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TIME COURSE LEAF N CONCENTRATION IN RICE UNDER DIFFERENT NITROGEN APPLICATION STRATEGIES AND DEVELOPMENT OF SIMULATION MODELS

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Abstract: An experiment was conducted at the Tamil Nadu Agricultural University, Coimbatore during the kharif and rabi seasons of 1994-'96. to study the time course leaf N concentration in lowland rice under different N timings. Application of I 50 kg N ha^{-1} in six staggered splits from planting to heading or in three splits from early tillering Ul heading sustained the leaf N concentration at increased levels for higher grain yields. Early N application and limitation of N supply at later stages decreased the plant N concentration during grain filling stages and reduced the grain yield. Continued application ol fertilizer N until heading stage favoured maintenance of N concentration in leaves during the post-antnests period. resulting in high grain yields. Based on the natural behaviour of time course leaf N concentration. simulation models ..... evolved based on the prediction ability and test of significance.

Key words: Leaf nitrogen, response !o N, rice. simulation model

INTRODUCTION

It can be assumed that a minimum concentration of nitrogen in the leaf is essential to achieve a given yield level. When the supply is sub-optimal. growth is retarded and senescence of older leaf is enhanced. Many workers have reported increase of N concentration in plant parts by N supply. Sivasamy *et al.* (1994) reported a quadratic relationship between the amount of N applied and N concentration over time. The fluctuation in N concentration over time depends upon the physiological stage or the crop and th N supply (Marschner, 1986) To increase the production potential of rice, it is necessary to maintain higher leaf N content in rice (Wopereis *et al.*, 1994).

Establishing relationships between leaf N concentration at various physiological stages and grain yield is necessary lo decide on N fertilization strategy for higher yield in rice. Prediction models on time course leaf N concentration help to suggest the time of N side-dressing. From a two-year field experiments (1994-'96) conducted at the Tamil Nadu Agricultural University. Coimbatore. with lowland rice, the time course leaf N concentrations at different growth stages of rice were estimated and simulation models was evolved from the natural behaviour.

MATERIALS AND METHODS

The experiment was conducted in the Wetland Research Farm. Tamil Nadu Agricultural University. Coimbatore in the kharif and rabi seasons of 1994-'96. Coimbatore is situated at 11° N latitude and E longitude at an altitude of 427 m. A mean annual rainfall of 630 mm is received in 43 days in the location. The mean maximum temperature ranges from 28 to 37 °C and the minimum temperature from 17 to 25 "C, The experiment field soil is classified as Typic Haplustalf (moderately drained deep clay loam) with pH 7.8. The soil was low in available N (110 kg ha ') and 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 one no-green manure treatment and three green manures viz., sesbania (*Sesbania rostrata*), cowpea (*Vigna unguiculata*) and parthenium (*Parthenium hysterophorus*). The green manures were applied in the kharif seasons only. Sub-plot treatments included one control (no N) and application of 150 kg N ha as urea (46%) ffl varying quantities. at different growth stages of the crop starting from transplanting lo heading (5-7 days before panicle exertion) as given in Table 1. The varieties used were ASD 18 (128 days) in kharif and ADT 38 (138 days) in rabi seasons. Plant samples were drawn at different stages of the crop growth for determination of N concentration in leaf, using the technique as suggested by Thiyagarajan *el al.* (1994b) N in leaf samples was analyzed by semimicro-kjeldahl method (Bremner and Mulvaney, 1982). Leaf N concentration (nL) is expressed on oven-dry basis as g kg^{-1}.

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Table 1. N timings treatments

Treatments	P	10 DT	ET	MT	PI	H	Total N, kg ha^{-1}
No	0	0	0	0	0	0	0
N_1	75	0	0	37.5	37.5	0	150
y	0	0	50	0	50	50	150
.	25	25	25	25	25	25	150
N,	0	0	SO	0	100	0	150

transplanting; ET = early tillering; MT - maximum tillering; PI Panicle initiation. H heading; MM mid maturity; M Maturity; DT - days after transplanting

