Leaf Colour chart-based nitrogen management—Impact on soil properties and nutrient uptake of short duration transplanted rice

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Abstract

A field experiment was conducted during Kharif, 2018 to study the effect of LCC based nitrogen management on growth of short duration transplanted rice. 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 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. LCC based treatments were evaluated against control, recommended method and Farmers practice. Results revealed that, LCC -4 was more beneficial in enhancing yield and nutrient uptake of rice. Physico-chemical properties and nutrient status of soil were not unaffected by treatments. LCC-4 with 150 kg N ha⁻¹ was superior in uptake of N, P and K (112.5, 46.8 and 115.2 kg ha⁻¹ respectively). LCC based nitrogen application was effective in improving uptake of nutrients thus resulting in satisfactory yields.

Keywords: LCC, nitrogen, Short duration transplanted rice, nutrient uptake, soil properties.

Introduction

In low land ecology, poor management practices, especially the fertilizer management is the key factor for the poor productivity of rice in India. Among all the reasons for lower productivity, inefficient utilisation of nitrogen is considered as an important one. Monitoring plant N status is important for improving the balance between crop N demand and N supply from soil and applied fertilizer. Since farmers generally prefer to keep leaves of the crop dark green and in a need to achieve high yields of rice, they have developed a tendency to apply fertilizer N in excess of crop requirements resulting in poor efficiency of applied Nitrogen. Advances in N management for rice include adjustment of the early N application to match the relatively low demand of young rice plants and varying rates and distribution of fertilizer N within the growing season to match crop demand for supplemental N. In this respect, the leaf N status of rice, which is closely related to photosynthetic rate and biomass production, serves as a sensitive indicator of the crop demand for N during the growing season (Singh et al., 2012) [1]. 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. The LCC emerged as economical and potential tool for synchronizing in-season demand and supply in field crops. Leaf Colour Chart will provide indirect assessment of leaf nitrogen status, which is closely related to photosynthetic rate and biomass production (Kropff et al., 1993) [2]. Leaf color chart has been used successfully to guide fertilizer N application in rice, wheat and maize (Ali et al., 2014) [3].

Material and methods

A field experiment was conducted during Kharif, 2017 to study the effect of LCC based nitrogen management on growth, yield and nitrogen use efficiency of short duration transplanted rice at College farm, College of Agriculture, Rajendranagar, Hyderabad (17°19' N and 78°24' E). The soil was moderately alkaline in pH (7.8), non-saline in EC (0.32 dS m⁻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). The experiment was laid out in RBD with 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 control with no nitrogen, Recommended method and Farmers practice with (120-60-40), (180-80-40) RDF respectively applied at fixed time intervals. Rice variety selected for the study was KNM-118 (Kunaram sannalu). 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$_2$O$_5$ and K$_2$O 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$_3$ and T$_7$. Entire dose of P as basal and K applied in 2O splits (basal + at 1$^{st}$ 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
The topmost fully expanded leaf from each hill was selected and leaf colour was compared by placing the middle part of the leaf on LCC and the leaf colour was observed. Whenever the green colour of more than 5 out of 10 leaves were observed equal to or below a set critical limit of LCC score, nitrogen was applied as per the treatment. The leafwax 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 in order to avoid the influence of sun light as it may reflect the LCC colour.

Soil analysis and nutrient uptake studies
Soil samples collected from each plot up to depth 15 cm after harvest of the crop were shade dried, pounded and sieved through 2 mm mesh. A representative sample was prepared for all treatments and preserved in polythene bags. Samples are analyzed for physico-chemical, physical and chemical properties following standard procedures. Available nitrogen in soil was determined by alkaline potassium permanganate method. Available phosphorus using Olsen’s reagent (0.5 N NaHCO$_3$, pH 8.5) in ascorbic acid method given by Watanabe and Olsen. Available potassium was extracted from soil with Neutral normal ammonium acetate at pH 7.0 was determined by using flame photometer (Elico CL 378). Plant samples collected at 30, 60, 90 DAT and at harvest. Samples were analyzed for N, P and K content by adapting standard procedures i.e., (Modified Kjeldhal’s method), (Direct acid digestion method and colorimetric estimation) and (Direct acid digestion method followed by Flame photometer method) respectively given by Piper. 1966. The values of NPK contents for grain and straw were recorded treatment wise and then N, P and K uptakes were determined for grain and straw yields of each treatments.

