

Precision nutrient management

Innovative technology for enhancing income in farming system

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India is one of the largest consumers of fertilizers in the world and also has 2nd highest arable lands. This is required to ensure food and nutritional security of huge population. But losses of fertilizer nutrients due to faulty application is a serious concern. The recovery efficiency of nutrients from fertilizers is about 30-50%, 15-20%, 50-80%, 1-5 and 5-12% for N, P, K, micronutrients and secondary nutrients, respectively. This poor nutrient use efficiency not only leads to a decrease in crop yield but also increases cultivation costs, environmental pollution and nutrient imbalance. The agronomic efficiency of the nutrient has also been decreasing every year since the introduction of the Green Revolution technologies. This low fertilizer use efficiency and indiscriminate use of fertilizers have increased the import of chemical fertilizers, which is also a major problem for the Indian economy. Therefore, there is an urgent need to explore or popularize the innovative technology for precise nutrient management. So far, various tools and technologies have been tested in the research center as well as in the farmers field such as: Green Seeker, Leaf Color Map, Soil Plant Analysis Development (SPAD), Nutrient Expert, Crop Manager, Site Specific Nutrient Management and Nutrient Recommendation based soil health card, nutrient indexing or soil test plant response. Precision nutrient management technologies have been shown to improve grain yield by 6-15%, net returns by 7-25%, nitrogen saving by 5-25 kg/ha and nutrient use efficiency also by 5-15%, which is beneficial for agriculture prosperity and increased income of the farmers of the country.

Keywords: Crop manager, Green seeker, Leaf colour chart, Nutrient expert, SSNM, STCR

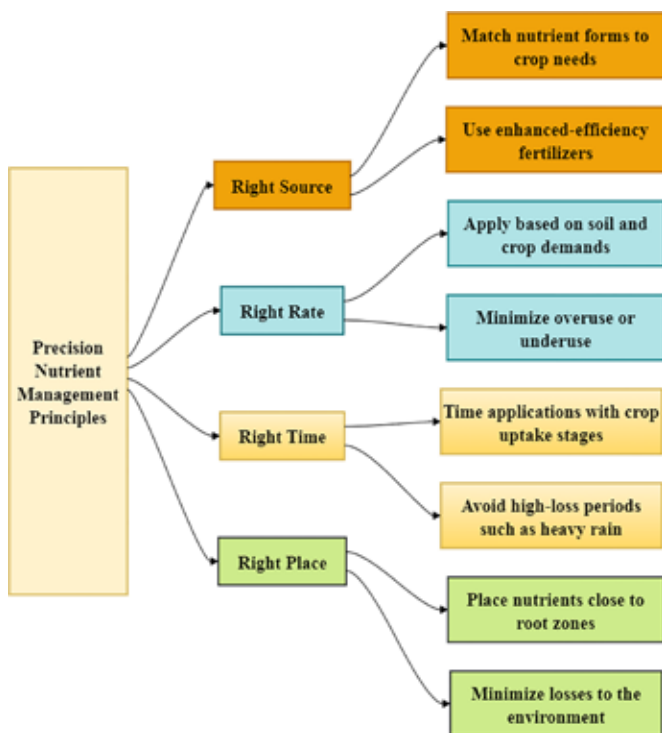
THE success of the green revolution in India is based on the use of three important technologies such as the use of chemical fertilizers, high-yielding varieties and assured irrigation. The green revolution has transformed India from a food importing country to a food exporting country. The global use of various fertilizers has also made a huge contribution to improving food production and is responsible for 30-50% of crop yields. However, the recovery efficiency of nutrients from these fertilizers is about 30-50%, 15-20%, 50-80%, 1-5 and 5-12% for N, P, K, micronutrients and secondary nutrients, respectively. This low recovery efficiency increases cost of cultivation, soil degradation, environmental pollution and global warming. Most farmers now only use urea as a source of nutrients for their plants and partially or completely forego the addition of other nutrients. Farmers have also reduced the use of organic nutrient sources such

as FYM, compost and the integration of green manure/ grain legumes. This is the main reason for the declining agronomic use efficiency of nutrients and crop yield and quality. Based on intensive research to date, nutrient management recommendations have been developed for almost all crops; this recommendation is referred to as the recommended fertilizer rate. This recommendation informs us about the dose and timing of use in general. This dose does not take into account field-to-field variation in soil fertility and other factors. This blanket recommendation not only reduces recovery efficiency, but also the crop yield and leads to multi-nutrient deficiencies, environmental pollution and harmful effects on other plants and animals. Due to low use efficiency and unbalanced fertilization, India's expenditure on importing nitrogenous fertilizers is very high, which is not good for the national economy.

