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Precision Agriculture Empowering Farmers with Site-Specific Nutrient Management: Key Tools and Techniques

Rameshwar Choudhary[1]*, Anand Kumar Diwakar[2], Sunil Kumar Prajapati[3], Vipin Kumar[3]

[1]Ph.D. Research Scholar, Department of Soil Science, Punjab Agricultural University, Ludhiana, Punjab 141004, India.
[2]M.Sc. (Ag.), Soil Science-Soil and Water Conservation, Banaras Hindu University, Varanasi, Uttar Pradesh, India
[3]Ph.D. Research Scholar, Division of Agronomy, ICAR-Indian Agricultural Research Institute, Pusa, New Delhi-110012, India

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*Corresponding Author
Rameshwar Choudhary*

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INTRODUCTION

The word 'precision' means exactness or accuracy. Precision agriculture is revolutionizing the way farmers approach crop management. At the forefront of this agricultural transformation is Site-Specific Nutrient Management (SSNM). By leveraging advanced technologies and data-driven insights, SSNM empowers farmers to tailor their fertilizer applications to the unique needs of each specific area within their fields. This targeted approach optimizes crop yields, enhances resource efficiency, and promotes sustainable farming practices, ensuring a brighter future for both farmers and the environment. Precision agriculture is a management strategy that gathers processes and analyses temporal, spatial and individual data and combines it with other information to support management decisions according to estimated variability for improved resource use efficiency, productivity, quality, profitability and sustainability of agricultural production. (International Society of Precision Agriculture, 2019) Precision farming or precision agriculture is a modern management strategy that employs the details of site-specific nutrient management, remote sensing, global information system, global positioning system, variable rate application to precise manages the production input.

OBJECTIVES

a) Promotion of new venture in the 'Agriculture and its allied sector' bringing together various component of agriculture to exploit the variability. Reduction in cost of cultivation due to site-specific crop management practices.

b) Increase in production efficiency of inputs due to site-specific management of inputs.

c) Reduction in the application of nutrients especially nitrogen fertilizer thus reducing nitrate in underground water and nitrous oxide to the atmosphere.

d) Reduction in the application of irrigation water thus reducing of nutrient along with deep percolations. Reducing erosion, runoff and sedimentation of water bodies.

3. WHY IS PRECISION NUTRIENT MANAGEMENT IMPORTANT?

a) Nutrient variability within a field can be very high (graphs to follow), affecting optimum fertilizer rates. Yield potential and grain protein can also vary greatly even within one field, affecting fertilizer requirements.

b) Increasing fertilizer use efficiency will become more important with increasing fertilizer costs and environmental concerns.

4. SITE SPECIFIC NUTRIENT MANAGEMENT

a) Site specific nutrient management (SSNM) is a general concept for optimizing the supply and demand of nutrients according to their variation in space and time.

b) SSNM utilizes the principles of application along with analysis of organic and inorganic sources of nutrients, soil and plant variability assessments, cropping systems, soil nutrient supplying capacities to plants, enhanced nutrient use efficiencies, productive capacities of varieties to achieve the desired goals (Shankar and Umesh, 2008).

c) SSNM applies certain principles that holds the concept of optimum utilization of nutrients and minimizes the losses that only to certain specific area of cultivation (Umesh *et al*., 2014).

d) The SSNM provide an approach for need based 'feeding' of crops with nutrients.

e) The ultimate goal of SSNM is high yield, high fertilizer use efficiency, and providing a locally-adopted nutrient management practice according to the requirement of a crop.

5. THE MAIN FEATURES OF SSNM

a) Site specific application of nitrogen, phosphorus and potassium and secondary and micronutrients based on soil tests are followed.

b) SSNM further provides guidelines for selection of the most economic combinations of nutrients.

c) Advocates wise and optimal use of existing indigenous nutrient sources such as crop residues and manures. Improve profitability and marketable crop quality.

d) Use of leaf color chart ensures that nitrogen is applied at the right time and in the amount needed by the crop which prevents wastage of fertilizer.

e) Integration with other integrated crop management (ICM) practices such as the use of quality seeds, optimum plant density, integrated pest management and good water management.

6. PLANT ANALYSIS-BASED SSNM

The principles of plant-based SSNM were developed for rice in Asia (Dobermann *et al*, 2002). Five key steps for developing field-specific fertilizer NPK recommendations have been developed.

a) ***Selection of the yield goal***

- Potential yield (Ymax.) is defined as the maximum possible grain yield limited only by climatic conditions of the site, where there are no other factors limiting crop growth.
- Yield target should not exceed 70-80% of Ymax.
- The logic behind selection of the yield goal to the extent of 70-80% of the Ymax is there is linear relationship between grain yield and plant N uptake until the target reaches 70-80% of Ymax. The internal NUE remains constant during the linear phase. So, that internal NUEs decrease at very high yield levels near Ymax.

b) ***Assessment of Crop Nutrient Requirement***

- The nutrient uptake requirements of a crop depend both on yield goal and Ymax. In SSNM, nutrient requirements are estimated with the help of quantitative evaluation of fertility of tropical soils (QUEFTS) models.

