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Leaf color chart (LCC) a reliable tool for nitrogen management in (Dry seeded rice and transplanted rice): A review

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Abstract
Effective nitrogen management is crucial for optimizing rice production while minimizing environmental impacts. The Leaf Color Chart (LCC) has emerged as a valuable tool for nitrogen management in rice cultivation. This review aims to provide an overview of the utilization and reliability of LCC in both dry-seeded rice (DSR) and transplanted rice (TPR) systems. The LCC method involves visually assessing leaf color as an indicator of plant nitrogen status. It offers a simple, cost-effective, and non-destructive approach to monitor and adjust nitrogen fertilizer application throughout the rice-growing season. LCC-based nitrogen management strategies can enhance nitrogen use efficiency, improve yield, and reduce nitrogen losses, thus promoting sustainable rice production. This review examines the scientific evidence supporting the use of LCC for nitrogen management in DSR and TPR. It explores various aspects such as LCC calibration, threshold values for different growth stages, and the correlation between LCC values and leaf nitrogen content. Additionally, the review discusses the practical application of LCC in different rice-growing regions and its compatibility with different rice varieties. Furthermore, the review highlights the advantages of LCC over conventional nitrogen management approaches, including cost savings, reduced environmental impact, and ease of implementation. It also addresses potential challenges and limitations associated with LCC, such as subjective interpretation and the influence of other factors on leaf color. Overall, this comprehensive review demonstrates that LCC is a reliable and practical tool for nitrogen management in rice cultivation, regardless of the cultivation system (DSR or TPR). It provides valuable insights for researchers, agronomists, and rice growers seeking to optimize nitrogen fertilizer application and improve sustainability in rice production systems. Future research directions and potential advancements in LCC-based nitrogen management are also discussed.

Keywords: Leaf color chart, nitrogen management, dry seeded rice and transplanted rice

Introduction
Rice (*Oryza sativa* L.) is one of the most important staple crops globally, feeding a significant portion of the world's population. To meet the increasing demand for rice and ensure sustainable production, efficient management of nitrogen fertilizers is crucial (Midya *et al.*, 2021) [1]. Nitrogen is a vital nutrient that significantly influences rice growth, development, and yield (Jahan *et al.*, 2020) [2]. However, improper nitrogen management can lead to yield losses, environmental pollution through nitrogen runoff or leaching, and increased production costs (Dinnes *et al.*, 2002) [3]. Traditionally, nitrogen management in rice cultivation has been based on agronomic practices, such as farmers' experience, soil testing, and crop growth stage-based fertilizer application (Banayo *et al.*, 2018) [4]. However, these methods often lack precision and fail to account for dynamic changes in crop nitrogen requirements throughout the growing season (Kivi *et al.*, 2022, Dinnes *et al.*, 2002) [5, 3]. Consequently, there is a growing need for reliable and efficient tools to optimize nitrogen management in rice.
In recent years, the Leaf Color Chart (LCC) has emerged as a promising tool for nitrogen management in rice (Ali *et al.*, 20015) [6]. The LCC method relies on visual assessment of leaf color as an indicator of plant nitrogen status (Tao *et al.*, 2020) [7]. By comparing the leaf color with a standardized color chart, farmers and agronomists can make informed decisions regarding nitrogen fertilizer application rates and timings (Golicz *et al.*, 2021) [8]. The LCC method offers several advantages, including simplicity, cost-effectiveness, non-destructive sampling, and real-time monitoring of crop nitrogen status (Oláh *et al.*, 2022) [9].
This review aims to provide a comprehensive evaluation of the LCC tool for nitrogen management in rice cultivation, focusing on both dry-seeded rice (DSR) and transplanted rice (TPR) systems (Mohanta *et al.*, 2021) [10].

We will explore the scientific evidence supporting the use of LCC, including its calibration, threshold values for different growth stages, and its correlation with leaf nitrogen content. Additionally, we will examine the practical application of LCC in diverse rice-growing regions and its compatibility with different rice varieties (Redfern *et al*., 2012) [11]. Moreover, we will discuss the advantages of LCC over conventional nitrogen management approaches, such as the potential for improved nitrogen use efficiency, enhanced yield, and reduced environmental impact (Dwivedi *et al*., 2016) [12]. We will also address the challenges and limitations associated with LCC, including subjective interpretation and potential confounding factors influencing leaf color (Elce *et al*., 2021) [13].