Results and discussion
Effect of LCC based N management on soil physico-chemical properties and nutrient availability
An overview of the data presented in Table.1 indicated that, physico-chemical properties like pH, EC and OC in post harvest soil were close to the initial soil status. Post-harvest nutrient status of soil i.e., available N, P and K were not significantly influenced by LCC based Nitrogen management. All the treatments were on par with nitrogen dose and LCC critical value. Initially soil was moderately alkaline with pH 7.81. After the experimentation, soil pH ranged from 7.71 to 7.76 in various treatments. Lowest pH (7.71) observed in T$_3$ (Farmers practice) might be due to, application of excess nitrogen (ammonium based) which have acidifying property in soil. While highest (7.76) was recorded in T$_1$ Initial soil has EC of 0.32 dS m$^{-1}$. Highest EC (0.36) at harvest was recorded with T$_7$. While lowest (0.31) was recorded with T$_5$. Initially soil was low (0.42%) in organic carbon. Highest OC (0.41) at harvest was recorded with T$_5$, T$_6$, T$_8$ and T$_9$. While lowest (0.40) was recorded with T$_1$, T$_2$, T$_3$ and T$_7$.

The available nitrogen status in the initial soil was low (210 kg ha$^{-1}$). Highest available nitrogen (208.4 kg ha$^{-1}$) in post harvest soil was recorded with T$_3$ (Farmers practice) which might be due to the application of large amounts of nitrogen (Johnkutty et al., 2000). While lower N availability in T$_1$ might be due to insufficient N application that was utilized for crop growth and uptake. These results were similar to the findings of Arvind et al. (2006). The available phosphorous status in the initial soil was medium (44.3 kg ha$^{-1}$). Highest available phosphorous (43.4 kg ha$^{-1}$) in post harvest soil was recorded with T$_3$. While lowest (39.7 kg ha$^{-1}$) was recorded with T$_1$ [No Nitrogen]. The higher soil P availability in T$_1$ (120 kg RDN at LCC 3 - RDF applied as 3 equal splits (1/3$^{rd}$ basal + 1/3$^{rd}$ + 1/3$^{rd}$) and farmers practice with 180 kg N ha$^{-1}$ might be due to less uptake of P by plant. The available potassium status in the initial soil was high (351.0 kg ha$^{-1}$). Highest available potassium (345.4 kg ha$^{-1}$) in post harvest soil was recorded with T$_2$. While lowest (328.1 kg ha$^{-1}$) was recorded with T$_1$ [No Nitrogen] (Table 1). Application of N in larger quantities might have decreased available P and K. As the applied N being the primary nutrient factor, the rice biomass and P and K uptake increased considerably with increasing rate of N application and LCC levels, that might be lead to a proportional decline in soil available P and K (Nachimuthu et al., 2007).

| Table 1: Soil physico-chemical properties and nutrient availability as influenced by LCC based nitrogen management in rice |
|---------------------------------------------------------------|
| **Treatments** | **Soil physico-chemical properties** | **Nutrient availability** |
| | **pH** | **EC (dSm$^{-1}$)** | **OC (%)** | **Available N (kg ha$^{-1}$)** | **Available P (kg ha$^{-1}$)** | **Available K (kg ha$^{-1}$)** |
| T$_1$ | No Nitrogen | 7.76 | 0.32 | 0.40 | 192.1 | 39.7 | 328.1 |
| T$_2$ | RDF (120-60-40 Kg N, P$_2$O$_5$, K$_2$O ha$^{-1}$) - RDN applied as 1 basal + 2 equal splits (½ basal + 1/4$^{th}$ + 1/4$^{th}$) | 7.74 | 0.34 | 0.40 | 201.3 | 41.7 | 345.4 |
| T$_3$ | Farmers practice (180-80-40 Kg N, P$_2$O$_5$, K$_2$O ha$^{-1}$) - RDN applied as 1 basal + 2 equal splits (½ basal + 1/4$^{th}$ + 1/4$^{th}$) | 7.71 | 0.31 | 0.41 | 208.4 | 40.4 | 335.3 |
| T$_4$ | 120 kg RDN at LCC 3 – RDN applied as 3 equal splits (1/3$^{rd}$ basal + 1/3$^{rd}$ + 1/3$^{rd}$) | 7.75 | 0.35 | 0.40 | 202.3 | 43.4 | 343.2 |
| T$_5$ | 150 kg RDN at LCC 3 - RDN applied as 1 basal + 2 equal | 7.73 | 0.34 | 0.41 | 205.8 | 43.3 | 342.5 |
Effect of LCC based N management on nutrient uptake by Rice:

