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NATURAL AND PREDICTED TIME COURSE BEHAVIOUR OF AMMONIUM NITROGEN RELEASE IN LOWLAND RICE SOILS

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Abstract: An experiment was conducted on Typic Haplustalf soil at the Tamil Nadu Agricultural University, Coimbatore to study the effects of green manuring and N timings on soil ammonium-N release pattern under lowland flooded rice soils. The main-plot treatments consisted of three green manures viz., sesbania (*Sesbania rostrata*), cowpea (*Vigna unguiculata*) and parthenium (*Parthenium hysterophorus* L.) to supply 54 kg N ha^{-1} and one non-green-manure treatment. Application of 150 kg N ha^{-1} as urea at varying quantities, at different growth stages of the crop along with one control formed the sub-plot treatments. Incorporation of green manures increased soil ammonium-N content. The effect was more pronounced during the peak period of soil ammonium-N release, which occurred between the second and fourth week after transplanting rice. Application of N fertilizer resulted in an immediate spurt in soil ammonium-N, but it declined within a few days. Due to faster N uptake by the crop, the decline was rapid during late growth stages. Continued splits (150 kg N ha^{-1} in six equal splits) ensured a steady ammonium-N supply throughout the growth period. Similarly, skipping of basal N and application of 150 kg N in three equal splits starting from early tillering stage onwards also adequately met the crop N demand for high yield. Mathematical models were developed on the ammonium-N release pattern from green manures and they predicted similar ammonium-N release pattern as observed in the experiments.

Key words: Ammoniacal N, green manure, lowland rice, N time course.

INTRODUCTION

During the past two to three decades, use of organic manures declined substantially, as chemical fertilizers became cheaper and readily available. The rising cost of fertilizers, concern about the long-term health of soil and environment and sustainability issues have now revived the interest on organic nitrogen sources, especially green manures (Ladha *et al.*, 1988). Green manuring with N fixing legumes can contribute to a substantial part of the N requirement of rice and supply organic matter to wetland rice soils (Bouldin, 1988). Integrated use of green manures and inorganic fertilizers can reduce N losses, increase soil fertility and sustain the long-term productivity and ecological stability (Gill and Meelu, 1982).

The rate of ammonium-N release from green manures in soil is determined by the growth stage, chemical composition and C:N ratio of green manures and also soil temperature (Singh *et al.*, 1992). The decomposition and release of N from green manures proceed very rapidly during the first few weeks followed by much slower phase thereafter (Bharadwaj and Dev, 1985). Reports show that rice seedlings readily assimilates ammonium-N released by green manures. Knowledge on ammonium-N release pattern in soil on mineralization of incorporated green manures and N fertilizers would help in chalking out proper N management strategies for high N recovery and rice yields. The objective of the study was to understand the behaviour of ammonium-N release pattern from green manures and N fertilizers in lowland flooded rice soils.

MATERIALS AND METHODS

The experiment was conducted in the Wetland Research Farm, Tamil Nadu Agricultural University, Coimbatore in the kharif seasons of 1994-'95 and 1995-'96. The soil of the experimental field was Typic Haplustalf, moderately drained, deep clay loam with pH 7.8. The soil was low in available N (110 kg ha^{-1}), low in available P_2O_5 (9.5 kg ha^{-1}) and high in available K_2O (325 kg ha^{-1}) in the surface soil of 20 cm depth.

The experiment was laid out in split-plot design replicated thrice. The main-plot treatments included a non-green-manure treatment (G_0) and three green manures viz., sesbania (*Sesbania rostrata*) (G_1), cowpea (*Vigna unguiculata*) (G_2) and parthenium (*Parthenium hysterophorus* L.) (G_3). Green manures grown outside the experimental plot were harvested on 45th day after seeding, chopped to about 5 cm length and incorporated in the main-plots seven days before planting. All

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green manures were applied on equal N basis, to supply 54 kg N ha^{-1}. At the time of application, the N contents in the green manures were, sesbania 0.87%; cowpea 0.61%; and parthenium 0.75% on wet-weight basis. Subplot treatments included application of 150 kg N ha^{-1} as urea (46%) at different growth stages of the crop starting from transplanting to heading (5-7 days before panicle exertion) and one control (no N) as given in Table 1.