N timings on leaf N concentration (g kg^{-1}) at different growth stages of rice

Crop growth stages														
	Kharif '94							Rabi 1994-'95						
Treat-ments	P	ET	MT	PI	H	MM	M	P	ET	MT	PI	H	MM	M
No	21.7	27.05	18.2	21,90	14.22	8.60	4.78	21.2	21.44	15JO	18.41	13.48	8.20	5.33
N_1	21.7	29.05	24.0	28.72	15.40	990	4.97	21.2	27.61	18.37	24.64	19.45	9.50	6.99
N_2	21 7	27.38	29.8	24 10	20.41	14.60	5.75	21.2	23.17	22.58	21.20	19.13	13.6	8.58
N_3	21 7	2849	31.6	28.06	18.97	14,20	6.18	21.2	26.3	20.83	23.42	20.08	14.50	9.00
N_4	21.7	27.28	29.9	23.61	20.59	14.65	5.96	21.2	22.8*	22.03	21.43	22.26	15.80	8.93
Sd		0.78	0.93	0.60	0.43	0.32	0.24	-	0.69	0.27	0.54	0.42	0.59	0.21
CD (0.05)		1.50	1.9	1.23	0.88	0 65	0.49	-	1.40	0.56	1,10	0.85	1.20	0.4.1

Table 3. N timings on leaf N concentration (g kg^{-1}) at different growth stages of rice

Crop growth stages														
	Kharif '95							Rabi 1995-'96						
Treat-ments	P	KT	MT	PI	H	MM	M	P	ET	MT	PI	H	MM	M
V,	20.5	25 36	24.23	23.23	16.44	10.63	6.86	24.5	27 Id	20.72	15.46	16 64	9.50	4.95
N.	20.5	32.20	26.40	30.18	25.20	11.61	9.80	24,5	.12.62	23.21	21.57	2342	12.60	7.15
V	20.5	28.42	31.95	25.18	25.00	17.78	11.48	24.5	25.62	24,72	20.11	25.90	14.80	9.10
N,	20.5	30.24	28.97	28.55	21.43	16.29	11.90	24.5	30.91	25.26	23.82	23.43	14.20	9,20
N,	20.5	27.30	30.35	24.68	27.28	18.19	9.80	24.5	26,04	24.45	20 10	28.00	17.10	8.15
Sd		0.49	0.81	0.36	0.39	0.18	0.22	-	077	0.45	0.48	0.65	0.47	0.35
CD (005)		0.96	1.65	0.73	0.80	0.37	0.45	-	1.58	0.91	0.98	1,32	0,95	0.72

RESULTS AND DISC

Since the effect of green manures on time course leaf N concentration was not significant during most of the sampling stages, the results are not presented here. The effect of nitrogen timings on leaf nitrogen concentration at different growth stages of the crop in different seasons is presented in Tables 2 and 3.

