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Nitrogen Management Using Leaf Colour Chart in Sali Rice (Variety: Ranjit Sub-1)

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Author's contribution

The sole author designed the study, analysed and interpreted the data, and prepared the manuscript.

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Abstract

Efficient nitrogen management is important for improving rice productivity while reducing avoidable nitrogen losses in lowland rice ecosystems. A field trial was conducted during the Kharif season of 2021 in farmers' fields in Nalbari district, Assam, to evaluate Leaf Colour Chart (LCC)-based nitrogen management in transplanted Sali rice (variety Ranjit Sub-1). The experiment compared two treatments: T1, LCC 4 with integrated nutrient management (INM), comprising *Azospirillum* and PSB at 4 kg/ha each, rock phosphate at 10 kg/ha and the recommended dose of potassium at 40 kg/ha; and T2, the recommended dose of NPK at 60:20:40 kg/ha. In T1, nitrogen was applied through three split applications of urea based on LCC readings after transplanting, without basal nitrogen application. The LCC 4 with INM treatment improved yield attributes, including plant height, tiller number per hill, panicle length, filled grains per panicle and test weight, compared with the recommended fertiliser dose. Grain yield increased from 4.72 t/ha under T2 to 5.20 t/ha under T1, while straw yield increased from 18.52 to 23.50 t/ha. The LCC-based treatment recorded higher nitrogen use efficiency (47.17 kg grain/kg N fertiliser) and agronomic efficiency of nitrogen (22.17 kg grain/kg N) than the recommended fertiliser dose. It also saved 24.75 kg/ha urea, equivalent to 11.38 kg/ha chemical nitrogen, and increased grain yield by 10.16% over T2. Economic returns were also higher under

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T1, with a benefit:cost ratio of 2.6 compared with 2.3 under T2. The findings indicate that LCC 4 with INM can support need-based nitrogen application, improve fertiliser efficiency and enhance profitability in transplanted Sali rice under farmers' field conditions.

Keywords: Leaf Colour Chart; nitrogen management; Sali rice; Ranjit Sub-1; nitrogen use efficiency; agronomic efficiency; integrated nutrient management.

1. Introduction

Rice (*Oryza sativa* L.) is one of the most significant cereal crops and serves as a staple food source for more than three billion people globally (Zhao et al., 2021; Rao & Das, 2023). Among the essential nutrients required for rice cultivation, nitrogen (N) plays a pivotal role in regulating plant growth and development (Wang et al., 2022). The application of N fertilisers has been shown to enhance rice growth and increase grain productivity; however, excessive N inputs can lead to environmental degradation and increased production costs (Lee, 2021). Consequently, chemical N fertilisation remains a widely adopted strategy for improving grain yield and quality in rice cultivation (Thakur et al., 2013).

Despite its widespread use, the recovery and utilisation efficiency of applied N in conventionally flooded paddy systems generally remain below 50%. This low efficiency is primarily attributed to substantial N losses through several pathways, including denitrification, ammonia volatilisation, leaching, surface run-off and drainage (Hameed et al., 2019; Chen et al., 2017). Nitrogen use efficiency (NUE), defined as the proportion of applied N that is absorbed by the crop, rarely exceeds 30% in lowland rice production systems (Baral et al., 2020).

The blanket application of nitrogen fertilisers results in a series of environmental pollution problems, including high energy consumption, greenhouse gas emissions and eutrophication of water bodies (Liu et al., 2021). Therefore, improving NUE is imperative for reducing N fertiliser application and promoting sustainable agriculture (Wang et al., 2022). NUE can be substantially increased by ensuring need-based and real-time N fertiliser application. The Leaf Colour Chart (LCC) has emerged as a valuable tool for nitrogen management in rice cultivation. LCC-based N management in cereals improves N use efficiency compared with blanket recommendations (Upadhayay & Bachkaiya, 2025; Ali et al., 2017). The LCC method involves the visual assessment of leaf colour as an indicator of plant nitrogen status. The LCC is inexpensive, easy to use, saves N and increases N use efficiency (Singh, 2022). It provides a simple, economical and non-destructive tool for monitoring crop nitrogen status and facilitating timely adjustments to nitrogen fertiliser application throughout the rice-growing period. Nitrogen management practices based on LCC readings have been reported to improve NUE, enhance crop productivity and minimise nitrogen losses, thereby contributing to more sustainable rice production systems (Rao & Das, 2023).

