Current photosynthesis as a deciding factor for economic application of nitrogen through physiological partitioning factor

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ABSTRACT

Gross photosynthesis (GP, i.e., the total amount of CO_2 absorbed), net photosynthesis (NP, i.e., the amount of CO_2 fixed through photosynthesis), respiration (GP-NP, i.e., the amount of CO_2 lost) and the current photosynthesis (the amount of CO_2 fixed during grain filling stage) are important physiological parameters in plant productivity. The amount of CO_2 fixed during reproductive phase (grain filling) directly contributes to the grain yield (economic yield) which has a direct bearing on harvest index and partitioning factor or partial factor productivity. Hence, the present study was undertaken to enhance or to avoid reduction in yield of rice crop during *kharif* season in drill-sown rainfed paddy. The results revealed the effect of nitrogen (N) application and scheduling of N-fertilizer on current photosynthesis in rice plant. The basal or without basal application of N is not important but scheduling of N (urea) fertilizer (weekly or fortnightly @ 10, 20 and 30 kg ha^{-1}) have directly influenced biomass accumulation as well as current photosynthesis. The current photosynthesis results in higher grain yield than other parameters. The application of N(urea) @ 20 kg or 30 kg ha^{-1} through physiological partitioning factor enhanced biomass and yield of rice and there was saving of fertilizer N up to 20 kg ha^{-1}. Net return , saving of fertilizer N (urea) up to 20 kg ha^{-1} and partial factor productivity appears to be better method of N-management in upland rice through leaf colour chart (LCC) @ 20 kg ha^{-1} on fortnightly basis compared to the recommended dose of Nitrogen and the farmer's practice besides without any adverse effect on the environment.

Keywords: agroecology, physiology, current photosynthesis, nitrogen management, rice

INTRODUCTION

Rice is the most important staple food crop of the world, particularly in Asia. Rice is also called as the king crop of the tropical Asia and has fed well the people of the region for a long time. It is being grown under more complex and unpredictable environment than most crops. The most favourable ecosystem for effecting vertical increase in production is irrigated system. Most of the research work so far has been concentrated on this system, as a result of which, the gap between average yield level of farmers and the potential yield level has been narrowed down substantially. However, the yield gap is still very wide in the rainfed ecosystem. Poor nutrient and rainwater management are among the major constraints in rice production in this region. Reduced average yield productivity levels of rainfed low land rice and upland rice are mainly responsible for the lower average productivity of rice in India. And hence enhancing the productivity by efficient nutrient management in upland rice has become a necessity.

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Among the major essential nutrients, nitrogen (N) is the most limiting element in rice growing soils and hence accounts for major input for higher productivity of rice. Since the rice growing conditions are congenial for loss of N, through denitrification from anaerobic condition, split application of N has been suggested to enhance its efficiency. Appropriate diagnosis of N in leaves to decide about top dressing the N-fertilizer is another strategy to increase N use efficiency. There are two nondestructive diagnostic techniques to know the N status of leaves, viz., Chlorophyll Meter or Soil Plant Analysis Development (SPAD 502) and Leaf Color Chart (LCC) [1]. Of the two, the LCC developed by IRRI, Manila, Philippines is a simple and inexpensive tool to determine the time of N-application in rice so as to synchronize it with the crop demand. It is an ideal device to optimize N-use, irrespective of quantity of N applied.

MATERIALS AND METHODS

A field experiment was conducted during *kharif* season to study the effect of Nitrogen management in drill-sown rainfed rice using LCC to decide the time and rate of N application under upland conditions of Northern transitional zone of Karnataka. A rice cv. Amruth was used as a test crop. The soil at the experimental site was silty loam, non saline and medium in available-nitrogen and available phosphorus besides rich in potassium. The treatments included application of different doses of fertilizer N (as urea) @ 10, 20 and 30 kg ha^{-1} per application based on weekly and biweekly LCC observations at critical value of LCC-3 (Plate I). Recommended quantity of Phosphorus and Potassium each @ 50 kg ha^{-1} was applied to all the treatments as basal dose. The first application of N, based on LCC was made after 21 days after emergence and the last application during 13^{th} week (reproductive phase). The treatments were designed taking into consideration the recommended practices and farmers practices in the field (Table 1). Further the observations were recorded on important growth (vegetative) parameters at various critical stages of growth, yield (reproductive) attributes besides final yield at harvest.

