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Effect of nitrogen Management practices on yield, economics and nitrogen use efficiency in lowland rice

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ABSTRACT
A Field experiment was conducted during kharif season of 2015 and 2016 at the Crop Research Station, Ghaghraghat, Bahraich. U.P. Application of nitrogen based on leaf colour chart was found significantly superior in terms of growth and yield attributes, grain and straw yield, and nitrogen use efficiency as compared to N - management based on split application. Application of 20% recommended dose of nitrogen (RDN) basal alongwith 80% RDN based on leaf colour chart reading - 4 (T_7) produced significantly highest grain (53.32 q ha^{-1}) and straw yield (71.92 q ha^{-1}) followed by 20% RDN as basal + rest 80% RDN based on LCC-5 (T_8) and LCC-3 (T_6). The percent increased in grain yield due to N-management based on LCC-4 was recorded to the tune of 67.93, 37.06, 31.16, 44.49, 22.43, and 13.27 with treatment T_2, T_3, T_4, T_5, respectively. Nitrogen management based on LCC- 4 (T_7) also gave the highest net income (Rs. 42580 ha^{-1}) and benefit cost ratio (2.53) followed by LCC-5 (T_8). This treatment also gave the higher nitrogen use efficiency in terms of agronomic efficiency (28.87 kg grain Kg^{-1} N), recovery efficiency (65.25%), physiological efficiency (44.25 Kg grain Kg^{-1} N) and factor of productivity (44.42).

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INTRODUCTION

Rice is one of the oldest and widest grown food crops of the world. It is also the major source of nutrition for more than half of the rice eating population. In India, it is cultivated in about 44 million hectare land with the production of 104 million tones. At current rate of population growth of 1.8% per annum, the rice requirement of the country is estimated to be around 140-160 million tones by 2020. Uttar Pradesh, the 2nd largest rice producing state of the country with an area of 5.9 million hectare. Average rice productivity of the state is about 2.8 t ha^{-1} which is considered to be the low. Among the various agronomic factors for low productivity of rice, optimum amount of fertilizer nitrogen application is one of the most potent factors for obtaining higher productivity of rice. Nitrogen plays an important role to boost up the productivity of rice. The nitrogen use efficiency in lowland rice ranged from 30-35% and seldom exceeds 50%. Rice crop needs large amount of N (15-25 kg N $tone^{-1}$ of rice yield) as crop responses is fast and high. Excessive N- application leads to an inefficient N - acquisition by the crop as contributes to contamination of surface and ground water, volatilization of ammonia and emission of green house gases viz, nitrous and nitric oxides to the atmosphere and increases "the far and depression" (Wilcox, 1930) in rice crop. Conversely, inadequate N- Supply results in reduced yield and profit.
Farmers normally apply N fertilizers at fixed time advocated N - split schedule (Pillai *et al*., 1993) in 1:2:1 or 2:1:1 ratio at basal, extreme tillering and panicle initiation stages, respectively without taking into account whether the plant really requires N at that time which was lead to loss or may not be found sufficient enough to harmonize nitrogen supply with actual crop N- demand (Ladha *et al*., 2000).
There is enormous variability in soil nutrient status or supply from field to field and /or farm-to-farm. This makes blanket recommendation of fertilizer application highly ineffective for lowland rice situations. Thus, site specific nitrogen management approach is warranted (Natarajan *et al.*, 1999). Application of nitrogen as per need of the crop and soil N-supply will enhance N- use efficiency in rice. Hence, use of leaf colour chart (LCC) help farmers to determine nitrogen demand of rice crop and apply nitrogen as and when needed, taking into account the variation in indigenous soil N-supply.
Plant need based tools for real time nitrogen management in rice through use of leaf colour chart (LCC) is becoming progressively popular among the farmers. It has been observed that more than 60% of applied

nitrogen is lost due to lack of harmonization between nitrogen demand and nitrogen supply (Yadav *et al*., 2004).

Leaf colour chart (LCC) can be used for adjustment of fertilizer N-application based on actual plant status (Balasubramaniam *et al.,* (1999). Need based N-application would result in greater agronomic efficiency of nitrogen fertilizer than the commonly practices method (Hussain *et al*., 2000).

Information on nitrogen management through leaf colour chart (LCC) in lowland rice is meager. There is, therefore need to manage costly input like nitrogen. Hence, an attempt was thus, made to study the effect of various nitrogen management practices including Leaf colour chart (LCC) on lowland rice.

