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Effect of N application timings on nitrogen use efficiency of rice

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ABSTRACT

Field experiments were conducted during two dry seasons of 2001 and 2002 on sandy loam soils to study the effect of nitrogen application timings on nitrogen use efficiency of irrigated rice. Application of nitrogen in three splits i.e. 1/3 at 7days after transplanting + 1/3 at maximum tillering and 1/3 at panicle initiation stage produced maximum grain yield of 4881 kg ha^{-1} which was at par with N application based on leaf colour chart. This N application timings resulted in the increase of yield by 1582 kg ha^{-1} which is 47.9% higher than recommended practice of N application i.e. 1/2 basal + 1/4 at maximum tillering and 1/4 at panicle initiation Highest values of N uptake (105.9 kg ha^{-1}), agronomic use efficiency (28 kg grain kg^{-1} N applied) and N utilization efficiency (72 kg N kg^{-1} N applied) were recorded by the new timing of N application. The N utilization efficiency was 1.7 times higher than that obtained by the recommended practice of N application.

Key words: *Irrigated rice, split application of N, Grain yield, N uptake, N-use efficiency*

The yield response of rice to nitrogen application is affected by varietal characteristics, plant density, soil condition, radiation, biotic and abiotic stresses and time of N application (Balasubramanian *et al* 1999 and Duraisami *et al.* 2001). The recovery of nitrogenous fertilizer is generally low (30-40%) and varies widely for the N applied at different growth stages (Rao *et al.* 1994). The nitrogen use efficiency is the lowest as compared to other nutrients due to its much mobility and losses through volatilization, dentrification, leaching and run off which in turn contribute substantially to environmental pollution and further depletion of stocks of nonrenewable energy sources used in fertilizer production (Das, 2004). The roots of transplanted paddy are able to absorb nutrients only after establishment (7-10 days after transplanting) indicating losses of basal application of nitrogen through various processes (Okajima, 1960). These losses can be minimized either by increasing urea granule size or by coating urea with nitrification retarding materials (Prasad *et al.* 1971). The nitrogen use efficiency may be enhanced with the adoption of ideal agronomic practices such as split application of nitrogen at critical stages of plant growth by synchronizing with the periods of efficient utilization (Dhurandar *et al.* 2000). Innovative tools such as chlorophyll meter (SPAD or LCC) have been introduced to monitor the crop N status in rice fields so that the fertilizers can be applied at the time when crop demands are most (Peng *et al.* 1996 and Balasubramanian *et al.* 1999). The present study was undertaken to study the effect of N application at various growth stages for enhancing the N-use efficiency in irrigated rice.

MATERIALS AND MEHTODS

The field experiments were carried out at Crop Research Station, Masodha, Faizabad (U.P.) India situated at 26.1 N latitude, 82.2 E longitude and altitude of 113 m above the mean sea level during two consecutive dry seasons of 2001 and 2002. The soil was sandy loam in texture having pH 7.8, organic carbon- 0.48%, cation exchange capacity-13.8 c mol (p) kg^{-1} soil, available N-185 kg ha^{-1}, available P_2O_5 is 24 kg ha^{-1} and available K_2O-232 kg ha^{-1}. The experiments were laid out in randomized block design with three replications having a plot size of 14 m^2. Seven treatments *viz.;* T_1- control (no nitrogen), T_2- 50% N at basal, 25% at maximum tillering (MT), and 25% N at panicle initiation (PI) stage, T_3-1/3 N at basal, 1/3 N at MT, 33% N at PI, T_4-25% N at MT and 50% N at PI stage; T_5-33% N at MT, 33% N at PI and 33% N at flowering stage, T_6- 33% N at 7 days after transplanting

