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Need based nitrogen management using leaf colour chart for short duration transplanted rice: Effect on nitrogen use efficiency

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Abstract
Field experiment was conducted during *Kharif*, 2018 with an objective to study the possibility of improving N-use efficiency by affecting fertilizer N as per need of crop using leaf colour chart (LCC) transplanted rice. Treatments included two doses of nitrogen (120 and 150 kg ha^{-1}) applied on basis of LCC- 3 and 4. In turn Nitrogen was applied in 3 equal splits @ 120 kg N ha^{-1} and (3 and 4) splits with half as basal, remaining @ 150 Kg ha^{-1}. These treatments were evaluated against control, recommended method and Farmers practice. Results revealed that, LCC-4 was found to be best in improving efficiency of applied nitrogen fertilizer. Among all the treatments, with regard to nitrogen use efficiency indices, highest efficiency was observed in T_7 {120 kg RDN at LCC 4} followed by recommended practice. LCC based nitrogen application was found to be effective in improving rice yields with limited nitrogen supply on plant need basis.

Keywords: LCC, nitrogen, nitrogen use efficiency, partial factor productivity, recovery efficiency, agronomic efficiency

Introduction
Every third person on earth consumes rice everyday in one form or the other and about 90% of the total rice produced is consumed in Asian countries. However, India’s productivity is very low when compared to other major rice growing countries in the world. Among all the reasons for low productivity, inefficient utilization of nitrogen in considered to be the most important one. Major consequence of inadequate Nitrogen supply is reduced leaf area, thereby, limiting light interception, photosynthesis and finally biomass growth and grain yield. The development and promotion of efficient practices for Nitrogen management in rice remains the high priority for increasing profitability in rice farming. Farmers generally apply nitrogen fertilizer in split schedule in 2:1:1 ratio at basal, tillering and panicle initiation stages, respectively, without considering whether the plant really requires N at the time. This may lead to loss or may not be found adequate enough to synchronize nitrogen supply with actual crop nitrogen demand [1]. Although farmers pretty well know that extra N fertilizer application costs money, they are more inclined to minimize the risk of deficiency which reduces N use efficiency.
For most soils of the country, nitrogen use efficiency in rice is only about 30 to 40% and about 1/3rd of applied nitrogen is lost by different losses [2]. Optimum use of nitrogen can be achieved by matching nitrogen supply with crop demand. Precise application of nitrogen fertilizer based on plant need and location in the field will greatly help in improving the fertilizer use efficiency in rice. A simple, quick and non destructive method for estimating the plant nitrogen demand is LCC that provides indirect assessment of leaf nitrogen status, which is closely related to photosynthetic rate [3] and biomass production [4]. The use of LCC for scheduling N application may not be uniform to all varieties which differ in inherent leaf color and regions that differ in climate, thereby necessitating individual or group standardization in different cultivated areas. Hence the present investigation was focused on standardizing the LCC critical value for short duration rice (KNM-118) under transplanted condition.

Material and Methods
Experimental site
The experiment was conducted during *Kharif*, 2018-2019 at College farm, College of Agriculture, Rajendranagar, Professor Jayashankar Telangana State Agricultural University (PJTSAU), Hyderabad. The geographical location of the experimental site was 17°19' 19.2" N Latitude, 78°24' 39.2” E Longitude with an altitude of 534 m above mean sea level.

Agro-climatologically the area is classified as Southern Telangana Agro Climatic Zone of Telangana State.

Experimental design and treatments

The experiment was laid out in Randomized Block Design with nine treatments and three replications. Treatments included two doses of nitrogen (120 and 150 kg ha^{-1}) applied on basis of two critical LCC values- 3 and 4. In turn N was applied in 3 equal splits incase of 120 kg N ha^{-1} and with 150 kg N ha^{-1} it was applied in 3 and 4 splits with half as basal. These LCC based treatments were evaluated against Recommended method, Farmers practice with (120-60-40), (180-80-40) RDF respectively applied at fixed time intervals and control with no nitrogen. The soil was moderately alkaline in pH (7.8), non-Saline in EC (0.32 dSm^{-1}), low in Organic carbon (0.42%), low in available N (210 kg ha^{-1}), medium in available P (44.3 kg ha^{-1}) and high in available K (351 kg ha^{-1}). KNM-118 (Kunaram sannalu) was the variety selected for the study. All agronomic practices were carried out as per the recommendations.