All this, therefore, necessitates the need for precise nutrient management (PNM) because precise nutrient management requires the application of nutrients by taking into account soil fertility, plant needs and matching the needs of plants to their requirements.

Principles and practices of precision nutrient management (PNM)

PNM involves applying nutrients in the right amount, at the right time, in the right place and from the right source, tailored to the specific needs of the crop and soil. This PNM approach uses tools such as soil health maps, crop models and decision support systems. This will help tailor nutrient application to plants' growth stages and nutrient requirements, ensuring resource efficiency.



Site specific nutrient management (SSNM)

Precision nutrient management through SSNM is essential to bridge the gap between the nutrient needs of high-yielding crops and the indigenous nutrient supply. It involves the following steps.

- **Establish a yield target:** The yield target is the average yield of the past 3-5 years where nutrients are not limiting and good crop management is practiced.
- **Estimate actual yield responses to fertilizer N application and associated agronomic efficiencies:** This is determined through nitrogen omission plots, which is the yield for a crop not fertilized with the N but fertilized with other nutrients.
- **Estimate the agronomic N efficiency (kg seed yield increased/kg of N applied) :**

$$= \frac{\text{Seed yield in N fertilized plot (kg/ha)} - \text{Seed yield in N limited plot (kg/ha)}}{\text{Amount of N applied in N fertilized plot (kg/ha)}}$$

- **Calculation of dose (kg/ha):**

$$= \frac{\text{Seed yield in N fertilized plot (kg/ha)} - \text{Seed yield in N limited plot (kg/ha)}}{\text{Agronomic N efficiency (kg seed yield increased/kg of N applied)}}$$

After calculating this dose, farmers can apply the nutrients according to crop needs to meet the nutrient demand at the crop specific growth stages for higher grain yield and minimizing nutrient losses. Data for calculation of SSNM based nutrient dose can be easily obtained from Krishi Vigyan Kendra or local government agricultural universities or ICAR institutes.

Soil test crop response (STCR)

This approach is based on soil test values, targeted crop production and nutrient use efficiency of the nutrient. After gathering the necessary information, the nutrient dose (kg/ha) is calculated using the following formula:

$$N \text{ dose (kg/ha)} = \frac{\text{Average yield} \times N \text{ uptake} - \text{Available N in soil (kg/ha)} \times \frac{100}{ANR (\%)}}{100}$$

Data for calculation of STCR based nutrient dose can also be easily obtained from Krishi Vigyan Kendra or local government agricultural universities or ICAR institutes.

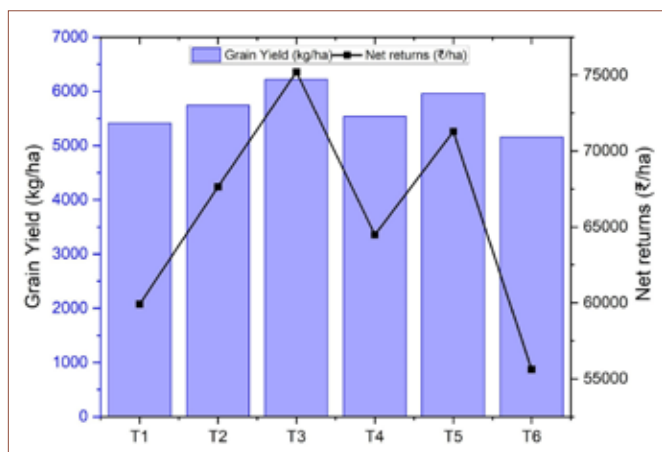
Soil test-based recommendation/nutrient indexing

The Soil Health Card scheme of Government of India is very helpful to provide nutrient recommendations according to the fertility status of the field. Farmers can send their soil samples to any government soil laboratory that analyses soil health and get an overview of their field. They analyze the soil sample at a reasonable cost and send a report on the fertility status of the field, based on which farmers can make a recommendation. Results from various studies have also shown that nutrient management based on soil health card has saved nutrient up to 10% and increased grain yield by 5-15%.