(DAT), 33% N at MT and 33% N at PI stage, T_7 - N application on the basis of leaf colour chart (LCC) when it showed below 4 i.e. at 35 and 55 days after transplanting. The nitrogen was applied at 100 kg N ha^{-1} through urea to all the treatments of split application including T_7. An uniform dose of 60 kg ha^{-1} each of P_2O_5 and K_2O were applied through single superphosphate and muriate of potash, respectively. Twenty five day old seedlings of rice cultivar Jaya were transplanted in first week of July at a spacing of 20 x 15 cm keeping 2-3 seedlings $hill^{-1}$. At harvest, the data on panicle m^{-2} were recorded from randomly selected 4 places by using quadrate of 0.25 m^2. Ten panicles were selected randomly from each plot for recording panicle weight and number of grains as well as chaffy grains (sterility %). The biological yield and grain yield was recorded at 14% moisture from each plot. Nitrogen concentration in grain and straw were estimated by modified micro kjeldhal method suggested by Jackson (1973). N uptake was computed by multiplying the N contents and their respective yields of grain and straw. The fertilizer nitrogen use efficiency (agronomic efficiency (AE), physiological efficiency (PE) and N utilization efficiency), harvest index and sterility were calculated by the following formula-

RESULTS AND DISCUSSION

Nitrogen application increased the grain and straw yield during both the years (Table 1).When a part of the N was applied basally, the grain and straw yield of rice was lower in comparison to split application (top dressing) of all N at different growth stages. Similarly delay in N application upto maximum tillering stage in a three split system also reduced the grain and straw yield by 379 and 613 kg ha^{-1}, respectively in comparison to maximum yield. Application of three splits of nitrogen *i.e.* 33% at 7 DAT, 33% N at MT and 33% N at PI stage (T_6) produced maximum grain yield of 4881 kg ha^{-1} that was 1582 kg ha^{-1} or 47.9% higher than in the recommended method of N application (T_2). The differences in grain yield between T_6 and T_7 (N application by LCC) was non-significant. This might be due to better absorption and distribution of nitrogen in effective plant parts i.e. flag leaf and panicles (Ladha *et al.* 1998) which resulted in higher values of panicles m^{-2} and panicle weight and possibly reduced loss of N during seedling establishment period (upto 7 DAT). Duraisami *et al.* (2001) also reported higher yields of rice with 5 splits of nitrogen i.e. 7 DAT. MT. MH. PI and flowering stages than three splits *i.e.* basal, tillering

$$\text{Agronomic efficiency (kg grain kg}^{-1}\text{ N applied)} = \frac{\left(\begin{array}{l}\text{Grain yield (kg ha}^{-1}\text{)}\\ \text{of N treated plot}\end{array}\right) - \left(\begin{array}{l}\text{Grain yield (kg ha}^{-1}\text{)}\\ \text{of control plot}\end{array}\right)}{\text{N (kg ha}^{-1}\text{) applied}}$$

$$\text{Physiological efficiency (kg grain kg}^{-1}\text{ N uptake)} = \frac{\left(\begin{array}{l}\text{Grain yield (kg ha}^{-1}\text{)}\\ \text{of treated plot}\end{array}\right) - \left(\begin{array}{l}\text{Grain yield (kg ha}^{-1}\text{)}\\ \text{control plot}\end{array}\right)}{\left(\begin{array}{l}\text{N uptake (kg ha}^{-1}\text{)}\\ \text{of treated plot}\end{array}\right) - \left(\begin{array}{l}\text{N uptake (kg ha}^{-1}\text{)}\\ \text{by control plot}\end{array}\right)}$$

$$\text{Nitrogen utilization efficiency (kg N uptake kg}^{-1}\text{ N applied)} = \frac{\left(\begin{array}{l}\text{N uptake (kg ha}^{-1}\text{)}\\ \text{of treated plot}\end{array}\right) - \left(\begin{array}{l}\text{N uptake (kg ha}^{-1}\text{)}\\ \text{of control plot}\end{array}\right)}{\text{N (kg ha}^{-1}\text{) applied}}$$

$$\text{Harvest index (\%)} = \frac{\text{Grain yield (kg ha}^{-1}\text{)}}{\text{Biological yield (kg ha}^{-1}\text{)}} \times 100$$

$$\text{Sterility (\%)} = \frac{\text{Chaffy grains panicle}^{-1}}{\text{Spikelets (grains + chaffy grains) panicle}^{-1}} \times 100$$

Table 1. Effect of split application of nitrogen on grain yield and its attributes of irrigated rice (mean of 2001-2002)

