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7. Site Specific Nutrient Management as Climate Smart Practice

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7.1 Introduction:

Site Specific Nutrient Management (SSNM) is a strategy to fertiliser management that strives to enhance crop production while reducing the negative impacts on the environment. Based on the unique requirements of the crops and the soil's properties, it entails the use of a mix of soil testing, crop monitoring, and nutrient management techniques to identify the right type, rate, timing, and placement of fertilizers. By ensuring that nutrients are delivered to crops only when they are required and in the appropriate proportions, this strategy lowers the possibility of nutrient losses due to leaching, volatilization, and runoff. By lowering greenhouse gas emissions and increasing the capacity of agricultural soils to store carbon, SSNM can help to mitigate the effects of climate change on agriculture. Farmers can minimize N2O emissions and the amount of fertiliser lost to the environment by applying fertilizers precisely and strategically depending on the unique requirements of the crops and soil conditions. The soil's organic matter content is improved by SSNM. This method offers a foundation for rice nutrient best management techniques and allows rice farmers to customize nutrient management to their own field conditions. It is an advanced knowledge base that emphasizes double and triple monocultures of rice (FAO, 2011). A Mekong Delta study revealed that employing SSNM increased grain yield by roughly 0.5 tonnes per hectare (Hach and Tan, 2007). Nitrous oxide (N2O) emissions from agriculture account for about 70–90% of total emissions (cgiar.org). It is a dynamical system that aids in optimizing crop production by matching the natural spatial and temporal requirements of plants through the use of the proper amount, source, rate of application, timing, and method. Prescriptive and corrective SSNM are two different types. Nutrient addition in prescriptive type is based on soil testing, crop, and climate considerations. Curative type refers to field management, and some examples include nutrient experts, leaf color charts, and SPAD metres for measuring chlorophyll. By delivering nutrients at the best rate and time, SSNM achieves excellent nutrient use efficiency without intentionally aiming to decrease or increase fertiliser consumption. Effective N management can lessen other environmental problems such eutrophication, acidification, air quality, and human health while assisting in adaptation and mitigation. By lowering total N application and/or timing applications to crop demands, SSNM minimizes N2O emissions and prevents N losses through volatilization, leaching, and runoff.

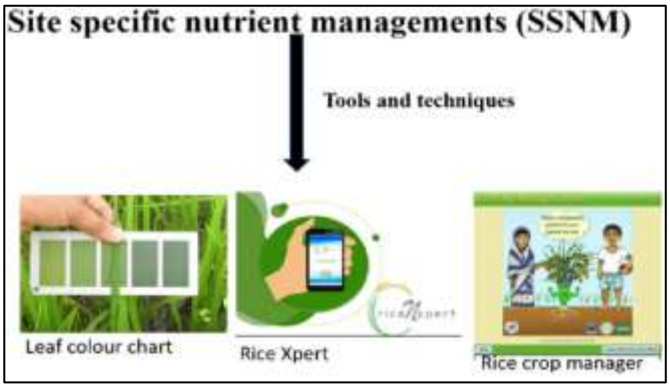

Figure 7.1: Some Prominent SSNM Tools for CRA

SSNM helps in improving NUE as it provides an approach for feeding crops like rice, maize, wheat, etc. with nutrients as and when needed. For efficient and effective SSNM, use of soil and plant nutrient status sensing devices, remote sensing, GIS, decision support systems, stimulation models for variable application of nutrients play an important role. It aims to:

A. Provide a locally-adapted nutrient best management practice tailored to field and season specific needs for a crop
B. Increase yield
C. Increase fertilizer use efficiency
D. Improve profitability
E. Improve marketable crop quality
F. Improve environment stewardship

Figure 7.2: Site-Specific Nutrient Management.

7.2 Important Features of SSNM:

Use of SSNM helps in optimizing the use of existing indigenous nutrient sources like crop residue, organic matter, etc. Application of nutrients (like N, P and K) is tailored according to site and season specific demands of the crop. Use of tools such as leaf color chart ensures that nitrogen supply is at right time and in amount required by crop which helps in reducing fertilizer waste. For determining the dose of phosphorus and potassium, nitrogen omission plot method is used. Hence ensuring that supply of P and K is in ratio required for maintain crop growth especially in rice. For zinc, sulphur and micronutrient application local randomization methods are followed. Economic combinations of available fertilizer sources. Integration of other crop management practices like use quality seeds, maintain optimum plant density, integrated pest management and good water management.