By providing a comprehensive review of the current state of knowledge on LCC as a tool for nitrogen management in rice, this paper aims to assist researchers, agronomists, and rice growers in making informed decisions regarding fertilizer application and optimizing nitrogen use efficiency (Ladha *et al*., 2005) [14]. Furthermore, we will discuss future research directions and potential advancements in LCC-based nitrogen management, highlighting the potential for further improvement and refinement of this valuable tool in rice cultivation.

The leaf color chart (LCC)

The Leaf Color Chart (LCC) is an inexpensive and user-friendly tool utilized for nitrogen management in rice cultivation. It consists of a 12-15-inch-long chart with several shades of green (Lindsay and Lindsay, 2017) [15]. The chart is made of durable, sunlight-resistant plastic and features multiple color lines arranged like leaf veins. The lightest shade is labeled -1, while the darkest green shade is labelled 8. Originally, the LCC had eight shades of unnamed green, but later versions developed by (Furuya, 1987) [16]. and the International Rice Research Institute (IRRI, 2005) [17] featured seven or six shades of green. The LCC is calibrated with a chlorophyll meter and serves as a guide for nitrogen top dressing in rice crops. It comes with a construction sheet in the local language, explaining how farmers can determine the optimal time for nitrogen application. The LCC is a versatile tool that can be used regardless of the nitrogen source applied, including inorganic, organic, or biofertilizers. It enables the assessment of canopy greenness as well as the green color of individual leaves (Gill *et al*., 2023) [18]. By comparing leaf color with the LCC, critical color grades or LCC values can be determined to guide nitrogen application.

According to the LCC, if a reading of 4 or above is obtained at panicle initiation, nitrogen application can be skipped. The critical leaf color reading for nitrogen top dressing varies, ranging from 3 for varieties with light green foliage (e.g., scented to aromatic rice varieties) to 4 for other varieties and hybrids (Thind and Gupta, 2010) [19]. In the case of transplanted rice, the critical LCC grade is 4, while for direct wet-seeded rice, it is 3. Crops exhibiting leaf colors below the critical values indicate nitrogen deficiency and require immediate application of nitrogen fertilizer to prevent yield losses. It is worth noting that for locally important rice varieties and specific crop establishment methods, the critical LCC values may need to be redefined after conducting one or two test seasons (Eda *et al*., 2021) [20]. Overall, the Leaf Color Chart (LCC) serves as an invaluable tool in optimizing nitrogen use in rice cultivation. It provides a simple and effective means of assessing nitrogen status, guiding fertilizer application decisions, and ultimately contributing to improved crop productivity and sustainability (Ladha *et al*., 2005) [21].

Critical color grades or LCC values

The determination of critical color grades or Leaf Color Chart (LCC) values is crucial for effective nitrogen management in rice cultivation. By utilizing the LCC tool, nitrogen application decisions can be made based on specific readings obtained (Shukla *et al*., 2004) [22]. For instance, if a reading of 4 or above is obtained at panicle initiation, nitrogen application can be skipped. The critical LCC values for nitrogen top dressing vary depending on the characteristics of rice varieties. For varieties with light green foliage, such as scented to aromatic rice varieties, a leaf color reading of 3 is considered critical (Fairhurst *et al*., 2007) [23]. For other varieties and hybrids, a reading of 4 is deemed critical. Similarly, in the case of transplanted rice, the critical LCC grade is 4, while for direct wet-seeded rice, it is 3. Crops displaying a leaf color below the critical values indicate nitrogen deficiency and require immediate nitrogen fertilizer application to prevent yield losses (Singh, 2014) [24]. However, it is important to note that critical LCC values can vary for locally important varieties and different crop establishment methods. Therefore, it may be necessary to redefine the critical LCC values after conducting one or two test seasons specific to the local context. By identifying and applying the critical LCC values, farmers and agronomists can effectively manage nitrogen fertilization, optimizing crop yield and reducing the risk of nitrogen deficiency (Majumdar *et al*., 2014) [25]. Continuous monitoring and adjustment of nitrogen application based on LCC readings can significantly contribute to improved nitrogen use efficiency and sustainable rice production (Cowan *et al*., 2021) [26].