Nitrogen uptake differed significantly at 30, 60, 90 DAT and Harvest by LCC based Nitrogen management (Table 2). It was observed that, at 30 DAT, highest nitrogen uptake (56.8 kg ha\(^{-1}\)) was recorded with \(T_1\) (Farmers practice) and was on par with \(T_9\) (150 kg RDN at LCC 4 - RDN applied as 1 basal + 3 equal splits (½ basal + 25 kg + 25 kg + 25 kg)). While lowest (14.1 kg ha\(^{-1}\)) was recorded with \(T_1\) [No Nitrogen] which was significantly inferior to all other treatments. At 60 DAT, highest nitrogen uptake (121.6 kg ha\(^{-1}\)) was recorded with \(T_9\) which was on par with \(T_1\) [Farmers practice]. While lowest (38.2 kg ha\(^{-1}\)) was recorded with \(T_1\) [No Nitrogen]. Similar trend was observed at 90 DAT. Where highest nitrogen uptake (115.1 kg ha\(^{-1}\)) was recorded with \(T_9\) which was on par with \(T_2\) (Recommended practice), \(T_3\) and \(T_7\). Lowest (52.1 kg ha\(^{-1}\)) was recorded with \(T_1\) [No Nitrogen]. At Harvest, Nitrogen uptake was analyzed in both grain and straw separately. Highest nitrogen uptake (81.4 kg ha\(^{-1}\)) in grain was recorded with \(T_9\) which was on par with \(T_3\) [Farmers practice], \(T_7\) and \(T_9\). While lowest (25.4 kg ha\(^{-1}\)) was recorded with \(T_1\) [No Nitrogen] which was significantly inferior to all other treatments. Nitrogen uptake (31.3 kg ha\(^{-1}\)) in straw was recorded with \(T_3\) [Farmers practice which was on par with \(T_2,\ T_7,\ T_9\) and \(T_9\). Lowest N-uptake by straw (14.2 kg ha\(^{-1}\)) was recorded with \(T_1\) [No Nitrogen]. It was found that, maximum absorption of nitrogen occurred between maximum tillering and flowering stage. This findings are in close conformity with Duan et al. (2005) [8]. Treatments imposed based on LCC-4 resulted in more N-uptake than farmers practice and recommended method. Since nutrient uptake is a function of biomass production, the rapid increase of biomass in \(T_9\) [150 kg RDN at LCC 4 - RDN applied as 1 basal + 3 equal splits (½ basal + 25 kg + 25 kg + 25 kg)] might have demanded more nutrients, thus resulting in higher rate of N uptake (Zaman, 1999) [9]. Nitrogen uptake was more at higher rate of nitrogen (150 and 180 kg N ha\(^{-1}\)) due to increased nitrogen content in plant tissue and crop yield probably because of adequate nitrogen available to plant for vegetative and reproductive growth (Reena et al., 2017) [10].