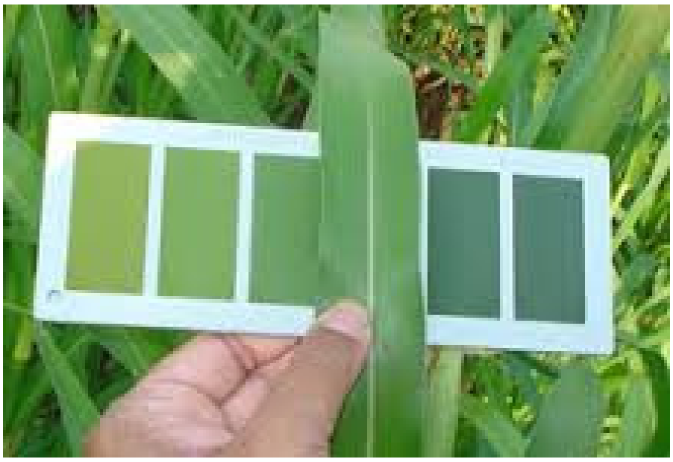

Plate I. Leaf Color Chart.

The data collected from the experiment was subjected to statistical analysis [2].The level of significance used in 'F' test was P=0.05. The data was analysed in randomized block design under Dry Soft Design Programme. The mean values were separately subjected to Duncan's Multiple Range Test (DMRT) at 5 per cent probability under MSTAT–C Programme.

RESULTS AND DISCUSSION

Application of N either at 20 or 30 kg ha^{-1} per application under LCC guidance significantly increased growth components of rice viz., number of tillers per row meter length, plant height, Leaf Area Index (LAI) and Dry Matter Yield (DMY) over the two controls and lower N rate (10 kg ha^{-1}) (Table 2 and 3). The number of tillers per meter row length increased up to panicle initiation and thereafter a decrease was observed, which could be due to senescence of the secondary tillers. Irrespective of crop growth stage, the number of tillers varied in accordance with the quantity of N applied, higher value recorded in treatments receiving higher quantity of nitrogen. The highest number of tillers per meter row length was noticed with application of 100 kg N in five splits, i.e., 20 kg N ha $^{-1}$ as basal plus the remaining quantity in four splits @ 20 kg ha^{-1} based on LCC observation (T_8) at the time of harvest. The farmers practice (T_{14}), which also received a total of 100 kg N ha^{-1} but in 3 splits accounted for lowest number of tillers per meter row length. Higher number of tillers with higher dose of N application was recorded [3] (Table 2). The plant height increased progressively with the growth of crop. The treatments which received N @ 20 kg ha^{-1} as basal plus LCC based N (T_{11}) or 20 kg ha^{-1} as basal plus 30 kg ha^{-1} LCC based N (T_{12}) accounted for the highest plant height at the time of harvest. The lowest plant height was recorded in T_4, this could be due to less amount of N (50 kg) applied during crop growth period (Table 2). Increased plant height with application of 20 kg N ha^{-1} as basal plus SPAD based N was observed [1].

Table 1. Treatment details and total N applied in different treatments during the crop growth period.