For estimation of ammonium-N, wet soil samples were collected periodically from four locations at 15 cm depth in each sub-plot, leaving border rows, using a soil sampler. At all observation dates, samples were collected before application of fertilizers. Soil was collected in plastic containers and closed tightly. After scrapping and discarding a thin film of topsoil, it was mixed thoroughly and analyzed for ammonium-N by the procedure suggested by Bremner and Keeney (1966). A part of the wet soil was oven-dried for estimating the moisture content and the ammoniacal N content was expressed as ppm on oven dry soil weight basis. Soil nitrate-N was not estimated because of the negligible concentration in flooded rice soils (Diekmann *et al.*, 1993).

RESULTS AND DISCUSSION

The data on the effect of green manures and N fertilizer on soil ammonium-N release pattern in kharif '94 and '95 are presented in Tables 2 and 3, respectively.

Effect of green manures

Throughout the crop growth period, the ammonium-N content in non-green-manure plots (Go) was lower than that in green manure applied plots. On most of the sampling dates, the superiority of any green manure over other green manures in soil ammonium-N was not significant. However, the difference between green manures and non-green-manure and also between the green manures was more conspicuous during the period from 17 to 30 DT (days after transplanting) in both years when the ammonium-N concentration was highest.

In kharif '94, while parthenium (G_3), recorded significantly high ammonium-N content up to 8 DT over other treatments, such effect on soil ammonium-N was evident with sesbania (GO and cowpea (G_2) at 17 and 30 DT. During this season ammonium-N concentration reached a peak of 51.79, 45.58 and 43.57 ppm for G_1, G_2 and G_3 respectively, compared to 29.90 ppm in non-green-manure plot.

In kharif '95, from 4 DT to 8 DT, cowpea (G_2) recorded significantly more ammonium-N than other treatments, whereas G_1 and G_3 were at par with GO As in kharif '94, notable difference in soil ammonium-N content between treatments was depicted from 17 to 30 DT when the ammonium-N content was higher. On 17 DT, highest ammonium-N content was observed in cowpea (G_2) followed by sesbania (G_1) and parthenium (G_3). The same trend was observed on 30 DT also. Maximum ammonium-N content for G_2, G_1 and G_3 i.e., 32.43, 30.43 and 26.00 ppm, respectively were recorded on 17 DT. In both years, green manures did not vary in their effect on ammonium nitrogen at early stages and late stages of crop growth, though the concentration was significantly more with green-manured plots compared to non-green-manure plot.

The time course behaviour of ammonium-N release from green manures showed that the soil ammonium-N content gradually increased with time after rice planting, reaching a peak between the second and fourth week and declined thereafter. The gradual increase in soil ammonium-N content in the initial stages may be probably due to the gradual decline in C:N ratio due to the release of CO_2 (Palm *et al.*, 1988) and the later decline may be due to the crop uptake (Roechan and Makarim, 1994) and loss of released N by different soil loss mechanisms (Bharadwaj and Dev, 1985; Singh *et al.*, 1992).

Though there existed variation in ammonium-N release among green manures, pronounced difference in the soil ammonium-N content between different green manures was evident only when the soil ammonium-N was at higher level (between the second and fourth week). According to Singh *et al.* (1992) decomposition and N mineralization of green manures are dependent not only on the C;N ratio but the N content also. The C:N ratio of

Table 1. Quantity of fertilizer N applied at different timings, kg ha^{-1}

Treatments	Timings					
	P	10 DT	ET	MT	PI	H
N_0	0	0	0	0	0	0
N_1	75	0	0	37.5	37.5	0
N_2	0	0	50	0	50	50
N_3	25	25	25	25	25	25
N_4	0	0	50	0	100	0

P = At planting; DT = Days after planting, ET = Early tillering, MT = Maximum tillering, PI = Panicle initiation, H = Heading;

Table 2. Extractable soil NH_4-N (ppm) as influenced by green manures and N timings - kharif '94