7.3 Plant Analysis Based SSNM:

It is considered that 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 of plant based SSNM is built around it. Five key steps for developing field-specific fertilizer NPK recommendations have been developed:

A. **Selection of The Yield Goal:** A yield goal exceeding 70-80 % of the variety-specific potential yield (Ymax) has to be chosen. Ymax is defined as the maximum possible economical yield limited only by climatic conditions of the site, where there are no other factors limiting crop growth. The logic behind selection of the yield goal to this level of potential yield is because the nutrient use efficiency at a very high level near Ymax decreases.
B. **Assessment of Crop Nutrient Requirement:** The nutrient uptake requirements of a crop depend on the yield goal and its potential yield. In SSNM, nutrient requirements are estimated with the help of quantitative evaluation of fertility of tropical soils (OUEFTS) model. Nutrient requirements for a particular yield goal of a crop variety may be smaller in a high yielding season than in a low yielding one.
C. **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 no-limiting. The INS is derived from soil, incorporated crop residues, irrigation water and BNF.
D. **Computation of Fertilizer Nutrient Rates:** Field-specific fertilizer N, P & K recommendations are calculated on the basis of of above steps (1-3) 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 40-60 % for N, 20-30 % for P, 40-50 % for K in rice under normal growing conditions.
E. **Dynamic Adjustment of N Rates:** Whereas, 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 Color 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 grain, N use efficiency and economic returns over the conventionally recommended N application involving 2-3 splits during crop growth. SPAD based N application resulted in a saving of 55 kg N/ha as compared to Soil Test Crop Response (STCR) based N application.

7.3.1 Soil-Cum-Plant Based SSNM:

In this case, nutrient availability in the soil, plant nutrient demands for a higher target yield (not less than 80 % of potential yield), and recovery efficiency of applied nutrients are considered for developing fertilizer use schedule to achieve maximum economic yield of a crop variety. To assure desired crop growth, not limited by hidden or apparent hunger 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 the help of documented information available for similar crop growing environments.

7.3.2 Site Specific Nutrient Management for Precision Agriculture:

SSNM is a component of site-specific crop management or precision agriculture." Precision agriculture can be defined as the application of principles and technologies to manage spatial and temporal variability associated with all aspects of agricultural production for the purpose of improving crop performance and environmental quality" (Pierce and Nowak, 1999).

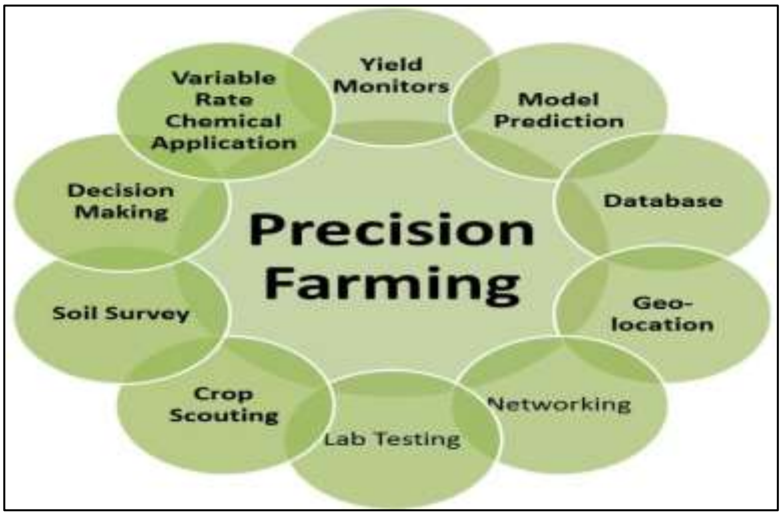

Figure 7.3: Precision Farming

A. Components of Precision Farming:

- Remote sensing
- Geographic information system (GIS)
- Differential global positioning system (DGPS)
- Variable rate applicator

Nutrient management in precision agriculture is governed by 4 R's: Right product, right time, right place and right time. Precision management is important for nutrient application because:

- Nutrient variability within a filed can be very high, affecting optimum fertilizer rates
- Yield potential and grain quality can also vary greatly within the same field, affecting fertilizer requirements
- Increasing fertilizer use efficiency will become more important with increasing fertilizer costs and environmental concerns.

