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Need-based fertilizer nitrogen management using leaf colour chart in hybrid rice (*Oryza sativa*)

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ABSTRACT

Field experiments were conducted during 2006–08 to study the response of hybrid rice cultivar PHB 71 to fertilizer N and to study the possibility of improving N-use efficiency by affecting fertilizer N as per need of the crop as guided by leaf colour chart (LCC). Treatments included six rates of N application (0, 60, 90, 120,150 and 180 kg/ha) applied in three equal splits at fixed growth stages. The two need-based N management treatments comprised of application of 20 kg N / ha as basal dose and application of 30 kg N /ha whenever greenness first fully opened leaf from the top was less than shade 4 or 5 on the LCC. Hybrid rice PHB 71 showed significant response to application of N up to 120 kg N /ha applied in three equal split doses. Beyond this level fertilizer N-use efficiency was significantly reduced. The LCC shade 4 proved better than LCC shade 5 for guiding real time N management and achieving higher N-use efficiency. Application of 80–110 kg N /ha using threshold LCC shade 4 inclusive of 20 kg N /ha as basal dose produced grain yield of rice which was at par with the application of 120 kg N /ha applied in three equal split doses.

Key words: Hybrid rice, Leaf colour chart, Nitrogen management, N-use efficiency

Improving fertilizer nitrogen (N)-use efficiency in rice is vital to achieve and sustain high crop yields and reduce N losses via ammonia volatilization, leaching of nitrate and denitrification. Fertilizer N is an expensive input but farmers have a tendency to apply N in large amounts to minimize the risk of deficiency. Efficiency of applied N generally declines with increased fertilizer use, and seldom exceeds 40 % (Cassman *et al.* 1993; Singh and Singh 2003). The requirement of rice for N fertilizer can vary greatly from field to field, season to season, and year to year because of high variability among fields, in soil N-supplying capacity (Cassman *et al.* 1996; Dobermann *et al.* 2003) and crop growth due to differences in climate factors (Kropff *et al.*1993).

Rice hybrids with short-duration and higher yield potentials are being developed to replace the inbred cultivars. Nitrogen requirement of hybrid rice cultivars is expected to be different from that of inbred rice cultivars. However, limited information is available on the N requirement of hybrid rice. To enhance N-use efficiency in the hybrid rice it is necessary to know the actual amounts of N required and the right time of its application. The real time N management approach can help avoid application of excessive amount of N fertilizer by matching time of fertilizer application with plant need. The guidelines evolved using leaf colour chart (LCC), can help apply crop demand-driven site-specific N applications and result in high productivity with profits.The need based N management in hybrid rice using LCC has the potential of replacing the blanket uniform fertilizer rates recommended across vast areas. It has already been found very useful in efficiently managing fertilizer N in inbred rice cultivars (Singh *et al.* 2007a, Singh *et al.* 2007). In the present study two different approaches of managing of N in hybrid rice were evaluated for achieving higher N use efficiency: (i) application of fertilizer N at fixed critical growth stages of rice, and (ii) need-based N management using LCC to achieve synchrony between crop N needs and N supply.

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MATERIALS AND METHODS

Field experiments were conducted for three years (2006 –08) with hybrid rice cultivar PHB 71 at Punjab Agricultural University Research Farm at Ludhiana (30^0 56’ N, 75^0 52’ E, and 247 m above the mean sea level) located in the Indo-Gangetic plain in the Punjab state of India. The soil of the experimental field was a Fatehpur loamy sand (Typic Ustipsamment) containing 804 g /kg and, 89 g /kg silt, 107 g/ kg clay, 4.0 g /kg organic C (Walkley and Black 1934), with *p*H 6.82, EC 0.17 dS/m, CEC 7.8 cmol (p+) /kg, Olsen P 5.9 mg/ kg (Olsen *et al*. 1954) and ammonium acetate extractable K 36.6 mg/kg. Under average climatic conditions, the area receives 760 mm of mean annual rainfall, about 80% of which occurs from July to October. Rainfall received during the rice-growing season (July to October) was 503, 350 and 960 mm during 2006, 2007 and 2008, respectively. The mean monthly temperatures during the rice growing seasons during the three years varied from 24°C to 34 °C.