Guidelines for using LCC

When using the Leaf Color Chart (LCC) for assessing leaf nitrogen status and determining nitrogen top dressing in rice, it is important to follow the established guidelines:

Leaf Selection: Choose the topmost fully expanded leaf for leaf color measurement, as it is highly correlated with the nitrogen status of rice plants. According to Tanno *et al*. (1982) [27], the reading by the color scale of the canopy green is more closely correlated with the average chlorophyll content of the three topmost leaves than the reading on a single leaf.

Measurement Technique: Hold the LCC vertically and place the middle part of the selected leaf approximately 1 cm in front of a color strip on the chart. Compare the leaf color with the shades on the chart to determine the corresponding score (Sudhalakshmi *et al*., 2008) [28].

Leaf Integrity: Ensure that the leaf is neither detached nor destroyed during the measurement process. The leaf should remain intact and undamaged (Terashima *et al*., 1994) [29].

Sunlight and Angle: Shield the leaf with your body while taking the LCC reading, as the leaf color chart reading can be affected by the angle of the sun and sunlight intensity. This helps minimize any interference from external lighting conditions (Terashima *et al*., 1994) [29].

Timing of Readings: Take readings between 8-10 am when there is less glare from the sun. Avoid taking readings very early in the morning when dew drops may make it difficult to obtain accurate readings (Sudhalakshmi *et al*., 2008) [28].

Consistency: Ensure that the same person takes the color measurements at the same time of the day consistently. This helps maintain consistency in the readings and reduces variability.

Sampling Size: Take readings for ten leaves at random from each plot. Calculate the average score and compare it to determine the need for nitrogen top dressing (Waskom *et al*., 1996) [30].
Frequency of Readings: Take LCC readings once a week, starting from 14 days after transplanting for transplanted rice or 21 days after seeding for wet-seeded rice (Figure 1). Continue taking readings once every 7-10 days until the first flowering stage. These guidelines, based on scientific research, will help ensure standardized and accurate measurements using the LCC, facilitating effective nitrogen management in rice crops (Tanno *et al*., 1982) [27].

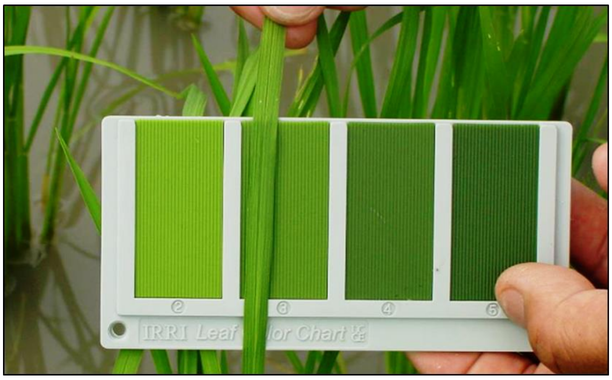

Fig 1: A standardized leaf color chart for assessing leaf N status by IRRI

Merits of using LCC
The Leaf Color Chart (LCC) offers several advantages and merits over alternative methods for assessing leaf nitrogen status and determining the timing of nitrogen top dressing in rice cultivation:

Simplicity and Ease of Use: The LCC is designed to be user-friendly, allowing farmers to easily assess the leaf nitrogen status and make informed decisions regarding nitrogen application. It involves a simple process of matching the color scores of the leaf with the standard chart, requiring minimal technical skill or expertise.

Cost-Effectiveness: Compared to other tools like the SPAD meter, the LCC is relatively inexpensive. This affordability makes it accessible to a wider range of farmers, including those with limited financial resources.

Eliminates Laboratory Analysis: With the LCC, there is no need to collect leaf samples, process them, or send them to a laboratory for analysis. This eliminates the time and cost associated with laboratory procedures, providing real-time results and allowing for immediate decision-making.

Minimal Technical Skill Required: Unlike the SPAD meter, which may require technical knowledge and expertise to operate accurately, the LCC is straightforward and does not demand specialized training. Farmers can easily adopt and utilize the tool without the need for extensive training or technical assistance (Daryabak *et al*., 2014) [31].
Overall, the LCC's merits lie in its simplicity, cost-effectiveness, and user-friendly nature. It empowers farmers with a practical and efficient means of assessing leaf nitrogen status and determining the optimal timing for nitrogen top dressing in rice crops. By eliminating the need for laboratory analysis and technical expertise, the LCC facilitates widespread adoption and usage, ultimately contributing to improved nitrogen management and enhanced crop productivity.

