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SITE SPECIFIC NUTRIENT MANAGEMENT FOR ENHANCED NUTRIENT-USE EFFICIENCY

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Introduction

World-wide use of various fertilizers has made a tremendous contribution in enhancing food productions. It has been estimated that nutrient inputs are responsible for between 30 and 50 per cent of crop yield. However, low nutrient-use efficiency and associated environmental pollution and global warming problems have raised serious concerns about the existing nutrient management practices. The recovery efficiency of fertilizer nutrients is about 20-40, 15-20 and 40 -50 % for N, P and K, respectively while for secondary and micronutrients it is substantially low ranging 5-12%. The important reasons for low and declining crop responses to fertilizer nutrients include continuous nutrient mining from the soil due to imbalanced nutrient use (7:2.8:1 NPK) leading to depletion of some of the major, secondary and micro nutrients like N, K, S, Zn, Mn, Fe, B etc., decreasing use of organic nutrient sources such as FYM, compost and integration of green manures / grain legumes in the cropping systems and mismanagement of irrigation systems leading to serious soil degradation qualitatively (Dobberman *et al.*, 2002).

Based on past 50-years intensive research, nutrient management recommendations have been developed for almost all cultivated crops. The recommendations developed tell about the amount different nutrients required on hectare basis and their time of application. Such blanket recommendations which largely did not take into account the variability in the inherent soil fertility and other edaphic characteristics resulted into over application of nutrients in some pockets and under application in other. This resulted in the wastage of fertilizers and low nutrient- use efficiency. Research conducted in many Asian countries, including Northwest India, has depicted the limitations of the conventional approach of fixed-rate, fixed-time (blanket) fertiliser recommendations. However, recognising the flaws of the blanket recommendations of nutrients, the concept of site-specific nutrient management of nutrients was developed. The original concept of site specific nutrient management (SSNM) to manage among-farm nutrient variability was developed in Asia for rice (Jata *et al.*, 2011).

Site Specific Nutrient Management

Many of nutrients required by rice plants come from soil. But the supply of nutrients is typically insufficient to meet the nutrient requirements for high rice yields. The use of fertilizers consequently essential to fill the gap between the crop needs for nutrients and the supply of nutrient from soil and available organic inputs. SSNM helps in improving nutrient use-efficiency as it provides an approach for feeding crops like rice, maize, wheat etc. with nutrients as and when needed. The major benefit for farmers from improved nutrients management strategy is an increase in the profitability. SSNM eliminates wastage of fertilizer by preventing excessive rates of fertilizer and by avoiding fertilizer application when the crop does not require nutrient inputs. It also ensures that N, P, K are applied in the ratio required by the intended crop.

Principle of SSNM

Site Specific Nutrient Management (SSNM) is an approach to feeding crops with nutrients as and when needed. The application and management of nutrients are dynamically adjusted to crop needs of the location and season. The SSNM approach aims to increase farmers profit through –

(i) Increased yield of crops per unit of applied fertilizer.
(ii) Higher rice yields, and
(iii) Reduced disease and insect damage.

Important features of SSNM

1. Optimal use of existing indigenous nutrient source such as crop residues and measures.
2. Application of Nitrogen (N), Phosphorous (P) and Potassium (K) fertilizer is adjusted to the location and season specific need of the crop.
(a) Use of the leaf colour chart ensures that nitrogen is applied at the right time and in the amount needed by the crop which prevents wastage of fertilizer.
(b) Use of nitrogen omission plots to determine the P & K fertilizer required to meet the crop needs. This ensures that phosphorous and potassium is applied in the ratio required by the rice crop.
3. Local randomization for application of zinc, sulphur and micronutrients are followed.
4. Selection of most economic combination of available fertilizer sources.
5. 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.

SSNM Approaches

The relatively new approach of nutrient recommendation is mainly based on indigenous nutrient supply of the soil and nutrient demand of the crop for achieving targeted yield. The SSNM recommendations could be evolved on the basis of solely plant analysis or soil cum plant analysis (Khurana *et al*., 2008).

Plant analysis based SSNM

It considers the nutrient status of the crop is the best indicator of soil nutrient supplies as well as nutrient demand of the crops. Thus the approach is built around plant analysis. Initially SSNM was tried for lowland rice, but subsequently it proved advantageous to several contemporary approaches of fertilizer recommendation in rice, wheatand other rice based production system prevalent in Asian countries proposed five key steps (given below) for developing field specific fertilizer NPK recommendations for rice, through the basic principles remain the same for other crops as well:

Selection of the yield goal: A yield goal exceeding 70-80 % of the variety specific potential yield (Y max.) has to be chosen. The Y max. is defined as the maximum possible grain yield limited only by climatic conditions of the site, where there are no other factors limiting the crops growth . The logic behind selection of the yield goal to the extent of 70-80% of the $Y_{max}$is that the internal nutrient use efficiencies decrease at very high yield levels near Y_{max}.

Crop growth models (eg. DSSAT) can be used to workout Y max. of crop variety under a particular climatic conditions.

Assessment of crop nutrient requirement: The nutrient uptake requirements of a crop depend on both on yield goal and Y_{max} in SSNM nutrient requirements are estimated with the help of QUEFTS (quantitative evaluation of fertility of tropical soils) models. Nutrient requirements for a particular yield goal of a crop variety may be smaller in a high yielding season in a low yielding one.