Treatments	Number of splits	Total N applied (kg ha^{-1})
T_1: 0 kg N basal + 10 kg N ha^{-1} based on weekly LCC reading	7	70
T_2: 0 kg N basal + 20 kg N ha^{-1} based on weekly LCC reading	4	80
T_3: 0 kg N basal + 30 kg N ha^{-1} based on weekly LCC reading	3	90
T_4: 0 kg N basal + 10 kg N ha^{-1} based on biweekly LCC reading	5	50
T_5: 0 kg N basal + 20 kg N ha^{-1} based on biweekly LCC reading	4	80
T_6: 0 kg N basal + 30 kg N ha^{-1} based on biweekly LCC reading	3	90
T_7: 20 kg N basal + 10 kg N ha^{-1} based on weekly LCC reading	7	80
T_8: 20 kg N basal + 20 kg N ha^{-1} based on weekly LCC reading	5	100
T_9: 20 kg N basal + 30 kg N ha^{-1} based on weekly LCC reading	4	110
T_{10}: 20 kg N basal + 10 kg N ha^{-1} based on biweekly LCC reading	5	60
T_{11}: 20 kg N basal + 20 kg N ha^{-1} based on biweekly LCC reading	5	100
T_{12}: 20 kg N basal + 30 kg N ha^{-1} based on biweekly LCC reading	4	110
T_{13}: RDN (33.3 kg N ha^{-1} at 21 DARE + 33.3 kg N ha^{-1} at 40 DARE + 33.4 kg N ha^{-1} at 60 DARE)	3	100
T_{14}: Farmers practice (20 kg N ha^{-1} basal + 40 kg N ha^{-1} at active tillering stage + 40 kg N ha^{-1} at panicle initiation)	3	100

DARE - Days after Rice Emergence; RDN - Recommended Dose of Nitrogen @100 kg ha^{-1}.

LAI increased rapidly up to panicle initiation but decreased at harvest. This could be due to senescence of leaves after the reproductive phase. The influence of LCC based N application on LAI followed the same trend as that of number of tillers per meter row length. At the time of harvest, the treatments T_2, T_8, T_{11} and T_{12} recorded higher LAI values and on par with each other. Application of N in more number of splits up to reproductive phase as per LCC guidance was responsible for retaining more number of active leaves till the maturity in the above treatments (Table 3). DMY of rice increased progressively with the crop growth in all the treatments. DMY at maximum tillering stage and panicle initiation was on par with all the treatments which received higher rate of N per split (20 kg N ha^{-1} or 30 kg N ha^{-1}) but, significantly higher than the lower rate of N application (10 kg N ha^{-1}) and recommended practice (T_{13}). This could be attributed to availability of nitrogen as per crop needs during its growth. At harvest, the treatments which received LCC based N, in more number of splits (4 or 5) @ 20 kg ha^{-1} (T_2, T_5, T_8 and T_{11}) or 30 kg ha^{-1} (T_{12}) each time produced significantly higher dry matter than other treatments. This could be due to higher photosynthetic area, better interception of solar radiation and presence of photosynthetically active leaves for longer period as evidenced by significantly higher LAI in these treatments. At harvest, DMY was significantly high but, on par with LCC based application @ 20 kg N ha^{-1} in treatments T_5, T_8 and T_{11}(Table 3). The results are in agreement with the earlier findings [4-5]. The data on yield components (Number of panicles per row meter length, panicle weight and number of filled grains are furnished in table 4), grain yield, straw yield, harvest Index and partial factor productivity (PFP) were influenced by different treatments (Figure 1 and 2). All the yield parameters and grain yield were favorably influenced when N was applied under LCC guidance especially at higher rate, i.e., 20 or 30 kg N ha^{-1} per application. Adequate N supply during growth and reproductive phases was probably responsible in enhancing yield parameters and in turn the grain yield. The maximum yield of 29.07q ha^{-1} was recorded in T_{11} but, it was statistically on par with the yield recorded in treatments T_2, T_3, T_5, T_6, T_8, T_9 and T_{12}. The extent of yield increased by T_{11} over control (T_{13}) was 13.82 per cent. Increased growth and yield parameters with the SPAD based N application was reported [1]. The application of N @ 10 kg ha^{-1} per application under LCC guidance accounted for lower values of yield parameters which could be attributed to inadequate N to meet the crop needs. The two controls, though received a total of 100 kg N ha^{-1} in three splits at fixed intervals, recorded significantly lower values for yield parameters and yield than LCC based N application at higher rate. This could be due to low availability of N at grain filling stage of the crop (Figure 1). Higher grain yield under SPAD based N management than the two controls was recorded [6].

