

Precision Nutrient Management for Sustainable Crop Production

Shreya^{1*}, Lav Bhushan² and Raj Paul Sharma³

¹M.SC. Scholar, ²SMS Soil Science, ³Professor and Head
Department of Soil Science, CSKHPKV Palampur, HP, India-176062

Corresponding Author

Shreya

Email: shreyasood3333@gmail.com



OPEN ACCESS

Keywords

Precision Nutrient Management, SSNM, STCR

How to cite this article:

Shreya., Bhushan, L. and Sharma, R. P. 2026. Precision Nutrient Management for Sustainable Crop Production. *Vigyan Varta* 7 (06): 51-54.

ABSTRACT

The rapid growth of the global population has significantly intensified pressure on food production systems, leading to an excessive reliance on chemical fertilizers. India has now emerged as the second-largest consumer of fertilizers globally, reflecting the intensification of nutrient use to sustain crop yields (Anonymous 2025). While excessive reliance on chemical fertilizers initially boosted yields, it has resulted in severe soil degradation, nutrient imbalances, and environmental contamination. These challenges highlight the urgent need for precision nutrient management (PNM), which utilizes advanced technologies to manage spatial and temporal variability in soil nutrient supply to increase productivity and efficiency in an environmentally responsible manner. PNM is strictly guided by the 4R principles: Right Source, Right Rate, Right Time and Right Place. Various diagnostic tools and decision-support systems (DSS) have been developed to bridge the gap between high-yielding crop requirements and indigenous soil supply. Handheld sensors like the soil plant analysis development (SPAD) meter and green-seeker allow for real-time monitoring of plant vigour and chlorophyll content. Furthermore, the Leaf Color Chart (LCC) provides a cost-effective method for need-based nitrogen application. Analytical approaches such as soil test crop response (STCR) and the omission plot technique establish quantitative basis for maximizing profit and yield. Digital tools like nutrient expert and rice crop manager provide location-specific recommendations that have been shown to increase yields across various agro-

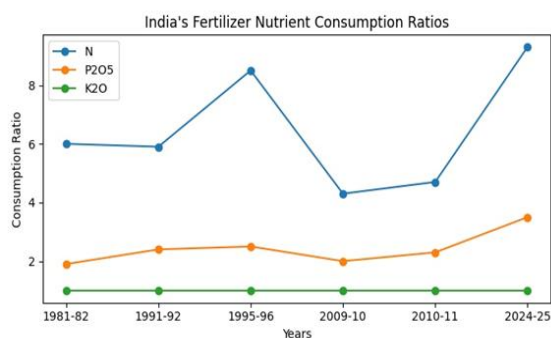
ecological zones.

INTRODUCTION

Precision nutrient management is a precise method of application of nutrients, based on the variability in soil and micro-climatic conditions that occur within the field. The traditional practice is to apply nutrients at one rate throughout the farming area. Such practice could lead to wastage of resources and maximum yields could not be achieved since spatial variability is altogether ignored (Patil, 2009). PNM considers soil variability, crop growth stages, nutrient demand and climatic conditions. It aims to provide the right nutrient source, in the right quantity, at the right time, and at the right place. India has experienced major changes in fertilizer consumption patterns over the years. Nitrogen fertilizers are often applied in excess compared to phosphorus and potassium, resulting in nutrient imbalance. Such practices reduce fertilizer use efficiency and negatively affect soil health. Precision nutrient management helps farmers increase productivity while reducing unnecessary fertilizer expenses.

Changing Fertilizer Consumption Pattern in India

The graph below shows the changing fertilizer nutrient consumption ratios in India. The excessive use of nitrogen compared to phosphorus and potassium indicates nutrient imbalance in agricultural soils.



Major Components of Precision Nutrient Management

1. Site-Specific Nutrient Management (SSNM): Site-Specific Nutrient Management (SSNM) provides a scientific, field-level strategy for dynamic nutrient management. Instead of relying on rigid, regional "blanket" fertilizer recommendations, SSNM targets the unique spatial and temporal variability within individual fields (Rodriguez, 2020).

2. Soil Test Crop Response (STCR): The STCR approach is a site-specific nutrient management strategy that replaces generalized blanket recommendations. It calibrates fertilizer adjustment equations based on specific yield targets and baseline soil fertility to ensure balanced fertilization, economic viability, and environmental sustainability (Murthy *et al.*, 2024).

3. Variable Rate Technology (VRT): Variable Rate Fertilization (VRF/VRT) relies on electronic sensors, accurate Global Positioning System (GPS) receivers, and prescription maps to identify field heterogeneity. This system automatically alters fertilizer application rates "on-the-go" to align with localized soil fertility variations and crop characteristics (Schumann, 2010)

4. Leaf Color Chart (LCC): Developed as an easy-to-use and highly inexpensive diagnostic tool, the LCC monitors leaf greenness against standard color swatches. It helps farmers determine optimal split-application timings to match actual plant nitrogen demands, dramatically improving nitrogen use efficiency (Fayaz *et al.*, 2022).

