 60 cm. soil depth. The total depletion from the root zone was computed to be 2.95 cm during the week. Based on tensiometric records for a 15 hour period between 5 pm on 25th and 8 am on 26th, 4.44 cm of applied irrigation were out of the profile and then there was an inferred upward movement through the 60-75 layer beginning on the 26th and subsequent days. The maximum recharge value was recorded on 2nd and 3rd day of the dryspell but subsequently the recharge rate falls with the progressive drying of profile which reduces the hydraulic conductivity.

It should be noted that $E_q(25)$, was employed to compute percolation data, the total was obtained as 1.58 cm for the week. Employing the water balance equation (27), the evapotranspiration(ET) for the week and the mean value of ET per day is this calculated to be 0.69 cm/day.

4.2.11 Variation of flux of water below the root zone of wheat under free system (WT_1) and closed system (WT_2) treatments over A 25 hour period¹

Table 19(A) lists the mean soil water pressure head data at 67.5 cm soil depth periodically for 6 intervals beginning

TABLE 19 : WHEAT EXPERIMENT: VARIATION OF SOIL WATER PRESSURE HEAD AND PERCOLATION FLUX ACCROSS 67.5 cm SOIL DEPTH OVER A 25 HOUR PERIOD (8 am on 30.1.93 TO 9 am on 31.1.93)

A. BASED ON 7 READINGS

Time	Mean Presssure Head(h)		Percolation flux(cm)		Total percolation Over 25 Hours(cm)	
	WT ₁	WT ₂	WT ₁	WT ₂	WT ₁	WT ₂
(30.1.93)						
8 am-5 pm	-135.04	-166.63	+0.009	+0.00036	+0.011	+0.002
5 pm-9 pm	-168.62	-170.71	+0.0004	+0.00016		
9 pm-12.30am	-170.81	-170.4	+0.0004	+0.00014		
12.30am-3am-	-167.67	-166.0	+0.0003	+0.0001		
3 am-6 am	-159.51	-160.67	+0.0003	+0.00024		
6 am-9 am	-145.40	-147.81	+0.0006	+0.00027		
(31.1.93)						

B. BASED ON 3 READINGS

Time	Mean pressure head(h)		Percolation Flux(cm)		Total percolation over 25 Hours (cm)	
	WT ₁	WT ₂	WT ₁	WT ₂	WT ₁	WT ₂
8 am-5 pm	-135.04	-166.63	+0.009	+0.00036	+0.012	+0.0018
5 pm-9 am	-151.36	-153.45	+0.0032	+0.00144		

with 8 am on 30.1.93 till 9 am 31.1.93 for treatments WT_1 and WT_2 . The flux values calculated based on the hydraulic gradient derived from mean pressure head values and using a world average $k(\theta)$ (31) and $h(\theta)$ (30) are seen to be + 0.011 cm and +0.002 cm for WT_1 and WT_2 treatments, respectively, for the 25 hour period. It should be noted here that with reference to Appendix 3.3 that the crop under WT_2 is poorer in respect of many yield parameters compared with that for the crop in WT_1 . The higher recharge values observed for WT_1 that WT_2 therefore seemed to be in order.

Table 19 (b) presents the flux values for WT_1 and WT_2 based on 3 tensiometer records only i.e. 8 am and 5 am on 30.1.93 and 9 am on 31.1.93. The flux values based on these records based on methods given in (3.4.6) are observed to be very close to that obtained with 7 tensiometer reading as shown in Table 19 (a). This is proof of the reliability of tensiometer reading record and it is possible to arrive at the true picture of water balance with only two readings dialy at 8 am and 5 am. Similar findings have been reported by Misra and Patra 1985.

4.2.12 Percolation flux data below the root zone of wheat and Groundnut

Table 20 presents the percolation through 67.5 cm soil depth based on the tensiometer records for wheat (WT_2 and WT_3) and groundnut (GT_1) from 1 p.m. on 4.1.93 to 1 pm. on 5.1.93. Irrigation was applied to these three closed system

TABLE 20 : WHEAT AND GROUNDNUT EXPERIMENT:PERCOLATION FLUX BELOW THE ROOT ZONES OF WHEAT AND GROUNDNUT (ACCROSS 67.5 cm SOIL DEPTH) over a 24 HOUR PERIOD FOLLOWING 5 DAYS OF IRRIGATION @ 1 cm. (AGE OF WHEAT CROP : 18 DAYS, AGE OF GROUNDNUT : 11 DAYS)