Treatments	Days after planting									
	0	2	4	6	8	17	30	38	55	85
Green manures										
G_0	14.20	16.94	17.08	15.92	16.31	18.11	29.91	23.43	15.63	13.77
G_1	13.89	17.55	17.01	16.72	17.82	33.82	51.79	29.72	22.07	15.01
G_2	13.95	20.62	18.51	17.23	17.25	30.66	45.58	30.67	19.07	14.44
G_3	14.59	22.00	20.90	19.49	19.09	25.64	43.57	28.63	19.43	14.23
Sd	0.39	0.94	0.86	0.69	1.21	1.35	2.00	1.16	1.33	0.61
CD (0.05)	NS	2.30	2.10	1.70	NS	3.30	4.90	2.85	3.25	NS
N Timings										
N_0	13.53	14.78	16.88	15.93	17.13	23.68	36.48	23.87	14.50	13.96
N_1	13.78	28.76	24.01	20.73	20.63	25.95	40.42	30.68	20.14	14.19
N_2	13.98	14.93	15.63	15.50	15.98	24.11	44.93	28.66	21.83	14.34
N_3	14.93	23.27	19.65	18.45	18.10	36.38	43.18	29.44	19.25	14.44
N_4	14.58	14.65	15.68	16.08	16.24	25.17	48.57	27.92	19.53	14.87
Sd	0.78	1.00	0.88	0.42	0.57	0.75	1.03	0.59	0.74	0.63
CD (0.05)	NS	2.05	1.80	0.85	1.16	1.52	2.10	1.20	1.50	NS

Table 3. Extractable soil NH_4-N (ppm) as influenced by green manures and N timings - kharif '95

Treatments	Days after planting									
	0	2	4	6	8	17	30	38	55	85
Green manures										
G_0	14.08	13.64	13.31	13.83	15.32	18.13	17.44	5.73	5.30	13.86
G_1	14.73	18.07	16.05	16.05	16.80	30.43	21.95	7.76	7.47	13.50
G_2	12.89	17.47	18.72	19.15	20.81	32.43	27.26	7.88	7.98	13.87
G_3	14.53	19.13	14.50	15.16	17.05	26.00	20.47	7.69	7.63	13.98
Sd	0.91	1.61	0.76	0.78	0.82	2.60	1.04	0.69	0.45	0.51
CD (0.05)	NS	3.95	1.85	1.90	2.00	6.30	2.55	1.70	1.10	NS
N Timings										
N_0	14.18	12.38	11.64	12.29	13.96	23.18	17.16	6.95	6.77	12.63
N_1	13.66	25.41	23.88	23.46	24.21	26.04	21.35	7.33	7.12	14.00
N_2	13.96	12.30	11.81	12.56	14.50	24.77	24.98	7.23	7.27	14.60
N_3	14.00	22.62	18.02	18.26	19.18	35.00	23.02	7.43	7.30	14.85
N_4	14.48	12.68	12.88	13.68	15.61	24.75	22.46	7.38	7.08	12.94
Sd	0.67	0.77	0.74	0.78	1.03	0.82	0.59	0.35	0.41	2.10
CD (0.05)	NS	1.58	1.51	1.60	2.11	1.68	1.20	NS	NS	NS

Table 4. Prediction models for ammonium-N content in soil

	Prediction model	r^2	Estimated parameters
Kharif '94			
G_0	$\ln NR = (a+cD+eD^2)/(1+bD+dD^2+fD^3)$	0.97	a = 2.7537; b = 0.0562; c = 0.1503; d = 0.0009; e = 0.0024; f = 2.2677 e-07
G_1	$NR = a+b\exp\{-\exp[-(D-c)/d]\}-[(D-c)/d]+11$	0.98	a = 16.8771; b = 45.5662; c = 24.4672; d = 6.5477
G_2	$NR^{0.5} = (a+cD+eD^2)/(1+bD+dD^2+fD^3)$	0.97	a = 4.1123; b = 0.0683; c = 0.2665; d = 0.0013, e = 0.0059; f = 2.6339 e-06
G_3	$NR = a+\{b/[1+(D-c)/d)^2]\}$	0.95	a = 15.4039; b = 28.8151; c = 28.5456; d = 8.9320
Kharif '95			
Go	$NR = a+bD^2+cD^{2.5}$	0.88	a = 0.0742; b = -0.0003; c = 4.7086 e-0.05
G_1	$NR = a+\{b/[1+(D-c/d)^2]\}$	0.86	a = 5.4056; b = 27.8553; c = 17.7526; d = 10.2435
G^2	$\ln NR = (a+Cd+eD^2)/(1+bD+dD^2+fD^3)$	0.98	a = 2.6729; b = -0.0669; c = -0.1321 d = 0.0016; e = 0.0019; f = -9.9103 e-06
G_3	$NR = a+\{b/(1+[(D-c)/d)^2]\}$	0.79	a = 4.1969; b = 22.4585; c = 17.2872; d = 13.4166

D = Days after transplanting; NR = Ammonium-N (ppm)

parthenium, cowpea and sesbania were 29, 14 and 11, respectively. Though the C:N ratio of parthenium was high, the N content (0.75%) was almost equal to sesbania (0.87%) and cowpea (0.61%). Further, from the C:N ratio alone one cannot predict the release of ammonium-N from green manures as the quality of the substrate (lignin, polyphenols, cellulose etc.) also affect the metabolic efficiency of the microbial decomposers that determines the NH_4-N release pattern (Rosswall, 1981).