For this purpose, various technology tools like: GPS, GIS, remote sensing, variable rate technology, laser, LCC, green seeker, chlorophyll meter or soil plant analysis development meter, etc. are being used. Computer or mobile phone-based tools are being increasingly used to facilitate improved nutrient management practices in farmers' fields, especially in geographies where blanket fertilizer recommendations prevail. Nutrient Expert® and Crop Manager are examples of decision-support systems developed for SSNM in cereal production systems. Nutrient Expert® is an interactive, computer-based decision-support tool that enables small holder farmers to rapidly implement SSNM in their individual fields with or without soil test data. While Crop Manager is a computer and mobile based application that provides small-scale rice, rice-wheat, maize farmers with site and season-specific recommendations for fertilizer application.

B. Problems in Adoption of SSNM:

- Fragmented land holding
- Lack of continuously monitoring the health and availability of the natural resources.
- Climatic aberrations
- Operational constraints
- Absence of a long standing and uniform agricultural policy
- Lack of success stories
- Lack of local technique expertise
- Land ownership, infrastructure and institutional constraints

C. Probable Strategies for Adopting SSNM:

- Farmer's co-operatives
- Pilot projects
- Agricultural input suppliers, extension advisors and consultant play important role in the spread of the technology
- Combined effort of Researchers and Government
- Public agencies should consider supplying free data such as remotely sensed imagery to the universities and research institutes involved in precision farming research.

D. Conclusion:

SSNM is gaining popularity with the passage of time obviously due to its in-built advantages over other contemporary approaches. With an increase in understanding of SSNM, decision support tools on fertilizer, best management practices will be developed for different crops and farming situation.

7.4 Importance of SSNM:

In order to meet all objectives of sustainable agriculture (increased food and fibre, profitability, efficiency of input use and an appropriate concern for the environment), a balance of adequate levels of nutrients is the key component.

Over the past four decades' crop management in India has been driven by increasing use of external inputs. Food grain production were more than doubled from about 98 million tonnes (MT) during 1969-2007 to a record 212 MT in 2001-2002, while fertilizer nutrient use increased by nearly 12 times from 1.95 MT to more than 23 MT in 2007-08 (Rao, 2009) [5].

Notwithstanding these impressive developments, food grain demand is estimated to increase about 300 MT yr-1 by 2025 for which country would require 45 MT of nutrients (ICAR, 2008) [2]. With almost no opportunity to increase the area under cultivation over 142 million hectares, much of the desired increase in food grain production has to be attained through yield enhancement in per unit area, in particular that of major staple food crops like rice, wheat and maize, which incidentally responded considerably to the introduction of green revolution technologies to contributing to more than 80% of total food grain production (Johnston et al. 2009).

Nutrient differences which exist within fields, and making adjustments in nutrient application to match these location or soil differences by using some form of field diagnostic, such as intensive soil sampling, soil sensing, aerial imagery, yield mapping etc. is known as Site specific nutrient management (SSNM).

Site-specific management allows for fine-tuning crop management systems along with 4R Nutrient Stewardship the right source, rate, time and place of nutrient use.

7.5 Elements of SSNM:

Site-specific management technology relies on the interaction of three broad and fundamental elements to be successful in its implementation. They are categorized in terms of information, technology and management.

A. Information:

In field variability, spatially or temporally, soil related properties, crop characteristics, weed and insect pest population and harvest data are important databases that need to be developed to realize the potential of site-specific management technology. Out of these, crop yield monitoring is the most mature component and logical starting point. Several years of yield data may be required to make a good decision.

Establishment of soil related characteristics within field, through regular soil sampling, is another database that is extremely important. Decision therefore, has to be made on what property to sample, how to sample and how often to sample so that interpretation from database can be made with greater confidence.

B. Technology:

The recent development in microprocessor and other electronic technologies for monitoring yields and sensing soil related variables are new tools available to make site specific farming a success. geographical positioning system (GPS) can be used to identify the locations where the data are taken. Some GPS users demand accuracy in identifying field location and differential global positioning systems (DGPS) is one of the improved GPS system that reduce position errors. Remote sensing technique can also be utilized to detect soil related variables, pest incidence and water stress.