Time	Meand Pressure Head(h)			Percolation flux (cm)			Total Percolation over 24Hours		
	Wheat		Groundnut	WT ₂	WT ₃	GT ₁	WT ₂	WT ₃	GT ₁
	WT ₂	WT ₃							
1 pm-5 pm	-68.74	-82.40	-61.03	+0.076	+0.012	-0.036	+0.476	+0.324	-0.111
5 pm-8 am	-70.31	-85.71	-66.97	+0.30	+0.30	-0.15			
8 am-1 pm	-67.17	-78.46	-61.63	+0.10	+0.012	-0.06			

microplots on 29.12.92 @ 1 cm. The age of wheat on 4.1.93 was 18 days and that of groundnut 11 days. The percolation values for the 24 hours period as computed and presented in this Table indicate that whereas the actively growing and older wheat crop is able to pull water from the lower layer @ nearly 0.4 cm/d, the sluggish and younger groundnut crop is allowing water to get out of the root zone @ 0.1 cm/day. It was not possible to calculate the ET values of the crops under these treatments in as much as neutron hydroprobe records/gravimetric water content values of the soil profile for the root zone were not available.

CHAPTER-V

SUMMARY AND CONCLUSION

SUMMARY AND CONCLUSIONS

Field experiments were laid out in 'closed' and 'free-system' microplots with rice (Pathara), wheat (Sagarika) and groundnut (OG 52-1) as test crops in order to study chiefly the hydrolysis and also other N transformation processes in the crop root zone, subsequent to application of prilled urea for groundnut and wheat and several urea based N sources viz Gypsum coated urea (GCU) urea nitrophosphate (UNP) (19-19-0), urea nitrophosphate (UNP) (27-9-0) and urea super granule (USG) and prilled urea plus encapsulated calcium carbide (ECC) to rice. The site of the experiment was medium land in the Regional Research Station in Orissa University of Agriculture and Technology Bhubaneswar (3.2)

The trials were laid out in a rice fallow during the dry season 1992-93. The fertilizer materials, viz, GCU, UNP (19-19-0) and (27-9-0) were received from Rastriya Chemicals and Fertilizers, Bombay. USG was received from IFFCO. ECC was received through the courtesy of Dr. N.K. Benarjee, Emeritus Scientist, IARI. The experimental design for rice was RBD with 3 replications and 10 treatments as detailed below :

- RT₁ : (PU (50% + 50% i.e., 38 kg N/ha as basal + 38 kg N/ha as top dressing)
- RT₂ : GCU @ 76 kg N/ha applied as one basal dose
- RT₃ : UNP (19-19-0) @ 76 kg N/ha applied as one basal dose
- RT₄ : UNP (27-9-0) @ 76 kg N/ha applied as one basal dose
- RT₅ : USG @ 76 kg N/ha applied as one basal dose
- RT₆ : PU @ 76 kg N/ha + ECC @ 30 kg/ha applied as one basal dose
- RT₇ : FYM @ 10 t/ha + ECC @ 30 kg/ha
- RT₈ : FYM @ 10 t/ha
- RT₉ : ECC @ 30 kg/ha
- RT₁₀ : Control (No nitrogen)

The microplots of rice were bordered by earthen bunds and were 1 x 1 m in size.

The experiments under wheat and groundnut were not replicated. While wheat was grown in two closed (91.5 x 91.5 cm) and one free system (2.5 x 2.5 cm) microplots, groundnut in only one microplot for fertilizer treatment. The closed system microplots were prepared by using wooden Plank border-cum-polythene sheets, while the wooden border reached 15 cm deep in soil and remained 15 cm above its surface the polythene reached upto 75 cm soil depth. The free system plot had no border but only earthen bunds around it. The closed system plots were devised in order to use ¹⁵N tagged urea and also not to allow irrigation water carrying ¹⁵N urea to seep out

in the lateral direction. The free system was put up for the sake of comparison with the results of the closed system and the effect of enclosure on crop growth, if any. Only ordinary prilled urea was used in the free system microplot. Groundnut was grown in a closed system microplot treated with ^{15}N tagged urea. The area surrounding of the microplots was used to plant wheat and groundnut without adding any fertilizer such that it served as no fertilizer control for the two crops. Separate "closed system" microplots of equivalent size were also used to grow wheat and groundnut and were treated alike in all respects but fertilizer with untagged prilled urea so as to periodically estimate the drymatter production of the growing crops without disturbing the crops in the ^{15}N treated microplots. The fertilizer treatment schedule for wheat and groundnut were as follows :

Wheat :

- WT₁ : ^{14}N @ 50 kg/ha as basal + ^{14}N
@ 50 kg/ha as top dressing in the form of urea.
- WT₂ : ^{15}N @ 50 kg/ha as basal application + ^{14}N @ 50 kg/ha
as top dressing in the form of urea.
- WT₃ : ^{14}N @ 50 kg/ha as basal + ^{15}N @ 50 kg/ha
as top dressing in the found of urea.
- WT₄ : Control (No nitrogen)

Groundnut :

- GT₁ : ^{15}N @ 50 kg/ha as basal application
in the form of urea.
- GT₂ : Control (No nitrogen)

Tagged urea fertilizers were applied through/aqueous solution both at basal and top dressing time and at sowing time to groundnut so as to provide both fertilizer and irrigation water to the crops (3.2.2.2, 3.2.2.3).

