AgriCos e-Newsletter
ISSN: 2582-7049
Volume: 02 Issue: 09 September 2021 Article No: 12

Site-Specific Nutrient Management: A Need-Based Approach to Sustainable Agriculture

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SUMMARY

With the onset of green revolution, farmers became more oriented towards high use of fertilizer in order to improve the yield of crops. Later in time, this resulted in wastage of input fertilizer, also the indigenous nutrient supply power of the soil. Site-Specific Nutrient Management (SSNM), a need-based feeding approach, serves as a modern practice which deals with the improvement of nutrient use efficiency by proper use of its soil inherent nutrient supply. As it is based on the spatial variability and need of the crop, the cost input gets reduced, giving profit to the system. This approach becomes highly efficient due to the integration of its 4R principle with different diagnostic tools viz., LCC, SPAD, Optical sensors and modern technology viz., GIS, GPS, remote sensing, soil survey, decision support system. Thus, not only improving the present condition of the soil but also restoring the soil quality for future needs leading to sustainability.

INTRODUCTION

Today in Agriculture, fertilizer use or nutrient management plays an important role in achieving and maintaining sustainability in food grain production. This resulted in higher fertilizer consumption demand in India, over the last few decades. India ranked 2nd in the world, in terms of fertilizer consumption, next to China. Most of the fertilizers in India are used in rice crop followed by wheat, pulses and oilseeds, but with low response in yield potential. The important reasons for low and declining crop responses to fertilizer nutrients include continuous nutrient mining from the soil due to imbalanced nutrient use leading to serious soil degradation, qualitatively (Das *et al.,* 2014). Thus, leading to tremendous loss of fertilizers and low Fertilizer Use Efficiency (FUE) which gave rise to interest in precision nutrient management tools in Agriculture. At this juncture Site-specific nutrient management (SSNM) is based on crop nutrient demand & variability in indigenous nutrient supplying capacity of the soil reserves as an ideal tool (Bana *et al.,* 2020).

Site-specific nutrient management (SSNM)

Site-Specific Nutrient Management was developed to calculate field specific requirements of fertilizer Nitrogen (N), Phosphorus (P) and Potassium (K) for cereals crops based on scientific principles. Initially, though it was developed for rice but later it was also implemented in other cereal crops viz., maize and wheat. SSNM is a component of precision agriculture, which provides guidelines that allows farmers to determine when and how much nutrients should be applied to their crop fields under actual growing conditions in a specific season and location. It is a repacking of management concepts that have been promoted for many years with regard to 4 R's stewardship principle i.e., right product, right time, right amount and right place. The SSNM approach not only specifically aim to either reduce or increase fertilizer use. Instead, it aims to apply nutrients at optimal rates and times to achieve high yield and high efficiency of nutrient use by the crop, leading to high cash value of the harvest per unit of fertilizer invested.

SSNM Can be thereby categorized into two groups-

- **Prescriptive Nutrient management:** It is based on the information generated before the planting of a crop. The amount and time of application are analysed before sowing relying on the nutrient supply of the soil, expected crop nutrient requirement for assumed target yield, expected nutrient use efficiency of the used fertilizer.
- **Corrective Nutrient management:** Relies on information generated after the planting of a crop or in the standing crop using different diagnostic tools viz., SPAD, LCC.

Nutrient Use Efficiency (NUE) with SSNM practice

The SSNM ensures NUE through the management of the essential nutrients and providing better yield.

- **Nitrogen management:** It can be done either through the use of fixed/ adjustable-dose N management or use of real-time N management. This can be achieved with the use of tools like LCC, SPAD.

Soil plant analytical device (SPAD) meter/ Chlorophyll meter

- SPAD meter was originally developed in Japan for nitrogen management in rice which provides need based variable rate of nitrogen (N) application for cereal crops. Most widely used device is the hand-held Minolta and SPAD-502. It saved 12.5–25% on the existing fertilizer N recommendation.

Leaf Colour Chart (LCC): (real-time/ crop-based)

- LCC is another simple and inexpensive tool first developed in Japan to increase the N use efficiency in rice and other cereal crops. It has been calibrated with the chlorophyll meter. The LCC shade 4 on the six-panel IRRI-LCC has been found to be the threshold score for transplanted coarse grain rice varieties prevalent in the Indo-Gangetic plains.

Green seeker: (optical sensor)

- Chlorophyll meter and LCC do not take into account the photosynthetic rates or biomass production and the expected yields for working out fertilizer Nitrogen (N) requirements. While, Green seeker optical sensors measure the spectral response from plant canopies to detect the N stress. It is also a hand-held instrument which measures the Normalized Difference Vegetative Index (NDVI) at various critical growth stages, generates data for crop conditions. These NDVI data from a standard plot, which has been sufficiently fertilized with N, can be compared with a reference plot for which the N requirement is to be determined.
- **Phosphorus & potassium management: a)** Use of nitrogen omission plots to determine the P & K fertilizers requirement of crops, **b)** Knowledge of relationship between P and K budget, residual effect of P and K fertilizers and changes in soil supply over time, **c)** A schedule for optimum time of K application depending on soil K buffering characteristics and an understanding of the relationship between K nutrition.
- **Management of other nutrients: a)** Local randomization for application of Zn, S and micronutrients are followed, **b)** Integration with other crop management (ICM) practices such as use of quality seeds, optimum plant density, integrated pest management and water management.