The basic idea of site specific farming is not only to measure field variability, but also to be able to apply inputs at varying rates almost instantaneously, "real time", according to the needs. Variable rate application machinery is a type of field implements that could be used to handle field application of inputs such as seed, fertilizer and pesticides at the desired location in the field, at the right amount, at the right time and for the right reasons. The application of variable rate technology (VRT) can be accomplished either as a map based VRA or a sensor based VRA. However, different types of sensors are now available (or under development) that can monitor crop yield, soil properties, and crop condition that can be used to controlled field operations.

C. Management:

Site specific farming makes farm planning both easier and more complex. The ability to combine information generated and the existing technology into a comprehensive and operational system is the third key area in the precision farming.

7.6 Basic Steps in SSNM:

Assessment of soil and crop variability, managing the variability and its evaluation are three basic steps in site specific nutrient management. The available technologies enable us in understanding the variability and by giving site specific agronomic recommendations we can manage the variability that make precision farming viable and final evaluation must be an integral part of any precision farming system.

A. Assessing Variability:

Assessing the variability is the critical first steps in precision farming. Quantifying the variability of the factors and processes and determining when and where different combinations are responsible for the spatial and temporal variation in crop yield is the challenge for the precision farming. we need both the space and time statistics to apply the precision farming techniques.

B. Managing Variability:

Once variation is adequately assessed, farmers must match agronomic inputs to know conditions employing management recommendations. Those are site specific and accurate use applications control equipment.

The potential for improved precision in soil fertility management combined with increased precision in application control make precise soil fertility management as attractive, but largely unproven alternative to uniform field management.

C. Evaluation:

There are three important issues regarding precision farming evaluation: economics, environment and technology transfer. The most important fact regarding the analysis of profitability of precision farming is that the value comes from the application of the data and not from the use of the technology. Potential improvements in environmental quality are often cited as a reason for using precision farming.

SSNM has successfully been tried in India using different approaches and demonstrated a potential not only to increase crop yields and farmer profits but also has shown increasing evidence of environmental friendliness owing to its balances and crop-need nutrient application (Satyanarayana et al., 2011).

7.7 Dissemination Tools for SSNM:

The widespread dissemination of improved nutrient management practices requires transforming the principles of SSNM into locally adapted tools that enable extension workers, crop advisors, and farmers to rapidly adopt and implement best management practices for specific fields and growing conditions. Computer-based decision support tools are the options to address this novel cause. IPNI South Asia program in collaboration with its International staff in South East Asia, International Rice Research Institute (IRRI) and the fertiliser industry is working to consolidate the complex and knowledge intensive SSNM information into simple decision support tools enabling farmers to rapidly implement SSNM. These tools include ‘Nutrient Expert’ developed by staff of IPNI South East Asia program, ‘Nutrient Manager’, a delivery system developed by IRRI, GIS based fertility maps, an initiative by IPNI South Asia program and other computer based decision tools.

7.8 SSNM for Potassium:

In many regions of India, recommendations for potassium for any given crop or cropping system were based on predefined K rates for sizable areas of production, ignoring the variability of soil fertility both at the spatial and temporal dimensions. Despite the fact that the majority of Indian soils were thought to be fertile and rich in potassium, recent studies revealed a falling tendency in most of the states. Heavy crop removal and minimal K additions by farmers led to widespread potassium depletion, which in turn caused K deficiency to arise in soils and crops. Over time, this caused a shift in fertility from high to medium or medium to low K status. Furthermore, due to variations in climate, crop-growing circumstances, and crop and soil management strategies, the crop requirements for K nutrition vary substantially among fields, seasons, and years. The International Plant Nutrition Institute (IPNI) in India has conducted research that conclusively demonstrates that fertiliser K recommendations are insufficient for current yield targets. As a result, the soil test K level, which was previously thought to be adequate, turns out to be insufficient to balance the high rates of N and P being applied (Tiwari, 2005).

There is a need for site-specific potassium management that takes into account the crop's unique needs for additional potassium and replaces the present and generalist fertiliser recommendations that were devised decades ago. In order to maintain the balance between K mining and a productivity target, Chatterjee and Sanyal (2007) described a method for site-specific K recommendations based on the results of soil tests. The K rates were computed by computing a factor with respect to available and non-exchangeable pools of K.