Treatments	Panicles (no. m^{-2})	Panicle weight (g)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Harvest index (%)	Sterility (%)
T_1-Control	117.3	1.58	2.01	2.82	41.6	15.2
T_2-1/2 B+1/4 MT+1/4 PI	142.7	1.97	3.30	4.81	40.7	12.3
T_3-1/3 B+1/3 MT+1/3 PI	188.8	2.40	3.84	5.52	41.1	11.9
T_4- 1/2 MT 1/2 PI	216.9	2.89	4.51	6.58	40.7	12.0
T_5 1/3 MT+1/3 PI +1/3 F	223.9	2.97	45.0	6.83	39.7	12.5
T_6-1/3 7DAT+1/3MT+1/3PI	227.0	2.99	4.88	7.45	39.6	12.1
T_7 –LCC	224.1	2.97	4.65	7.03	39.8	11.8
CD (P=0.05)	6.5	0.13	0.31	0.56	1.3	2.3

B- basal, MT-maximum tillering, PI – panicle initiation and F- flowering
DAT-days after transplanting
LCC-leaf colour chart

and PI. Similar effects have also been observed on straw yield.

The N content in grain and straw increased significantly with N application (Table 2). The N content in grain & straw was reduced significantly where 50% N was applied basally as compared to its top dressing at various growth stages. The N content in grain and straw were almost similar where N was top dressed either in 3 splits or applied by leaf colour chart.

Nitrogen application resulted significant increase in N uptake over control during both the years (Table-2). Basal application of nitrogen N (1/2 or 1/3) resulted significant reduction in total N uptake as compared to top dressing of nitrogen in two or three splits at various growth stages. The highest total N uptake of 105.94 kg ha^{-1} was recorded with 3 splits (T-6) which showed an increase of 71.91 and 44.50 kg^{-1} ha over control (T_1) and recommended practice of N application (T_2), respectively. The increase in N uptake was mainly due to increase in grain and straw yield accompanied by higher N content in grain and straw. These results are in agreement with those of Ramamurthy *et al.* (1997) Ladha *et al.* (1998) and Anonymous (2001).

Nitrogen utilization efficiency expressed in terms of agronomic efficiency, physiological efficiency

Table 2. N-Concentration, N-uptake and N-use efficiency (NUE) as influenced by time of nitrogen application for irrigated rice (Mean of 2001-2002)

Treatments	N-content (%)		Total N-uptake (kg ha^{-1})	Agronomic efficiency (kg grain kg^{-1} N applied)	Physiological efficiency (kg grain kg^{-1} N uptake	Nitrogen utilization efficiency (kg N uptake kg^{-1} N applied)
	Grain	Straw				
T_1-Control	1.23	0.31	34.03	-	-	-
T_2-1/2B+1/4 MT+1/4PI	1.35	0.35	61.44	12.91	47.14	27
T_3-1/3B+1/3 MT+1/3PI	1.42	0.38	75.20	18.31	44.47	41
T_4- 1/2 MT 1/2 PI	1.41	0.42	91.68	24.98	43.33	58
T_5 1/3 MT+1/3PI+1/3F	1.43	0.45	93.37	24.95	42.04	59
T_6-1/3 7DAT+1/3MT+1/3PI	1.45	0.47	105.94	28.74	39.97	72
T_7 –LCC	1.45	0.45	99.38	26.44	40.46	65
CD (P=0.05)	0.05	0.03	7.05	1.54	2.51	13

B- basal, MT-maximum tillering, PI – panicle initiation and F- flowering
DAT-days after transplanting
LCC-leaf colour chart

and nitrogen utilization efficiency is presented in Table 2. The nitrogen utilization efficiency and agronomic efficacy increased with split applications after seedling establishment as compared to split application starting from basal, where as reverse was true with physiological efficiency. The highest values of agronomic efficiency (28.74 kg grain kg^{-1} N applied) and nitrogen utilization efficiency (72 kg N, kg^{-1} N applied) were recorded when N was applied in three equal splits i.e. 1/3 at 7 DAT + 1/3 at MT+ at PI. The higher NUE with 1/3rd split application of total fertilizer N at 7 DAT may be due to better translocation, distribution and remobilization of absorbed N in different plant organs *i.e.* flag leaf and spiklets with which N used in CO_2 fixation (Ladha *et al.* 1998). The results are in conformity with those of Duraisami *et al.* (2001).

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