MATERIALS AND METHODS

A field experiment was conducted during kharif 2015 and 2016 at the Narendra Dev University of Agric & Tech. Crop Research Station, Ghaghraghat, Bahraich. The soil of the experimental site was sandy loam in texture with pH 7.9, organic carbon 0.74 %, available nitrogen 260.3 Kg ha^{-1}, phosphorus 26.1 Kg ha^{-1} and potash 136.4 Kg ha^{-1}. The experiment was conducted with eight treatments replicated four times in randomized block design. The treatments details are given in Table 1. All the treatments received a common dose of each phosphorus and potassium @ 40 kg ha^{-1} supplied as single super phosphate and muriate of potash, respectively. A common dose of $ZnSo_4$ @ 25 kg ha^{-1} was applied to all the treatments as basal. Twenty one days old seedlings of rice variety "NDR-359" was transplanted in first week of July in both the years using 2-3 seedling $hill^{-1}$ at hill spacing of 20x10 cm. The nitrogen in treatment 2 to 5 was applied as per scheduled given in table 1. The leaf color chart (LCC) readings were started from 15 day after transplanting at weekly interval, the nitrogen @ 96 Kg ha^{-1} was applied in three equal splits (32.0, 32.0 32.0Kg ha^{-1}) whenever LCC readings were achieved below the critical limits of LCC -3, LCC-4 and LCC-5. The plant samples (3 hills each time) were uprooted at 75 DAT for estimating biomass and leaf area index (LAI). Yield attributes like panicle length, panicle weight, grains $panicle^{-1}$, and grain weight $panicle^{-1}$ were recorded from 10 panicles collected randomly from each plot. The sample for counting 1000- grain weight was collected plot wise at harvest and later utilized for N-content. Uptake of nitrogen (kg ha^{-1}) was calculated by multiplying grain/straw yield Kg ha^{-1} into N-content and divided by 100. The physiological efficiency, recovery efficiency, agronomic efficiency and factor productivity of applied nitrogen for treatment T_1 to T_8 were computed using following formula as advocated by Cassmam *et al.*, (1996 b).

$$\text{Physiological efficiency (PE)} = \frac{\text{Increase in grain yield (kgha}^{-1}\text{) due to N}}{\text{Increase in plant N uptake (kgha}^{-1}\text{) due to N}}$$

$$\text{Agronomic efficiency (AE)} = \frac{\text{Increase in grain yield (kgha}^{-1}\text{) due to N}}{\text{Applied N (kgha}^{-1}\text{)}}$$

$$\text{Recovery efficiency (RE)} = \frac{\text{Increase in uptake of N (kgha}^{-1}\text{) due to N}}{\text{Applied N (kgha}^{-1}\text{)}}$$

$$\text{Factor productivity (FPn)} = \frac{\text{Grain yield (Kgha}^{-1}\text{) in control plot}}{\text{Applied N (kgha}^{-1}\text{)}}$$

During kharif season (2015 to 2016), the timing and quantity of N applied in all the treatments, were same. Hence, the data obtained for 2 years in the study were pooled for the 2 kharif seasons, and the mean data are presented in this paper.

RESULTS AND DISCUSSIONS

Dry matter production and LAI

Dry matter production of rice recorded at 90 days of transplanting was affected significantly due to various nitrogen management schedule (Table 1). Application of 20% RDN at sowing and rest nitrogen applied on the basis of LCC-4 (T_7) reading produced significantly highest dry matter of rice (57.6qha^{-1}) as compared to rest of the treatment. Crop fertilized with 20% nitrogen as basal and rest nitrogen applied on the basis of LCC-3 (T_6) being at par with nitrogen applied in 3 splits i.e. 30% RDN at sowing + 40% RDN - TD at tillering and 30% RDN TD at PIS (T_4) . Higher yield with N management based on LCC-3 or LCC-4 could be attributed to supply of nitrogen as per demand of rice crop resulted higher photosynthesis due to higher leaf area index (LAI) i.e. 6.43 and 6.22, respectively in above treatment as compared to rest of the treatments, which failed to supply of nitrogen to crop as per its demand caused poor nitrogen use efficiencies consequently reduced leaf area index (LAI) and dry matter production (Table 1). Similar higher dry matter yield with nitrogen management as per LCC -4 has been reported by Stalin *et al*., (2008).

Yield attributes

Data pertaining to yield attributes like panicles m^{-2}, panicle length, panicle weight, grains $panicle^{-1}$ and 1000-grain weight were presented in Table 2. Various nitrogen management practices affected yield attributes significantly. LCC based nitrogen management practices (T_6, T_7 and T_8) resulted significantly higher values of all the yield attributes as compared to either 3 or 2 split application. Significantly highest values of yield attributes were recorded with 20% of recommended dose nitrogen (RDN) applied as basal and rest 80% nitrogen based on LCC 4 (T_7) followed by treatment (T_8 and T_6). Among the split application, application of 30% RDN as basal + 40% RDN top dressing (TD) at tillering +30% RDN -TD at panicle initiation (T_4) recorded higher values of all yield attributes as compared to rest split application treatments. Higher values of yield attributes with LCC based nitrogen management could be attributed to need based nitrogen supply to crop utilized efficiently resulted in improvement in growth and yield attributes.