Twenty eight days old rice seedlings were transplanted in the rice experiment with 50 kg P_2O_5 /ha and 60 kg K_2O /ha in the shape of single super phosphate and muriate of potash, respectively, applied as basal dose. After transplantation all urea based N sources were broadcast on the pond water in the microplots so as to provide 76 kg N/ha in each case. In the case of PU treatment 38 kg of N/ha was provided as basal and the remaining 38 kg N/ha was applied as top dressing at maximum tillering stage. USG (1 cm size granules) were dibbled between alternate four hills following transplantation. Ammonia traps and soil solution samplers were set up in one of the three replications in rice experiment in order to measure volatile ammonia loss and NH_2-N concentration distribution in the soil solution at 7.5 cm depth over 8-9 days following fertilizer application. Hand in hand flood water samples were collected and employed for the determination of NH_2-N concentration.

Ammonia traps were set up in closed system and free system microplots in the wheat and groundnut experiment as well for the estimation of volatile ammonia loss.

An aluminium access pipe reaching a depth of 1 m was set up in the free system wheat plot to estimate soil water depletion non-destructively using a CPN neutron hydroprobe. Mercury-water tensiometers were installed in all the fertilizer treated plots for wheat and groundnut in order to record soil water pressure changes in 60 and 75 cm soil depth. The purpose of having access pipe and tensiometer was to determine the components of water balance in the wheat root zone between two irrigation cycles. Cultural practices including irrigation and plant protection measure etc. were adopted time to time depending on need. Upto 7 cm of water was maintained in the rice plots by application of irrigation intermittantly whereas measured amounts of irrigation water was applied to wheat and groundnut depending on need.

Samples of soil in 15 cm depth increments of profile were collected before the start of the experifments for the determination of physical and chemical properties layerwise. Soil samples were also collected from the microplots growing wheat and groundnut in order to estimate $\text{NH}_2\text{-N}$, $\text{NH}_4^+\text{-N}$ and $\text{NO}_3^-\text{-N}$ contents before and following fertilizer application (33.8).

Drymatter yield in wheat by 27 DAS, 71 DAS and groundnut by 71 DAS as well as grain and straw yields at harvest for these two crops as well as for rice together with yield parameters for the three crops were recorded. All physical and chemical determinations for FYM, fertilizer, irrigation water, soil,

flood water, soil solution, absorbed ammonia in ammonia traps, grain, straw, kernel, haulm and roots together with that required to characterise the soil were carried out following standard methods (33).

The texture of the soil in the experimental site was observed to be sandyloam upto 30 cm depth sandy clay loam with 30-75 cm layer and sandy clay below 75 cm upto 105 cm with the bulk density values decreasing from 1.7 to 1.8 g/cm³ in the top layers to 1.6 g/cm³ down below. The soil profile is neutral and nonsaline with very low values of organic carbon below 15 cm depth. The CEC value is low in top layers but increased below 45 cm. The clay is presumed to be a mixture of kaolinite and illite atleast in the surface layers but may contain dominantly 2:1 minerals in the lower layers. The soil has been classified as a member of the fine loamy mixed hypothermic family of an haplaquept.

The grain and straw yield data stemming from rice experiment were subjected to statistical analysis after they were expressed on oven dry basis. It was observed that the treatment effects were significant and the grain yields due to fertilization with different sources of urea based nitrogen were all at par although the highest yield was recorded under the USG treatment closely followed by that under prilled urea applied in two splits. Based on the yield levels, ECC was not promising whether it was used with PU,

FYM or when added by itself. The reason for including this material was its promise as a hydrolysis, nitrification and hence denitrification inhibitor as claimed by Dr. Banarjee who supplied this material. UNP materials which contained $\text{NO}_3^- \text{N}$ in addition to urea the lowest performers based on the magnitude of the yields recorded under those two treatments. The yield of GCU was equivalent to that from PU + ECC which proved superior to be UNP fertilizers. The effect of fertilizers on straw yield was almost identical to that observed for the grain yield data.

Highest nitrogen uptake as well as nitrogen uptake per quintal of grain was recorded under the USG treatment closely followed by that under split applied urea, the values for the other treatments being appreciably lower. Again both Agronomic efficiency and apparent N recovery data as measures of nitrogen use efficiency proved USG to be the best treatment closely followed by prilled urea applied in two splits and the remaining treatments, GCU and PU + ECC, may be at par while the UNP treatment may be considered as the most inefficient.

