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Nitrogen balance in wetland rice ecosystem as influenced by soil types

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Abstract : Nitrogen balance in the rice growing flooded soils of Cauvery Delta as influenced by the soil types and sources and levels of N were studied. The volatilization and leaching losses were higher in the light textured Madukkur series compared to those of the heavy textured Kalathur and Padugai series. Application of urea super granule (USG) recorded the lowest volatilisation loss and the highest leaching loss irrespective of the soils. The total loss of N was reduced when the coated N sources (Lac coated urea; Neem coated urea and Coal tar coated urea) were used in light textured Madukkur series. The N balance in the heavy textured Kalathur and Padugai series were positive (+780 and +455 mg pot^{-1} respectively) and in the light textured Madukkur series, it was negative (-79 mg pot^{-1}). ***(Key words : N source, N losses, N balance, Rice soils)***

Nitrogen balance studies are the means whereby the influence of various factors on the total soil N content in general and the pathways of transformations, utilisation and losses in particular are monitored. Flooded rice grows in a complex soil - water - atmosphere system in which many physical, chemical and biological processes influence the N transformations and its availability in soil and its utilisation and efficiency in rice crop. There has been a few N balance studies on dryland soil (Allison, 1965). Unfortunately such studies have not been made intensively on wetland soils in the tropics (Koyama and App, 1979) due to tedious nature of the work and limitations in the techniques to be adopted. Lack of N balance studies in wetland rice soils in the tropics presents a serious knowledge gap. Hence, using the major soil series of Thanjavur, the rice bowel of Tamil Nadu, an experiment was conducted to study the influence of the soils and sources and levels of N on the N balance in flooded rice soils, the results of which are reported in this paper.

Materials and Methods

The study was conducted under controlled green house conditions with the three major rice growing soil series of Cauvery delta viz., Madukkur, Kalathur and Padugai using different N sources viz., Prilled urea (PU), Ammonium chloride (AC), Neem cake coated urea (NCU), Coal tar coated urea (CTU), Lac coated urea (LCU) and Urea super granule (USG) each applied at 0, 51, 102 and 153 kg N ha^{-1} in a FRBD replicated twice.

Twenty kg air dried powdered soils were filled in a convergent type inside wax coated cement pots with dimensions of 30 x 30 cm in the upper side and 25 x 25 cm at the bottom, with a depth of 30 cm. A glass tube of 1 cm inner hole with a rubber tube and a pinch cock attachment was provided at the bottom of the pots, to facilitate the collection of leachate samples.

The soils in the pots were puddled repeatedly and allowed to settle for one week with a standing water of 5cm. At planting the required quantities of P_2O_5 and K_2O (at 50 kg ha^{-1}) in the form of super phosphate and muriate of potash respectively were added and mixed well. Fifty per cent of the N dose through the respective sources was added at planting by sprinkling the fertilizer materials viz., PU, AC, NCU, CTU and LCU on the surface and mixing with soil. In USG, it was point placed at 8-10 cm soil depth in between the four hills using 0.5 and 1.0 g size granules to manipulate the N dose as per treatment schedule. The rest 50 per cent of the N dose was top dressed in two splits, one on 18 DAT and the other on 36 DAT in all the fertilizer sources except in USG which was point placed on 24 DAT as a single dose. Four hills of two seedling each (var. ADT 36, 105 days duration) were planted per pot at 15cm spacing on either side. About 5cm of standing water in the pots was maintained throughout the crop growth.

The volatilisation loss of N was measured upto 60 DAT by semi open acid trap method (Mikkelsen *et. al.*, 1978) using circular iron frames of 12.5 cm dia and 35 cm length covered with polythene bags and placed inbetween the four rice hills.

Leachate samples were collected daily at the rate of 500ml day^{-1} from each pot for 10 days at each time of fertilizer application, and analysed for NH_4-N by colorimetry, NH_4-N by steam distillation with MgO and NO_3-N by colorimetry. From the contents of the different forms of N and the volume of leachate collected, the quantum of leaching loss of N was worked out.

At harvest, the soil and plant (grain, straw and root) samples were collected and analysed for total N contents. From the yield of grain, straw and roots and their total N content, the total N uptake of the crop was computed. The N input through seedlings was assessed from the N content and dry weight of the seedling used for transplanting in the pots.

The nitrogen balance sheets for the three soils were prepared taking in to account the inputs viz., soil initial total N, fertilizer N and N added through seedlings; and the N output viz., volatilization and leaching loss on N, crop removal and soil total N at harvest, in the soil - water - plant - atmosphere system.

Results and Discussion

The characteristics of the three soils used for the N balance study are presented in Table 1. The data on the volatilisation and leaching losses of N, Crop N uptake, soil total N at harvest and the N balance in the soils are presented in Tables 2-4.

