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Greenseeker-Morden tool for nitrogen management: A review

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Abstract
The most limiting nutrient in crop production, particularly in irrigated cereal-based cropping systems, is nitrogen. Nitrogen plays a crucial role in plant metabolism, serving as an essential component of proteins, chlorophyll, and various physiological processes. With the global population steadily increasing, the demand for food is also on the rise. To meet this demand, there is a necessity to enhance food production.
In the fiscal year 2019-20, India's total nitrogen consumption was recorded at 17.6 million metric tons. Unfortunately, the application of fertilizers has been done through blanket recommendations, leading to nitrogen losses through weed depletion, fixation, leaching, volatilization, and denitrification. Moreover, higher doses negatively impact soil quality. To address these challenges and synchronize nitrogen supply with demand, precision nitrogen management emerges as a valuable approach.
Among the real-time methods for nitrogen application, tools like leaf color charts, soil plant analysis development meters, chlorophyll meters, and the Green Seeker system are noteworthy. The Green Seeker system stands out as an integrated optical sensor with variable rate application and mapping capabilities to measure crop nitrogen requirements. This system utilizes light-emitting diodes (LEDs) to generate red light (660 nm) and near-infrared light (780 nm). Plant chlorophyll absorbs red light during photosynthesis, with healthy plants absorbing more red light and reflecting increased near-infrared light. The biomass estimation through NDVI measurement using the optical sensor proves to be a reliable predictor of yield potential.
Compared to traditional nitrogen application methods, Green Seeker aids in achieving expected yields while reducing pollution and increasing nitrogen use efficiency (NUE).

Keywords: Green seeker, nitrogen use efficiency, NDVI

Introduction
Nitrogen stands out as the most limiting nutrient in nearly all soil types. Implementing widespread fertilizer recommendations across extensive areas proves inefficient due to the considerable variation in nitrogen supply from one field to another. Crops exhibit varying nutrient requirements based on native nutrient levels and specific crop demands in different fields. Adapting nitrogen inputs to actual crop conditions and nutrient needs would be more advantageous. Currently, nitrogen use efficiency (NUE) for cereal production hovers around 21%, primarily due to the inefficient splitting of nitrogen doses and applications exceeding crop requirements. Broad-based blanket recommendations for fertilizer N in fields may result in lower nutrient use efficiency, given the substantial variability in soil nitrogen from field to field. Recognizing the pivotal role of nitrogen in productivity, adopting crop-specific nitrogen fertilizer applications through decision support tools like LCC, SPAD, and Green Seeker becomes crucial. This approach not only reduces nitrogen losses but also lowers the costs associated with fertilizers and their application.
The utilization of the NDVI technique proves indispensable in optimizing the nitrogen use efficiency of nitrogenous fertilizers, thereby contributing to increased crop yield.
In the study conducted by Mohanta *et al.* (2010) [8], it was found that nitrogen application guided by Green Seeker resulted in notably higher grain (4851 kg/ha) and straw (5862 kg/ha) yields. These outcomes were comparable to the grain (4668 kg/ha) and straw (6079 kg/ha) yields achieved through Nutrient Expert-based nitrogen application, as well as those from Leaf Color Chart (LCC)-based nitrogen application for rice.

According to Swamy *et al.* (2015) [12], different treatments were assessed, and the treatment involving 150 kg N/ha split into three applications at 30, 45, and 60 days after sowing (DAS) demonstrated significantly higher values for fresh cob yield with husk (15.65 t/ha), fresh cob yield without husk (9.48 t/ha), green fodder yield (19.84 t/ha), and stover yield (9.51 t/ha). This performance was comparable to the treatment using Green Seeker-based NDVI at 0.8, which yielded fresh cob with husk (14.4 t/ha), fresh cob without husk (8.15 t/ha), green fodder (18.33 t/ha), and stover (8.88 t/ha).

Kaur *et al*. (2017) [13] they noted that among the different treatments, 4 equal splits of 120 kg/ha nitrogen + guided by Green seeker N up to 3rd irrigation gave significantly higher value of Test weight (42.4 g) and grain yield (5.86 t/ha) as compare to other treatment.

Mali *et al*. (2017) [6] observed that the combination of applying 70% of the recommended nitrogen along with full doses of phosphorus (P_2O_5) and potassium (K_2O) as a basal application, coupled with Green Seeker-based nitrogen top dressing and nutrient management based on STCR, resulted in significantly increased chlorophyll content at 30 and 60 days after sowing (DAS). Additionally, this approach led to higher protein content in grains, increased plant height (measured at 60 DAS and harvest), and a greater number of total tillers. Furthermore, it contributed to longer ear length, higher grain weight per ear, and increased yields in terms of grain, straw, and overall biological yield in barley.