| Treatments | Nitrogen uptake (kg ha\(^{-1}\)) as influenced by LCC based nitrogen management in rice. |
|------------|--------------------------------------------------------------------------------------------|
|            | 30 DAT | 60 DAT | 90 DAT | Grain | Straw | Harvest | Total |
| \(T_1\) No Nitrogen | 14.1 | 38.2 | 52.1 | 25.4 | 14.2 | 39.6 |
| \(T_2\) RDF (120-60-40 Kg N, P\(_2\)O\(_5\), K\(_2\)O ha\(^{-1}\)) - RDN applied as 1 basal + 2 equal splits (½ basal + 1/4\(^{th}\) + 1/4\(^{th}\)) | 32.7 | 91.2 | 105.7 | 67.8 | 28.0 | 95.8 |
| \(T_3\) Farmers practice (180-80-40 Kg N, P\(_2\)O\(_5\), K\(_2\)O ha\(^{-1}\)) - RDN applied as 1 basal + 2 equal splits (½ basal + 1/4\(^{th}\) + 1/4\(^{th}\)) | 56.8 | 110.2 | 112.8 | 76.9 | 31.3 | 108.2 |
| \(T_4\) 120 kg RDN at LCC 3 - RDN applied as 3 equal splits (1/3\(^{rd}\) basal + 1/3\(^{rd}\) + 1/3\(^{rd}\)) | 26.0 | 62.1 | 80.8 | 44.2 | 19.1 | 63.3 |
| \(T_5\) 150 kg RDN at LCC 3 - RDN applied as 1 basal + 2 equal splits (½ basal + 1/4\(^{th}\) + 1/4\(^{th}\)) | 24.9 | 64.1 | 85.8 | 52.5 | 22.6 | 75.1 |
| \(T_6\) 150 kg RDN at LCC 3 - RDN applied as 1 basal+ 3 equal splits (½ basal + 25 kg + 25 kg + 25 kg) | 26.9 | 68.4 | 88.9 | 59.7 | 24.3 | 84.0 |
| \(T_7\) 120 kg RDN at LCC 4 - RDN applied as 3 equal splits (1/3\(^{rd}\) basal + 1/3\(^{rd}\) + 1/3\(^{rd}\)) | 32.9 | 85.6 | 102.4 | 71.2 | 28.2 | 99.4 |
| \(T_8\) 150 kg RDN at LCC 4 - RDN applied as 1 basal+ 2 equal splits (½ basal + 1/4\(^{th}\) + 1/4\(^{th}\)) | 33.3 | 89.4 | 103.8 | 72.4 | 29.0 | 101.4 |
| \(T_9\) 150 kg RDN at LCC 4 - RDN applied as 1 basal+ 3 equal splits (½ basal + 25 kg + 25 kg + 25 kg) | 47.8 | 121.6 | 115.1 | 81.4 | 31.1 | 112.5 |
| SE(m) ± | 4.5 | 8.3 | 7.1 | 3.4 | 1.6 | 2.6 |
| CD (p=0.05) | 13.4 | 24.9 | 21.4 | 10.3 | 4.7 | 7.8 |
| CV % | 23.6 | 17.7 | 13.1 | 9.7 | 10.9 | 5.2 |

Phosphorous uptake at harvest differed significantly by LCC based Nitrogen management (Table 3). Phosphorous uptake was analyzed in both grain and straw separately. Highest Phosphorous uptake in Grain (29.4 kg ha\(^{-1}\)) was recorded in \(T_9\) which was on par with \(T_3,\ T_7,\ T_9\) and \(T_9\). While lowest (10.4 kg ha\(^{-1}\)) was recorded with \(T_1\) [No Nitrogen] which was significantly inferior to all other treatments. Highest Phosphorous uptake in Straw (17.9 kg ha\(^{-1}\)) was recorded in \(T_9\) [Farmers practice] which was on par with \(T_2,\ T_7,\ T_9\) and \(T_9\). While lowest (7.2 kg ha\(^{-1}\)) was recorded with \(T_1\). Highest total Phosphorous uptake (46.8 kg ha\(^{-1}\)) was recorded with \(T_9\) which was on par with \(T_3\). While lowest (17.6 kg ha\(^{-1}\)) was recorded with \(T_1\). Similar were reported by Marahatta et al. (2017) [11] and Ravi et al. (2007) [12]. Treatments imposed based on LCC-4 resulted in more P-uptake than farmers practice and recommended method. This might be due to
ready availability of nitrogen for the crop that helped in enhanced absorption of phosphorous. More P-uptake was recorded with higher doses of nitrogen (150 and 180 kg ha\(^{-1}\)). Increase in P uptake with increased dose of N added evidence to the fact that, N application has synergistic effect on the uptake of other nutrients like P and K (Nachimuthu et al., 2007) [13]. Potassium uptake at harvest was significantly influenced by LCC based Nitrogen management (Table 3). Highest potassium uptake in Grain (27.4 kg ha\(^{-1}\)) was recorded in T\(_3\) which was on par with T\(_1\), T\(_4\) and T\(_5\). While lowest (9.3 kg ha\(^{-1}\)) was recorded with T\(_1\). Highest potassium uptake in Straw (90.6 kg ha\(^{-1}\)) was recorded in T\(_3\) (Farmers practice) which was found to be on par with T\(_5\) and T\(_6\). Lowest (26.3 kg ha\(^{-1}\)) was recorded with T\(_1\) (No Nitrogen). Highest Total potassium uptake (116.3 kg ha\(^{-1}\)) was recorded with T\(_3\) (Farmers practice) which was on par with T\(_5\). While the lowest (35.6 kg ha\(^{-1}\)) was recorded with T\(_1\) (No Nitrogen). The results are in agreement with Bai et al., 2013 [14] and Sui et al., 2013 [15]. K-uptake was higher in treatments imposed based on LCC-4 rather than recommended practice. This might be due to ready availability of nitrogen for the crop helped to enhanced absorption of potassium. Farmers practice with 180 kg N ha\(^{-1}\) and treatments with 150 kg N ha\(^{-1}\) were superior in terms of K-uptake. This increase in K uptake with increased dose of N was due to fact that, N application has synergistic effect on the uptake of other nutrients like P and K.