Software tools/ decision support system for SSNM

- **Nutrient Expert® and Crop Manager** are computer-based, examples of decision-support systems developed for SSNM in cereal production systems, which provides the small-scale farmers with crop and nutrient management advice customized to their farming conditions and needs. Software for Nutrient Expert: (http://software.ipni.net/article/nutrientexpert) Software for crop manager: (http://cropmanager.irri.org/home)

Modern technologies for SSNM

Global positioning system (GPS): GPS system are used on planting equipment for collecting geo-referenced planting data, starter fertilizer application and other inputs with proper controllers, variable rate application of inputs can be added to the management plan, grid sampling through GPS can provide more accuracy in soil test data, crop scouting can enhance field records, also on-the-go yield monitors could quickly track variability in the field. Each of these steps can be added over time, increasing the value of initial investments.

Real-time kinematic system (RTK): The most precise system currently used in crop production applications is the Real-Time Kinematic (RTK) system. The high-accuracy RTK guidance system helps to avoid costly skips and overlaps, saving on input costs for seed, fertilizer and pesticides.

Geographic information system (GIS): GIS consists of data and software designed for spatial analysis which includes soil survey data, soil test information, pest infestations, yield data, remote sensing imagery and other type of observations and records. To illustrate their spatial variability within the field and become additional layers in the database, response to inputs or interactions affecting yield can be predicted. Subsequent sample, nutrient application, and crop removal analysed as additional layers in the GIS database are used to calculate fertilizer recommendations, FUE and selected environmental parameters.

Soil survey: Variability in soil characteristics can be assessed through soil surveys. The efficiency of the data is based on keen survey. The web survey provides over 2300 geographically referenced digital soil surveys for free download from the USDA Natural Resource Conservation Service (NRC's) website. This information helps to relate soil characteristics to site specific variability observed in crop yield.

Remote sensing: Remote sensing is becoming a useful tool for precision farming using scanners on aircraft or satellites to monitor changes in wavelength of lights from field and growing vegetation. The relationship NDVI which is remote sensed as well as soil and crop property at selected ground, gives the true data by discriminating the healthy productive crops from unproductive crops. NDVI is used to delineate low, moderate and high vigour zones by using airborne, digital, multispectral imagery for delineation of sub-block management zones in vineyards.

Recommendation

The SSNM recommendations could be evolved on the basis of solely plant analysis or soil analysis or soil cum plant analysis. The 3 basic steps of SSNM approach are:
Step 1. Establishment of a grain yield target. **Step 2.** Effective use of existing nutrients. **Step 3.** Application of fertilizer to fill the deficit between crop needs and indigenous supply.

Benefits of SSNM

- SSNM increases and maintains yield by balancing the supply and demand of nutrients, resulting in more balanced plant nutrition. By improving the nutrient Use Efficiency (NUE), it provides **higher returns on investments** in fertilizer by lowering losses.
- Agriculture contributes 70-90% of nitrous oxide (N_2O) emissions, mostly from N fertilizer. SSNM **reduces N_2O emissions** by reducing total N application and/or timing applications to crop needs thus avoiding N losses.
- The more balanced NPK nutrition that comes with SSNM may lead to **improved resistance to plant diseases**. SSNM is functionally and biologically more diverse than the farmer's fertilizer practices (FFP).

Problems in Adoption of SSNM

- Conduction of on farm trials and soil tests forms the barrier for adoption of SSNM, the event of call support systems and farmer friendly tools and technique can be helpful in such scenario. Farmers tend to consider the net positive returns with high value crops, where yield increase can increase the profits or when the costs of fertilizer are high.
- Lack of continuously monitoring of the health and availability of the natural resources, lack of a long standing and uniform agricultural policy. Lack of local expertise and success stories of SSNM. Climatic aberrations and operational constraints.

CONCLUSIONS

Fertilizer recommendations are not sufficiently related to the site-specific yield potential and the soil fertility status of the farmer's field. As a result of which there are tremendous loses of fertilizers and degradation of soil fertility. Gill et al., reported that maximum N, P and K accumulation by crop was registered in SSNM followed by Improved State Recommendation (ISR) and it was lowest in Farmer's Fertilizer Practices (FFP). Khurana et al., also observed significant increase in NUE through the SSNM treatment compared to FFP. The fertilizer application based on more generic approaches such as simulation modelling, taking into account nutrient requirements of crop, indigenous nutrient supply, and recovery efficiency of the applied nutrients, can bring a drastic change in the traditional pattern of nutrient management by farmers. In this context, Site-Specific Nutrient Management (SSNM) can serve as a helpful tool in not only increasing the NUE but also in approaching towards Sustainable Agriculture in the near future.

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