The ammonia volatilization loss data pertaining to the fertilizer treatments for rice showed that upto 5.4% added nitrogen may be lost due to prilled urea treatment despite split application in the dry and cool atmosphere prevailing at the time of fertilizer application, the values for UNP and USG treatments being of an intermediate category (mean value: 3.4%) whereas the loss due to GCU and PU + ECC treatment

is the lowest (mean value : 2.3%). It was observed that in most of the treatments the peak value of loss of volatilised ammonia was attained around 5th day following fertilizer application rising from near zero value in the first day and again attaining negligible value in the 9th day which observation finds support from findings reported in the literature. However, part of this loss could have arisen from the soil nitrogen source and without using tagged urea it was not possible to determine the exact fraction of loss from the fertilizer source.

The concentration distributions of $\text{NH}_2\text{-N}$ in the flood water as well as in soil solution following fertilization was observed to describe ^{bell-shaped} /curves under all treatments, the peak values in these curves mostly attaining in the same time for the PU, UNP + (19-19-0) and GCU treatments although the concentration in solution in these three cases were seen to be minimal. In the UNP (27-9-0) and PU + ECC treatments the amounts of $\text{NH}_2\text{-N}$ were found to be appreciable possibly due to faster rate of downward migration. Under the USG treatment on the other hand, the amount detected in the flood water was of an intermediate magnitude compared to that in UNP and ECC treatments and was the consequence of upward diffusion of $\text{NH}_2\text{-N}$ subsequent to dissolution of USG within the soil. The distribution curves indicated that all the $\text{NH}_2\text{-N}$ is exhausted in the flood water between 80-150 h and that in the soil solution between 25-125 hours depending upon the

nature of the treatment. Based on these observed distribution curves it was inferred that hydrolysis of urea to ammonium was sluggish under the PU + ECC, UNP (27-9-0) and USG treatment whereas the process appears to be faster under GCU, UNP (19-19-0) and PU. The observed ammonia volatilisation loss data from these treatments appear to generally corroborate these observations.

In the wheat experiment the grain yields although of much smaller magnitudes, compared with those from the western parts of the State of Orissa/north India are very much higher due to N-fertilization compared to control. On the other hand, the pod yield of groundnut in response of 20 kg N/ha much higher than the State average (18 q/ha) which is the highest in the country in the dry season) and nearly two and half times that recorded for the control. The yield parameters recorded for both wheat and groundnut fully justify the yield response pattern stemming to applied fertilizers. Although wheat was provided with 100 kg N/ha as prilledurea the magnitudes of loss due to volatilisation of ammonia. was equivalent to that from split dose of PU for rice although lower expressed as percentage values.

The nitrogen transformation data recorded subsequent to basal application of prilled urea to wheat and groundnut suggest considerable boost received for mineralisation of soil nitrogen whereas fertilization at tillering time did not appear

to bring about such an effect. Although ^{15}N urea had been used in the microplots of wheat and groundnut unavailability of the results of atomic ratio analysis did not enable a complete analysis of the data recorded on nitrogen transformation in the case of wheat and groundnut under the present study.

Computation of components of the root zone soil water balance following 5 cm irrigation to wheat in the free system microplot indicated that the crop absorbs most of its required water in the top 30 cm of the profile and relatively smaller amount from the lower layers. The profile gets recharged with 1.85 cm of water from soil layers below 6 cm during the 7 day period following irrigation and that the mean ET value during this week was calculated to be 0.69 cm/d.

It was also observed that the tensiometer readings taken twice per day at 8 a.m. and 5 p.m. were as good, for calculating soil water percolation below the root zone, as 8-9 readings taken periodically over the day.

5.2 CONCLUSIONS

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

*Although the grain yields of rice due to different urea based N source treatments are statistically at par, USG/PU (applied in two splits) are equivalent in their effect and should be considered superior to GCU, and PU + ECC which in their

turn are superior to UNP treatments based on the agronomic efficiency parameters determined for these treatments.

*On the other hand, considering apparent N recovery percentage, the highest percentage of nitrogen is used by rice under the USG treatment intermediate amount in the case of PU applied in two splits and the lowest under GCU, PU + ECC and the UNP treatments.

*Loss of nitrogen due to volatilisation of ammonia can be the highest under PU (split applied) intermediate in the case of UNP (19-19-0), GCU, USG and PU + ECC and least with UNP (27-9-0).

*The rate of urea hydrolysis can be higher under PU, GCU and UNP (19-19-0) than that under USG, PU + ECC, UNP (27-9-0) as inferred from the $\text{NH}_2\text{-N}$ distribution data in the flood water and soil solution as well as NH_3 volatilisation loss magnitudes in the rice experiment.

*Application of fertilizer at sowing can boost the mineralisation of soil nitrogen whereas such an effect is not possible when N fertilisation is done at active tillering stage.

*Based on the measured values of components of water balance, 40-47 day old irrigated wheat grown in rice fallows of coastal Orissa can evapo.-transpire @ 0.69 cm/d, on an average, depleting most of the required water in the 0-30 cm layer of soil.

*Future research efforts should be directed to measure ammonium concentration in flood water and soil solution hand in hand with $\text{NH}_2\text{-N}$ concentration using ^{15}N tagged urea for obtaining a clearer quantitative picture of the urea hydrolysis in the root zone of rice.

