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Leaf Color Chart Can Increase Productivity and Foster Climate Smart Agriculture in Rice: A Case Study

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ABSTRACT

Optimum nitrogen application has been a major challenge to enhance agricultural productivity and sustainability in rice cultivation of Nepal. Nitrogen fertilizer must be applied only when necessary and must be based on the crop's nitrogen requirement. Losses of nitrogen from rice field can cause air pollutant production, global warming and climate change. Leaf Color Chart (LCC) poses potential climate smart practice in rice field. The use of LCC is a low cost and viable method for managing nitrogen in real time, enhancing the nitrogen use efficiency. To demonstrate the effectiveness of LCC based urea application for nitrogen management in rice, a field experiment was conducted at Masala Bali Bikash Kendra, Panchkhal from June to November, 2022. Variety selected for field experimentation was Makawanpur-1. The experiment compared government-recommended urea application with LCC-based application for which field was divided into two equal plots (300 sq m). Morphological growth was measured at different stages of rice and yield was taken at maturity. In rice, LCC-based urea application led to taller plants (128.5 cm) compared to blanket urea application (115.56 cm) at harvest. LCC-based urea application also had 34% more leaves (126) and 54.5% higher effective tiller count (17). Despite the same rate of nitrogen application, yield was 35% higher in LCC based practice (4694.73 kg ha^{-1}) than government recommended practice. Real time nitrogen application in splits based on LCC management led to better plant growth and yield, while fixed-time nitrogen application regardless of crop need in conventional blanket application resulted in nitrogen loss and lower yield. Considering the effect of nitrogen application through LCC management on rice productivity, it's clear that LCC offers valuable chances to enhance nitrogen use efficiency, rice yield, and farmers' profits.

Keywords: Crop growth, LCC, Nitrogen management, NUE, Rice, Yield

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INTRODUCTION

Rice has been an important crop for over 7000 years, feeding more than half of the world population (Izawa and Shimamoto 1996). It is a staple food playing a crucial role in ensuring global food security, nutrition and economic development (Bishwajit et al 2013). However, farmers apply substantial amount of fertilizer, especially the urea fertilizer without considering the soil and crop requirement (Moe et al 2019). This has raised concern on emission of greenhouse gases and nitrogen use efficiency in the rice field (Ferdous et al 2023).

The government recommends applying 120:60:40 NPK Kg ha^{-1} to farmers, meaning that 260.87 Kg of urea is applied per hectare. The current practice of applying the recommended dose of fertilizer for rice cultivation often results in lower yield and profitability due to inefficient usage. The inefficient use of nitrogen is widely considered to be the most critical factor contributing to low productivity (Shukla et al 2004). Nitrogen fertilizer must be applied only when necessary and must be based on the crop's nitrogen status. However, most farmers rely on the age (days after transplanting) of rice and not on nitrogen status of crop (Alam et al 2005). As a result, the utilization of nitrogen for crop growth, development, and yield becomes suboptimal. Studies have shown that a lack of synchronization between nitrogen demand and supply results in the loss of over 60% of applied nitrogen from the soil-plant system (Yadav et al 2004).

Losses of nitrogen from rice field can cause air pollutant production, global warming and climate change (Zhong et al 2016). Carbon dioxide (Co_2), methane (CH_4) and nitrous oxide (N_2O) are the greenhouse gases directly contributing to global warming, while ammonia (NH_3) is another prevalent gas produced in the rice field, plays an indirect role in global warming. NH_3 volatilization stands as the primary route for nitrogen loss, with roughly 10-60% of applied nitrogen in rice fields being susceptible to this loss. Leaching contributes to approximately 30-50% of total N losses (Gosh and Bhat 1998). Additionally, approximately 5-10% of the applied nitrogen may be lost through the process of denitrification (Nitu et al 2021). Therefore, it is crucial to adopt an appropriate nutrient management approach that takes into account the specific requirements of the crop, particularly regarding the application of N, P, and K.