Effect of N timings

In kharif, substantial variation in soil ammonium-N content was observed due to variation in N timings. The plots applied with N at planting (N_1 and N_3) recorded substantially higher ammonium-N content up to 8 days after transplanting compared to non-fertilized plots. Here again, plots that received more N (NO at that stage had more NH_4-N content than lower dose of N (N_3). At this stage the levels of ammonium-N with N_0, N_1 and N_4 timings were at par with each other and significantly lower than N_2 and N_3.

When soil ammonium-N was estimated at 17 DT (following the application of N at 10 DT), N_3 recorded significantly higher content (36.38 ppm in kharif '94 and 35 ppm in kharif '95) compared to all other treatments. On 30 DT, in kharif '94, N_4 recorded the highest ammonium-N content (48.57 ppm) followed by N_2 (44.93 ppm) and N_3 (43.18 ppm) whereas in kharif '95, N_2 recorded the highest NH_4-N content (24.98 ppm) followed by N_3 (23.02 ppm) and N_4 (22.46 ppm). During both seasons, the content was significantly lower for N_1 and N_0.

The effect of N application at maximum tillering (MT), panicle initiation (PI) or heading (H) stages till the successive stages was evident only in kharif '94, whereas in the succeeding year there was no difference between any treatments after 38 DT. In kharif '94, NH_4-N content in soil, immediately prior to fertilizer application at PI (38 DT) was highest in N_1 (30.68 ppm), which was superior to all other N timings. Nitrogen application at PI stage exerted its influence up to H stage in N| and N_2. At H stage (55 DT), significantly more NH_4-N was observed in N_2 (21.83 ppm) than in N_1, N_3 and N_4, which were at par. The variation in NH_4-N concentration due to N timings was evident up to heading stage (55 DT) in kharif '94, whereas such influence existed only up to PI stage in kharif '95.

The overall results of the present study have clearly brought out significant increase in NH_4-N due to green manure and fertilizer N application. The influence of green manures was more pronounced in the early stages of crop growth. There was a spurt in the NH_4-N content immediately after the application of fertilizer N. This observation is in accordance with that reported by John *et al.* (1989). Though N timings affected NH_4-N, the level of N applied at any stage did not have a prolonged effect at the succeeding crop growth stage. Application of N @ 75 kg ha^{-1} (N_1) or 25 kg ha^{-1} (N_3) at planting did not make any difference in soil NH_4-N content after one or two weeks. This indicates considerable losses from higher doses of N fertilizer if applied at early stage when the foraging capacity of the crop was limited. Similarly, application of 100 kg (N_4) or 25 kg (N_3) at PI stage did not cause any difference in soil NH_4-N content at heading stage.

The results show that the NH_4-N release from green manures coincides with the active vegetative stage of the crop. A part of the N demand would be met by the green manures and the balance amount can be satisfied by supplying N fertilizers at the appropriate stages. The N timing strategy of six splits @ 25 kg ha^{-1} each spreading from P to H stage (N_3) maintained the soil NH_4-N content at a rather high or equal level to the treatments which received 50 kg or 100 kg at any stage (N_1 or N_4), throughout the crop growth period. In N_2 also, the NH_4-N content was more than N_1 or N_4 during the active vegetative and reproductive stages. The strategy of N application from ET to H stages followed in N_2 treatment has maintained the NH_4-N content in soil sufficient enough to meet the crop demand. The low NH_4-N content in unfertilized plots (N_0) throughout the crop growth was naturally due to the absence of N application.

Prediction models for ammonium-N flux

Mathematical models for NH_4-N release pattern under different green manure treatments were developed. The best fitting models were selected based on the prediction ability and 'r^2' values (Table 4). These models allow prediction of soil ammonium-N content at any stage after planting rice.

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