Estimation of indigenous nutrient supplies: Indigenous nutrient supply (INS) is defined as the total amount of a particular nutrient that is available to the crop from the soil during the cropping cycle, when other nutrients are non-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 of approximate size embedded in the farmers' field, wherein all other nutrient except the one (N, P or K) in question are applied in sufficient amounts.

Computation of fertilizer nutrient rates: Field specific fertilizer N,P or K recommendations are calculated on the basis of above steps 1 to 3 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 to 60% for N, 20-30% for P and 40-50% for K in rice under normal growing conditions, when the nutrients are applied as water soluble fertilizer sources.

Dynamic adjustment of N rates: Whereas fertilizers P and K , as computed above are applied basally at the time of sowing / planting , the N rates and application schedules can be further adjusted according to crop demand using chlorophyll meter (popularly known as SPAD) or leaf colour chart (LCC). Recent on farm studies in India and elsewhere revealed a significant advantage of SPAD/ LCC based N management schedules in rice in rice and wheat in terms of yield grain, N use efficiency and economic returns over the conventionally recommended N application involving 2 or 3 splits during crop growth irrespective of N supplying capacity of the soils.

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 recovery-efficiency (RE) of applied nutrients are considered for developing fertilizer use schedule to achieve maximum economic yield of a crop variety. In order to ascertain desired crop growth, not limited by apparent or hidden huger of nutrients, soil is analyzed for all macro and micronutrients well before sowing/ planting. Total nutrient requirement for the targeted yield and RE are estimated with help of documented information available for similar crop growing environments. Field specific fertilizer rates are then suggested to meet the nutrient demand of the crop (variety) without depleting soil reserves. Such recommendation soften include 4 to 7 plant nutrients depending on the existence of multi-nutrient deficiency or nutrient inadequacy for high yield targets. Recent studies with intensive cropping system indicated that fertilizer recommendations with this approach offer greater economic gains compared with NPK fertilizer schedules conventionally prescribed by soil testing laboratories.

Decision support systems

Nutrient Expert® (http://software.ipni.net/article/nutrient-expert)

Nutrient Expert® is an easy-to-use, interactive, and computer-based decision support tool that can rapidly provide nutrient recommendations for an individual farmer field in the presence or absence of soil testing data. Nutrient Expert® is a nutrient decision support software that uses the principles of site-specific nutrient management (SSNM) and enables farm advisors to develop fertilizer recommendations tailored to a specific field or growing environment. NE takes into account the most important factors affecting nutrient management recommendations and uses a systematic approach of capturing information, which is important for developing a location-specific recommendation. Yet, NE does not require lot of data or very detailed information, as is the case with many sophisticated nutrient decision support tools, which could overwhelm the user. As a computer-based decision support tool, NE combines all the steps and guidelines in SSNM into a simple software tailored for farm advisors, especially the not-so-technical users such as extension agents and industry agronomists in developing countries. In such countries, many farm advisors from the both public and private sector do not have the data and facilities needed to run sophisticated models. Nutrient Expert® allows users to draw required information from their own experience, farmers' knowledge of the local region and farmers' practices. NE can use experimental data but it can also estimate the required SSNM parameters using existing site information. The algorithm for calculating fertilizer requirements in NE is determined from a set of on-farm trial data using SSNM guidelines. The parameters needed in SSNM are usually measured in nutrient omission trials conducted in farmers' fields, which require at least one crop season. With NE, parameters can be estimated using proxy information, which allows farm advisors to develop fertilizer guidelines for a location without data from field trials.

Decision Rules to Estimate Site-specific Nutrient Management Parameters

Nutrient Expert® estimates the attainable yield and yield response to fertilizer from site information using decision rules developed from on-farm trials. Specifically, NE uses characteristics of the growing environment: water availability (irrigated, fully rainfed and rainfed with supplemental irrigation) and any occurrence of flooding or drought; soil fertility indicators: soil texture, soil 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 farmer's cropping pattern; crop residue management and fertilizer inputs for the previous crop; and farmers' current yields. Data for specific crops and geographies are required in developing the decision rules for NE. The datasets must represent diverse conditions in the growing environment characterized by variations in amount and distribution of rainfall, crop cultivars and growth durations, soils and cropping systems.

Current Versions of Nutrient Expert®: Nutrient Expert® has been developed for specific crops and geographies. Nutrient Expert® for Hybrid Maize (NEHM) for favorable tropical environments (e.g., Southeast Asia) was developed in late 2009 and underwent field evaluation in Indonesia and the Philippines. Using NEHM as a model, the NE concept has been adapted to other crops and geographic regions or countries. In 2011, beta versions of NE for maize were developed for South Asia, China, Kenya and Zimbabwe. Likewise, beta versions of NE for wheat were developed for South Asia as well as China. In 2013, fieldvalidated versions of NE maize and NE wheat have been released for public use in South Asia and China.

Conclusion

Site specific nutrient management (SSNM) is a new concept. This concept is fundamental to precision nutrient applications in different crops. The SSNM provides an approach for need based feeding of crops with nutrients while recognizing the inherent spatial variability. This makes the efficient utilization of nutrients by crop plants and avoids the wastages of fertilizers. The environmental foot-prints of chemical fertilizers are also reduced. Crop yields increase by over 15 %, while amount of nutrients applied mostly decrease. Farm profitability and nutrient use efficiency increase convincingly by using this novel concept. For efficient and effective SSNM, use of soil and plant nutrient status sensing devices, remote sensing, GIS, decision support systems, simulation models, and machines for variable application of nutrients are important.

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