The Leaf color chart (LCC) was developed by International Rice Research Institute (IRRI), Manila, Philippines, to measure chlorophyll availability in rice. It reported that LCC, like the chlorophyll meter, provides accuracy for determining nitrogen deficiency and ascertains the amount of nitrogen fertilizer required for rice crops. It determines the degree of greenness in the rice leaf and available nitrogen content in plant (Alam et al 2005). It is a nitrogen management system based on crops, and it provides an inexpensive, easy-to-use, and simple alternative to chlorophyll meters or SPAD meters. LCC is usually 3 x 8 inches in size that includes six colors ranging from yellow green to dark green, with small variations one by one from the first color to the last sixth color (Nachimuthu et al 2007). The color of the leaves is compared to a standard color chart under the same environmental conditions. The lightest, more yellowish hue is labeled-1, and the deepest, darkest green hue is labeled-6. It is used to guide nitrogen top dressing in rice.

The Leaf Color Chart ensures the optimum use of nitrogen fertilizers in agriculture by applying the right quantity of fertilizer at the right time based on the needs of rice plants. The intensity of leaf color shows the relationship between nitrogen and photosynthesis, making it an indicator of the amount of nitrogen present in the plant. The main objective of applying LCC based nitrogen is to increase nitrogen use efficiency, high yields and reduce nitrogen losses.

Although LCC holds a major significance in nitrogen management in rice fields, it hasn't been popularized yet in Nepal. Farmers have been applying nitrogen fertilizer in their crops as per the blanket recommendation of the government at fixed doses at fixed intervals of time despite the nitrogen requirement of crops which has resulted in the loss of nitrogen. It has been proven that right time, right rate, right dose and right place of fertilizer application shows high yield and high utilization of fertilizer by crops. LCC follows the 4 R principle of fertilizer application and ensures proper utilization of N by crops. Therefore, if the farmers are made aware of the significance of LCC, it will provide gigantic opportunities to improve N utilization efficiency, rice yield, and net returns for farmers.

The experiment was conducted with the purpose of demonstrating the effectiveness of LCC based urea application in rice and comparing it with government blanket recommendation. The experiment was demonstrated among the scholars of agriculture to acquaint them with one of the climate smart practices in rice cultivation.

MATERIALS AND METHOD

Study site

A field demonstration was conducted at the government farm, Masala Bali Bikash Kendra, Panchkhal, Kavre (27.6449426° N latitude and 85.6199464° E longitude) during June to November, 2022.

Crop and variety

The rice variety popular in the region i.e., 'Makawanpur-1' was selected to cultivate in both the experimental plots.

Treatment details

Two treatment plots, i.e., T1 and T2 were designed for the demonstration. Plot T1 was designed to use Nitrogen based on LCC readings whereas Plot T2 was designed to use Nitrogen as per government recommendation.

Table 1: Treatment details of demonstration plot

Treatments	Treatment Details
T1	LCC Based Urea Utilization
T2	GoN recommended 120:60:40 NPK Kg ha^{-1}

Layout of experiment plot

Two fields of 300 sq m were selected. For sampling of plants, a plot of size 6×6 sq. m was designed inside each field and the area was marked for further sampling purpose.

Cultural practices

On the 15th of Asadh, 2079, 20-25 days old seedlings were transplanted. At LCC based plot, seedlings were transplanted at the rate of 1-2 seedling/ hill with planting distance of 20 cm × 20 cm (rr×pp) while at the government recommended plot, transplanting was done as commonly practiced by the farmers. Gap filling was done within 10 DAT. Application of fertilizers were done as follows:

LCC plot: Basal dose = 30:30:40 Kg NPK ha^{-1} and 30.67 Kg N ha^{-1} at 3 split doses.

GoN recommended plot: Basal dose = 60:60:40 Kg NPK ha^{-1} and 30 kg N ha^{-1} at 2 split doses.
Other cultural operations like weeding and irrigation were done as per needed. 10 plants from the plot were selected randomly and tagged for recording biometric observations.

Biometric observation

Plant height: After 15 days of transplantation, the plant height of selected plants was taken from both plots. Plant height was recorded from ground level to the tip of the flag leaf or panicle. The same process was repeated at every 15 days interval.

Tiller number: Total number of tillers were counted from tagged plants at 30 days after transplantation at every 15 days interval.

Leaf number: Total leaf number was counted from the selected plants at 15 days after transplantation at every 15 days interval.