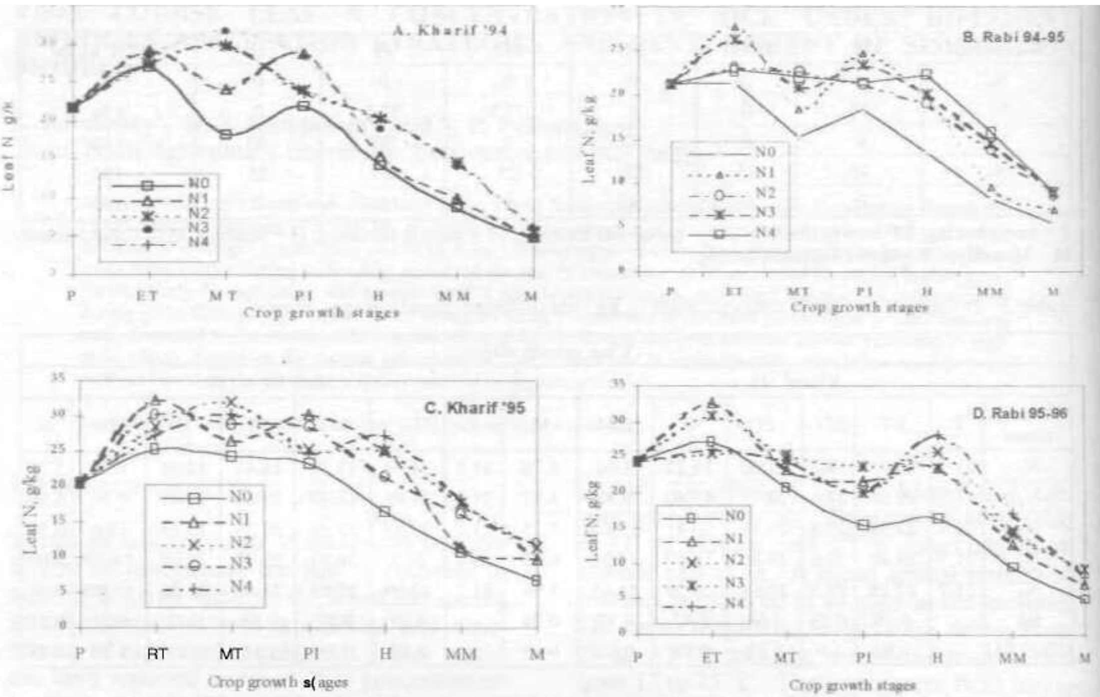

Fig 1. Time course of leaf N concentration under different N

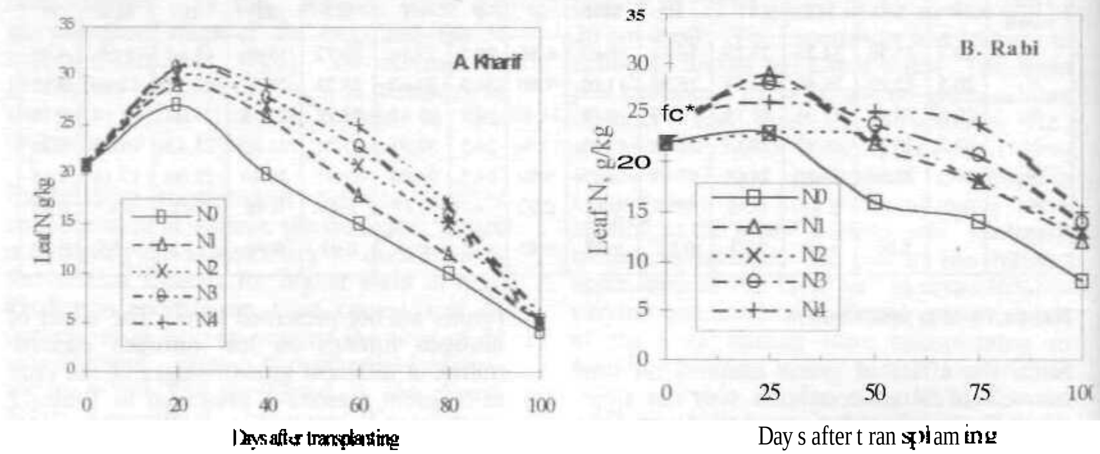

Fig 2. Leaf N at different N levels

Significant difference in nL was caused by varied timings of N application, particularly from MT to maturity (M) stage. The highest nL at ET was always noted in N, followed by N_3 and these two were mostly par a significantly superior to other treatments. At MT stage, highest nL was observed either in N_3 or N_2 followed by N_4. However, the difference in nL between these treatments was not appreciable By PI stage. N_1 or N_3 gave the highest nL, mostly in N_1. Further, it was noted that N_2 and N_4 had lower nL compared to N_1 or N_3 at this stage. At H stage, N_4 timing recorded highest nL (20.59 to 28.00 g kg^{-1} over the seasons) which was significantly superior to all other treatments. By mid-maturity (MM), N_4 took up the highest rank in nL and it was followed by N_3 or N_2 and the latter two treatments were at par in most of the seasons. The nL in N_2, N_3 and N_4 was very much higher than the N_1 and N_0 at this stage

Table 4 Grain yield of rice (t ha^{-1}) as influenced by N timings

Treatments	Kharif '94	Rabi '1994-95	Kharif '95	Rahi 1995-'96
N_0	.1.91	3 04	169	3.24
N_1	5 54	4.09	5.90	4.46
[illegible]	6.17	4.67	7.11	5.20
N,	6.40	5.37	7.39	5.84
N_4	5 55	4.09	5.21	4.38
Sd	0.19	0.20	0.10	0.13
CD (0.05)	0.39	0.41	0,20	0.27

Table 5. Prediction models for leaf N concentration under different N timings strategies - kharif seasons

Treatments	Mathematical model		Parameter values
		Kharif	
N_0	nl. a • h!) cD$^{1.5}$, dD$^{0.5}$ + ee^{-D}	0.95	a 53.3435: h 0.9593: c -0.0550: a -9.1138: e -32.2435
N,	a - bD - cD$^{1.5}$ - dD^{2} cD$^{2.5}$	0.91	a 21.1X9X; h - 1.1398: c -03X7: d- -0.0129: e 0.0013
	nl. a ' bD + cD^{2} < dD$^{2.5}$ eD^{3}	0.95	a 20.9538; h 1.1398; c -0 07X9; d • 0.0118: e -0.0005
Mi	nl. a • bD cD$^{1.5}$ r dD$^{1.5}$ ee^{D}	0,98	a 20.999! :h 0 9669: c -0.0370: a 0.0027: e -3.6334 41
	a bD ' cD^{2} + dD$^{2.5}$ eD	0.94	a 21.0213: h 0 91X3: c -0.0598: d 0.0089: -0 0004
		Rahi	
N_0	nl a + bD ' cD$^{1.5}$ • dD^{2} + ee^{-D}	0.93	a 22 9178: h 3.1219: c - -1 1850: - -0.0057
N,	nl a - bD cD^{1} - dD^{2} • eD^{2}	DM	a 22 9674: h - 3 7242: c -1.3241: d 0.1564: c -0.0063
V	nl a • bD •cD$^{1.5}$ dD^{2} eD$^{2.5}$	0.95	a 22.8933; h 0.9518; c -0.360.1; a 0.0469: c -0.0022
	nl a bD cD$^{1.5}$ > dD$^{2.5}$ ' eD^{3}	0,93	a = 22.946: b - 1.8060: c -0 4196: d 0.0056: c - -0.0003
N	nl a bD + cD$^{1.5}$ dD^{2} + eD$^{2.5}$	0.87	a 22.91 10: h 1.7677: c -0 7392; d 0.1029: tf -0.0048