**Table 3: Phosphorous and Potassium uptake (kg ha\(^{-1}\)) at harvest as influenced by LCC based nitrogen management in rice.**

| Treatments                      | P-Uptake (kg ha\(^{-1}\)) | K-Uptake (kg ha\(^{-1}\)) |
|--------------------------------|--------------------------|---------------------------|
|                                | Grain        | Straw      | Total       | Grain       | Straw      | Total       |
| T\(_1\)                        | 10.4         | 7.2        | 17.6        | 9.3         | 26.3       | 35.6        |
| T\(_2\)  RDF (120-60-40 Kg N, P\(_2\)O\(_5\), K\(_2\)O ha\(^{-1}\)) - RDN applied as 1 basal+2 equal splits (½ basal + 1/4\(^{th}\) + 1/4\(^{th}\)) | 24.7         | 15.8       | 40.5        | 21.9        | 78.5       | 100.4       |
| T\(_3\)  Farmers practice (180-80-40 Kg N, P\(_2\)O\(_5\), K\(_2\)O ha\(^{-1}\)) - RDN applied as 1 basal + 2 equal splits (½ basal + 1/4\(^{th}\) + 1/4\(^{th}\)) | 28.4         | 17.9       | 46.3        | 25.7        | 90.6       | 116.3       |
| T\(_4\)  120 kg RDN at LCC 3 – RDN applied as 3 equal splits (1/3\(^{rd}\) basal + 1/3\(^{rd}\) + 1/3\(^{rd}\)) | 16.2         | 10.7       | 26.9        | 15.0        | 54.9       | 69.9        |
| T\(_5\)  150 kg RDN at LCC 3 - RDN applied as 1 basal + 2 equal splits (½ basal + 1/4\(^{th}\) + 1/4\(^{th}\)) | 18.5         | 12.5       | 31.0        | 17.5        | 63.2       | 80.7        |
| T\(_6\)  150 kg RDN at LCC 3 - RDN applied as 1 basal+ 3 equal splits (½ basal + 25 kg + 25 kg + 25 kg) | 21.4         | 13.3       | 34.7        | 20.3        | 67.8       | 88.1        |
| T\(_7\)  120 kg RDN at LCC 4 – RDN applied as 3 equal splits (1/3\(^{rd}\) basal + 1/3\(^{rd}\) + 1/3\(^{rd}\)) | 26.3         | 16.1       | 42.4        | 24.1        | 79.6       | 103.7       |
| T\(_8\)  150 kg RDN at LCC 4 - RDN applied as 1 basal+ 2 equal splits (½ basal + 1/4\(^{th}\) + 1/4\(^{th}\)) | 26.5         | 16.2       | 42.7        | 24.1        | 82.9       | 107.0       |
| T\(_9\)  150 kg RDN at LCC 4 - RDN applied as1 basal+3 equal splits (½ basal + 25 kg + 25 kg + 25 kg) | 29.4         | 17.4       | 46.8        | 27.4        | 87.8       | 115.2       |
| SE(m) ±             | 1.3          | 0.8        | 0.9         | 1.2         | 3.0        | 2.3         |
| CD (p=0.05)          | 4.0          | 2.5        | 2.7         | 3.7         | 9.1        | 6.9         |
| CV %                | 10.4         | 10.2       | 4.3         | 10.4        | 7.4        | 4.4         |