LCC Reading: The six-panel leaf color chart was used for this experiment. 15 Days after transplantation, LCC readings were taken from selected plants. In each reading, the plots with average LCC reading below the critical value i e., 4, were applied nitrogen at the rate of 30.67 kg ha^{-1} through urea topdressing in T1 Plot (Devkota et al 2013). LCC readings were taken at every 7 days interval until flowering.

Yield: Three sampling sites of 1 sq m area were selected randomly. The number of panicles from the sample area were counted. Plants within the selected plot were cut and packed in sample bags. The panicles were cut and kept separately for each plot. Grains were threshed after measuring panicle length. Moisture content of grains was recorded. Grains from each plot were weighed and recorded every day until the constant weight was achieved. The constant weight was recorded as the actual weight.

Yield of the crop was calculated as:
Adjusted 14% moisture= Yield during harvesting (100-Moisture content of grain) / (100-14)
Harvest index was calculated as:
HI = Grain yield/ Biological yield × 100

RESULTS AND DISCUSSIONS

Amount of urea used with LCC based practices

Application of urea in LCC based nitrogen application amounted to 266.64 Kg ha^{-1} and at GoN recommended dose it was only 260 Kg ha^{-1}. There was about 6.64 Kg (2.30%) less urea when applied with GoN recommendation (Table 2). The timing and doses of fertilizer application differed between the two approaches.

In LCC plot, urea was applied whenever the crop showed nitrogen deficiency, but it was not the case in government recommendation plot. The use of LCC seeks to match crop N demand with fertilizer N supply, to optimize the crop's utilization of nitrogen (Nachimuthu et al 2007). According to Shrestha et al 2022, application of N-fertilizer according to crop demand in split doses is best management practice for rice cultivation. The results also showed that Makawanpur-1, a long duration rice variety, required slightly higher amount of fertilizer than recommended by GoN at the experiment site.

Table 2: Total amount of Nitrogen fertilizer (Urea) applied in different treatments.

S.N.	Treatments details	Total amount of Urea application (kg/ha)	No. Of split doses
1	LCC Based Urea Utilization	266.64	3
2	GoN Recommended 120:60:40 NPK kg/ha	260	2

Effect of LCC based management on plant height

The plant height was noticeably impacted across all observation dates. The average plant height observed for leaf color chart practice was 128.5 cm, while average plant height observed for government recommendation practice was 115.56 cm during the time of harvest. Higher plant height was obtained with nitrogen application based on LCC value compared to nitrogen application as per government recommendation. Rate of increment of plant height is consistently high in LCC based management.

Nitrogen application in splits according to crop specific need can be the reason for greater plant height as nitrogen promotes plant growth, increases the number and length of internodes which progressively increases the plant height (Amin 2011). LCC based management promotes plant growth, possibly by increasing the availability, uptake, and utilization of soil nutrients resulting from a higher rate of nitrogen splitting.