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APPENDICES

APPENDIX - 1

INFORMATION SHEET ON EXPERIMENTS AND CROP CALENDER

	Rice	Rice	Wheat	Groundnut
Design		RBD	-	-
Replication		3	-	-
Treatment		10	4	2
Plot Size		1x1m	0.95x0.95m & 2.5 x 2.5m	0.95x0.95m
Variety		Pathara	Sagarika	OG 52-1
Spacing		0.15x0.20m	0.20m row spacing	0.30m row spacing
Fertilizer application P_2O_5 (Kg/ha)		50	50	40
K_2c (Kg/ha)		60	50	40
N (Kg/ha) (As per treatment)		76	100	20
Date of sowing		1-1-93	13-12-92	13-12-92
Date of trans- planting		29-1-93	-	-
Date of top- dressing		3-3-93	8-1-93	-
Date of spraying of pesticides (Nuan and Dithan M-45)		26-2-93 & 14-3-93	26-2-93	26-2-93
Irrigation		Maintained under submergence (7cm) till flowering & then drained out	16cm	12.5 cm
Date of harvesting		14-4-93	11-3-93	19-4-93

APPENDIX - 2.1.1

RICE EXPERIMENT : VOLATILIZATION LOSS OF $\text{NH}_3\text{-N}$ FROM DIFFERENT NITROGEN FERTILIZER SOURCES FOLLOWING BASAL APPLICATION

Time (Hours)	Volatilization loss of $\text{NH}_3\text{-N}$ (kg/ha)					
	PU 50%+50%	GCU	UNP 19-19-0	UNP 27-9-0	USG	PU+ECC
4	0.057	0	0.074	0.163	0	0.163
11	0.086	0.112	0.054	0.104	0.133	0.104
18	0.057	0.024	0.074	0.074	0	0.074
23	0.057	0.083	0.074	0.074	0.015	0.104
28	0.057	0.112	0.074	0.055	0.133	0.133
42	0.086	0	0.074	0.074	0.074	0.104
48.5	0.086	0.112	0.163	0.074	0.104	0.104
52	0.057	0.074	0.252	0.055	0.015	0.074
66	0.086	0.104	0.370	0.133	0.133	0.133
71	0.144	0.074	0.133	0.104	0.163	0.104
75	0.086	0	0.074	0.074	0.163	0.055
89	0.057	0.133	0.133	0.074	0.104	0.133
94	0.316	0.311	0.074	0.055	0.192	0.074
99	0.144	0.133	0.055	0.074	0.104	0.163
113	0.057	0.133	0.252	0.055	0.133	0.104
118	0.144	0.055	0.163	0.074	0.163	0.074
123	0	0.015	0.340	0	0.104	0.055
137	0.024	0.074	0.163	0	0.104	0.015
142	0	0.055	0.015	0	0.074	0.015
147	0.290	0.055	0.104	0.055	0.074	0.015
161	0.024	0.055	0.104	0.015	0.133	0.055
166	0	0.055	0.055	0.015	0.104	0.104
171	0	0.015	0.055	0	0.015	0.055

APPENDIX 2.1.2

RICE EXPERIMENT : VOLATILISATION LOSS OF $\text{NH}_3\text{-N}$ FOLLOWING TOPDRESSING OF PRILIED UREA TO RICE (RT_1) AT MAXIMUM TILIERING STAGE (AT 15 cm AND 22.5cm HEIGHT)

Time (House)	Volatilisation Loss of $\text{NH}_3\text{-N}$ (Kg/ha)	
	15cm Height	22.5cm Height
3.5	0.073	0.073
9.5	0.073	0.128
15.5	0.155	0.101
21.5	0.073	0.046
27.5	0.046	0.101
41.0	0.128	0.128
45.5	0.101	0.101
50.5	0.155	0.101
64.5	0.155	0.128
69.5	0.129	0.075
74.5	0.156	0
88.5	0.059	0.075
93.5	0.059	0.059
98.5	0.059	0.075
113.0	0.102	0.059
117.5	0.075	0.102
122.5	0.059	0.075
136.5	0.059	0.102
141.5	0.102	0.059
147.5	0.102	0.102
160.5	0.075	0.102
166.0	0.059	0.075
170.5	0.102	0.156

APPENDIX - 2.2

RICE EXPERIMENT : TEMPORAL VARIATION OF CONCENTRATION OF $\text{NH}_2\text{-N}$ IN FLOOD WATER FOLLOWING BASAL APPLICATION OF UREA BASED NITROGEN FERTILIZERS TO RICE