Nalbari (26°N latitude and 91°E longitude) is one of the important agricultural districts of Assam, where rice is the major crop, cultivated over approximately 75 thousand hectares and producing 185803 metric tonnes annually, with an average productivity of 2.4 tonnes per hectare.

Although LCC-based nitrogen management has been reported as a practical approach for improving nitrogen use efficiency in rice, field-level evidence under farmers' field conditions for transplanted Sali rice variety Ranjit Sub-1 in Nalbari district is limited. In particular, the performance of LCC 4 when combined with integrated nutrient management requires local evaluation under the rainfall-prone rice-growing conditions of Assam.

The present study was undertaken to manage nitrogen in Sali rice using the LCC in farmers' fields in Nalbari district, Assam. Farmers generally use urea as a nitrogenous fertiliser through basal and split applications in Sali rice, and a major portion of the applied nitrogenous fertiliser may be lost due to heavy rainfall during the growing period, contributing to low productivity. The LCC may be useful in such situations for increasing rice productivity and farmers' profitability. The study is timely because there is a global emphasis on reducing chemical fertiliser inputs while ensuring food security, especially in tropical rice agro-ecosystems where high rainfall leads to nitrogen loss through denitrification, volatilisation and leaching.

2. Materials and Methods

The experiment was conducted in farmers' fields in three villages of Nalbari district, namely Sariahtoli, Sandheli and Phulguri, during the Kharif season of 2021 in Sali rice variety Ranjit Sub-1. The soils of the study sites had a sandy loam texture and acidic pH (5.8), low EC (0.09 dS/m) and a medium level of organic carbon content (0.62%). The initial soil available nitrogen, phosphorus and potassium contents were 321, 19.3 and 128.6 kg/ha, respectively.

The treatment combinations were T1: LCC 4 with INM (INM comprising *Azospirillum* and PSB at 4 kg/ha each + RP at 10 kg/ha + RD of K at 40 kg/ha) and T2: RDF of NPK at 60:20:40 kg/ha. Under T1, three split doses of urea were applied at 33.75 kg/ha based on LCC readings after rice transplanting at 21, 36 and 55 days, with no basal application of N. For INM, seedling root-dip treatment was done with *Azospirillum* and PSB at 4 kg/ha each. Rock phosphate at 10 kg/ha and K as MOP at 40 kg K/ha were applied as basal fertilisers before transplanting the rice crop. For T2, the recommended dose of NPK was applied at 60:20:40 kg/ha. For this treatment, the whole amount of SSP and MOP and one-third of urea fertilisers were applied as basal fertilisers, and the remaining urea was divided into two equal parts and applied at tillering (30 DAT) and panicle initiation (55 DAT).

The Leaf Colour Chart (LCC), consisting of five panels with varying shades of green and developed by the National Rice Research Institute, ICAR, Cuttack, was used for taking readings. LCC readings were taken continuously from 21 days after transplanting at weekly intervals until one week after panicle initiation, and nitrogen was applied according to LCC guidelines. The LCC was used to measure ten topmost, fully expanded leaves from disease-free rice plants in the morning between 08:00 and 10:00. In each plot, 10 plants were selected randomly for readings. If six or more leaves had readings below the critical LCC value, N was applied as recommended.