7.9 Models for SSNM:

The International Rice Research Institute (IRRI) has created a plant-based SSNM method that is now available for maize and wheat. This strategy concentrated on regulating spatial variation in native NPK supply that is peculiar to a given field, temporal variation in plant N status that occurs during a growing season, and medium-term variations in soil P and K supply that are caused by actual nutrient balance. In order to forecast soil nutrient availability and plant uptake in absolute terms in Asia's high-yielding irrigated rice systems, the method required a data management option. The link between grain production and nutrient accumulation as a function of climatic yield potential and the supply of the three macronutrients was described by a modified QUEFTS model (Janssen *et al*., 1990; Witt *et al*., 1999). An accessible manual for managing rice's nutrient content was written in 2002 using the scientific concepts of SSNM. Following an update (Fairhurst *et al*., 2007) and translation into the regional language of the region, this well-known guidebook, which offers recommendations on optimal rates of N, P, and K adjusted to field specific yield levels and indigenous supply of nutrients, was published.to regional language of Hindi (http://tinyurl.com/6lp8zj).

7.10 Nutrient Expert as A Decision Support Tool:

Figure 7.4: The user interface of the Nutrient Expert for Hybrid Maize software

Many Asian nations have begun to replace general fertiliser recommendations for large regions of rice, maize, or wheat with more site-specific recommendations tailored to local requirements. A transition from conventional on-station research to on-farm creation and evaluation of novel methods was made in conjunction with this approach. The complexity of the factors determining nutrient requirements continues to be a major problem for local extension organizations. Based on the site-specific nutrient management (SSNM) concepts outlined by Witt *et al*. (2009). The Nutrient Expert for Hybrid Maize (Fig. 4) is a computer-based decision support tool designed to help local experts quickly generate fertiliser instructions for tropical hybrid maize as described by Witt *et al*. (2009). With the use of this programme, scientists and extension specialists can create unique nutrient management techniques for assessment.

The Nutrient Expert for Hybrid Maize can assist a farmer in increasing yield and profit by offering advice on setting realistic production goals for his region and outlining the fertiliser management tactics necessary to meet those goals. Only information that a farmer or local expert may readily offer is needed for this software.

This Informational Set Consists of:

- The farmer's current planting density;
- The present yield and nutrient management strategy;
- The characteristics of the growing environment or an estimate of the achievable yield (if known)
- Indicators of soil fertility (such as soil color and texture, past usage of organic inputs, or projections of yield responses to N, P, and K fertiliser) (if known)
- Crop residue management, usage of organic inputs, and nutrient carryover from previous crop are used to adjust fertiliser P and K requirements as needed

The user will receive instructions on fertiliser management (and more) that are specific to his area (i.e., the environment for maize) and locally accessible fertiliser supplies after responding to a series of short questions.

The software also provides a straightforward profit analysis that contrasts the costs and advantages of the farmer's existing practice versus the suggested improved alternative approach. Moreover, Nutrient Expert for Hybrid Maize was created with the intention of being used as a learning tool.

It offers instant summary tables and graphs, quick guidance, and a great deal of freedom while browsing the software's modules. The guidelines offered by this software are in keeping with the scientific foundations of Site-Specific Nutrient Management (SSNM), and the following SSNM objectives served as the development of this software's guiding principles:

- Apply sufficient amounts of fertilizer N, P, K, and other nutrients to reduce nutrient-related restrictions and produce high output. Use local nutrient sources that are available on-farm.
- Reach high profitability in the short and medium terms

- Prevent the crop from consuming excessive amounts of nutrients
- Reduce soil fertility loss The Nutrient Expert for Hybrid Maize (Fig. 4) offers assistance with developing the best planting density for a particular site, assessing current nutrient management techniques, choosing a meaningful yield goal based on achievable yields, and estimating the NPK fertilizer rates necessary to achieve the chosen yield goal.
- Incorporating fertilizer sources and NPK rates
- Create a fertilizer application strategy (appropriate rate, appropriate source, appropriate place, and appropriate time); and
- Assess the predicted or actual impact of current and better practices.

7.11 Nutrient Manager:

Figure 7.5: Nutrient Manager for Rice

A user-friendly, interactive computer-based decision tool called Nutrient Manager (Fig. 5) was created in 2008 by the International Rice Research Institute (Buresh, 2008). Via a series of simple questions and answers, the tool is designed to gather the data essential for decision-making on nutrient management. This decision-making tool comprises of roughly 10-15 multiple-choice questions that a farmer or extension agent may readily respond to in about 15 minutes. To help farmers fertilize their fields at the proper time and amount, a fertiliser guideline with fertiliser requirements per crop growth stage is offered based on the replies to the questions. The rice-specific Nutrient Manager software can recommend fertiliser for a variety of rice cultivation techniques, such as transplanted vs. direct seeded rice, hybrids vs. varieties, and rice with a range of growth options, including short, medium, and long durations.