- (Note: A modified 'Quantitative Evaluation of Fertility on Tropical Soils' model (Janssen et al. 1990; Witt et al. 1999) provides the relationship between grain yield and N accumulation by the crop as a function of climatic yield potential and the supply of N forms the basis of plant-based SSNM for predicting soil N supply and plant N uptake in absolute terms.)
- Nutrient requirements for a particular yield goal of a crop variety may be smaller in high yielding seasons than the low yielding ones.

c) Estimation of Indigenous Nutrient Supplies

- Indigenous nutrient supply (INS) is defined as the total amount of a particular nutrient that is available on the crop from the soil during the cropping cycle, when other nutrients are not limiting.
- The INS is derived from soil incorporated crop residues, water and atmospheric deposition. It is estimated by measuring plant nutrient uptake in an omission plot embedded in the farmers' field, wherein all other nutrients except the ne (N, P or K) in question, are applied in sufficient amounts.

d) Computation of Fertilizer Nutrient Rates

- Field-specific fertilizer N, P or K recommendations are calculated on the basis of above steps and the expected fertilizer recovery efficiency (RE, Kg of fertilizer nutrient taken up by the crop per Kg of the applied nutrient).
- Studies indicated RE values of 40-60% for N, 20-30% for P, 40-50% for K in rice under normal growing conditions.

e) Dynamic Adjustment of N Rates

- Fertilizer P and K are applied basally (at the time of sowing), the N rates and application schedules can be further adjusted as per the crop demand by using chlorophyll meter (SPAD), Green seeker and Leaf Colour Chart (LCC).
- Recent on farm studies in India have revealed a significant SPAD/LCC based N management schedules in rice and wheat in terms of yield gain, N use efficiency and economic returns over the conventionally recommended N application involving 2-3 splits during crop growth.

7. SOIL-CUM-PLANT ANALYSIS BASED SSNM

In this case**,** nutrient availability in the soil, plant nutrient demands for a higher target yield (not less than 80% of Y_{max}), and RE (recovery efficiency) of applied nutrients are considered for developing fertilizer use schedule to achieve maximum economic yield of a crop variety. From the data available from different fixation studies of diff nutrient elements in soil, the ratio of nutrient supply in the soil versus nutrient applied in a given soil is established. These ratios provides a basis to know as to how much nutrient is required to be added to a soil to bring it to a level which is more than adequate for maximum growth, but less than that which would be toxic, or out of balance with other plant nutrients (Johnston *et al*, 2009). Based on optimum nutrient and observed nutrient ratios, field trials with different crops are conducted to formulate fertilizer recommendations covering the full range of nutrients, including macro, secondary, and micronutrients to achieve the yield goals (Portch and Stauffer, 2005).

8. TOOLS OF SITE SPECIFIC NUTRIENT MANAGEMENT

A). Soil, Plant and Water testing: For precision in farming, for maximizing crop production, maintaining soil health and minimizing fertilizer misapplication, fertilizers recommendations based on soil and plant test is preferable over agro-climatic zone based conventional fertilizer recommendation (Ramamurthy et al, 2009). STCR (soil testing crop response) – developed several fertilizer adjusted equations or STCR equations for

computation of fertilizer dose considering soil nutrient availability and quantity of nutrients required in major crops following target yield concept (ICAR, 2018). ICAR-IARI now developed STFR (soil test fertilizer recommendation) meter kit which is a digital and portable soil testing mini lab. It can analyze 14 soil parameters.

B). Proximal Plant and Soil Sensing: Proximal sensing technique can be utilized for plant and soil sensing for diagnosis of crop nutrient status and subsequently nutrient recommendations. It includes:

- **a)** Leaf colour chart (LCC)
- **b)** Green seeker
- **c)** Chlorophyll meter

a). *Leaf Colour Chart (LCC):* The leaf color chart (LCC) is an easy-to-use and inexpensive diagnostic tool for monitoring the relative greenness of a rice leaf as an indicator of the plant N status. It consists of four to six panels with color ranging from yellowish green to dark green. Farmers applied N fertilizer under situation of leaves becoming more yellowish green than the critical LCC panel of the particular crop and variety. There are two major approaches to manage fertilizer N using leaf colour chart (Witt et al, 2007). In the real-time approach, greenness of rice leaves is monitored at 7–10-dayinterval and a fertilizer N dose is applied whenever the greenness falls below a shade on leaf colour chart corresponding to threshold greenness level identified for a varietal group in a given region. In the fixed time approach, fertilizer N is applied in split doses at critical growth stages of the crop by adjusting the recommended standard N rate up or down as per the threshold leaf greenness on the leaf colour chart.