Shivanand *et al.* (2017) [14] they recorded among the different treatments, treatment Nitrogen management through SPAD sufficiency index 96-100% gave significantly higher value of Panicle length (24.5 cm), Number of productive tillers/hill (36.1), Panicle weight (4.13 g) and Test weight (25.07 g) which was at par with Green Seeker based nitrogen management with panicle length (24.1 cm), Number of productive tillers/hill (34.1), Panicle weight (4.0 g) and Test weight (25.03 g).

In the study conducted by Sruthi *et al*. (2017) [9], it was observed that nitrogen application guided by Green Seeker, based on normalized difference vegetation index (NDVI), resulted in significantly higher grain yield (8072 kg/ha) and harvest index (43.1%). These outcomes were comparable to the grain yield (7887 kg/ha) and harvest index (42.3%) achieved through Leaf Color Chart (LCC)-based nitrogen application (with a guideline of applying 25 kg N/ha if LCC is less than 5.0) and SPAD-based nitrogen application (with a guideline of applying 25 kg N/ha if SPAD is less than 50%) in maize.

According to Gurupadappa *et al*. (2018) [2], the application of nitrogen with a Leaf Color Chart (LCC) threshold of ≤ 6.0 resulted in significantly higher uptake of nitrogen, phosphorus (P), and potassium (K) at 30 days after sowing (DAS), 60 DAS, and harvest (184.2, 35.2, and 137.8 kg/ha, respectively). This performance was comparable to the outcomes achieved with Green Seeker at a threshold of ≤ 0.8 (156.7, 30.1, and 133.8 kg/ha, respectively), outperforming the Recommended Dose of Fertilizer (RDF) application (93.2, 24.1, and 125.4 kg/ha, respectively) and farmers' traditional practices (112.7, 25.8, and 129.6 kg/ha, respectively) in rice cultivation.

In their study, Sulochna *et al*. (2018) [10] noted that the application of nitrogen guided by Green Seeker, with 40 kg applied at 45 days after sowing (DAS) during the second irrigation and an additional 10 kg at 65 DAS during the third irrigation, resulted in the highest recorded nitrogen uptake in grain (86.76 kg/ha), straw (39.68 kg/ha), and total nitrogen uptake (126.44 kg/ha). Additionally, this approach led to elevated phosphorus uptake in grain (16.25 kg/ha), phosphorus in straw (2.91 kg/ha), and total phosphorus uptake (19.16 kg/ha). Furthermore, it contributed to increased potassium uptake in grain (19.38 kg/ha), straw (106.17 kg/ha), and total potassium uptake (125.56 kg/ha). Moreover, the agronomic efficiency was noted to be 19.68%, and the recovery efficiency reached 53.46% in wheat.

Kumar *et al*. (2019) [15] reveled that there was plant height (235 cm), leaf area index (4.10%) and grain yield (6.94 kg/ha) increase with treatment 75% as basal + rest N as guided by Green Seeker over treatment with 33% N as basal, 33% N at knee high stage and 34% N at silking stage.

As per the findings of Jyothsna *et al*. (2020) [3], among various nutrient management practices, the application of Green Seeker based on NDVI at 0.8 (with 35% Recommended Dose of Nitrogen (RDN) as basal and Green Seeker guided nitrogen at weekly intervals after 14 days after sowing (DAS) resulted in significantly higher grain yield at 8408 kg/ha. This performance was comparable to the grain yield achieved with SPAD based nitrogen application at a threshold of 40 (35% RDN as basal and SPAD guided nitrogen at weekly intervals after 14 DAS) and Green Seeker based on NDVI at 0.6 (35% RDN as basal and Green Seeker guided nitrogen at weekly intervals after 14 DAS). Furthermore, a significantly higher maize stover yield of 9923 kg/ha was recorded under nitrogen application guided by Green Seeker at NDVI value with a threshold of 0.8. Mohanty *et al*. (2020) [21] recorded that the application of nitrogen based on soil test crop responses gave significantly higher test weight (40.03 g), grain yield (4.34 t/ha) and harvest index (45.59%) which was at par with treatment green seeker guided nitrogen gave test weight (39.78 g), grain yield (4.31 t/ha) and harvest index (44.54%).