Table 2. Number of tillers per meter row length and plant height as influenced by LCC based N application.

Treatments	Number of tillers per meter length at			Plant height (cm) at		
	Maximum tillering stages	Panicle initiation stage	Harvest	Maximum tillering stage	Panicle initiation stage	Harvest
T_1	53.0^{f}	66.0^{d}	61.0^{ef}	28.43^{fg}	48.38^{c}	64.99^{f}
T_2	62.0^{b-d}	81.0^{ab}	71.0^{bc}	37.37^{bc}	56.88^{ab}	70.63^{d}
T_3	58.0^{c-f}	77.0^{bc}	71.0^{bc}	31.96^{e}	56.61^{ab}	72.82^{bc}
T_4	52.0^{f}	69.0^{cd}	59.0^{f}	28.06^{g}	47.69^{c}	60.65^{h}
T_5	63.0^{bc}	75.0^{bc}	72.0^{bc}	35.89^{b-d}	54.97^{b}	73.00^{bc}
T_6	62.0^{b-e}	74.0^{bc}	70.0^{cd}	31.42^{ef}	57.31^{ab}	73.50^{bc}
T_7	58.0^{c-f}	75.0^{bc}	63.0^{d-f}	32.47^{de}	48.22^{c}	64.56^{f}
T_8	72.0^{a}	88.0^{a}	83.0^{a}	37.76^{b}	57.94^{ab}	73.82^{ab}
T_9	67.0^{ab}	76.0^{bc}	64.0^{d-f}	41.93^{a}	56.21^{ab}	72.38^{c}
T_{10}	56.0^{ef}	73.0^{cd}	60.0^{f}	31.92^{e}	48.09^{c}	63.16^{g}
T_{11}	64.0^{b}	82.0^{ab}	77.0^{b}	37.76^{b}	61.31^{a}	74.78^{a}
T_{12}	64.0^{b}	77.0^{bc}	73.0^{bc}	41.99^{a}	57.67^{ab}	74.94^{a}
T_{13}	56.0^{ef}	73.0^{cd}	67.0^{c-e}	33.61^{de}	53.40^{bc}	69.65^{de}
T_{14}	55.0^{f}	72.0^{cd}	60.0^{f}	32.44^{de}	53.49^{bc}	68.58^{e}
LSD (5%)	5.55	6.86	5.98	3.10	5.99	1.14

In columns the means followed by same letter do not differ significantly DMRT.

Table 3. Leaf Area Index and Dry Matter Yield as influenced by LCC based N application.

Treatments	Leaf Area Index at			Dry Matter Yield (gm plant^{-1}) at		
	Maximum tillering stage	Panicle initiation stage	Harvest	Maximum tillering stage	Panicle initiation stage	Harvest
T_1	1.41^{i}	3.11^{ef}	1.20^{d}	2.77^{d}	8.20^{bc}	33.26^{cd}
T_2	1.62^{a}	3.39^{bc}	1.30^{a}	3.30^{a-c}	9.96^{a}	38.70^{ab}
T_3	1.50^{e}	3.27^{c-e}	1.21^{cd}	3.10^{a-d}	9.82^{a}	35.06^{c}
T_4	1.28^{k}	2.64^{h}	1.03^{g}	2.64^{d}	8.05^{c}	31.14^{d}
T_5	1.52^{d}	3.33^{b-d}	1.26^{b}	3.24^{a-c}	9.93^{a}	41.67^{a}
T_6	1.49^{ef}	3.21^{d-f}	1.22^{cd}	3.10^{a-d}	9.83^{a}	34.94^{c}
T_7	1.48^{f}	3.20^{d-f}	1.15^{e}	3.07^{cd}	9.70^{a}	34.44^{cd}
T_8	1.59^{b}	3.44^{a}	1.31^{a}	3.47^{a}	10.09^{a}	42.07^{a}
T_9	1.52^{d}	3.31^{b-d}	1.25^{bc}	3.27^{a-c}	9.91^{a}	36.10^{bc}
T_{10}	1.32^{j}	3.05^{g}	1.04^{g}	2.60^{d}	8.67^{bc}	32.90^{cd}
T_{11}	1.56^{c}	3.76^{a}	1.31^{a}	3.37^{ab}	10.00^{a}	40.09^{a}
T_{12}	1.63^{a}	3.39^{bc}	1.31^{a}	3.30^{a-c}	9.85^{a}	40.04^{a}
T_{13}	1.47^{g}	3.16^{ef}	1.08^{f}	2.83^{b-d}	8.90^{b}	33.54^{cd}
T_{14}	1.43^{h}	3.14^{ef}	1.11^{f}	2.97^{a-d}	8.80^{bc}	33.40^{cd}
LSD (5%)	0.02	0.13	0.04	0.51	0.75	3.05