Demerits of using LCC
The Leaf Color Chart (LCC) also has some limitations and demerits that should be considered:

Limited Sensitivity: The LCC may not be able to indicate smaller differences in leaf greenness accurately. As the color shades of the LCC fall in between two shades, the mean of the two scores is often taken, which can result in less precision and accuracy. This limitation may affect the ability to detect subtle variations in leaf nitrogen status.

Correlation and Calibration: The relative accuracy of the LCC in assessing leaf nitrogen status can only be determined when it is compared and correlated with readings from more precise instruments like chlorophyll meters. Additionally, calibration of the LCC with specific cultivar groups (such as semi-dwarf, local tall, or hybrid varieties) is necessary for accurate interpretation of results.

Limited Application for Basal Nitrogen: The LCC is primarily used to fine-tune top-dressed nitrogen application. It is not suitable for determining basal nitrogen application. Other methods or considerations may be needed to determine the appropriate initial nitrogen application for rice crops.

Dependency on Integrated Nutrient Management: The effectiveness of the LCC in assessing leaf nitrogen status depends on the integrated site-specific nutrient management strategy. For optimum response to nitrogen fertilizer, it is important that other essential nutrients like phosphorus (P), potassium (K), sulfur (S), and zinc (Zn) are not limiting. The LCC may not provide accurate results in cases where these nutrients are deficient or imbalanced.

Influence of Other Deficiencies: LCC values can be affected by deficiencies of other nutrients, particularly phosphorus (P) or potassium (K), which may lead to darker leaf coloration and potentially result in erroneous LCC readings. This highlights the need for local calibration of the LCC and careful interpretation of results. In comparison, the SPAD meter is less affected by such deficiencies.

Calibration for Variations: LCC values can be influenced by diurnal variations within a day, variations among different rice varieties, and seasonal changes. Therefore, regular calibration of the LCC specific to the local conditions, rice varieties, and growing seasons is necessary to ensure accurate and reliable results (Jayaram *et al*., 2014) [32].

It is essential to be aware of these limitations and consider them while using the LCC as a tool for nitrogen management in rice cultivation. Proper calibration, correlation with more precise instruments, and integration with comprehensive nutrient management strategies can help mitigate these demerits and improve the accuracy and usefulness of the LCC.

Future research directions and potential advancements in LCC-based nitrogen management

While the Leaf Colour Chart (LCC) has proven to be a valuable tool for nitrogen management in rice, there are several areas of future research that can further enhance its effectiveness and broaden its application. Some potential advancements and research directions for LCC-based nitrogen management are:

Refining LCC Calibration: Continuous efforts should be made to refine and update the calibration of LCC scores with actual nitrogen content in rice plants. This can be achieved through extensive field trials and correlation studies between LCC readings and precise measurements of nitrogen content, such as chlorophyll meter readings or laboratory analysis (Thind and Gupta, 2010) [19].

Integration with Precision Agriculture Technologies: Exploring the integration of LCC with precision agriculture technologies, such as remote sensing, unmanned aerial vehicles (UAVs), and satellite imagery, can enhance the spatial and temporal monitoring of rice crops. This integration can provide real-time information on nitrogen status, enabling site-specific nitrogen management and timely interventions (Pedersen and Lind, 2017) [33].

Development of Digital Tools and Mobile Applications: Creating digital tools and mobile applications that leverage LCC data can simplify data collection, analysis, and interpretation. These tools can automate LCC scoring, store historical data, provide real-time recommendations for nitrogen top dressing, and enable data sharing among farmers, extension workers, and researchers (Capossele *et al.*, 2018) [34].

Expansion to Other Crops and Agroecosystems: While LCC has primarily been used in rice cultivation, exploring its applicability in other crops and agroecosystems can be a promising research direction (Mahajan *et al.*, 2017) [35]. Evaluating the feasibility, accuracy, and cost-effectiveness of LCC-based nitrogen management in different crops and farming systems will broaden its practical use.