Observations on yield attributes, namely plant height (cm), number of effective tillers/plant, number of panicles/hill, panicle length, number of filled grains/panicle, grain yield, straw yield and seed test weight, were recorded. The recorded data were analysed for statistical significance using one-way ANOVA, and the standard error of the mean (SEm ±) and CD were computed. Economics was calculated using prevailing prices of inputs and outputs. Nitrogen use efficiency (NUE) and agronomic efficiency of nitrogen (AEN) were calculated as per the following formulae.

$$\text{NUE} = \frac{\text{Grain yield (kg)}}{\text{N applied (kg)}}$$

$$AE_N \text{ (kg grain/kg N applied)} = \frac{\text{Grain yield with N fertilizer applied} - \text{grain yield without N fertilizer}}{\text{Amount of N fertilizer applied}}$$

3. Results and Discussion

3.1 Yield Attributes and Yield of Rice

The results indicated that nitrogen management using LCC 4 with INM (INM with *Azospirillum* and PSB at 4 kg/ha each + RP at 10 kg/ha + RD of K at 40 kg/ha) and 110.25 kg total urea (with three split applications at 33.75 kg) significantly increased grain yield and straw yield compared with the treatment comprising RD of NPK with 135 kg total urea as basal (67.5 kg) and two equal split applications (33.75 kg each) (Table 1). The significant difference in straw yield was attributed to increased plant height (153.67 cm) under the LCC 4 with INM treatment. Greater vegetative growth, indicated by the significant increase in plant height, might be due to the timely supply of the required amount of nitrogenous fertiliser. The results are in conformity with previous findings (Krishnakumar & Haefele, 2013; Ali et al., 2017). LCC-based nitrogen management significantly enhances growth and yield, providing a promising alternative to traditional blanket recommendations (Subedi et al., 2018). The application of N based on LCC effectively matched rice crop N demand and improved utilisation, resulting in better crop yield (Bhat et al., 2015). The results are also in conformity with the findings of Gupta et al. (2011).

3.2 N Fertiliser Budgeting, NUE and AEN

The data revealed that the LCC 4 with INM treatment had a significant effect on nitrogen use efficiency (NUE), agronomic efficiency of nitrogen (AEN) and urea saving (Table 2). Need-based application of nitrogenous fertiliser as urea at 110.25 kg/ha in three equal splits (33.75 kg/ha) at specific rice growth stages based on LCC 4 observations recorded the highest AEN (22.17 kg grain/kg N fertiliser) and NUE (47.17 kg grain/kg N) compared with the recommended dose of nitrogenous fertiliser as urea at 135 kg/ha, where AEN and NUE were recorded as 12.34 kg grain/kg N fertiliser and 32.37 kg grain/kg N, respectively. Under LCC 4 with INM, the saving of urea fertiliser was 24.75 kg/ha over RDF, equivalent to 11.38 kg chemical nitrogen. Application of N using LCC matched crop demand at different physiological growth stages of rice and reduced nitrogen losses through volatilisation, denitrification and leaching, leading to higher NUE and AEN (Bhat et al., 2015). Synchronisation between crop N demand and available N supply is an important key to improving NUE (Gupta et al., 2011).

3.3 Economics of Cultivation

Economics (gross cost, gross return and B:C ratio) of rice cultivation under the treatments LCC 4 with INM and RDF were worked out and are presented in Table 3. Application of nitrogen through LCC with INM recorded the highest gross return (Rs 100880), net return (Rs 62380) and benefit:cost ratio (2.6) compared with RD of fertilisers (gross return Rs 91568, net return Rs 51718 and B:C ratio 2.3). The higher net return under LCC 4 with INM might be due to the steady supply of nitrogen synchronised with the peak period of nitrogen requirement, which resulted in higher yield. Similar results were obtained by Gupta et al. (2011). Previous workers also reported higher net returns and benefit:cost ratio with LCC-based nitrogen management compared with recommended practices (Moharana et al., 2017; Li et al., 2017). Thus, need-based N management through LCC resulted in higher profit for farmers. LCC is a reliable and practical tool for nitrogen management in rice cultivation.

