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Effect of Site Specific Nitrogen Management on Yield, Nitrogen Use Efficiency and Nutrient Uptake in Rice (*Oryza sativa* L.)

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ABSTRACT

A field experiment was conducted on a sandy loam soil during kharif season of 2012 with a view to study the effect of Site specific nitrogen management in rice on nutrient uptake, N use efficiency and grain yield. The leaf colour chart (LCC) and SPAD based N management can be used to optimize N application with crop demand or to improve existing fixed split N recommendations. We conducted a field experiment to determine the LCC and SPAD critical value for N application in irrigated rice. Treatments included 3 LCC based and 3 SPAD based N management contained the combination of three critical levels of LCC shade values (4, 4.5, 5) and three critical levels of SPAD (37, 39 and 41) values with different levels of N application were compared with recommended fertilizer dose (RFD) and soil test crop response (STCR) equation based fertilizer application. Nitrogen was applied in the form of urea as per treatment schedule and the SPAD and LCC assessed at 10 days intervals starting from 15 DAT. Result showd a considerable opportunity to increase yield, N use efficiency (NUE) and nutrient uptake through improved N management with LCC and SPAD values. The critical SPAD value of 41 with 30 Kg N ha^{-1} and critical LCC value of 4.5 with 30 kg N ha^{-1} were found to be suitable for guiding N application to achieve the highest grain yield.

Key words: *Kharif*, Rice, Yield, STCR.

INTRODUCTION

Nitrogen is one of the most limiting nutrients in rice in tropics. Adequate N supply is needed throughout the active growing period of rice. Thus proper N management is very crucial for successful rice production. Rice crop requires large amounts of N (15-25 kg N t^{-1} of rice yield) and crop response is fast and high. Excessive N application leads to an inefficient N acquisition by the rice crop and 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 end depression" [13] in rice crop.

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Conversely, inadequate N supply results in reduced yield and profit. Soil and to a certain extent irrigation water provide N, P and K and it is termed as the indigenous nutrient supply to rice.

There is enormous variability in soil nutrient status or supply from field and / or farm to farm. This makes blanket recommendation highly ineffective for most submerged rice situations. The blanket recommendations of N are developed for large tracts having similar climate and land forms and these vary from 60 to 240 kg ha^{-1} for different parts of Andhra Pradesh. Therefore, field specific approach is warranted [11]. Keeping in view the significance of N on productivity of rice, crop need based fertilizer application, reduce the N losses and also cost of fertilizer and application cost, an attempt has been made to examine the effect of site specific nitrogen management on rice.

In India, rice is cultivated round the year in one or other part of the country. It occupies 42.8 M ha with a production of 95.9 Mt and productivity of 2.23 t ha^{-1}. In Andhra Pradesh, rice is grown in an area of 4.7 M ha with a production of 14.4 M t and productivity of 3.06 t ha^{-1} .

MATERIAL AND METHODS

A field experiment was conducted on a sandy loam soil (Alfisol) at College Farm, College of Agriculture, Rajendranagar, Hyderabad during *kharif* season of 2012 with a view to study the effect of site specific nitrogen management in rice in terms of yield and nutrient uptake by the crop during crop growth period. Experiment was laid out in Randomized Block Design with 3 replications and 8 treatments *viz.*, T_1 (Recommended Fertilizer Dose of NPK i.e. RFD), T_2 (Soil test based N P K application using fertilizer adjustment equations), T_3 (N_{30} basal+ N_{30} if SPAD value is < 37), T_4 (N_{30} basal+ N_{30} if SPAD values is < 39), T_5 (N_{30} basal+ N_{30} if SPAD values is < 41), T_6 (N_{30} basal+ N_{30} if LCC value is < shade 4.0), T_7 (N_{30} basal+ N_{30} if LCC value is < shade 4.5), T_8 (N_{30} basal+ N_{30} if LCC value is < shade 5.0).

The recommended doses of P_2O_5 (60 kg ha^{-1}) and K_2O (60 kg ha^{-1}) were applied uniformly to all the treatments except in T_2.

The initial soil was sandy loam in texture. The physico chemical properties revealed that the soil was slightly alkaline (7.49 pH) in reaction, non saline (0.24 dS m^{-1}) in nature and medium in organic carbon (5.4 g kg^{-1}). The soil under study was low in available nitrogen (206 kg N ha^{-1}), medium in available phosphorus (17.5 kg P_2O_5 ha^{-1}) and potassium (223 kg K_2O ha^{-1}). The LCC readings were recorded in all the treatments (T_1 through T_8) at 10 days interval simultaneously along with SPAD readings starting from 15 DAT till 65 DAT and presented in table 1.

