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User Friendly Tools Suitable For Efficient Nitrogen Management in Field Crops

1. **Shivendra Singh**
Department of Agronomy, Chandra Shekhar Azad University of Agriculture and Technology, Kanpur 208002, Uttar Pradesh, India.
Email: shivendranduat@gmail.com
2. **Sunil Kumar Prajapati**
Division of Agronomy, ICAR-Indian Agricultural Research Institute, Pusa Campus, New Delhi-110012, India.
3. **Dhruvendra Singh Sachan**
Department of Agronomy, Chandra Shekhar Azad University of Agriculture and Technology, Kanpur 208002, Uttar Pradesh, India.
4. **Saurabh Tiwari**
Department of Fruit Science, Chandra Shekhar Azad University of Agriculture and Technology, Kanpur 208002, Uttar Pradesh, India.
5. **Gurwaan Singh**
Department of Agronomy, Dr. Rajendra Prasad Central Agricultural University, Pusa, Samastipur 848125, Bihar, India.

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Abstract

Nitrogen is a vital nutrient for enhancing the growth and yield of field crops, making its management essential for sustainable agricultural practices. Traditional nitrogen management approaches often rely on excessive fertilization, leading to environmental degradation and economic losses. Therefore, user-friendly and efficient tools are crucial for precise nitrogen management. This study evaluates three prominent tools: the Leaf Color Chart (LCC), Soil Plant Analysis Development (SPAD) Meter, and Green Seeker (Optical Sensor), for their effectiveness and practicality in field crop nitrogen management. The Leaf Color Chart is a simple, cost-effective tool that assesses crop nitrogen status based on leaf color changes. Its accessibility and ease of use make it a popular choice among farmers, particularly in resource-constrained regions. However, its accuracy and precision may be limited, and interpretation requires experience and subjectivity. The Soil Plant Analysis Development (SPAD) Meter measures the chlorophyll content in crop leaves, indicating the nitrogen status. It offers better precision compared to LCC and requires minimal training, making it widely adopted in many agricultural settings. Nevertheless, its performance might be influenced by environmental

factors and crop species, potentially affecting its accuracy. Green Seeker (Optical Sensor) is an advanced technology that evaluates crop reflectance to determine nitrogen requirements. It provides real-time data and objective measurements, reducing subjectivity and enabling site-specific nitrogen applications. Although it requires more initial investment and technical expertise, its potential for optimal nitrogen management is promising.

1. INTRODUCTION

Efficient nitrogen management is a key component of modern agricultural practices aimed at ensuring optimal crop productivity while minimizing environmental impacts (Chlingaryan *et al*., 2018). Nitrogen is an essential nutrient for field crops, but its improper application can lead to nutrient wastage, soil degradation, and water pollution. To address these challenges, the adoption of user-friendly tools has emerged as a promising solution to assist farmers in making informed decisions regarding nitrogen application. This study focuses on three user-friendly tools that have gained prominence in the field of efficient nitrogen management for crops: the Leaf Color Chart, Soil Plant Analysis Development (SPAD) Meter, and Green Seeker (Optical Sensor). Each of these tools offers unique advantages and applications, catering to diverse farming conditions and resource availability. The Leaf Color Chart is a simple and cost-effective tool widely used in resource-limited settings. It enables farmers to assess the nitrogen status of crops based on leaf color changes, providing valuable insights into nutrient deficiencies. Despite its simplicity, the Leaf Color Chart demands expertise for accurate interpretation, making it essential to explore alternative tools with enhanced precision and efficiency.

The Soil Plant Analysis Development (SPAD) Meter is a handheld device that measures the chlorophyll content in crop leaves (Dong *et al*., 2019). This measurement is indicative of the crop's nitrogen status and serves as a reliable indicator for nitrogen requirements. The SPAD Meter offers higher accuracy compared to the Leaf Color Chart, while still being user-friendly and requiring minimal training. The Green Seeker, on the other hand, employs cutting-edge optical sensor technology to measure crop reflectance and calculate nitrogen requirements in real-time. This advanced tool provides precise and objective data, allowing for site-specific nitrogen application. While it demands a higher initial investment and technical expertise, the Green Seeker holds great promise in optimizing nitrogen management for enhanced crop yield and reduced environmental impact. In this context, the objective of this study is to compare and evaluate the effectiveness, practicality, and suitability of these user-friendly tools for efficient nitrogen management in field crops. By understanding the strengths and limitations of each tool, farmers, agronomists, and policymakers can make informed decisions on adopting the most appropriate tool for their specific agricultural needs. Through this comprehensive analysis, we aim to highlight the significance of user-friendly tools in promoting sustainable agriculture, minimizing nitrogen waste, and enhancing crop productivity while safeguarding the

environment. By exploring the potential synergies between these tools, we hope to contribute valuable insights that support the optimization of nitrogen management practices, leading to a more productive, resource-efficient, and environmentally responsible agriculture sector.