Table 1. Yield attributes of rice (variety Ranjit Sub-1) under different treatments

Treatments	Plant height (cm)	Tiller number/hill	Panicle length (cm)	Number of filled grains/panicle	Grain yield (t/ha)	Straw yield (t/ha)	Test weight (g)
T1: LCC 4 with INM	153.67	18.3	29.46	216	5.20	23.50	21.23
T2: RD of NPK	116.67	15	28.0	184.3	4.72	18.52	19.21
SEm (±)	4.09				0.02	0.08	
CD at 5%	11.96	NS	NS	NS	0.06	0.23	NS

Table 2. N fertiliser budgeting, N use efficiency (NUE) and agronomic efficiency of N (AEN)

Treatments	Time and amount (kg/ha) of application of N as urea fertiliser at days after transplanting				Total urea applied (kg)	Urea saving (kg)	Chemical N saving (kg)	NUE (kg grain/kg N fertiliser)	AE_N (kg grain/kg N)
	Basal	21 days	36 days	55 days					
T1: LCC 4 with INM	-	33.75	33.75	33.75	110.25	24.75	11.38	47.17	22.17
T2: RD of NPK	67.5	33.75	33.75	-	135.0		-	32.37	12.34

Table 3. Economics of cultivation of rice under different treatments (Selling price of rice @ Rs 1940/quintal)

Treatments	Gross cost (Rs)	Gross return (Rs)	Net return (Rs)	B:C ratio
T1: LCC 4 with INM	38500	100880	62380	2.6
T2: RD of NPK	39850	91568	51718	2.3

4. Conclusions

The field trial showed that LCC 4 with integrated nutrient management was more effective than the recommended NPK fertiliser dose for managing nitrogen in transplanted Sali rice variety Ranjit Sub-1 under farmers' field conditions in Nalbari district. The treatment produced higher plant height, effective tiller number, panicle length, filled grains per panicle, test weight, grain yield and straw yield. Grain yield increased to 5.20

t/ha with LCC 4 with INM compared with 4.72 t/ha under the recommended fertiliser dose, while straw yield increased to 23.50 t/ha compared with 18.52 t/ha. The LCC-based treatment also improved nitrogen use efficiency and agronomic efficiency of nitrogen, with recorded values of 47.17 kg grain/kg N fertiliser and 22.17 kg grain/kg N, respectively. In addition, the practice saved 24.75 kg/ha urea and 11.38 kg/ha chemical nitrogen, and provided a higher benefit:cost ratio of 2.6 than the recommended fertiliser dose (2.3). These results indicate that need-based nitrogen application using LCC, when combined with INM, is a practical option for improving fertiliser use efficiency, yield and net return in Sali rice cultivation. The approach may also help farmers align urea application with crop demand during the growing season.

5. Limitations

This study was conducted during a single Kharif season in farmers' fields in three villages of Nalbari district; therefore, the results should be interpreted within this specific seasonal and location context. Only two nitrogen management treatments were compared, which limits the scope for assessing a wider range of LCC threshold values, fertiliser schedules or integrated nutrient combinations. The study focused on yield attributes, yield, nitrogen use efficiency, agronomic efficiency and economics, but did not include direct measurements of nitrogen losses through volatilisation, denitrification, leaching or run-off. Soil properties were recorded before the experiment; however, changes in soil fertility after harvest were not reported. The findings are based on Sali rice variety Ranjit Sub-1, so varietal differences in response to LCC-based nitrogen management were not assessed. Further multi-season and multi-location studies under varying soil, rainfall and management conditions would strengthen the validation of LCC 4 with INM under diverse rice-growing environments in Assam.

Declaration of AI Use

This manuscript was prepared through the combined contributions of all author(s), including contributions to the study design, data, content development, results, interpretation, and related scholarly work. The author(s) acknowledge the use of Grammarly and ChatGPT to assist with grammar checking, language refinement, reference formatting. These AI-assisted tools were not used as authors and did not replace the intellectual contributions or scholarly judgment of the author(s). All AI-assisted outputs, including content, references, and interpretations, were carefully reviewed, revised, verified, and approved by the author(s). The author(s) accept full responsibility for the accuracy, integrity, and final content of the manuscript.

Competing Interests

The author declares that they have no known competing financial interests, non-financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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