Integration with Nutrient Management Decision Support Systems (DSS): Integrating LCC data into existing nutrient management decision support systems can enhance their accuracy and precision (Gorai *et al.*, 2021) [36]. This integration can provide a holistic approach to nitrogen management by considering multiple factors, such as soil properties, climate conditions, crop growth stage, and LCC readings.

Assessing Economic and Environmental Impacts: Conducting comprehensive economic and environmental assessments of LCC-based nitrogen management can provide insights into the cost-effectiveness, profitability, and sustainability aspects (Falcone *et al.*, 2016) [37]. Evaluating the impact on crop yield, nitrogen use efficiency, greenhouse gas emissions, and water quality can support evidence-based decision-making and policy development.

By focusing on these research directions, the potential advancements in LCC-based nitrogen management can lead to improved nitrogen use efficiency, reduced environmental impacts, and enhanced profitability for farmers.

Potential savings in urea through the lcc technique

The application of the Leaf Color Chart (LCC) technique in irrigated rice cultivation has demonstrated potential savings in urea fertilizer (Thind and Gupta, 2010) [19]. For example, it has been reported that the use of LCC can save approximately 23 kg of nitrogen (equivalent to 50 kg of urea per hectare) in irrigated situations (Figure. 3). These savings can have significant implications for fertilizer management and cost reduction (Bhupenchandra *et al.*, 2021) [38].

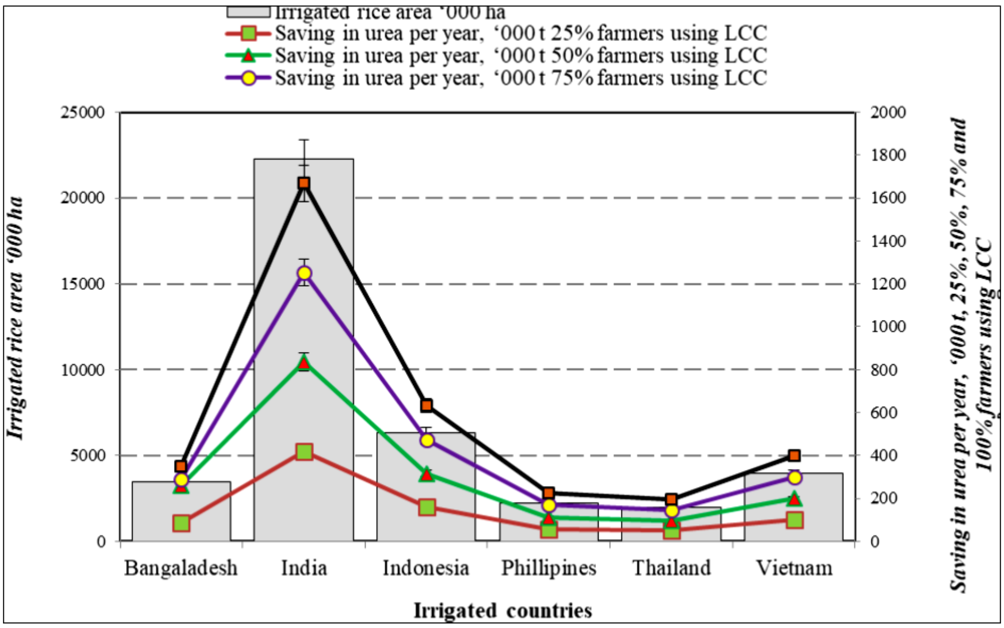

Fig 3: Depiction of urea savings through the LCC technique (Bhupenchandra *et al.*, 2021) [38]

To assess the potential annual savings of urea, the estimated figures for selected countries are listed and evaluated in the table below. In India, for instance, it is estimated that the adoption of LCC by 50 percent of farmers in the irrigated rice area of 22.3 million hectares could result in urea savings of approximately 834,000 tons. Moreover, countries such as Bangladesh, Vietnam, Indonesia, Thailand, and the Philippines have also successfully embraced the LCC technique, leading to potential savings in urea fertilizer. The adoption of LCC in these countries not only contributes to cost savings for farmers but also promotes efficient nitrogen management in rice cultivation, aligning with sustainable agricultural practices.

