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OPTIMIZING CROP YIELDS: A COMPREHENSIVE GUIDE TO SITE-SPECIFIC NUTRIENT MANAGEMENT AND PRECISION FARMING TECHNIQUES IN INDIA

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ABSTRACT

The Green Revolution in India relied on high-yielding wheat and rice varieties that thrived with increased water and fertilizer use. Although fertilizers boost soil fertility, improper and unbalanced application by farmers has raised concerns about nutrient management. Many farmers overuse nitrogen and phosphorus, neglecting other essential nutrients like potassium, leading to nutrient depletion, reduced productivity, and lower fertilizer efficiency. Site-specific nutrient management (SSNM) addresses this issue by applying nutrients based on crop needs, optimizing fertilizer use, preventing nutrient loss, and promoting balanced fertilization for improved yields and soil health.

KEYWORDS: Leaf color chart, Nutrient use efficiency, Precision farming, Site specific nutrient management

INTRODUCTION

The extensive usage of different fertilizers across the world has significantly increased food production. As per the estimates, nutrient inputs account for between thirty and fifty per cent of crop production. However, there are currently significant concerns regarding existing nutrient management methods due to low nutrient-use efficiency, associated environmental contamination, and global warming issues. For N, P, and K, respectively, the recovery efficiency of fertilizer nutrients is roughly 20–40, 15-20, and 40–50%, however, it is significantly inferior for secondary and micronutrients, between 5–12%. The constant nutrient mining from the soil as a result of imbalanced nutrient use leads to the diminution of some major, secondary, and micronutrients like N, K, S, Zn, Mn, Fe, B, etc., as well as the decreasing use of organic nutrient sources like FYM, compost, and the integration of green manures are some of the major causes of low and declining crop responses to fertilizers. Thus, the management of nutrients has always been crucial for crop growth as well as for the sustainability and health of the soil, economy, and society.

Recommendations for managing nitrogen levels in practically all farmed crops have been produced based on extensive research led over the previous 50 years. The produced guidelines specify the application time and the amount of various nutrients desired on a hectare basis. Such general recommendations led to the over use of nutrients in some areas and the underapplication of nutrients in others since they mainly ignored the heterogeneity in the innate soil fertility and other edaphic characteristics. Low nutrient-use efficiency and fertilizer waste were the outcomes of this. Research from several Asian nations has shown the drawbacks of the traditional method of recommending blanket fertilizers at a predetermined rate and time. However, the idea of site-specific nutrient management of nutrients was created in recognition of the limitations of the general nutrient recommendations.

SITE SPECIFIC NUTRIENT MANAGEMENT

The soil provides a large amount of the nutrients required by plants, but this natural supply is typically insufficient to meet the demands for high yields. To close the gap between the crop's nutrient requirements and what the soil and readily available organic inputs can supply, fertilizer application is essential. By precisely supplying nutrients like nitrogen (N), phosphorus (P), and potassium (K) to crops like rice, maize, and wheat when they are needed, site-specific nutrient management (SSNM) improves nutrient utilization efficiency. The main benefit of enhanced nutrient management for farmers using SSNM is higher profitability. By avoiding overapplication and making sure that fertilizers are not applied when crops don't require them, SSNM minimizes fertilizer waste. Additionally, it ensures that N, P, and K are applied in the exact ratios needed for that particular crop. The method of providing crops with nutrients on demand is referred to as the Principle of Site-Specific Nutrient Management (SSNM). Nutrient management and application are dynamically modified to meet crop needs specific to the region and time of year. Through higher crop yields per unit of fertilizer applied, overall higher yields, and decreased disease and insect damage, the SSNM strategy seeks to boost farmers' profits.

Soil testing remains to be a significant bottleneck. Thus, attempts have been made in India to create a type of SSNM programming that primarily uses modern technologies like LCC, SPAD, Nutrient Expert (NE), and Green Seeker which does not require a large data store. One of the main factors influencing increasing productivity, sustainability, profitability, and turbulence associated to climate change is precision nutrition. The production of food grains has increased owing to SSNM, but the efficiency of nutrient use has not increased beyond a certain point.