Nitrogen represents the primary limiting nutrient for crop growth on a global scale, and its efficient management is crucial for maintaining economic sustainability in agriculture. Approximately 50% of the nitrogen applied to the soil remains inaccessible to crops due to a combination of various losses, such as leaching, volatilization, and de-nitrification. Under irrigated and submerged conditions, the recovery of nitrogen is only around 35% because of poor effectiveness in supplying nitrogen to the crops, resulting from a lack of synchronization between nitrogen supply and crop demand. Both excessive and insufficient nitrogen applications can have detrimental effects, leading to reduced crop yields or the development of physiological disorders, such as hollow stem and other pathological problems. Therefore, the implementation of effective nitrogen fertilizer management strategies becomes essential to ensure optimal seed yield and seed quality in field crops. Many non-invasive techniques are now available to quantify leaf chlorophyll concentration by employing leaf greenness and absorbance/reflectance of light by intact leaf. LCC, Soil Plant Analysis Development (SPAD) meter, and hand-held Green Seeker optical sensor are among these diagnostic tools used frequently (Muñoz-Huerta *et al*., 2013). in cereals to improve nitrogen use efficiency in South Asia, when crop is already developing in the field to measure real-time nitrogen requirements.

2. NITROGEN FERTILIZER-SAVING TOOLS

2.1 ***Leaf Color Chart:*** Japan produced the first Leaf Color Chart. The International Rice Research Institute (IRRI) collaborated with the agricultural research systems of various Asian nations to develop an upgraded version of six panels LCC (IRRI-LCC, Six panels). IRRI recently created four panels of IRRI-LCC (four green color shades ranging from 2 to 5) that best match the spectral reflectance of plant leaves. It is now normal practice to utilize LCC for nitrogen application in numerous crops such as rice, maize, wheat, sugarcane, potato, cotton, and vegetables. Crop leaf nitrogen status is intimately related to photosynthetic rate and biomass output, and it is a sensitive indication of crop nitrogen demand fluctuations during the growing season. This tool helps to quick assess leaf nitrogen status and thereby helps in the application of nitrogen to maintain optimal nitrogen content in leaf that can be important for achieving high crop yield with effective nitrogen management. The LCC shall be used, by either of two equally efficient options, to monitor nitrogen status in the leaf from tillering into panicle initiation during rice cultivation (Prajapati *et al*., 2023). Farmers' preferences and locational factors, such as the frequency of visits by farmers to their fields and knowledge of essential growth stages for nitrogen application, can be taken into account when deciding on which option will be used.

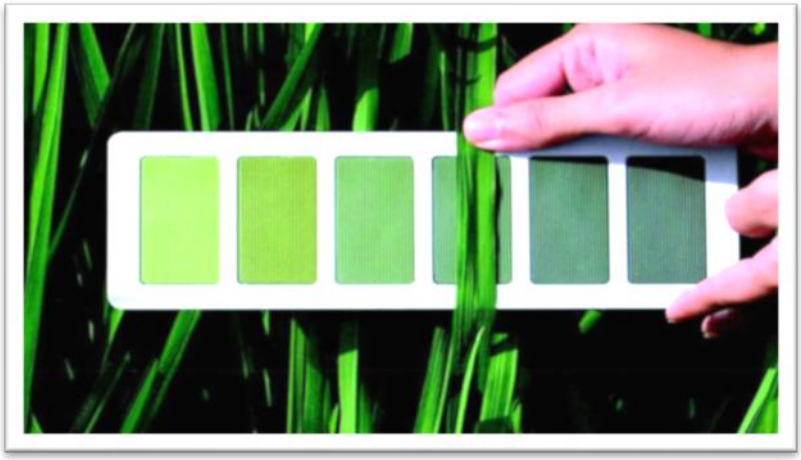

Fig 1 LCC use in Rice

How to use LCC?

LCC assesses the leaf's greenness, which serves as an indicator of its nitrogen content. To conduct this evaluation, randomly select a minimum of 10 healthy plants with consistent population distribution in a field. From each plant, choose the topmost fully expanded leaf. Place the leaf's middle portion on a chart and compare its color to the LCC color panels. Ensure that the leaf remains intact and undamaged during the process. To get accurate readings, measure the leaf color in the shade of your body, as direct sunlight can influence the results. For consistent results, have the same person take LCC readings at the same time of day on each occasion. Calculate the average LCC reading for the selected leaves. If a leaf's color falls between two shades (e.g., 3 and 4), consider the average value (3.5) for the reading. Gather readings from 10 leaves and determine the overall average. If the reading deviates significantly from 3, it indicates the need for nitrogen top dressing. Use the LCC once every 7-10 days, starting from the tillering stage (14 DAT), and continue until 5-10 days after panicle initiation. Nitrogen-deficient plants typically appear yellowish. You can confirm nitrogen deficiency when the LCC reading falls between panels 2 and 3. Interestingly, even with lower nitrogen application rates, plants may look healthier, but a low LCC reading still signifies nitrogen deficiency. Conversely, higher nitrogen application rates lead to well-developed plants with a closed canopy. The critical range for most transplanted rice is the LCC reading between panels 3 and 4. In cases where a high amount of nitrogen fertilizer is applied, leaves might appear dark green. If the leaf color appears darker than LCC panel No-4, it indicates an excess of nitrogen fertilizer.