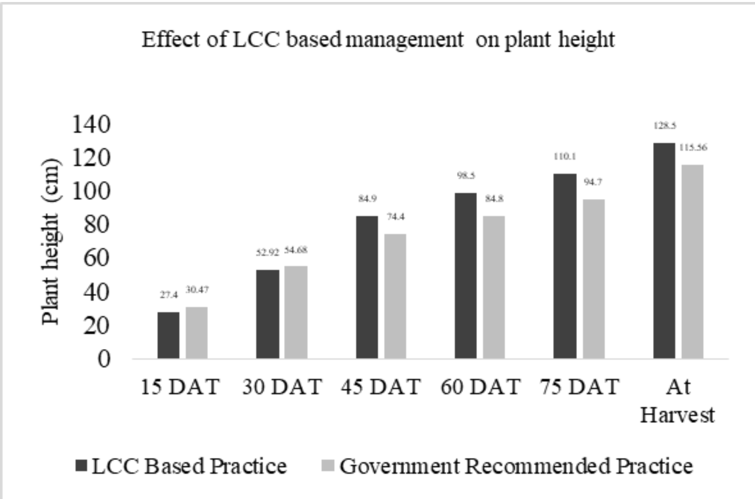

Figure 1: Graph showing the effect of LCC based management on plant height

Effect of LCC based management on leaf number

Nitrogen management practice had a significant influence on leaf number at all growth stages of the crop. The maximum leaf number for leaf color chart practice was 126 at 75 DAT, while maximum leaf number for government recommendation practice was 94 at 75 DAT. The application of nitrogen based on LCC value resulted in a notable increase in leaf number compared to applying nitrogen according to the recommendations of the government. The reason why the treatment based on LCC values resulted in a greater leaf number was due to the maintenance of a balanced nitrogen concentration, which improved the process of cell division and elongation, leading to an increase in both the number and size of leaves (Om et al 1989). The decline in number of leaves observed after 75 DAT was primarily due to the senescence of lower leaves (Subedi et al 2019). After panicle initiation, the stored metabolites remobilize from leaf sheath and stem to panicles resulting in decrease of leaf size and number (Chandrashekhar et al 2001).

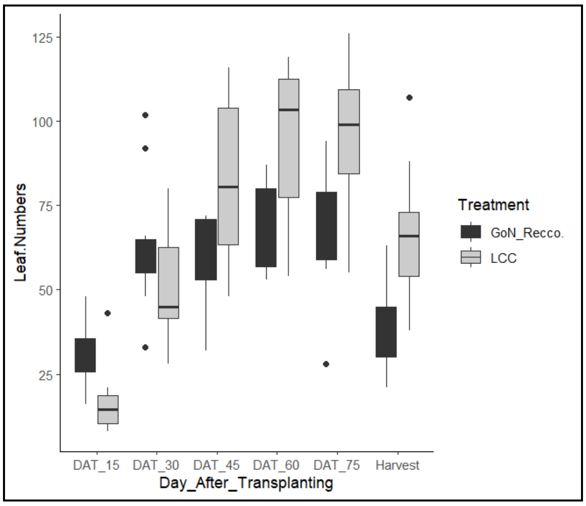

Figure 2: Box plot showing leaf numbers in LCC based nitrogen management and GoN recommendation

Effect of LCC based management on tiller number

The production of tillers is a significant characteristic for rice crop quality and grain yield. It is evident from the data recorded that LCC-based practice showed maximum tillers compared to government recommended practice. At 45 DAT, 60 DAT and 75 DAT, LCC-based practice exhibited higher plant tillers than government recommended practice.

It may have resulted due to the proper split application of nitrogen fertilizer in LCC based practice as N fertilizer increases the level of cytokinin within the tiller nodes, which further enhances the germination of tiller primordium, resulting in higher tiller population (Liu et al 2011). Increase in nitrogen supply induces tiller number and decrease in nitrogen supply reduces the tiller number. Therefore, the loss of nitrogen resulting from the fixed time application of N fertilizer regardless of crops need reduced the tiller number in government recommended practice.

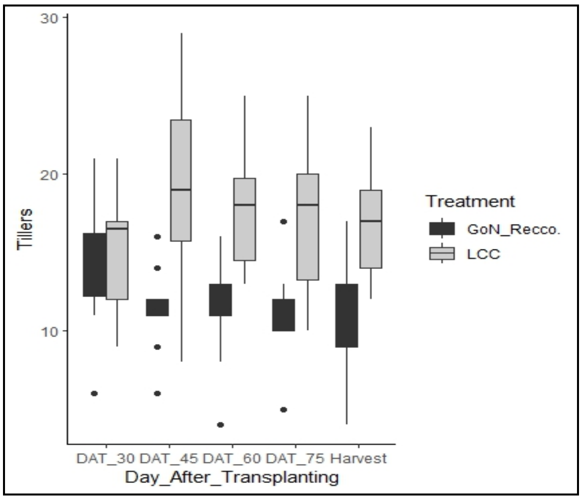

Figure 3: Boxplot showing tiller number in LCC based nitrogen management and GoN management

Effect of LCC based management on Yield

Table 3: Effect of LCC based management on Yield

S.N.	Treatments	Effective tillers	Yield (kg/ha)	Harvest Index
1	LCC Based Urea Utilization	17	4693.727	10.49
2	Recommended 120:60:40 NPK kg/ha	11	3469.884	14.93