The field experiments were laid out in a randomized block design with three replications. The treatments included six rates of N application (0, 60, 90, 120,150 and 180 kg/ha as urea), and two need-based N management treatments in which after applying a basal dose of 20 kg /ha, fertilizer N was applied using LCC threshold shades of 4 and 5. The colour of the fully expanded leaf from the top was compared with LCC every 7 to 10 days starting 15 days after transplanting (DAT). A fertilizer N dose of 30 kg N /ha was applied every time leaf colour was less green than LCC shade 4 or 5. Need-based fertilizer N applications were made upto initiation of flowering. Time and amount of fertilizer N applied in LCC treatments during the three years are described in Table1.

Field preparation for rice included two disc ploughings in dry soil followed by two puddlings. Thirty- day- old seedlings of hybrid rice cultivar PHB 71 were transplanted manually at 15cm × 20 cm in the fourth week of June. All the treatment plots received uniform dose of 13 kg P /ha, 25 kg K/ ha and 50 kg zinc sulphate (heptahydrate). Whole of the P, K and Zn was incorporated into the soil with the last tillage operation before transplanting. Fertilizer N in fixed N dose treatments was applied in three equal splits at transplanting, and three and six weeks after transplanting. The crop was irrigated daily during the first two weeks and thereafter as needed to prevent the soil surface from being without overlying water for more than two days. Rice was harvested manually in the third week of October. A sub- sample of grain and straw was collected for determining moisture content. Grain yield was expressed on the basis of 140 g /kg water content and straw yield was expressed on an oven dry weight basis.

Grain and straw samples were analyzed for total N content by a micro Kjeldahl method (Yoshida *et al.* 1976). N uptake was calculated by multiplying grain yield and straw yield by N content.

Recovery and agronomic efficiency of added N were calculated as:

Recovery efficiency (RE) (%)

$$RE = \frac{N\ uptake\ in\ fertilized\ plot\ (kg/ha) - N\ uptake\ in\ no\ N\ control\ plot\ (kg/ha)}{Fertilizer\ N\ applied\ (kg/ha)}$$

Agronomic efficiency (AE) (kg grain/kg N applied)

$$AE = \frac{Grain\ yield\ in\ fertilized\ plot\ (kg/ha) - Grain\ yield\ in\ no\ N\ control\ plot\ (kg/ha)}{Fertilizer\ N\ applied\ (kg/ha)}$$

Analysis of variance (ANOVA) was performed using IRRISTAT version 5.0. Least significance difference (LSD) at a 0.05 level of probability was used to test the significance

Table 1 Time (days after transplanting) and amount of fertilizer application in leaf colour chart treatments to hybrid rice cultivar PHB 71 during 2006–08

Treatment no.	Fertilizer N applied (kg/ha) at days after transplanting								Total N applied (kg/ha)
2006									
	0d	21d	30d	42d	51d				
T_4 (N120)	40	40		40					120
T_7 (LCC 4)	20	30			30				80
T_8 (LCC 5)	20	30	30	30					110
2007									
	0d	15d	21d	29d	35d	42d	50d		
T_4 (N 120)	40		40			40			120
T_7 (LCC 4)	20	30			30				80
T_8 (LCC 5)	20	30	30	30	30	30	30		200
2008									
	0d	15d	23d	30d	37d	42d	56d	66d	
T_4 (N 120)	40		40			40			120
T_7 (LCC 4)	20	30				30	30		110
T_8 (LCC 5)	20	30	30	30	30	30	30	30	230

of differences among treatment means.

RESULTS AND DISCUSSION

Grain yield

Grain yield of hybrid rice increased with the application of fertilizer N and significant increase was observed up to 120 kg N /ha, irrespective of the year (Table 2). Application of 120 kg N /ha increased the grain yield by 65.9, 64.6 and 54.4 % over no N control during 2006, 2007 and 2008, respectively. A further increase in N rate did not cause significant improvement in the rice yield compared to 120 kg N/ha. Rice generally responds to application of N upto 120 kg/ha in the Indo-Gangetic plains of India (Singh and Singh 2001). Under cool climate of Srinagar, Kour *et al.* (2007) reported that hybrid rice PHB 71 responded significantly to the application of fertilizer N up to 150 kg /ha. The lower N response of hybrid rice in the present study than that observed by Kour *et al.* (2007) could be due to differences in soil and climatic conditions, which affected N utilization and losses of N.