The plant samples were also analysed for nutrient contents to compute nutrient uptake by plants. Grain yield was also recorded to know the impact of different treatment combinations under adoption of LCC for site specific nitrogen management.

RESULTS AND DISCUSSION

The LCC values increased gradually as the crop progresses from tillering to flowering stage in all the treatments. At the initial stage, the LCC values were low (2.7 to 3.2 at 15 DAT) and highest values (4.03 to 4.67) were recorded at 65 DAT in all the treatments. The LCC values recorded at different days after transplanting (DAT) in different treatments were depicted in fig. 1. Significant differences in LCC values were not observed among the treatments up to 25 DAT.

At 55 DAT, the LCC values recorded were significantly higher than 4 in T_5 through T_8 than in T_1 to T_4 as these treatments received N at 45 DAT, all the treatments recorded LCC values of more than 4.0 and were significantly higher in T_5 through T_8 as these treatments received N at 55 DAT.

The LCC value of 5 was never attained in T_8 though it received 210 kg N ha^{-1} in 7 split applications including that of basal dose right up to 50% flowering. Probably the fertilizer N could have been lost as the soils are light in texture (sandy loam with 79.5% of sand).

Maiti *et al.*[9] reported that mostly LCC values increased N levels up to 65 DAT. Similar trend was observed in this study. However LCC values ranged from 2.97 to 5.70 but the highest value observed in this study was 4.67.

Balasubramanian *et al.*[2] suggested that LCC has shown great promise in optimizing N use in rice in different countries in Asia. The results were in conformity with the findings of Houshmandfar[5].

The SPAD values in general increased gradually from around 33.1 to about 41.6 in different treatments as the crop progresses from tillering to flowering stage (15 DAT to 65 DAT) except in T_1,T_2 and T_3 where in N was received in 3 splits only. The SPAD values observed at different dates after transplanting (DAT) in different treatments was depicted in fig 2. Significant difference in SPAD values were not observed among treatments up to 25 DAT. The SPAD values at 55 and 65 DAT in T_1, T_2 and T_3 (RFD & as per fertilizer adjustment equation and apply N_{30} if SPAD value < 37, respectively) were significantly low as compared to other treatments since there was a more delay in receiving N in these treatments.

Highest SPAD values of 41.6 and 41.0 were recorded in T_8 and T_5. which received highest N of 210 kg & 180 kg in 7 and 6 split doses respectively. The SPAD values in T_3 (apply N30 if SPAD value is < 37) ranged between 33.1 to 37.2 as it received only 90 kg N ha^{-1} in 3 splits.

The SPAD readings indicate chlorophyll content and higher chlorophyll content is the indication of higher photosynthetic efficiency of plants. Application of higher levels of nitrogen increases the chlorophyll content resulting in higher photosynthetic capacity which may lead to higher yields. These results are in conformity with the findings of [8] and [10].

Maiti[9] reported that the SPAD and chlorophyll meter readings for N management options in rice increased significantly with increasing level of N. The observed SPAD values in this experiment also followed the same trend.

Francis and Piekielek[4] observed that a chlorophyll meter or SPAD meter can measure relative difference in crop N status and is also able to detect the onset of an N stress before it is visible.

Grain yield was significantly influenced by dynamic N management practices where in, rate of N application and number of split applications varied (90 to 210 kg ha^{-1} in 3 to 7 splits respectively) as per treatmental demand from time to time. The grain yield ranged from 4901 kg ha^{-1} in T_3 (Apply N $_{30}$ if SPAD value is < 37) which received 90 kg N ha^{-1} in 3 splits to 5869 kg ha^{-1} in T_5 (Apply N_{30} if SPAD value is < 41) which received 180 kg N ha^{-1} in 6 splits. The grain yield recorded in other treatments which received N of 159 kg ha^{-1} (T_2 soil test based fertilizer adjustment equation) to 210 kg ha^{-1} (T_8 Apply N_{30} if LCC value is < shade 5.0) are found on par with each other. The treatments which received 90 kg N ha^{-1} (T_3) and 120 kg N ha^{-1} (T_1 and T_4) recorded significantly low yields and found on par with each other though number of split applications varied from 3 to 4. Treatment T8 (Apply N_{30} if LCC value is < shade 5.0) which received highest N (210 kg ha^{-1}) in 7 splits stood on par with other treatments that received 159 to 180 kg N ha^{-1} in 3 to 6 split applications (Table 4.9 and fig 4.5). There was no significant difference in grain yield recorded in T_2 (Soil test based fertilizer adjustment equations that received 159 kg N ha^{-1} in 3 splits) and T_6 (Apply N_{30} if LCC value is < shade 4.0 and received 150 kg N ha-1) though number of split application were more (5 no's) in the later treatment as compared to 3 splits in the farmer treatment.