Archana *et al*. (2021) [16] reveled that there was 49.1% in harvest index increase with treatment top dressing of N as per green seeker over treatment with top dressing of N as per LCC and RDF (120-60-40 kg/ha).

Importance of Nitrogen

- Plants require nitrogen, the primary nutrient element, in the largest quantity.
- All parts of a plant, especially the meristematic tissues and metabolically active cells, demand nitrogen.
- In the realm of crop production, nitrogen stands out as the most crucial plant nutrient.
- Almost all plant structures rely on nitrogen as a fundamental building block.
- Nitrogen plays a vital role as a component in enzymes, chlorophyll, nucleic acids, storage proteins, cell walls, and various other cellular constituents (Harper, 1994) [22].
- Nitrogen holds a distinctive position among plant nutrients due to its relatively high required quantities compared to other essential nutrients.
- It promotes root growth, crop development, and facilitates the uptake of other nutrients.
- Crop production is frequently limited by the availability of nitrogen (Pathak *et al*., 2005) [17].

Role of Nitrogen in plants

- The chlorophyll molecule, of which nitrogen is a constituent, facilitates the capture of sunlight energy through photosynthesis, ultimately fueling plant growth and grain yield.
- Within the plant, nitrogen assumes a crucial role in ensuring the availability of energy precisely when and where the

plant requires it, thereby optimizing yield.

- Encourages vegetative growth
- Imparts green colour to plants
- Essential constituent of protein
- Important role in the synthesis of auxins

What is Green Seeker?

- The Green Seeker serves as a valuable tool in crop research and consulting, providing essential data for determining the Normalized Difference Vegetative Index (NDVI) and Red to Near Infrared ratios.
- Functioning as a variable rate application and crop vigor mapping system, the Green Seeker enhances the precision and efficiency of managing crop inputs, particularly nitrogen.
- Real-time verification of available soil nitrogen is conducted by the system using intricate agronomic calculations, specifically NDVI.
- By utilizing NDVI data, the Green Seeker formulates an instant fertilizer prescription, ensuring the application of the right amount of nutrients at the optimal time for the plant.
- Operating on the reflection of light from the crop canopy, the Green Seeker's optical sensor produces NDVI values correlated with leaf chlorophyll, offering insights into nitrogen stress and crop vigor.
- These sensors leverage visible and near-infrared spectral radiation to detect nitrogen stress, with NDVI values serving as the foundation for nitrogen application decisions.
- The information gathered allows for the prescription of site-specific nitrogen rates aligned with the crop's needs.
- NDVI measurements, ranging from 0 to 1, serve as indicators of plant health, with higher values denoting better plant condition.
- The Green Seeker demonstrates the capability to predict crop yield potential (Harrell *et al*., 2011) [18].
- Readings from the Green Seeker aid in making objective decisions regarding fertilizer application, optimizing fertilizer use efficiency.
- Offering a more efficient and precise approach to managing crop inputs, especially nitrogen, the Green Seeker bases nitrogen recommendations on yield potential and the Response Index (RI).
- Throughout critical stages of crop growth, the Green Seeker estimates the appropriate amount of nitrogen required.

Types of green seeker

1. Handheld type
2. Mounted type

How it Works

The nitrogen sensor harnesses sunlight as a passive light source. It gauges the spectral reflection of the crop by capturing both the incident sunlight and the light reflected by the crop. Subsequently, the sensor utilizes a transfer function linking spectral reflection parameters to the nitrogen quantity in the crop to calculate nitrogen supply (Jun Ni Q.J., 2015) [19].

The downward sensor component receives the reflected light from the crop, comprising a mirror window, a strip filter, lenses, and a photocell. As the sunlight, with a specific flow density ω, reflects off the crop, it generates a photocurrent (ISCD) in the photocell following a defined relationship. (D. Patranabi 2003) [20].

$$ISCD = S' \times Hdownward = S' \times \beta' \times N \times \Psi$$

S '= the responsiveness of the photocell
Hdownward = the light received by the photocell
β '= the diminishing value of the photocell
N = culture reflection
Ψ = sensing angle of the sensor

Green Seeker System

Main Characteristics

- Operates as an active system.
- Functions both online and offline.
- Measures within the spectrum of red light and near-infrared light.
- Each sensor conducts measurements at a rate of 100 times per second.
- Allows the recording of zoning maps based on soil types.
- Capable of independent use as it can communicate with almost all fertilizers using the ISOBUS command.
- Computes the Normalized Difference Vegetation Index (NDVI).
- Applies fertilizer standards (solid, liquid) relative to the measured NDVI values.
- The Greenseeker software handles the calculation of application quantities and issues commands to the granulated fertilizer spreader or sprayer.