TIME (Hours)	Concentration of $\text{NH}_2\text{-N}$ (ppm)					
	PU 50%+50%	GCU	UNP 19-19-0	UNP 27-9-0	USG	PU+ECC
1	28.3	48.13	21.71	41.98	3.88	52.28
4	38.2	50.0	26.43	41.98	4.63	52.08
7	40.1	49.05	30.65	44.35	4.23	52.35
10	39.15	49.05	32.08	45.75	5.95	50.0
13	26.68	42.15	51.95	48.05	6.08	50.5
16	32.85	50.98	40.68	48.63	5.0	37.75
19	37.74	48.11	31.60	44.81	5.09	46.23
22	34.91	47.17	38.13	42.92	5.47	36.79
25	22.64	27.55	23.88	34.43	4.25	13.96
49	19.92	22.17	18.39	25.85	2.83	20.75
73	7.15	14.90	13.33	16.95	1.38	0.6
97	1.28	6.88	7.25	3.05	0	0
121	0.190	1.89	2.74	0.47	0	0
145	0.192	0.481	0.285	0.096	0.288	-
169	0	0	0	0	0	-

APPENDIX - 2.3

RICE EXPERIMENT : TEMPORAL VARIATION IN CONCENTRATION OF $\text{NH}_2\text{-N}$ IN SOIL SOLUTION BELOW 7.5 cm SOIL DEPTH FOLLOWING BASAL APPLICATION OF UREA BASED NITROGEN FERTILIZERS TO RICE

Time (Hours)	Concentration of $\text{NH}_2\text{-N}$ (ppm)					
	PU 50%+50%	GGU	UNP 19-19-0	UNP 27-9-0	USG	PU+ECC
4	2.64	3.58	0.75	1.64	0	10.96
7	1.96	2.32	1.79	0.69	0.18	29.82
10	2.32	2.32	1.96	1.43	0.89	33.21
13	2.67	1.79	1.61	1.61	0.71	34.21
16	2.13	1.30	1.85	1.57	-	31.94
19	3.30	2.08	1.98	1.89	0.38	33.49
22	2.31	1.73	2.12	11.83	1.00	25.58
25	1.64	1.35	1.92	22.89	0.77	23.46
49	0.48	2.12	0.96	19.23	7.79	6.15
73	0.19	1.76	0.37	10.93	28.24	0.56
97	0	0.28	0	2.13	25.19	0
121	0	0	0	0	9.81	0
145	-	-	-	-	0.77	-
169	-	-	-	-	0	-

APPENDIX - 2.4

RICE EXPERIMENT: TEMPORAL VARIATION IN CONCENTRATION OF $\text{NH}_2\text{-N}$ IN FLOOD WATER AND SOIL SOLUTION AT 7.5 cm DEPTH FOLLOWING TOP DRESSING OF PRILLED UREA @ 38 kg N/ha TO RICE (RT11u)

Time (Hours)	Concentration of $\text{NH}_2\text{-N}$ (ppm)	
	Flood water	Soil solution
0	0	0
1	18.10	0.20
4	40.82	3.01
7	39.37	5.18
10	36.78	5.18
13	34.19	3.42
16	31.6	1.48
19	27.50	0.21
22	24.96	0.11
26	19.46	0
49	1.90	0
73	0.10	0
98	0	0

APPENDIX - 2.5

RICE EXPERIMENTS VARIATION OF PH OF FLOOD WATER FOLLOWING BASAL APPLICATION OF UREA BASED NITROGEN FERILIZERS.

Time (Hours)	pH of Flood Water					PU+ECC
	PU 50%+50%	GGU	UNP 19-19-0	UNP 27-9-0	USG	
0	7.5	7.5	7.5	7.5	7.5	7.5
1	6.5	-	6.5	6.5	-	7.5
4	6.5	7.0	-	6.5	6.5	6.5
7	7.5	7.0	7.0	7.5	-	7.5
10	7.5	7.5	7.5	7.5	7.0	7.5
13	6.5	7.0	7.0	7.0	7.5	7.0
16	7.5	7.5	7.5	6.5	6.5	7.0
19	6.5	6.5	6.5	6.5	6.5	6.5
22	6.5	6.5	6.5	6.5	6.5	6.5
25	6.5	6.5	6.5	6.5	6.5	6.5
49	6.5	6.5	6.5	6.5	6.5	6.5
73	6.5	7.0	6.5	6.5	6.0	6.0
97	6.5	6.5	6.0	6.5	6.5	6.5
121	6.5	7.0	6.0	6.0	6.0	6.5
145	6.5	6.5	6.5	6.0	6.0	6.5
169	7.5	6.5	6.5	6.5	6.5	6.5

APPENDIX - 2.6.1

RICE EXPERIMENT TEMPERATURE VARIATION OF FLOOD WATER AND SOIL SURFACE FOLLOWING APPLICATION OF PRILLED UREA TO RICE FIELD TILLERING STAGE

Time (Hours)	Temperature (°C)	
	Flood water	Soil Surface
0	31	31
1 (15.30H)	29.5	30
4	25	26
7	25	25
10 (0.30H)	24	24
13	24	24
16	22	22.5
19	27	26
22 (12.30H)	31	30
25	29	28.5
49	30	29.5
73	29	28.5
98 (15.30H)	28	28