The grain yield ranged from 4910 kg ha^{-1} in T_3 which received 90 kg ha^{-1} in 3 splits to 5869 kg ha^{-1} in T_5 which received 180 kg ha^{-1} in 6 splits. Treatments T_2, T_5, T_7 & T_8 are on par with each other which received N ranging from 159-210 kg ha^{-1}. Treatments which received 90 kg N ha^{-1} to 120 kg N ha^{-1} T_3, T_1 & T_4 recorded significantly low yields. Alam *et al.* (2005)[1] reported that use of LCC for N management without any other change in the farmer's fertilizer or crop management increased the average grain yield by 0.1 to 0.7 t ha^{-1}across village and seasons in Bangladesh.

From this study, it can be inferred that among the three N management options N top dressing if LCC value < 4.5 is found to be highly effective as this approach is inexpensive and simple and easy to adopt by the farmers. . Significant increase in grain has also been reported by Mahajan [8, 12].

Significant difference in N uptake was observed among treatments. Highest N uptake of 92.4 kg ha^{-1} by grain was observed in T_7 (N_{30} if LCC value is < shade 4.5) followed by T_5 (N_{30} if SPAD value is < 41) which received 180 kg N ha^{-1}. N uptake by grain (47 kg ha^{-1}) was significantly low in T_3 that received only 90 kg N ha^{-1}. This is followed by T_1 (RFD), T_4 (N_{30} if SPAD value is < 39) and T_6 (N_{30} if LCC value is < 4.0) where in the uptake was 54.0, 55.0 and 68.3 kg ha^{-1} and the corresponding N applied was 90, 120, 120 and 150 kg ha^{-1}. The N uptake by straw in those treatments was also low. The N uptake by straw was also significantly influenced by different dynamic N management options.

The total N uptake ranged from 73.1 kg ha^{-1}(T_3) to 145.2 kg ha^{-1} (T_7). In general N uptake was in tune with that of N applied in different treatments and significantly increased with increased N dose except in T_8. Though T_8 received 210 kg ha^{-1} which was higher by 30 kg ha^{-1} over T_7 and T_5, the same was not reflected in N uptake. This can be attributed to leaching losses of N in light textured soils.

Uptake of P by grain and straw was also significantly influenced by N application. Highest P uptake by grain was observed in T_5 (8.7 kg ha^{-1}) and T_7 (8.5 kg ha^{-1}) which received 180 kg N ha^{-1}. However, highest P uptake by straw was noticed in T_8 (13.4 kg ha^{-1}) and T_2 (10.5 kg ha^{-1}) which received 210 and 150 kg N ha^{-1} respectively. Lowest P uptake of 6.1 kg ha^{-1} and 3.9 kg ha^{-1} by grain and straw respectively was recorded in T_3 that received only 90 kg N ha^{-1}.

Total P uptake was also significantly varied among the treatments and increased with increased N application and followed the trend as observed in straw. Highest total uptake was observed in T_8 (kg ha^{-1}) which received 210 and the lowest uptake of 10 kg ha^{-1} was recorded in T_3 that received 90 kg N ha^{-1} respectively.

Site specific and dynamic N management options significantly influenced the K uptake by grain and straw and found increased with increased N application up to 180 kg N ha^{-1}. Lowest total K uptake (grain + straw) of 141.5 kg ha^{-1} was recorded in T_3 (N_{30} if SPAD value is < 37) and that the highest K uptake of 216.3 kg ha^{-1} was observed in T_7 (N_{30} if LCC value is < 4.5) which received 90 and 180 kg N ha^{-1} respectively. Similar results were reported earlier by [6] and the higher K uptake was attributed to better soil condition and reduced K fixation. Similar result has been reported by [3].

Nitrogen, phosphorous and potassium uptake was higher at 180 kg N kg ha^{-1} at all the growth stages. Similar results were reported earlier by [7].