Nutrient management

The recommended dose of fertilizer @ (120-60-40) and (180-80-40) N, P_2O_5 and K_2O kg ha^{-1} were applied to T_2 and T_3 treatments respectively. NPK were applied through urea, single super phosphate and Muriate of potash (single super phosphate for control) sources respectively. Half of the recommended dose of N was applied as basal for all treatments except for T_4 and T_7. Entire dose of P as basal and K applied in 2 splits (basal + at 1st top dressing of Nitrogen) for all treatments. RDN was applied at 0, 18, 35 DAT for T_2 and T_3. For treatments T_4 to T_9, nitrogen was applied based on their respective LCC critical values using RDN of 120 kg ha^{-1} for T_4 and T_7 and RDN of 150 for T_5, T_6, T_8 and T_9 treatments.

LCC observation

LCC (IIRR five panel) observations were taken at weekly intervals starting from 21 days after transplanting (DAT) to 50% flowering. Normally LCC readings are taken from 18 days after transplanting when basal dose is not applied. If basal dose is applied, readings need to be taken from 21-25 DAT. Ten disease-free rice hills were selected at random in each plot. The topmost fully expanded leaf from each hill was selected and its colour was compared by placing the middle part of the leaf on LCC and the leaf colour was observed (Fig 1). Whenever the green colour of more than 5 out of 10 leaves are equal to or below a set critical limit of LCC score, nitrogen was applied as per the treatment. The leaf was not detached or destroyed. The average LCC reading were determined for each treatment. Readings were taken in the morning (8-10 AM) under the shade of body to avoid the influence of sun light as it may reflect the LCC colour.

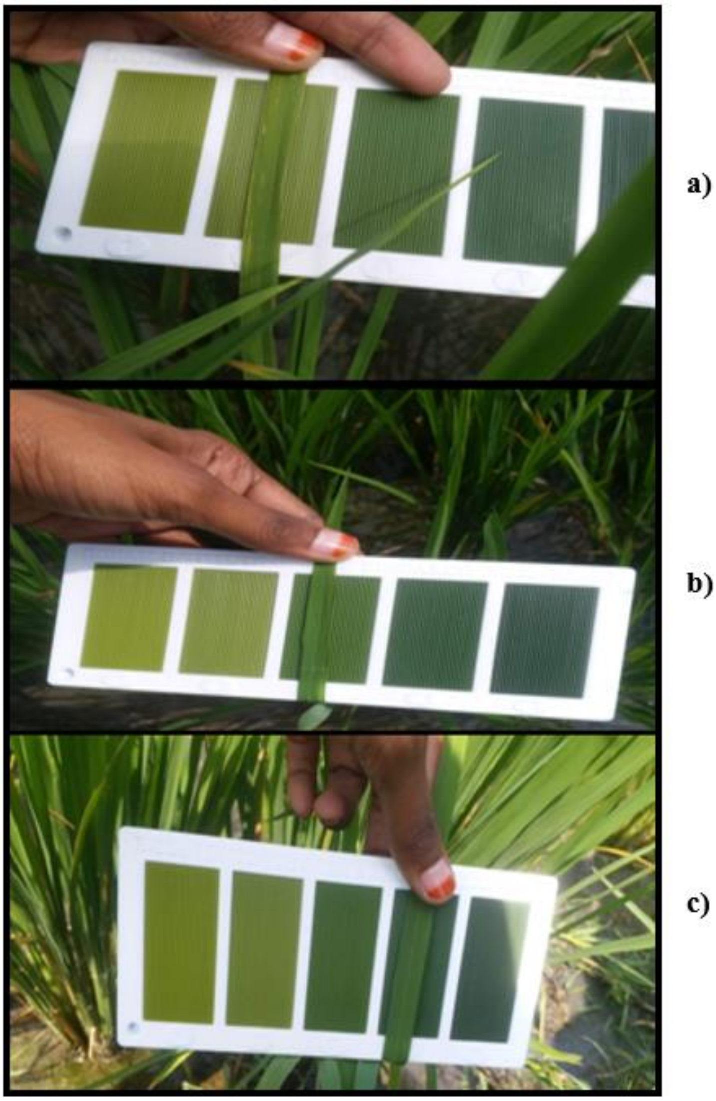

Fig 1: Picture depicting LCC observation in the field a) LCC-2; b) LCC-3; c) LCC-4