APPENDIX 2.6.2

(RICE EXPERIMENT)

SOIL AND AIR TEMPERATURE DURING COLLECTION OF VOLATILISAED AMMONIA

PERIOD : (FOLLOWING BASAL APPLICATION)

Date	Soil Temperature (30cm)		Mean Air Temperature
	Morning	Afternoon	
30.01.93	24.2	25.2	22.9
31.01.93	24.6	25.2	23.0
01.02.93	24.6	25.2	23.6
02.02.93	25.0	25.5	24.1
03.02.93	24.6	25.0	22.5
04.02.93	24.5	25.2	22.3
05.02.93	24.6	25.5	23.2
06.02.93	25.0	25.6	23.5
07.02.93	25.2	25.6	24.2

PERIOD : (FOLLOWING TOP-DRESSING)

03.03.93	27.5	28.6	25.3
04.03.93	28.0	29.0	25.9
05.03.93	28.5	29.5	27.6
06.03.93	29.0	30.0	28.9
07.03.93	28.7	29.8	26.9
08.03.93	28.8	29.8	26.1
09.03.93	29.0	30.0	27.4
10.03.93	29.0	30.0	26.7

<i>Treatment</i>	<i>Plant Height (cm)</i>	<i>No. of Tillers/ Clump</i>	<i>No. of Effective Tiller/ clump</i>	<i>Panicle Length (cm)</i>	<i>No. of Grains/ panicle</i>	<i>Spikelet Sterility percentage</i>	<i>Thousand Grain weight(g)</i>
<i>RT₁</i>	64.5	25.1	22.8	18.8	57.4	21.48	23.5
<i>RT₂</i>	63.4	20.7	19.5	19.0	54.5	19.73	24.6
<i>RT₃</i>	58.5	17.5	13.8	17.9	79.6	14.22	24.2
<i>RT₄</i>	59.4	20.1	17.7	17.5	74.8	16.44	24.4
<i>RT₅</i>	60.0	20.2	20.1	19.0	56.1	25.69	23.9
<i>RT₆</i>	65.6	21.4	20.4	17.0	46.2	25.84	24.9
<i>RT₇</i>	58.8	16.4	16.1	17.6	40.1	15.93	24.2
<i>RT₈</i>	54.9	19.3	17.7	17.1	41.4	20.38	24.8
<i>RT₉</i>	61.2	18.7	18.1	17.6	47.6	14.08	24.5
<i>RT₁₀</i>	56.2	17.3	16.8	16.9	38.7	11.64	24.1

APPENDIX - 2.7

YIELD PARAMETERS OF RICE

Treatment	Plant Height (cm)	No. of Tillers/ Clump	No. of Effective Tiller/ clump	Panicle Length (cm)	No. of Grains/ panicle	Spikelet Sterility percentage	Thousand Grain weight (g)
RT ₁	64.5	25.1	22.8	18.8	57.4	21.48	23.5
RT ₂	63.4	20.7	19.5	19.0	54.5	19.73	24.6
RT ₃	58.5	17.5	13.8	17.9	79.6	14.22	24.2
RT ₄	59.4	20.1	17.7	17.5	74.8	16.44	24.4
RT ₅	60.0	20.2	20.1	19.0	56.1	25.69	23.9
RT ₆	65.6	21.4	20.4	17.0	46.2	25.84	24.9
RT ₇	58.8	16.4	16.1	17.6	40.1	15.93	24.2
RT ₈	54.9	19.3	17.7	17.1	41.4	20.38	24.8
RT ₉	61.2	18.7	18.1	17.6	47.6	14.08	24.5
RT ₁₀	56.2	17.3	16.8	16.9	38.7	11.64	24.1

APPENDIX - 3.1

(WHEAT AND GROUNDNUT EXPERIMENT)

A. VOLATILISATION LOSS OF AMMONIA FOLLOWING BASAL APPLICATION OF 50 KgN/ha (PU) TO WHEAT AND GROUND NUT

Time days	Volatilisation Loss of $\text{NH}_3\text{-N}$ kg/ha			
	Groundnut	Wheat		
	GT ₁	WT ₁	WT ₂	WT ₃
1	-	-	-	-
2	-	-	-	-
3	-	-	-	-
4	-	-	-	-
5	-	-	-	-
6	0.086	0.21	0.212	0.212
7	0.086	0.053	1.957	0.212
8	0.172	0.159	0.185	0.159
9	0.057	0.212	0.086	0.291
10	0.086	0.212	0.545	0.238

B. VOLATILISATION LOSS OF AMMONIA FOLLOWING TOPDRESSING OF 50 Kg N/ha (PU) TO WHEAT

Time Day	Volatilisation Loss of $\text{NH}_3\text{-N}$ (kg/ha)		
	WT ₁	WT ₂	WT ₃
1	0.079	0.115	0.086
2	0.291	0.141	0.029
3	0.529	0.172	0.172
4	0.695	0.115	0.086
5	0.212	0.172	0.154
6	0.238	0.144	0.086
7	0.132	0.144	0.144
8	0.238	0.086	0.312
9	0.132	0.230	0.402

APPENDIX 3.2
(WHEAT AND GROUNDNUT EXPERIMENT)

SOIL AND AIR TEMPERATURE DURING COLLECTION OF VOLATILISED AMMONIA.