In columns the means followed by same letter do not differ significantly DMRT.

Table 4. Number of panicles per meter row length, panicle weight, number of filled grains per panicle as influenced by LCC based N application.

Treatment	Number of panicles per meter length	Panicle weight (g)	Number of filled grains per panicle
T_1	60.00^{cd}	2.29^{d}	64^{b-f}
T_2	66.00^{a-c}	2.81^{a-c}	74^{ab}
T_3	64.00^{a-d}	2.79^{a-c}	68^{b-d}
T_4	53.00^{e}	2.08^{e}	58^{f}
T_5	70.00^{a}	2.99^{a}	76^{a}
T_6	63.00^{b-d}	2.69^{a-c}	70^{a-d}
T_7	60.00^{cd}	2.61^{bc}	69^{a-d}
T_8	70.00^{a}	2.88^{ab}	72^{a-c}
T_9	66.00^{a-c}	2.90^{ab}	68^{b-d}
T_{10}	58.00^{de}	2.16^{d}	59^{ef}
T_{11}	68.00^{ab}	2.92^{ab}	71^{a-d}
T_{12}	66.00^{a-c}	2.99^{a}	71^{a-d}
T_{13}	62.00^{bd}	2.66^{bc}	65^{de}
T_{14}	61.00^{bd}	2.57^{c}	68^{b-d}
LSD (5%)	5.66	0.27	5.48

In columns the means followed by same letter do not differ significantly DMRT.

The effect of different treatments on harvest index was same as their effect on grain yield. Increased N rates in LCC based N application increased the harvest index favourably. Similar observations were made by the recommended practice and farmers' practice, though received 100 kg N ha^{-1} accounted for significantly lower harvest index due to lower grain yield production. Application of N @ 10 kg ha^{-1} per application under LCC based treatments (T_1,T_4, and T_{10}) showed comparatively lower harvest index values than other treatments, which could be attributed to inadequate N to meet the crop needs (Figure 2). PFP recorded a lowest value of 25.45 in T_{12} to a high of 36.26 in T_4, while, PFP of T_2,T_5 and T_{10} was on par with T_4, the PFP of T_9,T_{13} and T_{14} was on par with T_{12} (Figure 2). Higher the amount of N applied, lower was the PFP. The PFP was higher when N was applied in lower doses indicating better utilization of the applied N [7].