Green seeker™ technology

This Green Seeker is an optical sensor that can be better used to calculate the optimal nitrogen dose in agriculture. This instrument is used to measure the Normalized Difference Vegetation Index (NDVI) of plants and this NDVI value is correlated with the nitrogen content in the plant. The sensor emits red and infrared light, and the reflected light is used to calculate the NDVI. High values in the plant indicate good nitrogen content, while low values indicate poor nitrogen status of the plant. This instrument can be a good precision nitrogen management tool for real-time nitrogen management in agricultural system. The GreenSeeker™ sensor measures the NDVI of a high nitrogen (N-rich) strip and an adjacent area representing the farmer's practice. The device can be used by walking approximately 100 paces at the center of each plot, holding the sensor 24-48 inches above the crop canopy. NDVI readings of the sensor are entered into the Sensor-

based Nitrogen Rate Calculator. The results of various studies in the rice-wheat cropping system of India have also shown good results for saving nitrogen, reducing cost of cultivation and improving nitrogen use efficiency and agronomic use efficiency. Some mobile applications have now also been developed that can be used to easily calculate the nitrogen dose in agriculture.



Effect of Green Seeker™ based nitrogen management on maize productivity and profitability

where T consists of state recommendation with 150-80-60 kg/ha. T₂ and T₃ consists of Nutrient Expert recommendation for 6 t/ha and 7 t/ha respectively. T₄ and T₅ include Nutrient Expert recommendation with Green Seeker™ reading for second split for 6 t/ha and 7 t/ha respectively. T₆ State recommendation with green seeker for second split comprised (Source: Shyam *et al.* 2021).

Soil-plant analysis development (SPAD)

The SPAD meter, also called a chlorophyll meter, is used to measure the green intensity (chlorophyll content) in plant leaves. This measurement is essential for nitrogen fertilization in crops because it is related to the nitrogen content in the plants. The SPAD value of the plant is calculated at the different growth stages and then these SPAD values are compared with the set threshold values. This helps farmers apply nitrogen fertilization in real time when the crop needs additional

nitrogen, reducing the risk of over- or under-fertilization and improving nitrogen use efficiency.

Leaf colour chart (LCC): It is a user-friendly, cost-effective nitrogen management tool that can be used by uneducated farmers and only requires hands-on practice once or twice. The Leaf Color Chart is utilized for assessing nitrogen fertilizer requirements in rice crops, consisting of four green strips, from yellow-green to dark green. Nitrogen management by this tool involved very few steps such as randomly selecting at least 10 disease-free rice plants or hills in a field, where plant population is uniform. The topmost, youngest, fully expanded leaf is selected from each hill or plant, which best reflects the N status of the plants. The middle part of the leaf is placed on the LCC and its color is compared with the color panels. The leaf color is measured under the shade of one's body, as direct sunlight affects leaf color readings. The readings of the 10 leaves are taken, and the average is determined. If the LCC value is more or less than 3, N fertilizer top dressing is needed. The Leaf Color Chart is applied every 7 to 10 days, beginning from the onset of tillering (14 days after transplanting), and this schedule is maintained until 5 to 10 days after panicle initiation.

IPNI nutrient expert® for android tablets and smart phones

The International Plant Nutrition Institute (IPNI) has developed this Android-based versions of the Nutrient Expert® app for various crops such as maize,



Nutrient Expert® for Maize Philippines (Web App Version 1, July 2016)

Nutrient Expert® for Maize is a nutrient decision support tool for hybrid, open-pollinated, and traditional corn varieties in the Philippines.

It helps you to:

- develop an optimal planting density for your location
- evaluate current nutrient management practices
- determine a meaningful yield goal based on attainable yield
- estimate fertilizer NPK rates required for selected yield goal
- translate fertilizer NPK rates into fertilizer sources
- develop an application strategy for fertilizers (right source, right rate, right time, right place), and
- compare the expected and actual benefit of current and improved practices.

To start, click a button

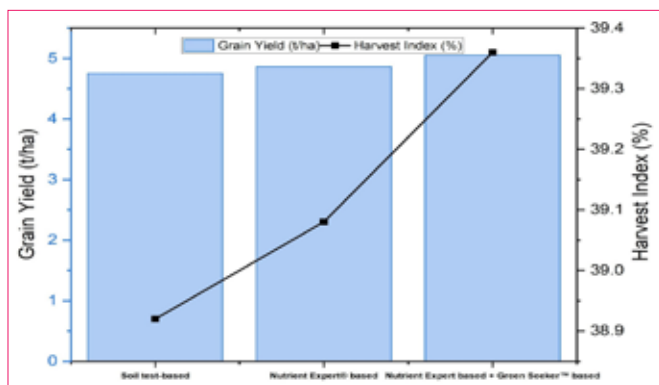
- Current NM Practice
- Planting Density
- SSNM Rates
- Sources and Splitting
- Profit Analysis



A summary recommendation can be sent to farmers via short messaging service (SMS), while a full report can be emailed.