Grain yield in LCC based practice was recorded 4693.73 Kg ha^{-1}, whereas it was recorded only 3469.88 Kg ha^{-1} in government recommended practice. As we observed the higher number of leaves in the LCC based management plot, it suggests a higher nitrogen assimilation rate in leaf. LCC based management resulted in effective utilization of nitrogen, which in turn led to an increase in chlorophyll concentration in leaves and higher photosynthetic rate, ultimately leading to a greater availability of photosynthates during grain development (Subedi et al 2019). Therefore, the application of nitrogen fertilizer based on the LCC value maintained the appropriate level of leaf nitrogen leading to improved crop growth and a higher yield of rice grains (Ali et al 2017). During the pre-heading stage and the ripening stage of rice, nitrogen plays a role in the accumulation of carbohydrates in the culms and leaf sheaths and in the grains respectively (Ahmad et al 2016). The recommended practice of dividing the application of nitrogen fertilizer into two equal splits at fixed intervals resulted in lower grain yield due to inefficient utilization of nitrogen.

However, harvest index of LCC based management plot is lower than government recommended plot. It could be due to the fact that crops with high yields produce a lot of biomasses overall, including both harvested and unharvested portion (such as leaves, stems, roots and tillers). The crop's HI, however, may be low because the unharvested portions of the plant does not increase crop production.

CONCLUSION

The study demonstrated that LCC practice of nitrogen application gives better results in terms of plant height, leaf number, tiller number and yield than government recommended practice of nitrogen application. Compared to the conventional application of nitrogen, LCC based nitrogen application increased the nitrogen use efficiency, total nitrogen uptake and biomass and grain yield. The reason behind the superior performance of LCC based nitrogen management can primarily be because of more split application of N fertilizer during growing season along with balanced approach to fertilization. LCC based nitrogen management showed higher plant height after 45 days after transplanting due to split application when rice nitrogen demand was increasing. LCC based application of Nitrogen also showed higher leaf and tiller number. The yield in LCC based nitrogen management was 4693.73 Kg ha^{-1} i.e., 35% more than the GoN recommended dose. The main reason for increased yield was higher effective tiller number in LCC based nitrogen application. The result has confirmed crop nitrogen requirement can be judged with leaf greenness which can be measured through low-cost devices like LCC at farmers' field (Hou et al 2020). So, it suggests adopting LCC based nitrogen management practice as it focuses on the application of nitrogen in splits according to crop specific need which prevents the loss of nitrogen. It also provides directions for how to apply nitrogen fertilizer in a way that keeps the leaf nitrogen content at an optimum level, resulting in a successful rice harvest and efficient nitrogen usage.

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AUTHORS' CONTRIBUTION

Ashmita Lamsal: Data collection, data analysis and interpretation, literature review, writing and manuscript preparation.
Aadarsh Poudel: Data collection, organization of experimental dataset, data visualization, literature review.
Yamuna Dhital: Data collection, editing, manuscript preparation.
Pradip Kumar Tharu: Data collection, literature review.
Nabin Kumar Singh: Data collection, assisted with organization of experimental data and data visualization.
Roshan Subedi: Supervision, writing-review and editing, assisted with data visualization.

CONFLICTS OF INTEREST

The authors have no any conflict of interest to declare.

REFERENCES

Ahmad N, Z Ahmad, M Junaid and A Akhtar. 2016. Bridging the Yield Gap in Rice Production by Using Leaf Color Chart for Nitrogen Management. Journal of Botany. **2016**:1-6.

Alam M, JK Ladha, SR Khan, Foyjunnessa, Harun-ur-Rashid, AH Khan and RJ Buresh.2005. Leaf color chart for managing nitrogen fertilizer in lowland rice in Bangladesh. Agronomy Journal. **97**:949-959.

Amin, MEH.2011. Effect of different nitrogen sources on growth, yield and quality of fodder maize (*Zea mays* L.). Journal of Saudi Society of Agriculture Sciences. **10**(1):17-23.

Bishwajit G, S Sarker, MA Kpoghomou, H Gao, L Jun, L and D Yin.2013. Self-sufficiency in rice and food security: a South Asian perspective. Agriculture and Food Security. **2**(10): 1-6.