Real time N management using LCC threshold value of 4 with a basal dose of 20 kg N /ha produced grain yield, which was statistically similar (mean yield of 6.32 versus 6.39 tonnes/ ha) to that obtained with applying 120 kg N /ha applied in three equal split doses (Table 2). Fertilizer N using LCC threshold value of 5 resulted in significantly higher yield in 2006 but yields were similar to that achieved with LCC 4 during 2007–08. These data suggest that leaf colour of hybrid rice PHB 71 is almost similar to that of inbred lines. Earlier, Singh *et al.* (2007a) and Singh *et al.* (2007) found that LCC 4 with a basal dose of 20 kg N/ha can be used for efficient N management in several inbred rice cultivars. The straw yield of rice in different treatments followed a trend similar to that of grain yield (Table 2).

Use of LCC with a critical shade 4 for N management in hybrid rice resulted in the application of 80-110 kg N /ha, thus effecting a saving of 10-40 kg N /ha compared to application 120 kg N /ha in three equal splits at fixed growth stages, depending on the variability of soil and climate (Table 2). Management of N using LCC shade as threshold greenness of leaves 5 resulted in the application of high rates of N (110 to 230 kg N /ha) during the three years of the study. Like with inbred rice cultivars (Singh *et al.* 2007a), LCC threshold value 4 seems to be optimum for need-based N application to hybrid rice.

Benefit: cost ratio of following different N management strategies as worked out during different years are listed in Table 2. Application of 120 kg N /ha in three split dose could produce the highest yield level but with benefit-cost ratio varying between 37.3 and 38.1. On the other hand when need based N management strategy based on LCC threshold 4 was followed, similar yield levels were achieved with benefit cost ratios varying from 44.2 to 55.8 indifferent years. Then data confirm that need based N management strategy can result in both high yield and higher profits for the farmer.

Nitrogen uptake

A perusal of data in Table 3 shows that total N uptake by rice increased with the increasing levels of N in all the three years. The increase in N uptake was, however, significant up to 120 kg N/ha during all the three years (Table 3). The uptake of N increased by two-fold with the application of 120 kg N/ha over no N control. Total N uptake generally followed the trend as observed with grain yield. Thereby confirming that grain yield of rice was delivered by the amount of N taken by the crop. Kour *et al.* (2007) reported that the uptake of N increased significantly up to 150 kg N/ ha. In 2006, total N uptake in LCC 4 treatment was significantly lower than in LCC 5 and 120 kg N /ha treatments, most likely due to lower grain yield. In 2007 and 2008 rice

Table 2 Effect of fertilizer N rate and use of leaf colour chart on grain yield, straw yield and N uptake of hybrid rice cultivar PHB 71 during 2006-08

Treatment no.	Total N applied	Grain yield (tonnes/ha)			Straw yield (tonnes/ha)			Benefit:cost rario**		
	(kg/ha)	2006	2007	2008	2006	2007	2008	2006	2007	2008
T_1	0	4.34	3.87	3.62	5.63	5.81	4.78	–	–	–
T_2	60	6.36	5.17	4.87	7.74	7.76	6.93	67.1	60.5	66.4
T_3	90	7.03	6.00	5.15	8.03	8.81	7.88	49.5	46.8	46.8
T_4	120	7.20	6.37	5.59	9.17	8.94	7.88	38.0	37.3	38.1
T_5	150	7.59	6.58	5.47	8.91	9.93	8.70	32.1	30.8	29.8
T_6	180	7.56	6.43	5.79	9.27	9.64	8.55	26.6	25.1	26.3
T_7 (LCC 4)	*80, 80,110	6.67	6.35	5.95	7.67	9.95	7.50	52.1	55.8	44.2
T_8 (LCC 5)	*110, 200, 230	7.82	6.73	5.45	8.71	10.83	9.35	44.5	23.6	19.4
LSD (P=0.05)		0.73	0.55	0.44	0.593	0.830	0.414			

*Total fertilizer N applied during 2006, 2007 and 2008, respectively

**Value of the grain output (₹ 6 500, 7 300 and 8 500 /tonne during 2006, 2007 and 2008 respectively) divided by cost of fertilizer N (₹ 10.26, 10.39 and 10.39/kg N during 2006, 2007 and 2008 respectively)

Table 3 Effect of fertilizer N rate and use of leaf colour chart on nitrogen use efficiency and benefit: cost ratio of hybrid rice cultivar PHB 71 during 2006–08

