for the application of P either to rice alone or both for the irrigated pulse and rice was comparable under sub plots. In the main plots, STL based NPK recommendation registered higher P use efficiency than that of the blanket recommendation.

The apparent recovery per cent of the applied P in *Pisanam* rice (Table 5) varied from 3.44 to 23.14 with an average of 10.43 per cent. Application of P to both the crops in the legume-paddy sequence had registered a higher P recovery in rice crop (13.24%) than the P application to rice alone (7.63%). Under main plots, the STL based NPK application had recorded a higher P recovery than that of the blanket recommendation. The increased P use efficiency as well as P recovery in rice under STL based fertilization in this experiment was due to the lower level of P applied through STL recommen dation than that of the blanket and that the recovery of nutrients was found always higher under lower levels than that of the higher levels as reported by Velu (1989). Similarly the all- basal application of P favoured more P recovery in rice than that of the split. This is in agreement with the reports of Mahapatra (1969), who was of the view that rice responded well to basal application of P because of its poor ability to utilise soil P in early stages.

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EFFECT OF NITROGEN SOURCES ON THE AVAILABILITY OF INORGANIC NITROGEN FORMS IN SANDY CLAY WETLAND RICE SOIL

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ABSTRACT

Field experiments were conducted during *Kharif* and *rabi* seasons of 1991-92 to study the effect of nitrogen (N) sources on the availability of different inorganic N forms in Typic Ustropept Wetland rice soil. The results indicated that the NH_4 - N, NO_3 - N and available N content of the soil declined with crop growth during both the seasons. Increasing levels of N application up to 175 kg N ha^{-1} increased the NH_4-N, NO_3-N and available N content of the soil. Application of neem cake coated urea (NCU) recorded the lowest content of NO_3-N in the soil during both the seasons. Among the applied N sources, NCU followed by urea gypsum, prilled urea + green leaf manure recorded the highest NH_4-N and available N content of the soil in both the seasons.

KEY WORDS : Inorganic Nitrogen Forms, Neem Cake Coated Urea, Urea gypsum, Wetland Rice.

The soil contains nitrogen (N) as organic compounds, NH_4-N and NO_3- N forms. The amount of N availability in soil is small. Application of suitable and effective N source will make the soil productive for rice crop. Therefore, the present study on the effect of N sources on the availability of different forms of N in sandy clay wetland rice soil was undertaken.

MATERIALS AND METHODS

Field experiments with ADT 36 rice variety during the *kharif* (July-Oct) and IR 20 rice variety during the *rabi* (Oct-Feb) crop season of 1991-92 were carried out using different N sources in the Typic Ustropept sandy clay wetland rice soil of Thambirabarani tract to study the effect of N sources on the availability of different forms of N for rice. The soil of the experimental fields were alkaline pH (8.1 & 8.0) with available $KMNO_4$-N content of 210 and 240 kg ha^{-1}, available Olens's -p content of 22 and 27 kg ha^{-1}, available NH_4 OAc-k of 222 and 246 kg ha^{-1}, cation exchange capacity of 18 and 17 cmol (p^+) kg^{-1} and organic carbon content of 0.43 and 0.48 per cent for *kharif* and *rabi* seasons respectively. The exchangeable NH_4 -N and NO_3-N contents during *kharif* and *rabi* seasons were 10 and 12 ppm and 0.60 and 0.70 ppm respectively.

The treatments were control (without N) prilled urea (PU) at 75, 125, 175 and 225 kg Nha^{-1}, combined application of PU at 75 kg Nha^{-1} with green leaf manure at 50 kg N ha^{-1} (PU+GLM), ammonium chloride (AC) at 125 kg N ha^{-1} neem cake coated urea (NCU) at 125 kg N ha^{-1}, urea gypsum (UG) at 125 kg N ha^{-1}, urea nitricphosphate 27:9:0 (UNP) AT 125 KG N ha^{-1}, PU at 75 kg N kg^{-1} + *Azospirillum* (PU+AZOS). The experiments were tried in a randomised block design with three replications.