Crop manager

Crop manager is a web-based platform for field-specific information on crop and nutrient management to increase yields and income of rice farmers (<https://www.irri.org/crop-manager>). The International Rice Research Institute (IRRI) and its partners have developed site-specific nutrient management (SSNM) principles to determine the optimal nutrient management practices for individual rice fields. Key components of these principles include the timing, quantities, and types of fertilizers used. Recommendations generated by the Rice Crop Manager (RCM) are provided to farmers via a one-page printout and SMS to enhance and guide crop management. This approach allows extension workers to use a computer or smartphone to offer farmers the crop management advice tailored to their specific field conditions. IRRI has developed crop manager for three states, viz., Uttar Pradesh (<http://webapps.irri.org/in/up/rwcm/>), Odisha (<http://webapps.irri.org/in/od/rcm/>; Sharma et al., 2019) and Bihar (<http://webapps.irri.org/in/br/cmrs/>).



Effect of precision nitrogen management on maize productivity, harvest index and nitrogen content (Source: Hasanain et al. 2021)

rice, and wheat for China and South Asia; soybean for China; and maize for the Philippines. This application aims to promote the dissemination of 4R-based nutrient management recommendations—applying the right source of nutrients at the right rate, at the right time, and in the right place—which is a major priority for IPNI. Available in English and local languages such as Chinese, Hindi, and Tagalog, the app can be downloaded for free from <http://software.ipni.net>. Once installed on a mobile device, it provides nutrient recommendations even without an internet connection.

Integration of precision nitrogen management tools

It is imperative to incorporate precision nutrient management tools because the majority of these tools are either crop-specific, soil health-specific, or time-specific. For example, nutrient experts, crop managers, SSNM, or STCR-based crop management are useful for calculating nutrient dosages and for basal nutrient application, while tools like leaf color charts, green seeker, and SPAD are useful for real-time nitrogen management for fertilizer splitting or top dressing. Therefore, it is important to integrate these tools so that it is easy to target both the top dressing and the basal dressing. Farmers can obtain a higher yield with the same or less amount of nutrient application if the top dressing and basal dressing doses are applied according to the crop's needs and the soil's ability to supply nutrients.

SUMMARY

Input intensive green revolution technologies have significantly increased food production in India through fertilizers, high-yielding varieties and irrigation and made the country self-reliant in food production. In present time to sustain the India's agri food system, efficient use of resources has become the paramount. The declining resource use efficiency especially that of the

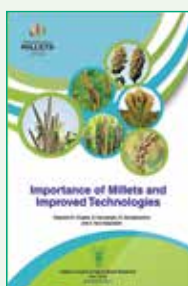
low fertilizers use efficiency pose many challenges for food and environmental sustainability. Lower nutrient recovery from fertilizers and unbalanced application have led to soil degradation, increasing environmental footprints, pesticide residues in the system and escalating cost of production. PNM technologies provide tailored solutions based on soil and crop needs with tools such as SSNM, STCR, Green Seeker™, SPAD meters, and Nutrient Expert® and Crop Manager. The PNM is of vital significance more especially for N. Real time N management through PNM not only increases Nitrogen Use Efficiency (NUE), but also enhances crop productivity and environmental safety. The integration

of these tools ensures efficient nutrient use, higher yields and lower losses. Farmers should be trained in these PNM technologies and the KVK, SAU and ICAR institutes should provide practical training to farmers. Also, the government should ensure the availability of these PNM tools to farmers so that they can use them easily. This will not only help improve nutrient use efficiency but also improve grain yield, net returns, farmers' income and nitrogen saved and also reduce the burden of nutrient import on the Government of India.

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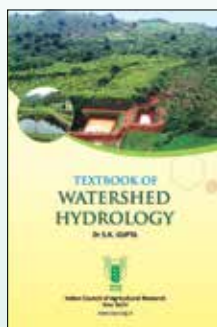
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