The total N content of the soils at harvest varied between 431 and 683 ppm (8620 and 13660 mg pot^{-1}). All the three soils differed markedly wherein Padugai series recorded the highest soil total N followed by Kalathur and Madukkur series. The different N sources as well as N levels tried did not contribute to the built up of the total N content in soil. This was possible due to the fact that the proportion of added N was relatively small compared to the native soil N.

The total volatilisation loss of N varied between 5.8 and 42.0 mg N pot^{-1} for the different sources and levels of N tried in the different soils. The mean loss was the highest in Madukkur series (24.0 mg N pot^{-1}) followed by Padugai (21.0 mg N pot^{-1}) and the lowest was in Kalathur series (18.9 mg N pot^{-1}). The volatilization losses under AC followed by PU, were markedly higher than the rest of the N sources and it was the lowest under USG. The losses under CTU, NCU and LCU were in between and comparable. The above trend of results were almost similar in all the three soils. Applications of AC and PU, having very high solubility might have released more of NH_4-N into the flood water there by recorded higher loss of N over the rest. The restricted dissolution and movement of the applied N to the flood water under the placement of USG at 8-10 cm soil depth was the reason for the lower volatilization loss in USG treatment as reported by Saravanan *et. al.* (1988).

The total leaching loss of N was the highest in Madukkur series followed by Kalathur and Padugai which were comparable among themselves. Madukkur being a light textured soil with low CEC and higher hydraulic conductivity favoured easy downward movement and leaching of the applied N compared to the other soils. Application of USG registered the highest leaching loss of N under all soils and N levels. Point placement of USG at 8-10 cm soil depth might have facilitated easy downward movement of the dissolved and mineralised components of USG as was reported by Katyal *et al.* (1985). Application of the other N sources by broadcast and incorporation in the soil might have facilitated better contact and adsorption of the applied N by soil colloids, thereby recorded lower leaching loss of N compared to USG. The use of coated N sources in reducing the leaching loss of N more particularly in Madukkur series has also been clearly brought out in this study suggesting the usefulness of these coated N sources in the light textured soils in reducing the leaching loss of nitrogen.

The total N uptake by the rice crop varied from 141 to 875 mg N pot^{-1} for the different sources and levels of N tried under different soils. Among the three soils, the N uptake of rice in Padugai series was the highest (485 mg N pot^{-1}) followed by Madukkur (444 mg N pot^{-1}) and Kalathur (436 mg N pot^{-1}) which were comparable.

The higher native fertility status of the Padugai series having higher organic carbon, total N and available N might have contributed to the increased N uptake in rice compared to the other soils. Among the Madukkur and Kalathur soil series, though the fertility status of Madukkur series was lower than that of Kalathur, still, it registered an N uptake in rice comparable with that of the Kalathur series. Madukkur series being a light textured soil and having predominantly. Kaolinitic group of clay minerals, responded well for the application of N and registered higher incremental N uptake by the crop for the successive increase in the application of N. This is in corroboration with the reports of Guruswamy (1979). Application of USG recorded the highest N uptake, followed by LCU, CTU, NCU, AC and PU which were comparable. This was so under all N levels and all soils except in Madukkur series in which USG was also comparable with other N sources viz., LCU and NCU, which could be attributed to the higher amount of N losses observed under USG application in Madukkur series compared to Kalathur and Padugai series. Hense, USG was also found comparable with LCU and NCU in the light textured Madukkur series.

The different soil series used in the pot experiment were found to have a significant role on the N balance of the rice soils (Fig 1). Both positive and negative N balance were observed among the soils studied. The N balance of rice soils was found to closely follow the clay content and texture of the soil. Sandy clay textured Kalathur series recorded a positive and the highest N balance (+780 mg N pot^{-1}) followed by the Padugai series of sandy clay loam texture (+455 mg N pot^{-1}). In the sandy loam textured Madukkur series, the N balance was not only the lowest, but was also negative (-179 mg N pot^{-1}). The reduced volatilization and leaching losses on N under the Kalathur and Padugi series might have contributed for the positive N balance in these soils. On the contrary, the Madukkur series registering greater losses of N due to its lighter texture and low CEC might have contributed for the negative N balance and this is in agreement with the reports of Vlek *et al.* (1980). Panda *et al.* (1982) had also observed a negative N balance in laterite sandy soils of Bhubanshwar.

Though the differences among the N sources and N levels did not attain the level of significance, a numerically higher N balance was observed under the use of USG than the other N sources and at lower N levels than at the higher levels of N application. The biological activity of rice soils, which was reported to be higher in the unfertilized or low N fertilized situations by Koyama and App (1979) lend support to the above observations and that is why the N balance was relatively higher under the use of USG which was point placed at 8-10 cm soil depth, resulting in a low N content in the top soil compared to that of the other N sources applied and incorporated in the surface soil.