Grain and straw yield

The N-management based on leaf color chart (LCC-3, LCC-4 and LCC-5) produced significantly highest yield as compared to nitrogen management based on conventional blanket split application of nitrogen (Table 2). Among the leaf colour chart based N-Management, LCC-4 based nitrogen application (T_7) produced significantly highest grain (53.32 q ha^{-1}) and straw (71.92 q ha^{-1}) yield followed by LCC-5 based N-application i.e. 47.07 q ha^{-1} grain and straw yield 61.95 q $^{-1}$ ha and LCC-3 based N-management (T_6) with grain (43.55 q ha^{1}) and straw yield (55.40 q ha^{-1}). Among the split application of nitrogen, three splits either 30% RND as basal + 40% RDN - top dressed at tillering + 30% RDN - top dressed at panicle initiation stage (T_4) or 50% RDN as basal + 25% RDN top dressed at tillering + 25% RDN top dressed at panicle initiation stage (T_3) were on par but produced significantly higher yield over two split of nitrogen (T_2). The percent increase in grain yield by LCC-4 based nitrogen application (T_7) was recorded to the tune of 67.93, 37.06, 31.16, 44.49, 22.43 and 13.27 as compared to T_2, T_3, T_4, T_5, T_6 and T_8, respectively.

The higher grain and straw yield with LCC based N-management was mainly attributed to higher values of growth and yield attributes owing to supply of nitrogen as per demand of the crop, utilized the nitrogen efficiently, and transferred the photosynthets to sink. Similar higher grain and straw yield of rice with N-management based on LCC-4 was recorded by Islam *et al*., (2009), Krishna Kumar and Haefele (2013).

Nitrogen uptake

Total uptake of nitrogen through grain + straw was affected significantly due to different nitrogen management treatments (Table 3). The total uptake of N was ranged from 51.7 Kg N ha^{-1} to 103.96 Kg N ha^{-1} with various N-management treatments. However, the lowest nitrogen uptake i.e. 22.6 $Kgha^{-1}$ was recorded with no NPK treatment. Significantly highest nitrogen uptake (103.9 kg ha^{-1}) was recorded with 20% nitrogen applied as basal + 80% nitrogen based on LCC-4 (T_7) followed by 20% nitrogen as basal and rest 80% nitrogen on the basis of LCC-5 (T_8). Nitrogen management on the basis of leaf colour chart utilized the applied nitrogen efficiently as compared to blanket split application treatments resulted higher nitrogen uptake.

The higher uptake of nitrogen with LCC based N management was due to need based supply of nitrogen to plant. These findings are in agreement with that Deka Medhi and De Datta (1996), Stalin *et al*., (1999) and Stalin et *al*., (2008).

Nitrogen use efficiency parameters

The factor productivity for applied N (FP_N) is a useful measure of N use efficiency because it provides as interactive index of total economic output (grain yield) relative to the utilization of N from the indigenous soil N supply and applied N (Cassman *et al*., 1996a). It reflects both agronomic efficiency (AE) and the balance between the indigenous soil N supply and applied N. The AE is a function of both physiological efficiency (PE) and recovery efficiency (RE) of applied N. The PE ranged from 38.57 to 44.25. The poor efficiency in some treatments indicated that factor other than N-supply might have affected the N-utilization. The RE values were highest in treatment where N- management was based on LCC-4 (65.27) (T_7) followed by N management based on LCC-5 (57.38) (T_8), and N-management based on LCC-3 (53.75) (T_6). The AE varies from (10.9 to 28.87). Improved timing and formulation of applied N could improve the AE to some extent. The average grain yield of 18.67 q ha^{-1} and N uptake of 22.6 kg ha^{-1} was recorded under control which represents the indigenous soil N supply. The FP_N ranged from 26.45 to 44.42.

It is possible to increase FP_N by increasing the amount of uptake and utilization of indigenous N sources, and by increasing the efficiency of applied N to produce grains. In this context, LCC based nitrogen management will improve the N-use efficiency of lowland rice system, thus FP_N will serve as a useful parameter for identifying the constraints.