Reference

1. Midya A, Saren BK, Dey JK, Maitra S, Praharaj S, Gaikwad DJ, *et al*. Crop establishment methods and integrated nutrient management improve: Part i. crop performance, water productivity and profitability of rice (*Oryza sativa* L.) in the lower indo-gangetic plain, India. Agronomy. 2021 Sep 16;11(9):1860.
2. Jahan A, Islam A, Sarkar MI, Iqbal M, Ahmed MN, Islam MR. Nitrogen response of two high-yielding rice varieties as influenced by nitrogen levels and growing seasons. Geology, Ecology, and Landscapes. 2022 Jan 2;6(1):24-31.
3. Dinnes DL, Karlen DL, Jaynes DB, Kaspar TC, Hatfield JL, Colvin TS, *et al*. Nitrogen management strategies to reduce nitrate leaching in tile-drained Midwestern soils. Agronomy journal. 2002 Jan;94(1):153-171.
4. Banayo NP, Haefele SM, Desamero NV, Kato Y. On-farm assessment of site-specific nutrient management for rainfed lowland rice in the Philippines. Field Crops Research. 2018 May 1;220:88-96.
5. Kivi MS, Blakely B, Masters M, Bernacchi CJ, Miguez FE, Dokoohaki H. Development of a data-assimilation system to forecast agricultural systems: A case study of constraining soil water and soil nitrogen dynamics in the APSIM model. Science of The Total Environment. 2022 May 10;820:153192.
6. Ali AM, Thind HS, Sharma S, Singh Y. Site-specific nitrogen management in dry direct-seeded rice using chlorophyll meter and leaf colour chart. Pedosphere. 2015 Feb 1;25(1):72-81.
7. Tao M, Ma X, Huang X, Liu C, Deng R, Liang K, Qi L. Smartphone-based detection of leaf color levels in rice plants. Computers and electronics in agriculture. 2020 Jun 1;173:105431.
8. Golicz K, Hallett SH, Sakrabani R. Old problem, the Millennial solution: Using mobile technology to inform decision making for sustainable fertilizer management. Current Opinion in Environmental Sustainability. 2021 Apr 1;49:26-32.
9. Oláh L, Tanaka HK, Varga D, editors. Muography: Exploring Earth's Subsurface with Elementary Particles. John Wiley & Sons; 2022 Jan 25.
10. Mohanta S, Banerjee M, Malik GC, Shankar T, Maitra S, Ismail IA, Dessoky ES, Attia AO, Hossain A. Productivity and profitability of kharif rice are influenced by crop establishment methods and nitrogen management in the lateritic belt of the subtropical region. Agronomy. 2021 Jun 24;11(7):1280.
11. Redfern SK, Azzu N, Binamira JS. Rice in Southeast Asia: facing risks and vulnerabilities to respond to climate change. Build Resilience Adapt Climate Change Agri Sector. 2012 Apr 23;23(295):1-4.
12. Dwivedi BS, Singh VK, Meena MC, Dey A, Datta SP. Integrated nutrient management for enhancing nitrogen use efficiency. Indian J. Fertil. 2016 Apr;12:62-71.
13. Elce V, Handjaras G, Bernardi G. The language of dreams: application of linguistics-based approaches for the automated analysis of dream experiences. Clocks & Sleep. 2021 Sep 19;3(3):495-514.
14. Ladha JK, Pathak H, Krupnik TJ, Six J, van Kessel C. Efficiency of fertilizer nitrogen in cereal production: retrospects and prospects. Advances in agronomy. 2005 Jan 1;87:85-156.
15. Lindsay L, Lindsay D. Anza-Borrego Desert Region: Your Complete Guide to the State Park and Adjacent Areas of the Western Colorado Desert. Wilderness Press; 2017 Oct 10.
16. Furuya S. Growth diagnosis of rice plants by means of leaf color. Japan Agricultural Research Quarterly. 1987 Jan 1;20:147-53.
17. IRRI. Use of leaf color chart (LCC) for N management in rice. Philippines International Rice Research Institute. 2005; Website www. http://irri.org/).
18. Gill A, Rajput A, Sharma A, Devi OR. Soil Farming Techniques for Climate Resilient Agriculture; c2023.
19. Thind HS, Gupta RK. Need based nitrogen management using the chlorophyll meter and leaf colour chart in rice and wheat in South Asia: a review. Nutrient Cycling in Agroecosystems. 2010 Dec;88:361-380.
20. Ead AS, Appel R, Alex N, Ayranci C, Carey JP. Life cycle analysis for green composites: A review of literature including considerations for local and global agricultural use. Journal of Engineered Fibers and Fabrics. 2021 Jun;16:15589250211026940.
21. Ladha JK, Pathak H, Krupnik TJ, Six J, van Kessel C. Efficiency of fertilizer nitrogen in cereal production: retrospects and prospects. Advances in agronomy. 2005 Jan 1;87:85-156.
22. Shukla AK, Ladha JK, Singh VK, Dwivedi BS, Balasubramanian V, Gupta RK, Sharma SK, Singh Y, Pathak H, Pandey PS, Padre AT. Calibrating the leaf color chart for nitrogen management in different genotypes of rice and wheat in a systems perspective. Agronomy Journal. 2004 Nov;96(6):1606-21.
23. Fairhurst T, Witt C, Buresh R, Dobermann A, Fairhurst T. Rice: A practical guide to nutrient management. Int. Rice Res. Inst; c2007.
24. Singh BI. Site specific and need based management of nitrogen fertilizers in cereals in India. Advances in fertilizer technology: Biofertilizers. 2014;2:576-605.
25. Majumdar K, Dey P, Tewatia RK. Current nutrient management approaches. Indian J Fertil. 2014 May;10:14-27.
26. Cowan N, Bhatia A, Drewer J, Jain N, Singh R, Tomer R, *et al*. Experimental comparison of continuous and intermittent flooding of rice in relation to methane, nitrous oxide and ammonia emissions and the implications for nitrogen use efficiency and yield. Agriculture, Ecosystems & Environment. 2021 Oct 1;319:107571.
27. Tanno F, Masunaga T, Ito O. A visual method for estimating nitrogen status of rice plants. Soil Science and