The operating principle

The calculation of the Normalized Difference Vegetative Index (NDVI) involves analyzing the red bands and near-infrared, providing a comprehensive assessment of various aspects related to plant health, including.

- Plant biomass
- Crop yield
- Nitrogen content in plants
- Chlorophyll levels in plants
- Evaluation of water stress
- Detection of plant diseases
- Identification of destructive insects

What does Green Seeker Handheld do?

Measures plant NDVI readings, where

$$NDVI = \frac{\text{NIR Reflected} - \text{Red reflected}}{\text{NIR Reflected} - \text{Red reflected}}$$

NDVI, ranging from 0 to +1, operates on the principle that chlorophyll in plants absorbs red light while reflecting near-infrared light. A higher NDVI reading is indicative of a healthier plant, with the value 0 signifying a lack of vegetation. Vigorous and healthy plant growth is characterized by low red-light reflectance and high near-infrared reflectance, resulting in elevated NDVI values.

Upon triggering, the sensor activates and emits brief bursts of red and infrared light, subsequently measuring the reflected amounts of each. This technology, employed by Green Seeker, offers diverse applications in detecting variations in plant health that may not be apparent to the naked eye.

How does the sensor work?

The functionality of the sensor relies on the utilization of light-emitting diodes (LED), specifically designed to produce red light at 660 nm and near-infrared (NIR) light at 780 nm. In the photosynthesis process, plant chlorophyll absorbs red light as an energy source. Notably, healthy plants exhibit increased absorption of red light and higher reflection of NIR.

As for the basic specifications of the sensor, Green Seeker sensors feature a field of view of approximately 24 inches. Furthermore, each sensor is capable of delivering 10 output readings per second.

Procedure for using Green Seeker

1. To capture observations with the Green Seeker, position the sensor above the crop canopy at a height ranging from approximately 24 to 48 inches and activate it by pulling the trigger.
2. Verify the reading displayed on the device.
3. The sensor's field of view is oval-shaped, expanding in size as the sensor's height increases (approximately 10 inches wide at 24 inches above the ground, and 20 inches wide at 48 inches above the ground).
4. For readings encompassing a larger area, walk while keeping the trigger engaged and maintain a consistent height above the target. The display continuously updates, collecting multiple readings and presenting an average upon releasing the trigger, with a maximum measurement interval of 60 seconds.
5. Pull the trigger to initiate a new measurement. The unit automatically turns off after completing the measurement. To clear the screen and commence a new measurement at any time, pull the trigger.
6. Regarding the Height of Reading, it is noteworthy that NDVI readings, obtained at varying heights above the crop canopy, exhibit consistency. This uniformity stems from the normalized ratio computation, which proportionally adjusts even with changes in sensor distance from the crop. The recommended sensing height for optimal results is situated between 24 to 48 inches above the plants.
7. In terms of Suitable Crops, algorithms have been specifically devised for wheat, rice, and maize. Ongoing research endeavors are actively focused on developing algorithms tailored for additional crops such as potatoes, sugar beets, sugarcane, barley, cotton, and sunflowers.
8. As for the Time of Observation, NDVI assessments can be conducted at any point during the day or night, providing flexibility in data collection.
9. The applicability of NDVI across various Plant Developmental Stages is another notable aspect. This method can be applied at any developmental phase, allowing for assessments from emergence to physiological maturity. The specific stage of observation can be tailored to meet experimental objectives.
10. In terms of the Number of Samples per Plot, the typical approach involves capturing one sample per plot within a fixed duration, which is contingent on the plot size. For instance, a duration of approximately 5 seconds is often employed for a 5-meter plot.

Procedure of Reading

Calibration

A nitrogen-rich strip is crucial for the calibration process, and the required quantity varies depending on the specific crop and region. The length of this strip typically ranges from 300 to 500 feet, ensuring it adequately represents the entire field. This strip serves as a key element in developing a crop-specific algorithm, providing essential data for accurate calibration.

How to Calculate Fertilizer Rate?