Treatment no.	Total N applied (kg/ha)	Total N uptake (kg/ha)			Agronomic efficiency (kg grain/kg N applied			Recovery efficiency of N (%)		
		2006	2007	2008	2006	2007	2008	2006	2007	2008
T_1	0	60.0	59.3	52.4						
T_2	60	95.6	89.5	77.4	33.7	21.7	20.8	59.3	50.5	41.7
T_3	90	112.7	109.3	86.8	29.9	23.6	17.0	58.6	55.6	38.2
T_4	120	126.7	119.1	101.4	23.8	20.8	16.4	55.6	49.9	40.8
T_5	150	137.7	131.1	107.7	21.7	18.1	12.3	51.8	47.9	36.8
T_6	180	147.6	131.4	116.1	17.9	14.2	12.0	48.7	40.1	35.4
T_7 (LCC 4)	*80, 80,110	101.7	116.2	106.4	29.1	31.0	21.2	52.2	71.2	49.1
T_8 (LCC 5)	*110, 200, 230	129.6	141.2	119.4	31.6	14.3	8.0	63.3	41.0	29.1
LSD P=(0.05)		11.7	12.4	8.3	2.8	2.6	3.1	7.1	9.2	5.9

*Total fertilizer N applied during 2006, 2007 and 2008 respectively

seasons, using LCC 4 as critical shade the values of N uptake were similar to that with treatment receiving 120 kg N /ha (Table 2). In 2008, the N uptake values were significantly higher with the addition of 180 kg N /ha over the treatments receiving 120 kg N /ha applied in three equal split doses at three fixed timings. However, N uptake values in the treatment to which fertilizer was applied using LCC as the threshold 5 were significantly higher than that obtained with LCC 4 as the threshold (Table 3).

Fertilizer N- use efficiency

Agronomic efficiency (AE) was maximum at 60 kg N / ha and then decreased with increasing N level up to 180 kg N /ha during 2006–08 (Table 3). During 2007, AE (kg grain/ kg applied N) was maximum at 90 kg N /ha and then gradually decreased with increasing N rate up to 180 kg N /ha. At 120 kg N /ha, AE ranged from 16.4 to 24.2 (mean value of 20.5) kg grain/ kg N. Since grain yield response to applied N follows law of diminishing returns, a number of workers (Kour *et al.* 2007, Singh *et al.* 2007a, Singh *et al.* 2007b) have reported a decreasing trend in AE with increasing N rate due to higher values of AE at lower N rates. The AE was higher in 2006 than in 2007 and 2008, possibly due to better climatic conditions which helped to achieve high yields. Need-based N application using LCC 4 and LCC 5 resulted in higher AE compared to that obtained with the application of 120 kg N/ ha during 2006 (Table 3). Scheduling of fertilizer using LCC with a critical shade 4 resulted in marked increase in AE compared to optimum N rate of 120 kg N/ ha. The values of AE ranged from 21.2 to 31.4 (mean value 27.3) kg grain/ kg N, which was significantly higher than that achieved with 120 kg N /ha. Since use of LCC with a threshold value of 5 resulted in the application of very high N rates, particularly during 2007–08, values of AE were low.

Like AE, the RE of applied N gradually decreased with increasing N rate with minimum values observed at 180 kg N /ha, except during 2007 (Table 3). In 2007, RE increased from 50.5% at 60 kg N/ha to 55.6% at 90 kg N /ha and then decreased to 40.1% at 180 kg N /ha. The lower values of RE at high N rates are most likely due to greater N losses through leaching, denitrification and ammonia volatilization. At 120 kg N /ha, scheduling of fertilizer N using LCC with a threshold value of 4 resulted in significantly higher RE of 57.8 % (ranged from 49.9 to 71.2%) compared with 120 kg N /ha. The RE was very low with LCC 5 because it resulted in the application of high amount of fertilizer N.

Application of 120 kg N /ha in three equal split doses at 0, 21 and 42 DAT is the optimum N dose for hybrid rice cultivar PHB 71. For hybrid rice PHB 71, use of LCC 4 as the critical shade with a basal dose of 20 kg N /ha worked out to be the best need-based N management option as it helped to achieve grain yield equivalent to that produced by applying 120 kg/ha in three equal split doses with saving of 10–40 kg N /ha and resulting in high values of AE and RE. The need based N management strategy will also lead to profits to the farmers as compared to when 120 kg N /ha was applied at fixed crop growth stages.

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