Leaf Color Chart

The relative greenness of a rice leaf can be tracked utilizing the leaf color chart (LCC), a simple and inexpensive diagnostic tool that displays the nitrogen (N) status of the plant. Nitrogen status of rice is a sensitive indicator of changes in crop N needs throughout the growing season as it is highly correlated with the photosynthetic rate and biomass production of the plant. Achieving optimal leaf N content and high rice yields through effective nitrogen management requires a tool that can rapidly evaluate the state of nitrogen in the leaves and direct the administration of nitrogen fertilizer. The LCC is a four-panel plastic strip with a range of colours from yellowish green to dark green that is shaped like a ruler. With two equally useful options available for use, it is utilized to monitor leaf N status from the tillering stage to panicle initiation or later. Farmers' preferences and site-specific factors, such as how often they visit their fields and how well-informed they are about the crucial growth stages for nitrogen treatment, will determine which of these options they choose. Farmers who engage in other profitable endeavours tend to favour the fixed-time/adjustable-dose option due to its time-saving nature, whereas farmers who are not well-versed in the essential phases for the ideal timing of nitrogen fertilizer N typically favour the real-time option.

HOW TO USE THE LCC?

1. Choose ten or more healthy, disease-free rice plants or hills at random from a field with a uniform population of plants.
2. Select the leaf that is completely extended at the top of each plant or hill. For comparison, position the leaf's centre section in relation to the LCC's colour panels. Make sure the leaf stays intact and attached throughout the procedure.
3. Measure the colour of the leaves beneath the body's shadow as leaf colour readings are influenced by direct sunshine. The same individual should, if at all feasible, take LCC readings at the same time of day each time.
4. Determine the average LCC reading for the selected leaves.

When N is not applied to plants, they turn yellow. Confirmation of a nitrogen deficit occurs when the LCC result falls between panels 2 and 3. The essential range for the majority of transplanted rice is between panels 3 and 4, which is where the LCC reading falls. The leaves of plants with high N rates exhibit a deep green colour. There is an excess of fertilizer N seen in the leaf colour, which is darker than the LCC panel no. 4.

SPAD (SOIL PLANT ANALYSIS DEVELOPMENT)

The SPAD meter is becoming more and more popular since it provides a non-destructive method of measuring the chlorophyll content of leaves and is portable, accurate, rapid, and easy to use. The SPAD meter is perfect for tracking plant development and nutritional condition over time because it is non-destructive and allows for several measurements on the same plant. The gadget is also reasonably priced, long-lasting, and low maintenance, which makes it a cost-effective option for growers and researchers alike. Its utility is further increased by its portability, which makes it easy to utilize in the field. To ensure that their crops stay healthy, productive, and optimized for yield and quality, farmers can use the SPAD meter to quickly assess the chlorophyll content of the plants, identify possible problems early, and take corrective action, such as adjusting fertilizer application rates or addressing pest and disease concerns.

WORKING OF SPAD

The SPAD meter is a tool used to quantify the amount of chlorophyll in plant leaves. When a photon is absorbed, it uses a reverse-biased p-n junction to produce an electrical signal. The optical absorption principle serves as the foundation for the measurement. A tiny, non-invasive sensor on the leaf's surface that emits light at particular wavelengths between 500 and 700 nm or up to 940 nm is part of the meter. These are visible light wavelengths that are similar to the absorption peak of chlorophyll a, which is the main type of chlorophyll found in green plants. The SPAD meter calculates the chlorophyll content by measuring the amount of light absorbed by the chlorophyll. The tool measures the relative amount of chlorophyll content, which is correlated with the amount of nitrogen present in plant tissue. Greater tissue nitrogen and chlorophyll content are indicated by higher SPAD values, whereas lower readings imply lower nitrogen and chlorophyll content.