This feature makes the software available to a broad range of rice farmers. In addition to taking into account the residual fertility, final recommendations on the rate and timing of fertiliser application were made after subtracting and balancing the nutrient contributions from organic sources, sediment, and irrigation water inputs. The programme also enables farmers to choose the fertiliser mixtures they like from the local fertiliser sources to satisfy the crop's nutritional needs. A computerized version of Nutrient Management for Rice in the Philippines was created by IRRI and partners in the Philippines in 2010.

Extension personnel and farmers can use it online or via a mobile device. The web site for released internet applications of Nutrient Manager is: www.irri.org/nmrice. Because to its balanced and crop-need-based nutrient administration, SSNM has been successfully tested in India utilizing a variety of methods, demonstrating the ability to not only boost crop yields and farmer income but also to show increasing evidence of environmental friendliness.

Based on the SSNM principles, the new nutrient decision support tool NE for wheat suggests a balanced application of nutrients depending on the crop's needs. Those involved in the development of wheat in India, including those from the government research and extension system, commercial businesses, the International Maize and Wheat Improvement Center (CIMMYT), and the International Plant Nutrition Institute, collaborated to create the tool (IPNI).

Contrary to current approaches, it enables crop consultants to quickly generate fertiliser recommendations tailored to particular fields in order to increase wheat farmers' yields and economic advantages. Specifically, for the South Asian IGPR, SSNM-NE is a newly created precision nutrient management technique that is directed by DSS software and improves crop yields, environmental quality, and overall agricultural sustainability.

A. The Recommendations Made by This Software Are:

- There were no significant water restrictions (such as droughts) during the growing season, any issues with micronutrients and acidity are carefully handled,
- Utilization of high-yielding wheat cultivars;
- Absence of significant damage from pests and diseases;
- Appropriate use of fertiliser.

B. The Software Also Needs Some Readily Available Data, Including:

- Current farmers' yield;
- Farmers' fertilization practices;
- Attainable yield of a location;
- Managing residues in the current wheat crop;
- Credits or adjustments for nutrients from organic inputs;
- Nutrient carryover from previous crop; and
- Outcome of omission plot trial (if available)
- Calculating the predicted levels of N, P, and K in the farmer's field using data on the soil type, soil color, organic matter content, soil analytical information (if available), and soils with a history of P fixation.

7.12 References:

1. Buresh, R.J., 2008, Management made easy: A new decision-making tool is helping rice farmers optimize their use of nutrient inputs. International Rice Research Institute, Rice Today, OctoberDecember 2008, Phillipines.
2. Chatterjee, S. and Sanyal, S.K., 2007, Site-specific potassium management for rice grown in selected alluvial soils of West Bengal. Better Crops, 1(1): 22-25.
3. Fairhurst, T.H., Witt, C., Buresh, R.J. and Dobermann, A., 2007, Rice: A practical guide to nutrient management. International Rice Research Institute (IRRI), International Plant Nutrition Institute (IPNI) and International Potash Institute, Los Banos.
4. FAO. 2011. Save and grow – a policymaker's guide to the sustainable intensification of smallholder crop production. Rome.
5. Hach, C.V. & Tan P.S. 2007. Study on site-specific nutrient management (SSNM) for high-yielding rice in the Mekong Delta. Omorice, 15:144–152.
6. https://cgspace.cgiar.org/bitstream/handle/10568/69016/CCAFSpbNutri ent.pdf
7. Janssen, B.H., Guiking, F.C.T. Van der Eijk, D., Smaling, E.M.A., Wolf, J. and Van Reuler, H., 1990, A system for quantitative evaluation of the fertility of tropical soils (QUEFTS). Geoderma, 46: 299-318.
8. Verma, P., Chauhan, A., & Ladon, T. (2020). Site specific nutrient management: A review. *Journal of Pharmacognosy and Phytochemistry*, *9*(5S), 233-236.
9. Satyanarayana, T., Majumdar, K., & Biradar, D. P. (2011). New approaches and tools for site-specific nutrient management with reference to potassium. *Karnataka Journal of Agricultural Sciences*, *24*(1).