The inorganic N sources were broadcasted in three equal splits (basal, tillering and panicle initiation stages). All the treatments received uniform basal doses of 50 kgP_2O_5 and 50 kg K_2O ha_{-1}. After deducting the P added through UNP complex, the rest of the P was broadcasted basally through single superphosphate. The green leaf manure at the rate of 50 kg N ha^{-1} was applied and incorporated in the respective plots seven days prior to transplanting. Azospirillum was applied through seed treatment, seedling root dip and mainfield application (0.6, 1 and 2 kg of cultures for one ha respectively)

Surface soil samples (0-15 cm) were collected from each plot in between rows of transplanted rice at tillering (stage I), panicle initiation (state II) stages and at harvest (stage III) of the crop. Several random samples were collected from each plot, mixed and representative samples were drawn. The soil samples were dried in shade, powdered and sieved to 2mm size. The inorganic N was extracted

Table 1. Soil NH_4-N (ppm) at different stages of crop and seasons

Tr. No.	Treatments	*Kharif* '91				*Rabi* '92			
		Stage I	Stage II	Stage III	Mean	Stage I	Stage II	Stage III	Mean
T_1	Control (N_0)	9.3	5.6	5.6	6.8	7.4	5.6	5.6	6.2
T_2	PU (N_{75})	20.5	16.8	14.9	17.4	14.9	13.1	11.2	13.1
T_3	PU (N_{125})	41.1	31.7	28.0	33.6	24.3	22.4	20.5	22.4
T_4	PU (N_{175})	42.9	33.6	29.9	35.5	35.5	33.6	24.3	31.1
T_5	PU (N_{225})	46.7	37.3	33.6	39.2	37.3	35.5	26.1	33.0
T_6	AC (N_{125})	44.8	35.5	31.7	37.3	39.2	37.3	22.4	33.0
T_7	NCU (N_{125})	59.7	44.8	39.2	47.9	52.3	48.5	37.3	46.0
T_8	PU (N_{75}) + GLM	48.5	39.2	35.5	41.0	41.1	44.8	28.0	38.0
T_9	UG (N_{125})	57.9	42.9	37.3	46.0	50.4	46.7	35.5	44.2
T_{10}	UNP (N_{125})	31.7	26.1	26.1	28.0	22.4	20.5	18.7	20.5
T_{11}	PU (N_{75}) +AZOS	22.4	18.7	16.8	19.3	16.8	14.9	13.1	14.9
	Mean	38.7	30.2	27.1	32.0	31.1	29.4	22.1	27.5
		Stage		Treatment	Interaction	Stage		Treatment	Interaction
	SE	0.87		1.66	2.08	0.73		1.39	2.41
	CD (5%)	1.70		3.30	5.80	1.50		2.80	4.80

Table 2. Soil NO_3-N (ppm) at different stages of crop and seasons

Tr. No.	Treatments	*Kharif*'91				*Rabi* '92			
		Stage I	Stage II	Stage III	Mean	Stage I	Stage II	Stage III	Mean
T_1	Control (N_0)	0.36	0.52	0.36	0.41	0.68	0.52	0.36	0.52
T_2	PU (N_{75})	3.40	2.68	2.44	2.84	2.64	2.52	2.08	2.41
T_3	PU (N_{125})	4.44	3.60	3.48	3.84	3.60	3.36	3.04	3.33
T_4	PU (N_{175})	4.56	3.72	3.60	3.96	3.72	3.48	3.08	3.43
T_5	PU (N_{225})	4.68	3.88	3.64	4.07	3.84	3.60	3.16	3.533
T_6	AC (N_{125})	6.96	5.32	3.36	5.21	5.48	4.52	2.92	4.31
T_7	NCU (N_{125})	2.24	1.44	1.32	1.67	1.68	1.32	1.08	1.36
T_8	PU (N_{75}) + GLM	4.80	4.00	3.84	4.21	4.68	4.52	3.32	4.17
T_9	UG (N_{125})	3.20	2.36	2.12	2.56	2.76	2.68	2.20	2.55
T_{10}	UNP (N_{125})	7.12	5.44	3.72	5.43	5.64	4.56	3.24	4.48
T_{11}	PU (N_{75}) +AZOS	3.36	2.52	2.24	2.71	2.80	2.36	1.92	2.36
	Mean	4.10	3.23	2.74	3.36	3.41	3.04	2.40	2.95
		Stage		Treatment	Interaction	Stage		Treatment	Interaction
	SE	0.12		0.23	0.40	0.09		0.17	0.29
	CD (5%)	0.24		0.46	0.80	0.18		0.34	0.58