Nitrogen Use Efficiency Indices calculation

Different nutrient use efficiencies were calculated using following formulae given by [5] Cassman, [6] Fageria and Baligar, [7] Dobermann and [8] Fageria.

a) **Partial factor productivity:** PFP_N (kg grain kg N applied^{-1}) is a useful measure in conventional cropping systems that can provide an integrative index of the total economic output in relation to the utilization of all N sources in the system. It is a long term indicator of the impact of applied nitrogen on productivity. It was calculated as per the formula,

$$PFP_N = \frac{\text{Grain Yield (kg)}}{\text{N fertilizer applied (kg)}}$$

b) **Agronomic efficiency:** AE_N (kg grain kg N applied^{-1}) is an index to express the yield-increasing effect with applied N. Agronomic efficiency closely reflects the direct production impact of applied fertilizer and relates directly to economic return. It is a short term indicator of the impact of applied nutrients on productivity. It depends on management Practices. It was calculated as per the formula,

$$AE_N = \frac{\text{Grain yield in (LCC "N" fertilized plots) - (Control)}}{\text{Quantity of N fertilizer applied in LCCN fertilized plot}}$$

c) **Recovery efficiency:** RE_N (%) is used to express the percentage of fertilizer nitrogen recovery in above-ground plant biomass. Recovery efficiency is one of the complex forms of Nitrogen use efficiency expressions and is most commonly defined as the difference in nitrogen uptake in above ground parts of the plant between the fertilized and unfertilized crop relative to the quantity of nitrogen applied. It indicates, amount of nitrogen taken up by the plant out of total applied nitrogen. It is affected by the fertilizer application method (timing, amount, placement and form) and also the factors which determine size of the crop nutrient sink (genotype, climate, plant density, abiotic/biotic stresses). It was calculated as per the formula,

$$RE_N (\%) = \frac{\text{[Total N uptake in "N" fertilized plot] - [total N uptake control plot] x 100}}{\text{Quantity of N fertilizer applied in N-fertilized plot}}$$

d) **Physiological Efficiency**- PE_N (kg straw yield increase per kg increase in N uptake) is the ability of a plant to transform nutrients that are acquired from the fertilizer into economic yield (grain). It depends on genotype, management practice and environment. Low PE_N suggests sub-optimal growth (i.e., nutrient deficiencies, mineral toxicities, heat stress, drought stress, pests). It was calculated as per the formula,

$$PE = \frac{\text{Biological yield in treated plot- Biological yield in control plot (kg ha}^{-1}\text{)}}{\text{Total nutrient uptake in treated plot- total nutrient uptake in control plot (kg ha}^{-1}\text{)}}$$

e) **Agro Physiological Efficiency**-APE_N (kg grain yield increase per kg increase in N uptake) is defined as, economic production (grain yield) obtained per unit of nutrient uptake. It was calculated as per the formula,

$$APE = \frac{\text{Grain yield in treated plot- Grain yield in control plot (kg ha}^{-1}\text{)}}{\text{Total nutrient uptake in treated plot- total nutrient uptake in control plot (kg ha}^{-1}\text{)}}$$

f) **Internal Utilization Efficiency**-IE_N (kg yield per kg nutrient uptake) is the ability of the plants to transform nutrients acquired from all sources (soil, fertilizer) into economic yield (grain). It depends on genotype, management practices and environment. A very high IE_N suggests deficiency of the nitrogen. Low IE_N suggests poor internal nutrient conversion due to other stresses (mineral toxicities, nutrient deficiencies, heat stress, pests, drought stress). It was calculated as per the formula,

$$IUE = \frac{\text{Grain yield (kg ha}^{-1}\text{)}}{\text{Total nutrient uptake (grain+ straw) from all sources (kg ha}^{-1}\text{)}}$$

g) **Partial nutrient balance** -PNB (kg nutrient uptake per kg nutrient applied). It is also called the removal/use ratio or the output/input ratio. When PNB = 1, the amount of nutrient removed equals the input of N. When PNB< 1, more N is being applied to crop than is being removed, and the N not removed could be either stored in the soil and/or flows through to the environment thereby causing ecosystem degradation. PNB> 1, more N is being removed than is being supplied, which indicates that the soil is being mined of nutrients, eventually depleting the soil fertility. It was calculated as per the formula,

$$PNB = \frac{\text{Total nutrient uptake (grain+ straw) (kg ha}^{-1}\text{)}}{\text{Total amount of nutrient applied (kg ha}^{-1}\text{)}}$$