Plant Nutrition. 1982;28(4):541-549.
28. Sudhalakshmi C, Velu V, Thiyagarajan TM. Leaf colour chart for nitrogen management in rice–A review. Agricultural Reviews. 2008;29(4):306-310.
29. Terashima I, Funayama S, Sonoike K. The site of photoinhibition in leaves of *Cucumis sativus* L. at low temperatures is photosystem I, not photosystem II. Planta. 1994 Mar;193:300-306.
30. Waskom RM, Westfall DG, Spellman DE, Soltanpour PN. Monitoring nitrogen status of corn with a portable chlorophyll meter. Communications in Soil Science and Plant Analysis. 1996 Feb 1;27(3-4):545-560.
31. Daryabak M, Filizadeh S, Jatskevich J, Davoudi A, Saeedifard M, Sood VK, *et al*. Modeling of LCC-HVDC systems using dynamic phasors. IEEE Transactions on Power Delivery. 2014 Mar 20;29(4):1989-1998.
32. Jayaram LC, Lakshmi TV, Padhi MG. Suitability of projection for Defense Series Maps. High-Precision Positioning. 2014:16.
33. Pedersen SM, Lind KM. Precision agriculture–from mapping to site-specific application. Precision agriculture: Technology and economic perspectives. 2017:1-20.
34. Capossele A, Gaglione A, Nati M, Conti M, Lazzeretti R, Missier P. Leveraging blockchain to enable smart-health applications. In2018 IEEE 4th International Forum on Research and Technology for Society and Industry (RTSI) 2018 Sep 10 (pp. 1-6). IEEE.
35. Mahajan G, Kumar V, Chauhan BS. Rice production in India. Rice production worldwide. 2017:53-91.
36. Gorai T, Yadav PK, Choudhary GL, Kumar A. Site-specific Crop Nutrient Management for Precision Agriculture–A Review. Current J. Appl. Sci. Technol.. 2021 May;40(10):37-52.
37. Falcone G, De Luca AI, Stillitano T, Strano A, Romeo G, Gulisano G. Assessment of environmental and economic impacts of vine-growing combining life cycle assessment, life cycle costing and multicriterial analysis. Sustainability. 2016 Aug 13;8(8):793.
38. Bhupenchandra I, Athokpam HS, Singh NB, Singh LN, Devi SH, Chongtham SK, Singh LK, Sinyorita S, Devi EL, Bhagowati S, Bora SS. Leaf color chart (LCC): An instant tool for assessing nitrogen content in plant: A review. The Pharma Innovation Journal 2021;10(4):1100-1104.