**Conclusion**

Most of applied N in fields is lost due to lack of synchrony of plant N demand with N supply. LCC is a simple and easy-to-use tool which helps farmers in avoiding excess application of N in rice crop. Also improves the balance between crop N demand and N supply from soil and applied fertilizer. The LCC based management in rice suggests that, availability and uptake of nutrients in soil and plant can be enhanced. Moreover, there can be considerable opportunity to increase farmers yield and N application can be saved with no yield loss by revising the fertilizer recommendation.

**References**

1. Singh B, Singh V, Singh Y, Thind HS, Kumar A, Gupta RK et al. Fixed-time adjustable dose site-specific fertilizer nitrogen management in transplanted irrigated rice (*Oryza sativa* L.) In South Asia. Field Crops Research. 2012; 126:63-69.
2. Kropff MJ, Cassman KG, Van Laar HH, Peng S. Nitrogen and yield potential of irrigated rice. Plant Soil Journal. 1993; 155/156:391-394.
3. Ali AM, Thind HS, Sharma S. Prediction of dry direct-seeded rice yields using chlorophyll meter, leaf color chart and GreenSeeker optical sensor in northwestern India. Field Crops Research. 2014; 161:11-15.
4. Piper CS. Soil and Plant Analysis. Hans Publishers, Bombay, 1966.
5. Johnkutty L, Kandawamy OS, Palaniappan SP. Time course leaf N concentration in rice under different nitrogen application strategies and development of simulation models. Journal of Tropical Agriculture. 2000; 37:40-45.
6. Arvind KS, Singh VK, Dwived BS, Sharmaj SK, Yogendra S. Nitrogen use efficiencies using leaf colour chart in rice (*Oryza sativa*) wheat (*Triticum aestivum*) cropping system. Indian Journal of Agricultural Sciences. 2006; 76(11):651-656.
7. Nachimuthu G, Velu V, Malarvizi P, Ramasamy S, Gurusamy L. Standardisation of leaf colour chart based nitrogen management in direct wet seeded rice (*Oryza sativa* L.). Journal of Agronomy. 2007; 6(2):338.
8. Duan YH, Zhang YL, Shen QR, Chen H, Zhang Y. Effect of partial replacement of NH\(_4\) by NO\(_3\) on nitrogen uptake and utilisation by different genotypes of rice at the seeding stage. Plant Nutrition Fertilizer Science. 2005; 11(2):160-165.
9. Zaman MH. Improving nitrogen management for transplanted rice: Use of chlorophyll meter (SPAD 502), Leaf Colour Chart (LCC) and controlled release nitrogen fertilizer. *M. Sc. (Ag.) Thesis*. Tamil Nadu Agricultural University, Coimbatore, India, 1999.
10. Reena, Dhyani VC, Chaturvedi, Sumit, Shikha. Dynamics of yield, nitrogen uptake and nitrogen use efficiency in wheat (*Triticum aestivum*) crop as influenced by leaf colour chart and chlorophyll meter
based real time nitrogen management. *International Journal of Agriculture Sciences*. 2017; 9(54):4930-4933.

11. Marahatta S. Increasing productivity of an intensive rice based system through site specific nutrient management in Western Terai of Nepal. *Journal of Agriculture and Environment*. 2017; 18:140-150.

12. Ravi S, Ramesh S, Chandrasekaran B. Exploitation of hybrid vigour in rice hybrid (*Oryza sativa* L.) through green manure and leaf colour chart (LCC) based N application. *Asian Journal of Plant Sciences*. 2007; 6(2):282-287.

13. Bai KJL, Murthy KVR, Naidu MV. Effect of graded levels and time of nitrogen application on nutrient uptake, yield and economics of semi-dry rice (*Oryza sativa* L.) Journal of Research ANGRAU. 2013; 41(2):21-25.

14. Sui B, Feng X, Tian G, Hu X, Shen Q, Guo S. Optimizing nitrogen supply increases rice yield and nitrogen use efficiency by regulating yield formation factors. *Field Crops Research*. 2013; 150:99-107.