PERIOD : (FOLLOWING BASAL APPLICATION)

Date	Soil temperature (30cm Depth)		Mean Air Temperature
	Morning	Afternoon	
14.12.92	21.5	23.6	20.9
15.12.92	21.6	23.5	20.8
16.12.92	21.3	23.0	20.2
17.12.92	21.0	23.0	19.9
18.12.92	21.0	23.5	20.3
19.12.92	21.5	23.5	21.0
20.12.92	21.6	24.0	21.1
21.12.92	22.0	23.0	22.1
22.12.92	21.6	23.8	21.1
23.12.92	21.8	24.0	20.9
24.12.92	21.5	23.5	20.5

PERIOD (FOLLOWING TOP DRESSING)

		26.5	24.8
08.01.93	24.5	26.6	24.4
09.01.93	24.5	26.6	24.6
10.01.93	24.6	26.5	25.5
11.01.93	25.0	27.0	25.1
12.01.93	25.0	27.5	25.8
13.01.93	25.5	26.6	26.3
14.01.93	25.5	26.0	21.5
15.01.93	24.0	26.0	21.8
16.01.93	24.0	26.0	22.9
17.01.93	24.0		

APPENDIX 3.2
(WHEAT AND GROUNDNUT EXPERIMENT)

SOIL AND AIR TEMPERATURE DURING COLLECTION OF VOLATILISED AMMONIA.

PERIOD : (FOLLOWING BASAL APPLICATION)

Date	<u>Soil temperature (30cm Depth)</u>		Mean Air Temperature
	Morning	Afternoon	
14.12.92	21.5	23.6	20.9
15.12.92	21.6	23.5	20.8
16.12.92	21.3	23.0	20.2
17.12.92	21.0	23.0	19.9
18.12.92	21.0	23.5	20.3
19.12.92	21.5	23.5	21.0
20.12.92	21.6	24.0	21.1
21.12.92	22.0	23.0	22.1
22.12.92	21.6	23.8	21.1
23.12.92	21.8	24.0	20.9
24.12.92	21.5	23.5	20.5

PERIOD (FOLLOWING TOP DRESSING)

08.01.93	24.5	26.5	24.8
09.01.93	24.5	26.6	24.4
10.01.93	24.6	26.6	24.6
11.01.93	25.0	26.5	25.5
12.01.93	25.0	27.0	25.1
13.01.93	25.5	27.5	25.8
14.01.93	25.5	26.6	26.3
15.01.93	24.0	26.0	21.5
16.01.93	24.0	26.0	21.8
17.01.93	24.0	26.0	22.9

YIELD PARAMETERS OF WHEAT AND GROUNDNUT

A. WHEAT

Treatment	No of clumps/m ²	Plant height (cm)	No. of tillers/ clump	No.of Effective tillers/ clump	Length of panicle (cm)	No.of filled grains/ panicle	Spikelet sterility percentage	Thousand grain weight(g)
WT ₁ *	45	65.9	7.1	6.3	16.6	36.9	35.56	37.3
WT ₂	42	54.0	3.5	3.4	14.9	28.1	40.09	38.8
WT ₃	45	56.6	4.3	4.0	15.8	35.9	37.67	36.5
WT ₄	38	44.7	3.6	2.7	14.7	26.1	38.19	36.9

B. GROUNDNUT

Treatment	Plant Height (cm)	No.of Branches/ Plant	No.of pegs/ Plant	No. of Pods/ Plant	Dry weight of Pods/ Plant(g)	Shelling percentage	Hundred kernel weight(g)
GT ₁	38.4	3.8	19.7	17.5	14.95	62.52	39.3
GT ₂	29.8	5.5	14.6	8.1	7.26	54.65	34.2

APPENDIX - 4

ANALYTICAL RESULTS OF MANURE, FERTILIZER AND IRRIGATION WATER SAMPLES.

	Total N	NH_2N	$\text{NH}_4^+ \text{N}$	$\text{NO}_3^- \text{N}$
1. (Manure) FYM	1.06%	-	-	-
(Fertilizers)				
2.1. UNP (19-19-0)	-	12.77%	-	14.23%*
2. UNP (2-7-9-0)	-	8.66%	-	10.34%*
(Irrigation water) 0		4 ppm	-	6.9 ppm

* Calculated by difference from total N percent.