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Table 1. Important characteristics of the soils used for the study

Characteristics	Madukkur series	Kalathur series	Padugai series
Textural class	Sandy loam	Sandy clay	Sandy clay loam
Soil Taxonomy	Udic Haplustalf	Entic Chromustert	Typic Ustifluvent
Bulk density (Mg m^{-3})	1.45	1.26	1.18
Hydraulic conductivity (cm hr^{-1})	5.47	3.95	3 66
Organic carbon (per cent)	0.66	0.70	0.78
Total N (per cent)	0.043	0.059	0.063
Available N (kg ha^{-1})	236	240	262
Available P (kg ha^{-1})	13.8	18.6	20.1
Available K (kg ha^{-1})	190	246	258
C.E.C (c eq kg^{-1})	10.8	28.6	30.5

Table 2. Nitrogen balance in Madukkur series

Treatments	N input (mg pot^{-1})				N output (mg pot^{-1})					N balance (mg pot^{-1}) (B-A)
	Initial soil total N	N added through fertilisers	N added through seedlings	Total (A)	Volatilization loss of N	Leaching loss of N	Crop removal	Soil total N at harvest	Total (B)	
N sources										
PU	8680	920	24.3	9624	28.8	37.1	372	8930	9374	-250
AC	8680	920	24.3	9624	29.7	29.1	426	8770	9258	-366
NCU	8680	920	24.3	9624	25.2	32.2	467	8870	9394	-230
CTU	8680	920	24.3	9624	25.8	33.9	429	8870	9359	-265
LCU	8680	920	24.3	9624	24.3	30.6	462	8970	9500	-124
USG	8680	920	24.3	9624	15.9	57.4	517	9050	9644	+20
N levels (kg ha^{-1})										
N0	8680	0	24.3	8704	6.3	8.7	141	8790	8946	+241
N51	8680	460	24.3	9164	16.0	23.9	317	8690	9047	-116
N102	8680	920	24.3	9624	24.0	34.0	431	8960	9450	-174
N153	8680	1380	24.3	10084	34.8	52.3	585	9090	9762	-322

	N sources	N levels	Interaction		N sources	N levels	Interaction
SE	314	222	543	CD (5%)	NS	NS	NS

Table 3. Nitrogen balance in Kalathur series

Treatments	N input (mg pot^{-1})				N output (mg pot^{-1})					N balance (mg pot^{-1}) (B-A)
	Initial soil total N	N added through fertilisers	N added through seedlings	Total (A)	Volatilization loss of N	Leaching loss of N	Crop removal	Soil total N at harvest	Total (B)	
N sources										
PU	11760	920	24.3	12704	22.5	27.5	361	12977	13388	+634
AC	11760	920	24.3	12704	23.1	26.6	352	13000	13402	+697
NCU	11760	920	24.3	12704	19.8	24.5	383	13000	13427	+723
CTU	11760	920	24.3	12704	20.4	26.1	415	13043	13505	+801
LCU	11760	920	24.3	12704	18.6	23.8	421	13027	13490	+786
USG	11760	920	24.3	12704	13.2	37.8	671	12976	13698	+994
N levels (kg ha^{-1})										
N0	11760	0	24.3	11784	6.1	8.0	146	12390	12550	+766
N51	11760	460	24.3	12244	13.8	18.6	294	12883	13209	+955
N102	11760	920	24.3	12704	18.8	26.7	422	13092	13559	+855
N153	11760	1380	24.3	13164	26.3	38.0	585	13036	13685	+521

	N sources	N levels	Interaction		N sources	N levels	Interaction
SE	322	328	557	CD (5%)	NS	NS	NS

Table 4. Nitrogen balance in Padugai series

Treatments	N input (mg pot^{-1})				N output (mg pot^{-1})					N balance (mg pot^{-1})
	Initial soil total N	N added through fertilisers	N added through seedlings	Total (A)	Volatilization loss of N	Leaching loss of N	Crop removal	Soil total N at harvest	Total (B)	(B-A)
N sources										
PU	12600	920	24.3	13544	25.8	23.1	432	13394	13875	+331
AC	12600	920	24.3	13544	25.2	21.3	476	13533	14055	+511
NCU	12600	920	24.3	13544	22.2	21.2	443	13346	13832	+288
CTU	12600	920	24.3	13544	22.8	22.5	433	13466	13945	+401
LCU	12600	920	24.3	13544	21.6	20.9	449	13513	14004	+460
USG	12600	920	24.3	13544	13.5	29.9	683	13440	14166	+622
N levels (kg ha^{-1})										
N0	12600	0	24.3	12624	5.8	7.1	206	13200	13419	+795
N51	12600	460	24.3	13084	15.4	16.0	341	13290	13662	+578
N102	12600	920	24.3	13544	20.9	21.7	480	13512	14035	+491
N153	12600	1380	24.3	14004	29.2	31.7	633	13550	14244	+240

	N sources	N levels	Interaction
SE	475	336	823
CD (5%)	NS	NS	NS

FIG.1 NITROGEN BALANCE (mg N. pot^{-1}) IN RICE SOILS