Table1: Treatments details

Treatment No.	Details	Total N-applied (Kg ha^{-1})
T1	No NPK	-
T2	50% RDN-B+50% RDN-TD at tillering	120
T3	50% RDN-B+25% RDN-TD at tillering + 25% RDN-TD at PIS	120
T4	30% RDN-B +40% RDN - TD at tillering +50% RDN - TD at PIS	120
T5	25%RDN-B +75% RDN-TD at Tillering	120
T6	20% RDN-B + 80% RDN - based on LCC-3 (N- applied at 18, 28 and 42 DAT)	120
T7	20% RDN –B + 80% RDN - based on LCC-4 (N-applied at 14, 21 and 35 DAT)	120
T8	20% RDN- B + 80% RDN - based on LCC-5 (N-applied 14, 21 and 28 DAT)	120

TD - Top dressed, T- tillering, PIS - Panicle initiation stage, RDN - Recommended dose of nitrogen, LCC- Leaf Colour Chart, DAT - Days after Transplanting, B-basal

Table 2: Growth and yield attributes of rice as affected by different N-management treatments (mean of 2 years)

Treatment	Dry matter accumulation of rice at 90 DAT	Leaf area index (LAI) at 75DAT	Panicles m^{-2}	Panicle Length (cm)	Panicle weight (g)	Grains panicle^{-1} (No)	1000-grain weight (g)	Grain yield (qha^{-1})	Straw yield (qha^{-1})
T1	17.69	3.82	285	22.72	2.40	65.4	24.95	18.67	22.12
T2	33.20	4.96	331	25.10	2.69	69.6	25.96	31.75	41.50
T3	40.92	5.50	341	25.60	2.98	73.2	25.70	38.90	51.15
T4	41.96	5.73	344	25.80	3.10	74.3	26.05	40365	52.45
T5	38.48	5.10	335	25.42	2.87	70.4	25.75	36.90	48.10
T6	44.56	6.11	344	26.10	3.23	76.7	26.10	43.55	55.40
T7	57.60	6.43	379	26.82	3.61	78.3	26.35	53.32	71.92
T8	49.32	6.22	354	26.01	3.43	75.6	25.90	47.07	61.95
CD(P=0.05)	7.85	0.19	19.4	0.54	0.17	2.1	0.39	3.21	2.80

Table 3: Economics, agronomic efficiency, recovery efficiency, physiological efficiency and factor productivity as affected by different nitrogen management practices.

Treatments	Gross income (Rsha^{-1})	Net income (Rs ha^{-1})	BCR	Grain yield (qha^{-1})	Total N-uptake (kgha^{-1})	Total N applied (Kgha^{-1})	AE_N (kg grain kg^{-1} N	RE_N (Kg N uptake kg^{-1} N)	PE_N (kg grain Kg^{-1} N uptake)	FP_N
T1	24444	1244	1.05	18.67	22.6	-	-	-	-	-
T2	41763	14282	1.51	31.75	54.7	120	10.9	26.75	40.74	26.45
T3	51183	23473	1.84	38.90	68.7	120	16.85	38.41	43.88	32.40
T4	53435	25725	1.92	40.65	73.2	120	18.31	42.17	43.43	33.86
T5	48530	20820	1.29	36.90	59.0	120	15.19	30.33	43.43	30.74
T6	57208	29866	2.09	43.55	87.1	120	20.73	53.75	38.57	36.28
T7	70246	42580	2.53	53.32	100.9	120	28.87	65.25	44.25	44.42
T8	61935	33946	2.21	47.67	91.46	120	24.16	57.38	42.11	39.71
CD (P=0.05)	-	-	-	3.21	11.62	-	-	-	-	-

AE_N - Agronomic efficiency, RE_N - Recovery efficiency, PE_N – Physiological efficiency, FP_N – Factor productivity

Economics

Nitrogen management based on leaf colour chart (LCC) gave higher gross income and net income as compared to nitrogen management based on split application. The maximum gross income (Rs. 70246 ha^{-1}) and net income (Rs. 42580 ha^{-1}) recorded with 20% N as basal and rest N applied as per LCC-4 (T_7) which was followed by N, management on the basis of LCC-5 (T_8) with gross income of (Rs. 61935 ha^{-1}) and net income (Rs. 33946 ha^{-1}) with benefit: cost ratio (2.21) also affected followed the similar trend as in case of gross income and net income. Among the split application treatments rice received 30% RDN as basal + 40% RDN TD at tillering and 30% RDN at PIS (T_4) gave the highest net income, and benefit : cost ratio. Three splitting of nitrogen application was found statistically superior over 2 splits application.

Higher yield with N management based on LCC was found to be the main reason having high gross income, net income and benefit: cost ratio.

Nitrogen management through leaf colour chart (LCC) was found superior to split application in terms of net income and benefit: Cost ratio. However, 3 splitting i.e. 30% RDN basal + 40% RDN TD at tillering + 30% RDN - TD at PIS was found superior to rest split N-treatments. Under lowland rice cultivation, the nitrogen application should be followed i.e. 20% of recommended dose of nitrogen applied as basal and rest 80% nitrogen as per leaf color chart (LCC-4) to obtain higher net income and benefit: cost ratio.

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