Nitrogen Harvest Index (HI_N), Internal Efficiency (IE), Partial Factor Productivity for N (PFP_N) were calculated using grain yield, total N uptake and total N applied for different treatments and presented in table 4.15. Net returns and Benefit cost ratio were calculated and presented in table 4.16. Nitrogen harvest index in different treatments ranged from 0.60 to 0.68 but all the treatments are on par with each other. Internal efficiency (Kg grain/Kg N uptake) decreased with increased N application and was low in T_8 (39.36), which received 210 kg N ha^{-1}, and high in T_3 (68.32) which received 90 kg N ha^{-1}. Since the uptake of N was low in the treatments (T_3, T_1&T_4) that received 90 to 120 kg N ha^{-1} and most of it might have been transmitted to grain there by resulted in more internal efficiency. The Internal Efficiency followed the path $T_3 > T_1 > T_4 > T_2 > T_6 > T_5 > T_7 > T_8$.

The lower values of N use efficiency at high N rates are most likely due to greater losses through leaching, denitrification and ammonia volatilization. The Partial Factor Productivity for N (PFP_N) also followed the same trend almost as that of IE with highest PFP_N of 54.4 in T_3 and lowest PFP_N of 26.4 in T_8 and followed the path $T_3 > T_4 > T_1 > T_6 > T_2 > T_7 > T_5 > T_8$ akin to the law of diminishing returns.

Table.1: Leaf colour chart (LCC) readings of fully opened leaves from top at 10 days intervals from early tillering to flowering stage

Treatments	Days after transplanting (DAT)					
	15	25	35	45	55	65
T_1 Recommended fertilizer dose (RFD) (120-60-40 N-P-K kg ha $^{-1}$ in 3 splits, entire P as basal and K in 2 splits)	2.90	3.00	3.07	3.37	3.46	4.16
T_2 N P K application as per fertilizer adjustment equations (159- 67- 88 N-P-K kg ha^{-1}N in 3 splits, entire P as basal and K in 2 splits Yield target 6.5t ha^{-1})	3.21	3.23	3.77	3.77	3.80	4.20
T_3 N_{30} basal+ N_{30} if SPAD value is < 37	2.70	3.03	3.06	3.41	3.86	4.03
T_4 N_{30} basal+ N_{30} if SPAD values is < 39	2.73	3.06	3.56	3.57	3.86	4.06
T_5 N_{30} basal+ N_{30} if SPAD values is < 41	2.86	3.03	3.60	3.86	4.06	4.63
T_6 N_{30} basal+ N_{30} if LCC value is < shade 4.0	2.73	3.03	3.30	3.70	4.10	4.40
T_7 N_{30} basal+ N_{30} if LCC value is < shade 4.5	2.80	3.06	3.60	3.83	4.16	4.56
T_8 N_{30} basal+ N_{30} if LCC value is < shade 5.0	2.76	3.07	3.46	3.83	4.20	4.66
SE(d) ±	0.17	0.176	0.153	0.18	0.141	0.14
CD (0.05)	NS	NS	0.46	NS	0.24	0.414

Note: Recommended dose of P& K (as in T_1) were applied to the treatments in T_3 to T_8.