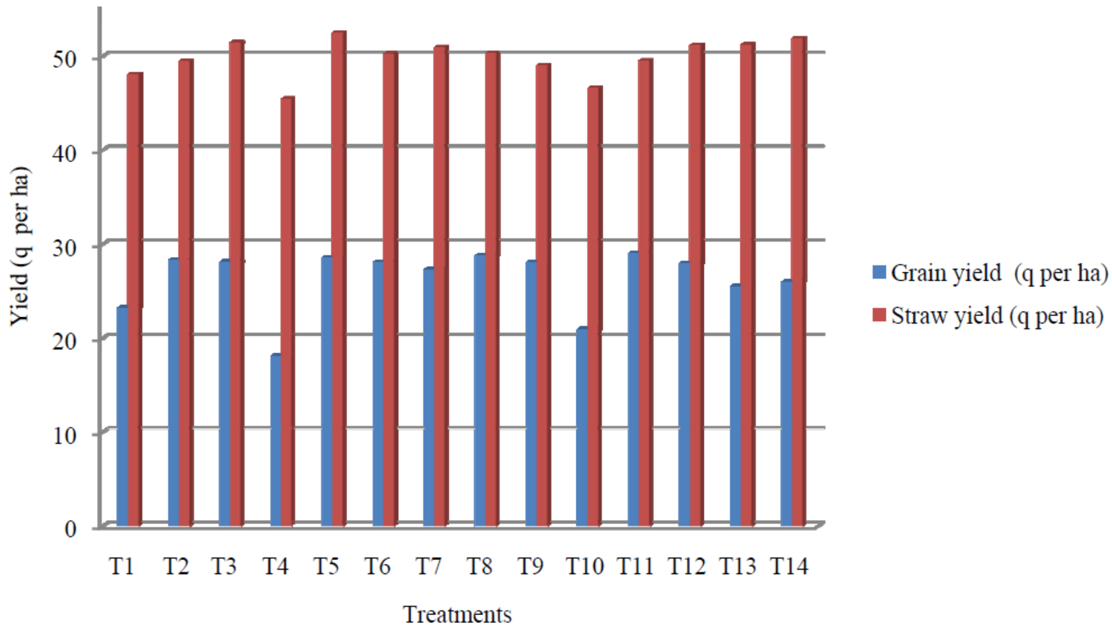

Figure 1. Grain yield and Straw yield as influenced by LCC based N application.

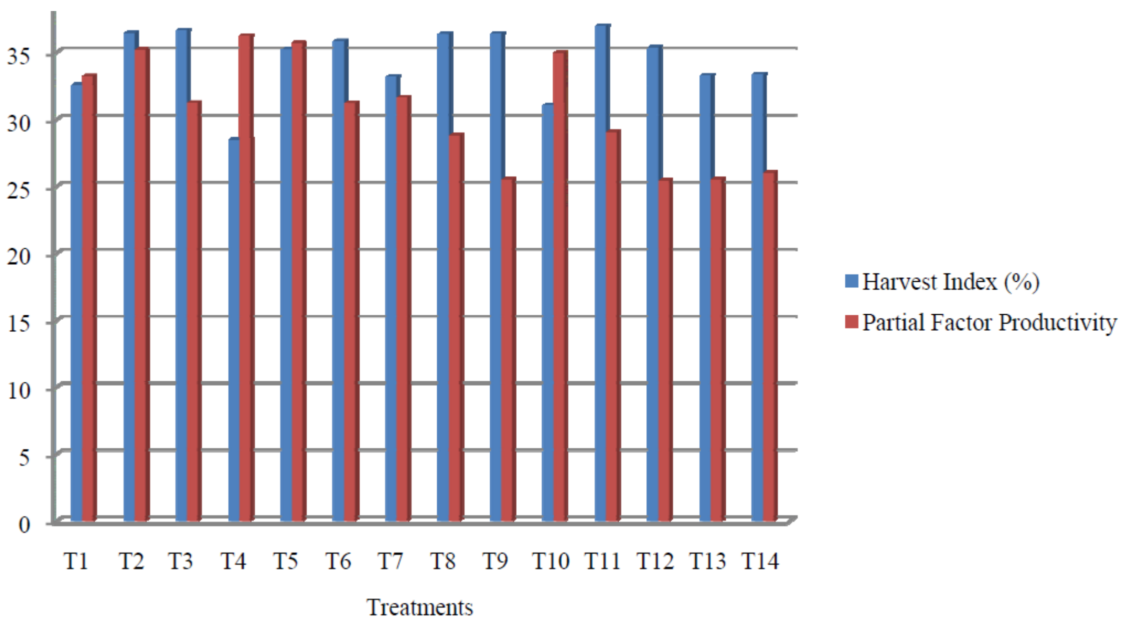

Figure 2. Harvest Index and Partial Factor Productivity as influenced by LCC based N application.