from the soil using 1 N sodium sulphate solution (Onken and Herbert, 1977). The extract was analysed for NH_4-N by micro kjeldahl's distillation method (Bremner and Keeney, 1966), and NO_3- N by colorimetric method (Sims and Jackson, 1971). The available - N content of the soil was estimated by alkaline permanganate method (Subbiah and Asija, 1956).

RESULTS AND DISCUSSION

The inorganic N forms, more particularly NH_4-N constituted an extremely dynamic N system in the rice soil and was reported as the most influencing factor on yield (Savant and De Datta, 1982). The soil NH4-N at different stages of *kharif* and *rabi* seasons are shown in Table 1.

The soil NH_4-N varied from 5.6 to 59.7 ppm during *kharif* season and from 5.6 to 52.3 ppm during the *rabi* season, with overall mean values of 32.0 and 27.5 ppm during *Kharif* and *rabi* seasons respectively. With the advancement of the crop growth from tillering to harvest, a gradual decline in the NH_4-N content of the soil was observed in both the crop seasons which could be attributed to the higher uptake of NH_4-N by the growing rice crop. Application of N irrespective of the levels and sources recorded significantly higher NH_4-N in soil over control. Among the treatments, NCU and UG at 125 kg N ha^{-1} being on a par, recorded significantly higher soil NH_4-N content compared to all other treatments in both the seasons. The possible reason for this may be the slow and steady release of the NH_4-N from the neem or gypsum coatings for hydrolysis. The concentration of NH4+ ion at any time was not very high and this also enables the adsorption of most of the NH4+ ions at the exchange sites (Pandey *et al* 1990. A gradual increase in the soil NH_4-N content was observed with the increasing levels of applied N (Saravanan *et al.*, 1987). The NH_4 -N in soil under the application of PU at 175 and 225 kg N ha_{-1} was almost comparable with AC and UNP applied at 125 kg N ha^{-1} due to the quick hydrolysis and subsequent loss of N through various path ways like volatilisation, leaching and denitrification (Ventura and Yoshida, 1977) On equal N basis (at 125 kg N ha^{-1}) the application of PU+GLM registered a higher NH_4-N content over PU, AC and UNP during both the seasons, which might be due to the enhanced ammonification power of the soil with green leaf manure (Ramaswami and Raj, 1976). Application of *Azospirillum* did not increase the soil NH_4 - N content.

In the interaction effect of stages against treatments, NCU and UG, which were markedly superior to the rest of the N sources under main

Table 3. Soil available -N (kg ha^{-1}) at different stages of crop and seasons

Tr. No.	Treatments	*Kharif*'91				*Rabi* '92			
		Stage I	Stage II	Stage III	Mean	Stage I	Stage II	Stage III	Mean
T_1	Control (N_0)	253	205	182	213	262	211	185	219
T_2	PU (N_{75})	266	218	194	226	274	224	197	232
T_3	PU (N_{125})	291	247	224	254	302	249	225	259
T_4	PU (N_{175})	297	251	226	258	304	254	227	262
T_5	PU (N_{225})	298	251	226	258	305	255	228	263
T_6	AC (N_{125})	292	248	224	255	302	250	225	259
T_7	NCU (N_{125})	308	261	237	269	316	265	238	273
T_8	PU (N_{75}) + GLM	301	252	234	262	313	259	236	269
T_9	UG (N_{125})	307	259	235	267	314	263	237	271
T_{10}	UNP (N_{125})	290	246	218	251	300	248	223	257
T_{11}	PU (N_{75}) +AZOS	267	220	196	228	274	224	197	232
	Mean	288	242	218	249	297	246	220	254
		Stage		Treatment	Interaction	Stage		Treatment	Interaction
	SE	0.34		0.65	1.13	0.34		0.64	1.12
	CD (5%)	0.70		1.30	2.30	0.70		1.30	N.S.

effect of treatments, were also found comparable with PU+GLM during panicle initiation and harvest stages of *kharif* season and during the panicle initiation stage of *rabi* season.