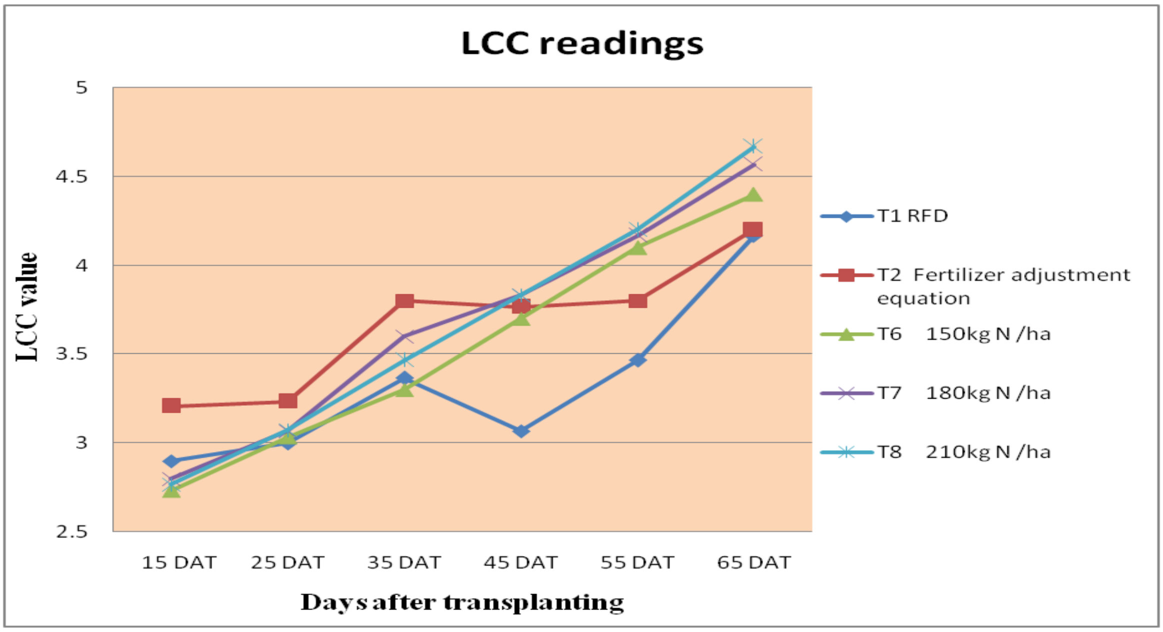

Fig. 1: LCC values as effected by site specific and dynamic nitrogen management of rice at every 10 days interval after transplanting

Table 2: Chlorophyll (SPAD) meter readings as influenced by Site specific and dynamic nitrogen management options

Treatments	Days after transplanting (DAT)					
	15	25	35	45	55	65
T_1 Recommended fertilizer dose (RFD) (120-60-40 N-P-K kg ha $^{-1}$N in 3 splits, entire P as basal and K in 2 splits)	33.1	34.8	37.0	34.7	34.9	37.2
T_2 N P K application as per fertilizer adjustment equations (159- 67- 88 N-P-K kg ha^{-1}N in 3 splits, entire P as basal and K in 2 splits Yield target 6.5t ha^{-1})	35.0	36.1	40.8	35.7	35.5	37.6
T_3 N_{30} basal+ N_{30} if SPAD value is < 37	33.1	37.0	37.2	37.1	36.8	35.4
T_4 N_{30} basal+ N_{30} if SPAD values is < 39	33.5	37.4	38.8	39.8	39.6	39.8
T_5 N_{30} basal+ N_{30} if SPAD values is < 41	33.0	37.4	38.6	39.6	39.6	41.0
T_6 N_{30} basal+ N_{30} if LCC value is < shade 4.0	33.8	37.4	38.7	39.4	39.6	40.1
T_7 N_{30} basal+ N_{30} if LCC value is < shade 4.5	33.3	37.4	38.6	39.8	39.8	39.8
T_8 N_{30} basal+ N_{30} if LCC value is < shade 5.0	33.6	37.4	38.9	39.0	39.9	41.6
SE(d) ±	1.43	1.07	1.12	1.15	1.18	1.22
CV (0.05)	7.39	5.07	5.02	5.24	5.32	5.40
CD (0.05)	NS	NS	NS	3.5	3.6	3.7

Note: Recommended dose of P& K (as in T_1) were applied to the treatments T_3 to T_8

Table 3: Effect of site specific nitrogen management on grain yield (kg ha^{-1}) of rice

Treatments	N applied (kg ha^{-1}) and no. of split applications (in parenthesis)	Grain yield (kg ha^{-1})
T_1 Recommended fertilizer dose (RFD) (120-60-40 N-P-K kg N ha $^{-1}$ in 3 splits, entire P as basal and K in 2 splits)	120 **(3)**	5133 **b**
T_2 N P K application as per fertilizer adjustment equations (159- 67- 88 N-P-K kg N ha^{-1}N in 3 splits, entire P as basal and K in 2 splits Yield target 6.5t ha^{-1})	159 **(3)**	5412 **b**
T_3 N_{30} basal+ N_{30} if SPAD value is < 37	90 **(3)**	4901 **bc**
T_4 N_{30} basal+ N_{30} if SPAD values is < 39	120 **(4)**	5159 **b**
T_5 N_{30} basal+ N_{30} if SPAD values is < 41	180 **(6)**	5869 **a**
T_6 N_{30} basal+ N_{30} if LCC value is < shade 4.0	150 **(5)**	5370 **bc**
T_7 N_{30} basal+ N_{30} if LCC value is < shade 4.5	180 **(6)**	5879 **a**
T_8 N_{30} basal+ N_{30} if LCC value is < shade 5.0	210 **(7)**	5622 **a**
SE(d) ±	_	163.2
CD (0.05)	_	480

Table 4: Effect of site specific and dynamic Nitrogen management options on N, P and K uptake at harvest of the rice crop