1. In the first step, the process involves identifying a reference curve by scanning the N-rich strip and noting the corresponding NDVI value, typically set at 0.8. This value is then used to determine the appropriate reference curve, represented by a sage green line.
2. Moving on to the second step, the non N-rich area of the field is scanned, and the NDVI value is used to intersect the predefined reference curve. This intersection helps identify the Normalized Rate. For instance, if the non-reference NDVI is 0.6, the resulting Normalized Rate would be 0.3.
3. The third step entails determining the Crop Factor. This involves identifying the row associated with the specific crop in a designated crop table. The column corresponding to the maximum yield for the particular crop and region is located at the top of the table. The point of intersection between the identified row and column provides the Crop Factor.
4. Finally, in the fourth step, the Fertilizer Rate is calculated by multiplying the Normalized Rate by the Crop Factor. For example, if the normalized rate is 0.30 and the crop factor is 439, the estimated fertilizer rate would be 131.7. This value is then rounded up to the nearest 5-10 lbs, resulting in a recommended fertilizer rate of approximately 135 lbs N/ac.

Nitrogen Rich Strip

- An area of field with high rate of nitrogen or non-N limiting conditions.
- 40-50 pounds N/acre, over the average rate.
- 10 ft wide, 300 ft long.
- Simple, affordable.
- Starting from preplant application to 30 days planting wheat.
- Compare N rich with farmer practice (visual difference)
- Sensors to calculate needed N
- Mid-season N application
- Approach helps determine N coming from the environment
- Minimize environmental damage from excess N

Moreover, NDVI readings may be subject to various complicating factors, such as distinct cultivars and variations in row spacing. Soil conditions, including imbalances in nutrition such as pH levels and nutrients other than nitrogen (N), can also impact the accuracy of NDVI measurements. Additionally, the presence of weed patches, diseases affecting vegetation, and instances of water-logging are factors that could introduce variability and influence NDVI readings.

What is Response Index (RI)

The field environment dictates the yield response to additional nitrogen (N), denoted as N responsiveness (RI).

RI is calculated as the difference between the grain yield under N-rich conditions and the grain yield check (0-N).

$$\text{In season RI} = \frac{\text{NDVI of N rich strip}}{\text{NDVI of the field rate}}$$

In-season, RI is a dynamic factor that undergoes changes annually

Advantages of green seeker

- Installation is straightforward, calibration is quick, and the method is non-destructive.
- Effectively addresses variability within the field.

- Determines fertilizer rates based on the current condition of the crop.
- Automatically adjusts application rates in real-time as the sensor readings are collected during the applicator's journey through the field.
- Provides real-time data.
- Requires minimal labor.
- Compatible with existing rate and control systems.
- Operates seamlessly in all weather conditions, day or night.
- Functions with or without a GPS signal.
- Does not rely on historical data or mapping.
- Allows for the identification of distinct management zones within the field.

Misconceptions about green seeker

Misconception 1: "Green Seeker is a Nitrogen Sensor "

Facts: Green Seeker operates as a biomass sensor.

Nitrogen leaf content proves to be an inadequate predictor of yield potential.

There exists a strong correlation between biomass/color, as measured by Green Seeker, and yield potential.

Misconception 2: "I can see variability with my eyes I don't need a sensor"

Facts: ✓ While macro variations in a field are observable, detecting subtle changes is challenging.

It is difficult to recall specific locations and degrees of variations within the field over time.

Misconception 3: "If you give me your yield goal, I'll tell you how much nitrogen to apply"

Facts: Adopting a "Yield Goal" fertility approach is not the most economically and environmentally sound strategy.

Without real-time, in-season information, it becomes challenging to accurately estimate mineralization rates, residual nitrogen (N), or the amount of lost N.

Limitations of Green Seeker

- Significant upfront expenses
- Need for calibration
- Requisite technical expertise
- Predominance of marginal and small-scale farmers
- Limitations in sensor functionality during early crop stages or near maturity
- Inability to distinguish between weeds and crops
- Challenges in application during the early stages of transplanted rice

Conclusion

Green Seeker technology presents an opportunity for farmers to optimize crop production and reduce production costs by applying only the necessary amount of nitrogen (N) fertilizer. Through a sensor-based decision support management approach, Green Seeker effectively decreases the total amount of nitrogen applied, thereby enhancing Nitrogen Use Efficiency (NUE) while maintaining yields comparable to traditional practices and modern tools like Leaf Color Chart (LCC) and Soil-Plant Analysis Development (SPAD) meter. By accurately estimating the required nitrogen levels at critical crop growth stages, Green Seeker minimizes nitrogen usage without compromising yield. In comparison to conventional fertilizer practices, Green Seeker-based nitrogen application consistently outperforms, particularly benefiting the growth and productivity of cereal crops. The combination of a prescribed nitrogen dose at sowing and corrective doses guided by the Green Seeker optical sensor at different crop stages holds great promise for achieving higher yields.

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