NUTRIENT EXPERT

The International Plant Nutrition Institute (IPNI) developed Nutrient Expert® (NE), a nutrient decision support tool, based on the ideas of site-specific nutrient management (SSNM) and 4R nutrient management. Regardless of the availability of soil testing data, NE is a user-friendly, interactive, computer-based application that rapidly offers fertilizer recommendations to specific farmer’s fields (Pampolino et al., 2012). NE gives crop advisors a simple and effective way to use site-specific data already available to apply SSNM principles. Apart from providing nutrient recommendations suited to a particular place, the application also facilitates modification according to the farmer's available resources. Nutrient Expert calculates the achievable production and yield response to fertilizer based on site information and decision rules derived from on-farm trials. NE specifically uses the following features of the growing environment:

soil fertility indicators (soil texture, colour, and organic matter content), soil test for P or K (if available), historical use of organic materials (if any), and problem soils (if any); crop sequence in the farmer's cropping pattern; crop residue management and fertilizer inputs for the previous crop; and farmers' current yields. Notably, NE also uses these features of the growing environment. Establishing the NE decision rules need data for particular crops and regions. The datasets need to depict a range of growing environment characteristics, such as soil types, cropping techniques, crop cultivars and growth periods, and rainfall amount and distribution variations.

GREEN SEEKER

Green Seeker is a valuable tool for data necessary to calculate Red to Near-Infrared ratios and the Normalized Difference Vegetation Index (NDVI) in the field of crop research and consulting. As a variable rate application and crop vigour mapping technology, Green Seeker improves the accuracy and efficiency of regulating agricultural inputs, especially nitrogen. For real-time verification of the amount of soil nitrogen available, complex agronomic computations more especially, the NDVI are employed. Green Seeker's instantaneous fertilizer prescription, which is based on NDVI measurements, ensures that plants receive the proper amount of nutrients at the appropriate time. Green Seeker generates NDVI values based on the reflection of light from the canopy and correlates them with the concentration of chlorophyll in the leaves. Based on the needs of the crop, these NDVI measurements form the basis for decisions on nitrogen delivery. Higher values indicate better plant condition. NDVI measurements are used as markers of plant health, with a range of 0 to 1. Crop yield potential can be predicted by the Green Seeker (Harrell et al., 2011). By optimizing fertilizer use efficiency, readings from the Green Seeker help one make objective decisions about applying fertilizer. The Green Seeker provides a more accurate and effective method of managing agricultural inputs, particularly nitrogen. It based its recommendations for nitrogen on yield potential as well as the Response Index (RI). The Green Seeker calculates the right quantity of nitrogen needed at key phases of crop growth.

THE OPERATING PRINCIPLE

The Normalized Difference Vegetative Index (NDVI), provides a thorough assessment of numerous aspects of plant health, such as plant biomass, crop yield, nitrogen content in plants, chlorophyll levels in plants, evaluation of water stress, detection of plant diseases, and identification of destructive insects, is calculated by analysing the red bands and near-infrared light.

Green seeker Measures plant NDVI readings by, NDVI = NIR (reflected)– Red(reflected)/NIR (reflected)+ Red(reflected)

Based on the idea that plant chlorophyll absorbs red light while reflecting near-infrared light, the NDVI scale ranges from 0 to +1. A greater NDVI score corresponds to a healthy plant, and a value of 0 indicates a deficiency of vegetation. High near-infrared reflectance and low red-light reflectance, which translate into higher NDVI values, are indicative of robust and healthy plant growth. Green Seeker uses this technology, which has a variety of uses in identifying changes in plant health that might not be visible to the naked eye.

CONCLUSION

In India, the implementation of precision farming and site-specific nutrient management (SSNM) is a viable strategy to maximize crop yields while improving soil health and nutrient-use efficiency. To enable precise nutrient delivery, reduce waste, and increase farmer profitability, tools like the Leaf Color Chart, SPAD meter, Nutrient Expert, and Green Seeker are essential. With the management of soil fertility variations and crop nutrient requirements, these technologies support sustainable agriculture practices that are critical for tackling climate change and ensuring food security.

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