Advantages of Using LCC

- It is cheaper and does not require high cost.
- It does not require high skill for application which makes it easy to.
- Larger area can be easily covered.
- LCC reduces the nitrogen losses occurred during conventional methods (broadcasting/split application of nitrogen fertilizers).
- 26-29% saving of nitrogen, productivity, agronomic efficiency and yield of crop is reported in many studies.

2.2 ***Soil Plant Analysis Development (SPAD) Meter***: The SPAD meter is a handheld device widely used for quick, precise, and non-destructive assessment of leaf chlorophyll concentrations. It finds extensive applications in research and agriculture across various plant species (Ling *et al*., 2011). By instantly measuring chlorophyll content or plant greenness, the SPAD meter helps mitigate the risks of yield-limiting deficiencies or excessive fertilization expenses (Prajapati *et al*., 2023. It allows the early detection of subtle changes or patterns in plant health that may not be visible to the naked eye. The non-invasive measurement process involves clamping the meter onto leafy tissue, and within less than 2 seconds, an indexed chlorophyll content reading ranging from -9.9 to 199.9 is obtained. The SPAD meter enables the evaluation of nitrogen requirements by comparing in-field SPAD readings with university guidelines or suitably fertilized reference strips. Notably, research demonstrates a strong correlation between SPAD measurements and leaf nitrogen content

Fig:2 A detailed image of SPAD meter

How to measure SPAD readings?

To determine the SPAD reading, the fully expanded leaf of the youngest plant is selected. Readings are taken from the midrib of the leaf blade, and an average of 10-15 readings is collected per plot or field. If the calculated average SPAD value falls below a critical threshold, it indicates a nitrogen deficiency, necessitating the immediate application of nitrogen to prevent potential yield losses. To monitor the leaf nitrogen status effectively, this assessment process should be repeated at regular intervals of 10-15 days, up to the pre-flowering stage or when the initial 10% flowering begins.

Fig 3 SPAD use in Corn and Wheat crops

Advantages

- SPAD instantly measures chlorophyll content of the plants on a scale of -9.9 to 199.9.
- It measures Non-destructive measurement.
- It does not affected by water spills.
- It shows up to 30 measurements.
- Use of SPAD does not require any pre required technical skills; anyone can use it at any time.

2.3 *Green Seeker (Optical sensor):* The Green Seeker handheld crop sensor is a cost-effective and user-friendly tool designed to evaluate the well-being and strength of plants, enabling improved decisions on nutrient management in the field. This device combines optical sensing, variable rate application, and mapping capabilities to measure the crop's nitrogen needs. By quickly obtaining readings of the crop's health, this information guides objective decisions on the optimal amount of fertilizer to apply, leading to a more efficient utilization of fertilizers that benefits both the bottom line and the environment (Prajapati *et al*., 2023).

Fig 4 Green Seeker tool

How to Use Green Seeker?

When using the device, simply pull the trigger to obtain the NDVI (Normalized Difference Vegetation Index) value, which reflects the greenness density of a particular patch of land. The sensor emits quick bursts of red and infrared light, measuring the amount of each type of light reflected by the plants. As long as the trigger is held, the sensor continues sampling the scanned area. The NDVI reading, ranging from 0.00 to 0.99, is displayed on the LCD screen. This reading directly indicates the crop's health, with higher values indicating healthier plants. Green plants tend to absorb more red lights and reflect more infrared light. The greater the difference in reflected light signals, the denser and more vigorous the plants.

To get accurate readings, hold the sensor about 24-48 inches above the crop canopy and keep pulling the trigger. If you need to measure a larger area, walk with the sensor while maintaining a consistent height above the crop surface and keep the trigger engaged. The display continuously accumulates multiple readings and provides the average value after releasing the trigger. If you want to measure new readings,

simply clear the display by pulling the trigger again.

Advantages

- Save money by applying only the necessary fertilizer for optimal crop health, leading to reduced production costs and increased net savings.
- Minimize environmental impacts by using fewer chemicals in the application process.
- Efficiently manage nitrogen usage and decrease nitrogen losses through various methods.
- Affordable data collection enables objective decision-making for all operations.
- No need for extra equipment; utilize free apps and mobile devices with Bluetooth connectivity.

Conclusion

Efficient nitrogen management in field crops is facilitated by user-friendly tools. The Leaf Color Chart is suitable for resource-limited settings, while the SPAD Meter and Green Seeker offer higher accuracy. Tool choice depends on budget, expertise, crop type, and environmental conditions. Integrating these tools promotes sustainable farming, reducing nitrogen waste, and optimizing crop productivity while minimizing environmental impacts. Collaborative efforts among stakeholders are crucial for driving adoption and ensuring a productive, sustainable, and environmentally responsible agricultural sector.

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