Treatments	Nutrients uptake at harvest of the crop (kg ha^{-1})								
	N			P			K		
	Grain	Straw	Total uptake	Grain	Straw	Total uptake	Grain	Straw	Total uptake
T_1 Recommended fertilizer dose (RFD) (120-60-40 N-P-K kg ha^{-1} N in 3 splits, entire P as basal and K in 2 splits)	54.0	28.7	82.7	7.0	5.60	12.6	25.2	143.2	168.4
T_2 N P K application as per fertilizer adjustment equations (159- 67- 88 N-P-K kg ha^{-1}N in 3 splits, entire P as basal and K in 2 splits Yield target 6.5t ha^{-1})	75.1	34.3	109.4	7.5	10.5	18.0	33.5	172.1	205.6
T_3 N_{30} basal+ N_{30} if SPAD value is < 37	47.0	26.1	73.1	6.1	3.9	10.0	22.4	119.1	141.5
T_4 N_{30} basal+ N_{30} if SPAD values is < 39	55.0	28.1	83.1	7.4	5.0	12.4	30.0	141.5	171.5
T_5 N_{30} basal+ N_{30} if SPAD values is < 41	91.1	53.0	144.1	8.7	6.6	15.3	44.8	172.1	216.9
T_6 N_{30} basal+ N_{30} if LCC value is < shade 4.0	68.3	42.3	110.6	7.1	4.4	11.5	32.1	144.8	176.9
T_7 N_{30} basal+ N_{30} if LCC value is < shade 4.5	92.4	52.8	145.2	8.5	6.8	15.3	44.7	171.6	216.3
T_8 N_{30} basal+ N_{30} if LCC value is < shade 5.0	86.1	57.6	143.7	7.6	13.4	21.0	42.2	169.3	211.5
SE(d) ±	4.0	3.04	4.40	0.27	0.45	0.46	1.20	9.56	9.24
CV (0.05)	9.7	13.0	6.7	6.2	11.2	5.4	6.0	10.7	8.5
CD (0.05)	12.1	9.23	13.4	0.8	1.4	1.4	3.6	29.0	28.1

Note: Recommended dose of P& K (as in T_1) were applied to the treatments T_3 to T_8

Table 5: Effect of site specific and dynamic Nitrogen management options on N use efficiency

Treatments	Nitrogen harvest Index (NH) (Grain N uptake/Total plant N uptake)	Internal Efficiency (IE_N) (kg grain/kg N uptake)	Partial Factor Productivity (PFP_N) (kg grain yield/kg N applied)
T_1 Recommended fertilizer dose (RFD) (120-60-40 kg N-P-K ha^{-1} N in 3 splits, entire P as basal and K in 2 splits)	0.65	62.15	42.8
T_2 N P K application as per fertilizer adjustment equations (159- 67- 88 N-P-K kg ha^{-1}N in 3 splits, entire P as basal and K in 2 splits Yield target 6.5t ha^{-1})	0.69	49.54	34.0
T_3 N_{30} basal+ N_{30} if SPAD value is < 37	0.63	68.32	54.4
T_4 N_{30} basal+ N_{30} if SPAD values is < 39	0.66	61.93	43.0
T_5 N_{30} basal+ N_{30} if SPAD values is < 41	0.63	40.90	32.6
T_6 N_{30} basal+ N_{30} if LCC value is < shade 4.0	0.62	49.02	36.1
T_7 N_{30} basal+ N_{30} if LCC value is < shade 4.5	0.64	40.54	32.7
T_8 N_{30} basal+ N_{30} if LCC value is < shade 5.0	0.602	39.36	26.4
SE(d) ±	0.02	2.87	1.12
CV (0.05)	6.4	9.7	5.2
CD (0.05)	NS	8.7	3.4

Note: Recommended dose of P& K (as in T_1) were applied to the treatments T_3 to T_8

CONCLUSION

The grain yield ranged from 4910 kg ha^{-1} in T_3 which received 90 kg ha^{-1} in 3 splits to 5879 kg ha^{-1} in T_7 which received 180 kg ha^{-1} in 6 splits. Treatments T_2, T_5, T_7 & T_8 are on par with each other which received N ranging from 159-210 kg ha^{-1}. In general N uptake was in tune with that of N applied in different treatments and significantly increased with increased N dose. However N uptake in T8 was low and not matched with the N received by the treatment as compared to T_7 & T_5. Though N harvest index (HI_N), Internal Efficiency (IE_N), Partial factor productivity (PFP_N) were comparatively low in T_2, T_5 and T_7 treatments.

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