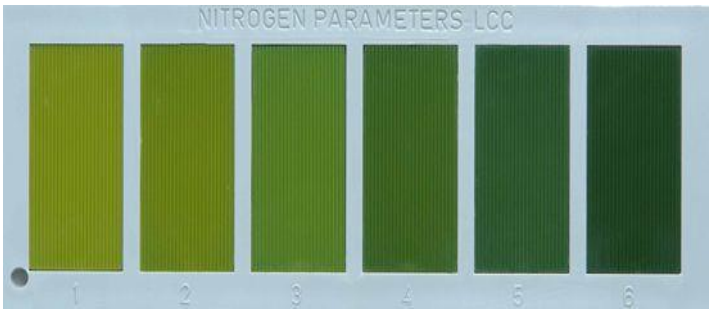

Fig.1 Leaf color chart

b). *Green seeker:* A green seeker handheld crop sensor can detect wavelengths of reflected light from the crop canopy and produce a normalized difference vegetation index value called NDVI that is correlated with leaf chlorophyll. It will take into account both leaf greenness and crop biomass to guide fertilizer N management on site-specific basis. Active light sources are used here in GS for measuring the N status of the crop foliage using NDVI principle and compare each strip with the N rich strip and the rate of N application is calculated and applied accordingly.

Fig. 2 Green seeker

c). *Chlorophyll meter:* The soil plant analysis development (SPAD)/chlorophyll meter is one of the most commonly used diagnostic tools to measure crop nitrogen status. Released in 1984 (Minolta Co. ltd., Japan). The hand-held Minolta Soil Plant Analysis Development (SPAD) 502®, known as SPAD meter is the most used chlorophyll meter for SSNM in South Asia. When, SPAD value is between 29 and 32, indicating that additional fertilizer is necessary. Note: it was observed that sensor based nitrogen management had reduced the dose of fertilizer nitrogen application, increased crop productivity and enhanced nitrogen use efficiency.

Chlorophyll meter

C. Information and communication Technologies (ICTs)

ICTs are utilized by the policy makers, extension workers, farmers etc. for adoption of agro- technologies including crop fertilizer recommendation at present development era of information technology.

It includes:

a) Decision Support System (DSS)

b) Smartphone apps and web services

a) *Decision Support System (DSS):* DSS are interactive computer based frameworks or software system that use information and models for crop yield estimation and fertilizer recommendation in agricultural system. Crop models are computer programs that mimic the growth and development of crops (Oteng-Darko *et al.*, 2013). Agricultural production systems simulator (APSIM) model used for predictions of crop production. InfoSoil model used for soil quality assessment and fertilizer recommendation (Rabbinge *et al.*, 1994) QUEFTS model can be utilized for quantitative assessment of native fertility of tropical soils, crop yield potential. It was first used for maize crop and then its generic versions are used for all type of crops.

Software	Full form	Details	References
MODVEX	Model Development and Validation Expert	Model development and validation system	(Kumar and Chaeturvedi, 2009)
APSIM	Agricultural Production Systems simulator	Modeling framework for a range of crops	(Kumar and Chaeturvedi, 2009)
GWM	General Weed management Model	General weed model in row crop	(Kumar and Chaeturvedi, 2009)

WOFOST	World Food Studies	Wheat and maize, water, and nutrient	(Kumar and Chaeturvedi, 2009)
WAVE	Water and Agrochemicals in the soil, crop and Vadose	Environment Water and agrochemicals	(Kumar and Chaeturvedi, 2009)
GOSSYM and COTONS	Gossypium and cotton	application for cotton	(Murthy *et al*., 2004)
CERES-maize	Crop environment resource synthesis	assessed nitrogen requirements by maize	(Amissah-Arthur and Jagtap, 1995)

b) ***Smartphone apps and Web services:*** Umang mobile app – developed by National informatics Centre (NIC), Ministry of electronics and information technology (MeitY) which provides soil fertility status and fertilizer information. Crop Doctor – tells about the nutrient deficiency and recommendation in several crops. Fertilizer calculator app: used for calculating fertilizer quantity as per available stock in any locality. Soil health card: it was launched on 19th February, 2015 as website as well as mobile app.

CONCLUSION

SSNM is gaining popularity with passage of time obviously due to its in-built advantages over the other approaches. Current blanket fertilizer recommendations are not adequate for achieving higher nutrient use efficiency. With increase in the understanding of SSNM, decision support tools on fertilizer, best management will be developed for different crops and farming situations The use of GPS in Agriculture is limited but it is fair to expect wide spread use of GPS in future. Real time nitrogen management using SPAD, LCC and green seeker significantly enhanced grain yields with improved nitrogen use efficiency in major cereal crops. Nutrient expert and QUEFTS- model can help in improving formulations of site specific and balanced fertilizer management strategies.

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