Results and Discussion

The NUE decreases with increased amount of N applied and it also depends on time of applied N [9]. Partial factor productivity (PFP_N) of nitrogen is useful to measure nitrogen use efficiency because it provides integrative index that quantifies total economic output (Yield) related to utilization of input (nitrogen). It was observed that, highest partial factor productivity (49.09 kg grain kg^{-1} N applied) was recorded with T_7 {120 kg RDN at LCC 4 - RDN applied as 3 equal splits (1/3rd basal + 1/3rd + 1/3rd)} which was on par with T_2 {RDF (120-60-40 Kg N, P_2O_5, K_2O ha^{-1}) - RDN applied as 1 basal+ 2 equal splits (½ basal + 1/4th+ 1/4th)}. Lowest (28.94 kg grain kg^{-1} N applied) was recorded with T_5 {150 kg RDN at LCC 3 - RDN applied as 1 basal+ 2 equal splits (½ basal + 1/4th+ 1/4th)} (Table 1). Similar findings were reported by others [10]. The high partial factor productivity in T_7 which is based on LCC might be due improved growth, yield, N accumulation and N uptake than farmers practice and recommended method. Relatively lower PFP_N was recorded in farmers practice with 180 kg N ha^{-1} than treatments imposed based on LCC-4. The decreased PFP_N with increasing amounts of N applied can be attributed to relatively less improvement in tonnage in presence of higher nutrient supplementation beyond certain level as generally observed in all nutrients (law of diminishing returns) [11].

Agronomic efficiency shows that, how much productivity improvement was gained by the use of nitrogen input. Highest agronomic efficiency (29.31 kg grain kg^{-1} N applied) was recorded with T_2 {RDF (120-60-40 Kg N, P_2O_5, K_2O ha^{-1})- RDN applied as 1 basal+ 2 equal splits (½ basal + 1/4th + 1/4th)} which was on par with T_7 {120 kg RDN at LCC 4 - RDN applied as 3 equal splits (1/3rd basal + 1/3rd + 1/3rd)} and T_9 {150 kg RDN at LCC 4 - RDN applied as1 basal + 3 equal splits (½ basal + 25 kg + 25 kg + 25kg)}. Lowest

(11.17 kg grain kg^{-1} N applied) was recorded with T_4 {120 kg RDN at LCC 3 -RDN applied as 3 equal splits ($1/3^{rd}$ basal + $1/3^{rd}$ + $1/3^{rd}$)} (Table 1). Similar findings were reported by others [12]. N losses from soil-plant system are large in farmers practice, leading to low AE_N, when N application is not synchronized with crop demand. The increase in AE_N using LCC resulted from better synchronization of timing of fertilizer N applications and the crop's need for N fertilizer [13].

Table 1: Partial Factor Productivity (PFP_N), Agronomic Efficiency (AE_N) and Recovery Efficiency (RE_N) of Nitrogen as influenced by LCC based nitrogen management in rice

	Treatments	PFP_N Kg grain kg^{-1} N applied	AE_N kg increase in grain yield kg^{-1} N applied	RE_N % of increase in N uptake kg^{-1} N applied
T_1	No Nitrogen	-	-	-
T_2	RDF (120-60-40 Kg N, P_2O_5, K_2O ha^{-1}) - RDN applied as 1 basal+ 2 equal splits (½ basal + $1/4^{th}$ + $1/4^{th}$)	45.82	29.31	46.72
T_3	Farmers practice (180-80-40 Kg N, P_2O_5, K_2O ha^{-1}) - RDN applied as 1 basal + 2 equal splits (½ basal + $1/4^{th}$ + $1/4^{th}$)	34.58	20.83	38.08
T_4	120 kg RDN at LCC 3 – RDN applied as 3 equal splits ($1/3^{rd}$ basal + $1/3^{rd}$ + $1/3^{rd}$)	31.79	11.17	19.69
T_5	150 kg RDN at LCC 3 - RDN applied as 1 basal + 2 equal splits (½ basal + $1/4^{th}$ + $1/4^{th}$)	28.94	12.45	23.60
T_6	150 kg RDN at LCC 3 - RDN applied as 1 basal+ 3 equal splits (½ basal + 25 kg + 25 kg + 25 kg)	39.63	19.84	35.46
T_7	120 kg RDN at LCC 4 – RDN applied as 3 equal splits ($1/3^{rd}$ basal + $1/3^{rd}$ + $1/3^{rd}$)	49.09	28.48	49.83
T_8	150 kg RDN at LCC 4 - RDN applied as 1 basal+ 2 equal splits (½ basal + $1/4^{th}$ + $1/4^{th}$)	39.29	22.79	41.15
T_9	150 kg RDN at LCC 4 - RDN applied as1 basal + 3 equal splits (½ basal + 25 kg + 25 kg + 25kg)	43.55	27.06	48.52
	SE(m) ±	1.4	1.6	1.7
	CD (p=0.05)	4.4	4.9	5.2
	CV %	6.4	13.0	7.8