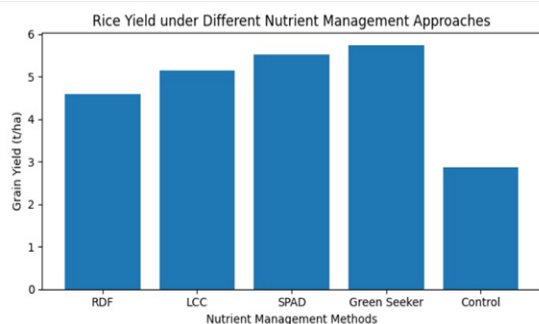
5. SPAD Meter: The Soil Plant Analysis Development (SPAD) chlorophyll meter is a

non-destructive optical tool used to gauge a crop's nitrogen status. It works by calculating the difference in light transmittance at red (650 nm) and infrared (940nm) wavelengths through the leaf blade, providing a highly correlated estimation of plant chlorophyll and nitrogen concentrations (Yuan *et al.*, 2016).

6. Green Seeker: The Green Seeker is an active optical remote sensing device used for site-specific, in-season nitrogen management. By recording the Normalized Difference Vegetation Index (NDVI), the sensor evaluates real-time crop vigor and utilizes standardized optimization algorithms to recommend precise nitrogen top-dressing requirements (Bijay-Singh *et al.*, 2011; Farid *et al.*, 2022).

Effect on Crop Yield

Several research studies have shown that precision nutrient management significantly improves crop yield and nutrient efficiency. The graph below shows the impact of different nitrogen management approaches on rice yield. Green Seeker and SPAD-based management produced higher yields compared to conventional fertilizer practices.



Advantages of Precision Nutrient Management

- Enhances fertilizer use efficiency
- Reduces nutrient losses and environmental pollution
- Improves crop productivity and quality
- Maintains long-term soil fertility

- Increases farmer income and profitability
- Promotes sustainable agriculture

Challenges in Adoption

Despite its advantages, the adoption of precision nutrient management in India faces several challenges such as high initial cost, lack of technical knowledge, limited access to advanced tools, and inadequate awareness among farmers. Training and government support are essential to increase its adoption at the field level.

Future Prospects

The future of precision agriculture is closely linked with artificial intelligence, nano-sensors, robotics, drones and satellite-based monitoring systems. These technologies will help farmers monitor soil and crop health in real time and make better nutrient management decisions. Smart fertilizers and digital decision-support tools are expected to revolutionize sustainable farming practices.

CONCLUSION

Precision Nutrient Management is a revolutionary approach for sustainable crop production. It not only improves crop yield and fertilizer efficiency but also protects soil health and the environment. By integrating modern technologies with scientific nutrient management practices, farmers can achieve higher productivity better profitability and long-term agricultural sustainability.

REFERENCES:

- Anonymous. 2025. Amrit Kaal: Empowering India's farmers through Strategic Fertilizer Policy. *Press Information Bureau (PIB)* Government of India.
- Bijay-Singh, Sharma RK, Jaspreet-Kaur, Jat ML, Martin KL, Yadvinder-Singh, Varinderpal-Singh, Chandna P,

- Choudhary O P, Gupta R K, Thind HS, Jagmohan-Singh, Uppal HS, Khurana HS, Ajay-Kumar, Uppal RK, Vashistha M, Raun WR, and Gupta R. (2011). Assessment of the nitrogen management strategy using an optical sensor for irrigated wheat. *Agronomy for Sustainable Development*, 31, 589-603.
- Farid HU, Khan ZM, Anjum MN, Shakoor A, and Qureshi HS. (2022). Precision nitrogen management for cotton using (Green Seeker) handheld crop sensors. *Environmental Sciences Proceedings*, 23(1), 12.
- Fayaz S, Kanth RH, Bhat TA, Valipour M, Iqbal R, Munir A, Nazir A, Mir M S, Ahanger S A, Al-Ashkar I, and Sabagh AE. (2022). Leaf Color Chart (LCC)-Based Precision Nitrogen Management for Assessing Phenology, Agrometeorological Indices and Sustainable Yield of Hybrid Maize Genotypes under Temperate Climate. *Agronomy*, 12(12), 2981.
- Fertilizer Association of India (2024–2025). *Fertilizer Statistics and Nutrient Consumption Report*.
- Murthy RK, Nagaraju B, Govinda K, Uday Kumar SN, Basavaraja PK, Saeedulla HM, Gangamrutha, GV Srivastava S and Dey P. (2024). Soil test crop response nutrient prescription equations for improving soil health and yield sustainability—a long-term study under Alfisols of southern India. *Frontiers in Plant Science*, 15
- Patil V. C. (2009). Precision nutrient management: A review. *Indian Journal of Agronomy*, 54(2), 113–119.
- Rodriguez D.G.P. (2020). An assessment of the site-specific nutrient management (SSNM) strategy for irrigated rice in Asia. *Agriculture*, 10(11), 559
- Schumann, A. W. (2010). Precise placement and variable rate fertilizer application technologies for horticultural crops. *Hort Technology*, 20(1), 34-40.
- Yuan Z, Cao Q, Zhang K, Ata-Ul-Karim ST, Tian Y, Zhu Y, Cao W, and Liu X. (2016). Optimal leaf positions for SPAD meter measurement in rice. *Frontiers in Plant Science*, 7.