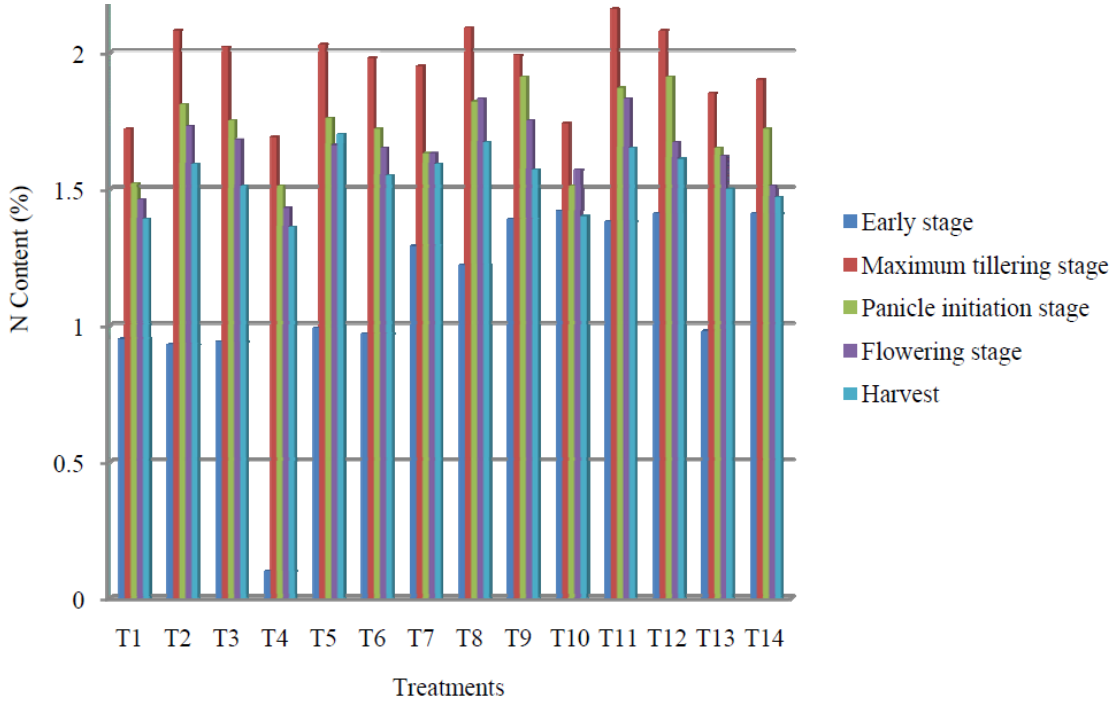

Figure 3. Plant N content (%) in rice at different growth stages as influenced by LCC based N application.

The N content of plant increased rapidly from early stage to maximum tillering stage but, decreased gradually thereafter up to harvest in all the treatments. The decrease in plant N content after tillering stage is attributed to the dilution effect. Higher N content in plant at 30 days after transplanting and a decrease thereafter was observed [8]. At early growth stages, higher plant N content was recorded in the treatments, which received basal application of N. However, at later growth stages, the N content varied among the treatment in accordance with the variable quantity of N applied in split doses. At harvest, the LCC based N application @ 20 kg N ha^{-1} each time accounted for significantly higher N content in plant than other treatments (Figure 3). Considering the influence of LCC based nitrogen application on growth and yield of rice and saving of fertilizer N, application of nitrogen to synchronize it with the crop demand as determined by LCC observations appears to be a better method of N management in rainfed rice in North transitional zone of Karnataka.

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