Recovery efficiency is an indicator of the potential for nitrogen loss from the field and also helps to obtain the efficiency of nitrogen management practices. Highest recovery efficiency (49.83%) was recorded with T_7 {120 kg RDN at LCC 4 - RDN applied as 3 equal splits (1/3rd basal + $1/3^{rd}$ + $1/3^{rd}$)} which was found to be on par with T_2 {RDF (120-60-40 Kg N, P_2O_5, K_2O ha^{-1})- RDN applied as 1 basal + 2 equal splits (½ basal + $1/4^{th}$ + $1/4^{th}$)} and T_9 {150 kg RDN at LCC 4 - RDN applied as1 basal+ 3 equal splits (½ basal + 25 kg + 25 kg + 25kg)} (Table 1). While lowest (19.69%) was recorded with T_4 {120 kg RDN at LCC 3 -RDN applied as 3 equal splits ($1/3^{rd}$ basal + $1/3^{rd}$ + $1/3^{rd}$)}. This means that a large amount of N is lost in soil–plant system. Similar findings were reported by [14]. High value of nitrogen use efficiency in terms of recovery efficiency reported in LCC based treatments over farmers practice might have been attributed to synchronization of adequate supply of nitrogen to the demand of crop and timely availability of nitrogen which led to efficient utilization of applied nitrogenous fertilizer by crop with the saving of 30-60 kg N ha^{-1} with minimum losses (16.7-33.4 percent N saving) [15].

Physiological Efficiency (PE_N), Agro Physiological Efficiency (APE_N), Internal Utilization Efficiency (IE_N) and Partial nutrient balance (PNB) decreased with increasing N rate from 120 kg ha^{-1} to 150 kg ha^{-1} LCC based treatments and 180 kg ha^{-1} and related data was shown in (Table 2). Physiological Efficiency (PE_N), Agro Physiological Efficiency (APE_N) and Internal Utilization Efficiency (IE_N) were not influenced by LCC based Nitrogen application. However, highest Physiological Efficiency (154.42 kg straw yield increase per kg increase in N uptake) was recorded with T_4 {120 kg RDN at LCC 3 – RDN applied as 3 equal splits ($1/3^{rd}$ basal + $1/3^{rd}$ + $1/3^{rd}$)}.While lowest (134.03 kg straw yield increase per kg increase in N uptake) was seen in T_9 {150 kg RDN at LCC 4 - RDN applied as1 basal + 3 equal splits (½ basal + 25 kg + 25 kg + 25kg)} other than control. Agro Physiological Efficiency was also seen highest (72.39 kg grain yield increase per kg increase in N uptake) in T_4 {120 kg RDN at LCC 3 – RDN applied as 3 equal splits ($1/3^{rd}$ basal + $1/3^{rd}$ + $1/3^{rd}$)}. Lowest (66.47 kg grain yield increase per kg increase in N uptake) was recorded with T_3-Farmers practice. This might be due to higher dose of nitrogen in farmers practice that led to more loss of applied nitrogen fertilizer rather than uptake of it. Highest Internal Utilization Efficiency (66.38 kg yield per kg nutrient uptake) was observed in T_7 {120 kg RDN at LCC 4 – RDN applied as 3 equal splits ($1/3^{rd}$ basal + $1/3^{rd}$ + $1/3^{rd}$)} and lowest (63.41 kg yield per kg nutrient uptake) was recorded with T_1{No Nitrogen}.