It wetland rice soils, the NO_3-N formation is usually restricted due to the anaerobic condition prevailing in the soil. The oxidation of NH_4 -N to NO_3 - N is possible to a greater extent in the oxidised surface layer. The NO_3 -N content of the soil at different phases of the crop during *kharif* and *rabi* season are shown in Table 2. The NO_3-N content of the soil varied from 0.36 to 7.12 ppm during *kharif* season and from 0.36 to 5.64 ppm during *rabi* season, with over all mean values of 3.36 and 2.95 ppm during *kharif* and *rabi* season respectively. The NO_3-N content of the soil decreased with the advancement of crop growth in both the seasons. This might be due to the increased uptake of nitrogen at the later stages which reduced the availability of NH_4-N for nitrification (Savant and De Datta, 1982).

Among the sources tried on equal N basis (125 kg N ha^{-1}), the NO_3-N content in the soil was the highest under the use of UNP and AC compared to the rest of the N sources tried during *kharif* season. During *rabi* season, the combined application of PU+GLM being on a par with the above two N sources also recorded higher NO_3-N content in the soil over the rest of the treatments. The higher content of NO_3-N with the application of green leaf manure was also reported by Ramaswami and Raj (1976).

Application of NCU recorded significantly lower NO_3-N content in the soil than the rest of the N sources. The treatment UG came next. This was possible due to the effect of the alkaloid in the neem cake and coaltar which inhibits the nitrification process (Muneshwar and Singh, 1986). In the interaction effect of stages against treatments, application of UNP and AC which recorded a higher NO_3-N in soil under the main effects were also comparable with PU+GLM as well as PU at harvest during *kharif* season. But during *rabi* season the former three which recorded higher NO_3-N in soil under the main effects were PU alone in the harvest stage.

Increasing levels of N beyond 125 kg N ha^{-1} did not increase the NO_3-N in soil. This might be due to the restricted activity of the nitrifying bacteria under flooded soil condition as reported by Senapti *et al* (1992). The effect of *Azospirillum* on the NO_3-N content of the soil was negligible. The available N constitues the easily oxidisable organic N fraction and the inorganic N sources of the soil. It gives an indication of the N supplying capacity of the soil by serving as a potential reserve for the

N nutrition of rice (Broadbent, 1979). The available N content of the soil at different stages of *kharif* and *rabi* seasons are shown in Table 3. The available N content of the soil varied between 182 and 308 kg ha^{-1} for the different treatments during *kharif* season and between 185 and 316 kg ha^{-1} during *rabi* season. The mean available N content of the soil during *kharif* and *rabi* seasons were 249 and 254 kg ha^{-1} respectively. A progressive and marked decline in the available N status of the soil was observed with the advancement of crop growth, the highest being at tillering stage, followed by panicle initiation and the lowest at harvest in both the seasons. This might be due to the continuous crop removal of N from soil. Application of N at all levels and sources, had markedly increased the available N in soil at all stages of observation during both the crop seasons. Increasing levels of applied N up to 175 kg N ha,$^{-1}$ progressively increased the soil available N.

Among the N sources tried, NCU, UG and PU + GLM registered significantly higher soil available N over the rest in both the seasons and the might be attributed to the slow and steady mineralisation and the reduced loss of applied N. The superiority of the above three N sources at 125 kg N ha^{-1} could be seen by the increased available N in soil over that of PU even at 225 kg N ha^{-1}. The soil available-N content of the treatments AC, PU and UNP at 125 kg N ha^{-1} could be seen by the increased available N in soil over that of PU even at 225 kg N ha^{-1}. The soil available - N content of the treatment AC, PU and UNP at 125 kg N ha^{-1} were on a par among themselves during both the seasons. The application of *Azospirillum* did not produce appreciable increase in the soil available N. The interaction effect of stages against treatments was significant only in the *kharif* season. The treatments UG and NCU which were superior to the rest of the treatments under the main effect was comparable with PU+CLM at harvest stage.

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