Time course leaf N concentration

The effect of N timings on leaf N concentration was more prominent from ET stage onwards and it extended up to mid-maturity (MM) stage (Fig I). During the crop establishment period i.e., from P 10 ET stage, the growth and N uptake were slow and hence the demand of N was low. Application of urea at planting did not make any variation in leaf N concentration at ET stage. So it was clear that the required N to meet the crop demand during the initial stage of crop growth could be made good from the N mineralized from soil organic matter (SOM) itself as suggested by hiyagarajan *et al.* (1994a).

The gaps between the N concentration curves for lifferent N timings were wider from ET to PI stage after which the difference got narrowed. The width of curves during the crop growth periods was possibly influenced by the timing of N fertilizer as reported by Daradjat *et al.* (1994).

Towards the " reproductive phase, the position of curves was mostly decided by N application at H stage. Application of 25 kg N or 50 kg N • ' at H stage enabled the crop to steadily maintain the leaf N concentration without any drastic deflection from the previous stages. The strategy of applying small splits from planting to heading as done in enabled the plant to maintain the leaf N concentration at a higher level throughout the crop growth period. Similarly, postponing the first dose of N application till the ET stage and subsequent two splits up to the heading stage (N2) gave higher leaf N during the active vegetative phases and also reproductive phases and made up the earlier loss. Nitrogen increased the leaf N content and the N uptake, which ultimately increased the yield, as evidenced from higher leaf N uptake and consequent yield in N_3 and N_2 timings (Table 4). The deflection of nL in N| timing, in which the N application was stopped by PI stage, was drastic after H stage. On the other hand, application of 100 kg N at PI (N_4) did not increase the nL appreciably over N_2 or N_3 after H stage.

In ll treatments, the leaf N concentration declined gradually up to heading stage after which it was rather drastic up to maturity stage. The decline of N concentration during the pre-anthesis period was possibly due to the expansion of dry matter in plant parts and that during the post-anthesis period due to translocation of N to the grains and also losses of N from the crop (Wetselaar and Farquhar, 1980),

Application of 150 kg N ha in six staggered splits from planting to heading (N_3) or in three splits from early tillering to heading (N_2) sustained the leaf N concentration at optimum levels for higher grain yields. Early N application and limitation of N supply at later stages decreased the plant N concentration during grain filling stages and reduced the grain yield. The strategy of N fertilizer application that continued up heading stage favoured maintenance of N concentration in leaves during the post-anthesis period, which ultimately resulted in higher grain yields. Possibly a high proportion of N was sequestered into the storage pools as amides (Marschner,

The results indicate that to achieve higher yields it is imperative to maintain optimum leaf N concentration throughout the crop growth, especially from MT to MM stages which would be possible by split application of N from P or ET and continued up to H stage as done in N_3 and N_2 treatments respectively, in this experiment. Though the native soil N supply maintained the desired nL up to ET stage, variation in the crop N status after ET up to flowering or mid-maturity Stage fully controlled the yield variation (Wopereis *et al.*, 1994). The increase in N concentration after H stage was possible by the continued uptake capacity of the crop and the non-limitation of soil N supply (Cassman and Samson. 1994). Higher nL in N_3 and N_2 increased the radiation efficiency and photosynthetic activity (Yoshida, 1981), consequently higher biomass accumulation and grain yield.

Prediction models for leaf N concentration

The N concentration in leaf at different growth stages of rice pooled over the same seasons was regressed upon days after transplanting, to develop mathematical models. The best-fitted models based on the prediction ability and r^2 have been selected for predicting the leaf N concentration at any growth stage under specific N application strategies. The models are presented in Table 5. The predicted time course behaviour of leaf N is depicted in Fig.2. These models provide a chance for assessing mathematically the plant N status to decide the time of N side-dressing.

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