Budhar, MN.2005. Leaf colour chart with nitrogen management in direct seeded puddled rice (*Oryza sativa* L). Fertilizer News**. 50**(3):41-44.
Chandrasekhar J, G Rana Rao and KB Reddy.2001. Physiological analysis of growth and productivity in hybrid rice (Oryza sativa). Indian Journal of Plant Physiology. **6**(2): 142-146.
Devkota K, S Yadav, J Ranjit, D Sherchan, A Regmi, M Devkota, T Akhtar, E Humphreys, B Chauhan, V Kumar, A McDonald and RK Malik. 2014. Fertilizer management. **In**: Guidelines for dry seeded rice (DSR) in the Terai and mid hills of Nepal. **Pp.** 18-20**.**
Ferdous J, F Mahjabin, M Abdullah al Asif, I Jahan Riza and M Mofizur Rahman Jahangir.2023. Gaseous Losses of Nitrogen from Rice Field: Balancing Climate Change and Sustainable Rice Production. IntechOpen. Doi: 10.5772/intechopen.108406
Gosh BC and R Bhat.1998). Environmental hazards of nitrogen loading in wetland rice fields. Environmental Pollution. **102**(1): 123-126.
Hou W, M Tränkner, J Lu, J Yan, S Huang, T Ren, R Cong, and X Li. 2020. Diagnosis of Nitrogen Nutrition in Rice Leaves Influenced by Potassium Levels. Frontiers in plant science, 11, 165. https://doi.org/10.3389/fpls.2020.00165
Izawa T and K Shimamoto.1996. Becoming a model plant: The importance of rice to plant science. Trends in Plant Science. **1**(3): 95-99.
Ladha JK, H Pathak, TJ Krupnik, J Six and CV Kessel. 2005. Efficiency of fertilizer nitrogen in cereal production: retrospect and prospects. Advances in Agronomy. **87**: 85-156.
Liu Y, YF Ding, QS Wang, DX Meng and SH Wang.2011. Effects of nitrogen and 6-benzylaminopurine on rice tiller bud growth and changes in endogenous hormones and nitrogen, Crop Sci. **51**: 786-792.
Moe K, SM Moh, AZ Htwe, Y Kajihara and T Yamakawa. 2019. Effects of integrated organic and inorganic fertilizers on yield and growth parameters of rice varieties. Rice Science. **26**(5):309-318.
Nachimuthu G, V Velu, P Malarvizhi, S Ramasamy and L Gurusamy. 2007. Standardization of leaf color chart-based nitrogen management in direct wet seeded rice (*Oryza sativa* L.). Journal of Agronomy. **6**: 338-343.
Nitu TT, UM Milu and MMR Jahangir.2021. Cover crops and soil nitrogen cycling. **In**: Cover Crops and Sustainable Agriculture (R Islam and R Sherman, eds); **pp**. 209-226.
Om H, RK Joon and OP Singh.1989. Effect of time of transplanting and age of seedling on growth and yield of dwarf rice. Indian Journal of Agronomy. **34**(3): 325-327.
Sathiya K and T Ramesh.2009. Effect of split application of nitrogen on growth and yield aerobic rice. Asian Journal of Experimental Sciences. **23**: 303-306.
Satpute SB, T Das, DT Surje and SK Maity.2015. Nitrogen management using Leaf Color chart (LCC) and nitrogen level in Kharif rice. Indian Journal of Applied Research. **5**(2): 818-820.
Shrestha J, TB Karki and MA Hossain. 2022. Application of Nitrogenous Fertilizer in Rice Production: A Review. Journal of Nepal Agricultural Research Council. **8**:16–26. https://doi.org/10.3126/jnarc.v8i.44815
Subedi P, SK, Sah, SK, Marahattha and DR Yadav. 2019. Effect of Nitrogen Management and Varities on Growth and Yield of Dry Direct Seeded Rice. Tropical Agriculture Science. **42**(2): 453-460.
Yadav RL, AT Padre, PS Pandey and SK Sharma. 2004. Calibrating the Leaf Color Chart for Nitrogen Management in Different Genotypes of Rice and Wheat in a System. Agronomy journal. **98**:1606-1621.
Zhong Y, X Wang, J Yang, X Zhao and X Ye. 2016. Exploring a suitable nitrogen fertilizer rate to reduce greenhouse gas emissions and ensure rice yields in paddy fields. Science of the Total Environment. **565**: 420-426.