Partial nutrient balance was significantly affected by LCC based nitrogen management (Table 2). Highest (0.74 kg nutrient uptake per kg nutrient applied) was observed with T_7 {120 kg RDN at LCC 4 – RDN applied as 3 equal splits ($1/3^{rd}$ basal + $1/3^{rd}$ + $1/3^{rd}$)} which was on par with T_2 {RDF (120-60-40 Kg N, P_2O_5, K_2O ha^{-1}) - RDN applied as 1 basal+ 2 equal splits (½ basal + $1/4^{th}$ + $1/4^{th}$)} followed by T_9 {150 kg RDN at LCC 4 - RDN applied as1 basal + 3 equal splits (½ basal + 25 kg + 25 kg + 25kg)}. While lowest (0.44 kg nutrient uptake per kg nutrient applied) was recorded with T_5 {150 kg RDN at LCC 3 - RDN applied as 1 basal + 2 equal splits (½ basal + $1/4^{th}$ + $1/4^{th}$)} other than control. This indicated that, more N was applied to crop than it is being removed, and the N not utilized may either be stored in the soil and/or flows through to the environment thereby causing ecosystem degradation. Decreasing N-use efficiency at greater N rates indicated that rice plants could not absorb or utilize N at greater rates or N losses exceeded the rate of plant uptake. Some [16] and [17] have reported a decrease in use efficiency of nitrogen at greater N application rates. N-use efficiency in rice, which has both physiological and soil N supply components, have decreased with increase in soil Nitrogen supply [18].

Table 2: Physiological Efficiency (PE_N), Agro Physiological Efficiency (APE_N), Internal Utilization Efficiency (IE_N) and Partial nutrient balance (PNB) of Nitrogen as influenced by LCC based nitrogen management in rice

	Treatments	PE_N kg straw yield increase per kg increase in N uptake	APE_N kg grain yield increase per kg increase in N uptake	IE_N kg yield per kg nutrient uptake	PNB kg nutrient uptake per kg nutrient applied
T_1	No Nitrogen	-	-	63.41	-
T_2	RDF (120-60-40 Kg N, P_2O_5, K_2O ha^{-1}) - RDN applied as 1 basal+ 2 equal splits (½ basal + 1/4th + 1/4th)	143.81	68.50	66.11	0.69^{a2}
T_3	Farmers practice (180-80-40 Kg N, P_2O_5, K_2O ha^{-1}) - RDN applied as 1 basal + 2 equal splits (½ basal + 1/4th + 1/4th)	138.80	66.47	65.22	0.53
T_4	120 kg RDN at LCC 3 – RDN applied as 3 equal splits (1/3rd basal + 1/3rd + 1/3rd)	154.42	72.39	66.30	0.48
T_5	150 kg RDN at LCC 3 - RDN applied as 1 basal + 2 equal splits (½ basal + 1/4th + 1/4th)	150.67	67.38	65.06	0.44
T_6	150 kg RDN at LCC 3 - RDN applied as 1 basal+ 3 equal splits (½ basal + 25 kg + 25 kg + 25 kg)	143.13	69.22	66.19	0.60
T_7	120 kg RDN at LCC 4 – RDN applied as 3 equal splits (1/3rd basal + 1/3rd + 1/3rd)	139.97	68.72	66.38	0.74^{a}
T_8	150 kg RDN at LCC 4 - RDN applied as 1 basal+ 2 equal splits (½ basal + 1/4th + 1/4th)	143.18	67.21	65.56	0.60
T_9	150 kg RDN at LCC 4 - RDN applied as1 basal + 3 equal splits (½ basal + 25 kg + 25 kg + 25kg)	134.03	67.85	66.09	0.66^{b}
	SE(m) ±	10.17	6.92	4.72	0.01
	CD (p=0.05)	NS	NS	NS	0.05
	CV %	12.27	18.02	12.49	4.34

Conclusion

Improving synchrony between crop N demand and N supply from the soil and/or the applied N fertilizer is an important strategy for enhancing N use efficiency. It can be achieved by following need based Nitrogen application based on periodic assessment of plant N status and delaying application of fertilizer N until the level falls below a fixed threshold level. Leaf Colour Chart enables farmers to dynamically adjust nutrient use to fill the deficit between the nutrient needs of crop and the nutrient Osupply from naturally occurring indigenous sources like soil, crop residues and manures. Also it enables the crop to completely utilize the applied N fertilizer. LCC is low cost tool that helps in not only improving use efficiency of applied N fertilizer bus also prevents excess N application thus saving the fertilizer cost.

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