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Precision Nutrient Management: As a tool to enhance Nutrient Use Efficiency

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Abstract

Precision nutrient management is one of the key components of the precision agriculture governing all the major problems of improving productivity, sustainability, profitability and climate change. Soil test based nutrient management recommendations have improved food grain production but have not improved the nutrient use efficiency beyond a certain limit. Assessment of plant nutrient demand from plants is more effective strategy as plant growth at any given time is an integration of effect of nutrient supply from all the sources and is thus a reliable measure of its availability. The affordable and environment friendly tools like leaf colour chart are gaining popularity among farmers. Precision agriculture is an integrated information and production-based farming system that is designed in order to increase long term, site-specific and farm production efficiency, productivity and profitability while reducing unintended impacts on wildlife and the environment. The systematic execution of best management practices into a site-specific system provides the best opportunity to develop a truly sustainable agriculture system. Management of the right source at the right rate, right time and in the right place is best accomplished with the right tools. Different technologies are available to help make decisions related to nutrient management, from soil sampling to fertilizer application to yield measurement. These tools enhance the ability to fine-tune nutrient management decisions and develop the site-specific nutrient management plan for each field.

Keywords: Climate change, Leaf colour chart, Precision agriculture, Sustainability

Introduction

Precision agriculture is defined as the science of applying 'right-input' at 'right time' in 'right-amount' at 'right place' and in 'right-manner' for enhancing productivity, conserving natural resources and avoidance of any environmental as well as social issue. Researchers have realized the importance of feeding the crops rather than feeding the soil. The current research is focused more towards synchronizing nutrient supply with plant needs. Precision agriculture has already achieved an unmatched growth in the developed countries. Developing countries in Asia have been comparatively slow in understanding, developing and adopting the practices of precision agriculture. Moreover, precision agriculture is often misunderstood as a complex technological intervention meant for large crop fields in the developed world. Such a perception about precision agriculture is a myth and there is no data available about 'scale' or 'size' requirement for precision farming. Precision agriculture is made possible by new technologies (geographic positioning systems (GPS), sensors, geographic information systems (GIS), advanced software and precision application equipment). It aims to manipulate inputs such as fertilizer, irrigation, dairy effluent, seed rate spatially and temporally at the sub-paddock scale for cost efficiencies and productivity and environmental gains. Globally, the affordability and accessibility of these technologies helped precision agriculture emerge as a research discipline in the 1980s and a strong focus has always been to enhance nutrient use efficiency by matching inputs to site-specific field conditions.

Precision Nutrient Management

Precision nutrient management is the science of using advanced, innovative, site-specific technologies to manage spatial and temporal variability in inherent nutrient supply from soil to increase productivity, efficiency and profitability of agricultural production systems. It requires proper understanding of the spatial variability in soil (Jin and Jiang, 2002). Studies have highlighted the advantages of precision nutrient management in decreasing the loss of nutrient. Snyder (1996) found that precision nitrogen management practices can effectively decrease fertilizer nitrogen use as compared to traditional nitrogen management. Generally, soil properties differ greatly across space and time. The spatial availability of nutrients in soil under agricultural systems is the combined effect of chemical, physical as well as biological properties of soil, landscape attributes including slope, elevation, environmental factors as well as management practices (Wang et al., 2009). Traditionally, the spatial and temporal variability of nutrients in soils is assessed based on a rigorous field sampling followed by soil testing leading to more requirement of time and energy. At present, development of tools such as chlorophyll meters, leaf colour chart and optical sensors provide facilitates instant nutrient management decisions.

Recent advances show that the need-based nutrient management in crop fields can be established through geo-spatial technologies such as global positioning system (GPS), geographical information system (GIS), remote sensing, real time and variable rate applications (VRA) (Gebbers and Adamchuk, 2010). The need-based variable-rate fertilizer application strategy can enhance fertilizer use efficiency by overcoming the problem of over as well as under fertilization (Schirrmann and Domsch, 2011).

Precision Nutrient Management Tools

Optical Sensors

Optical sensors assess visible and near infrared (NIR) spectral response from plant canopies to detect the nitrogen stress (Ma et al., 1996). Chlorophyll contained in the palisade layer of the leaf governs much of the visible light (400-720 nm) reflectance although reflectance of the NIR electromagnetic spectrum (720- 1300 nm) depends on structure of the mesophyll tissues. Spectral vegetation indices such as the normalized-difference vegetation index (NDVI) calculated as (FNIR – FRed)/(FNIR + FRed), where FNIR and FRed are, respectively, the fractions of emitted NIR and red radiation reflected back from the sensed area, provide details about photosynthetic efficiency productivity potential and potential yield (Kaur et al., 2010).

Chlorophyll Meters

Chlorophyll meters are reliable alternatives to conventional tissue analysis as plant nitrogen nutritional assessment tools. Chlorophyll meter which is used widely is the hand-held Minolta SPAD-502. The SPAD 502 chlorophyll meter (Soil-Plant Analysis Development) is a quick, non-destructive hand-held device developed by Minolta, Osaka, Japan. It quickly provides an estimate of leaf nitrogen status as chlorophyll content (Boggs et al., 2003) by clamping the un-plucked leafy tissue in the meter using two LEDs (light emitting diodes) emitting red (wavelength = 650 nm) and infrared (wavelength = 940 nm) light. The red and infrared radiations are made to pass through the leaf. A portion of light is absorbed and the rest is transmitted through the leaf. A silicon photodiode detector transforms it into an electrical signal. The amount of light reaching the detector is inversely proportional to the amount of chlorophyll in the path of the light. Leaf chlorophyll content is displayed in arbitrary units that is between 0 to 99.9 and the meter readings are unit less which need to be calibrated with chlorophyll or nitrogen content and leaf greenness.

Leaf Colour Chart

Leaf colour chart is a high-quality plastic strip with different shades of green colour that ranges from light yellowish green to dark green. The use of LCC technology was reported in Japan by Furuya (1987). An improved version of six-panel LCC (IRRI-LCC, six-panel) was developed through association of the International Rice Research Institute (IRRI) with agricultural research systems of several countries in Asia (IRRI, 1996). The LCC score of the first fully exposed leaf is observed at 7-10 days interval starting from 15-20 days after transplanting or sowing till initiation of flowering and prescribed amount of fertilizer nitrogen is applied whenever the colour of rice leaves falls below the critical LCC score. The LCC shade 4 has been found to be the threshold score for transplanted coarse grain rice varieties widespread in the Indo-Gangetic plains (Hussain et al., 2003). The threshold LCC value was reported to be 3.5 in the lower Gangetic plain in Bangladesh. The critical LCC value (IRRI-LCC, four panel) of 2 and 3.5 was found to be appropriate for scented and aromatic transplanted semi-dwarf indica or transplanted hybrid rice, respectively.

Varinderpal-Singh et al. (2007) conducted 350 on-farm experiments conducted by in the Indian Punjab using six panel, IRRI-LCC for managing fertilizer N in rice, 9.4–54.2 kg N ha^{-1} less fertilizer was applied without any reduction in yield as compared to the farmers' practice of applying blanket N at fixed-time intervals (Fig. 1).

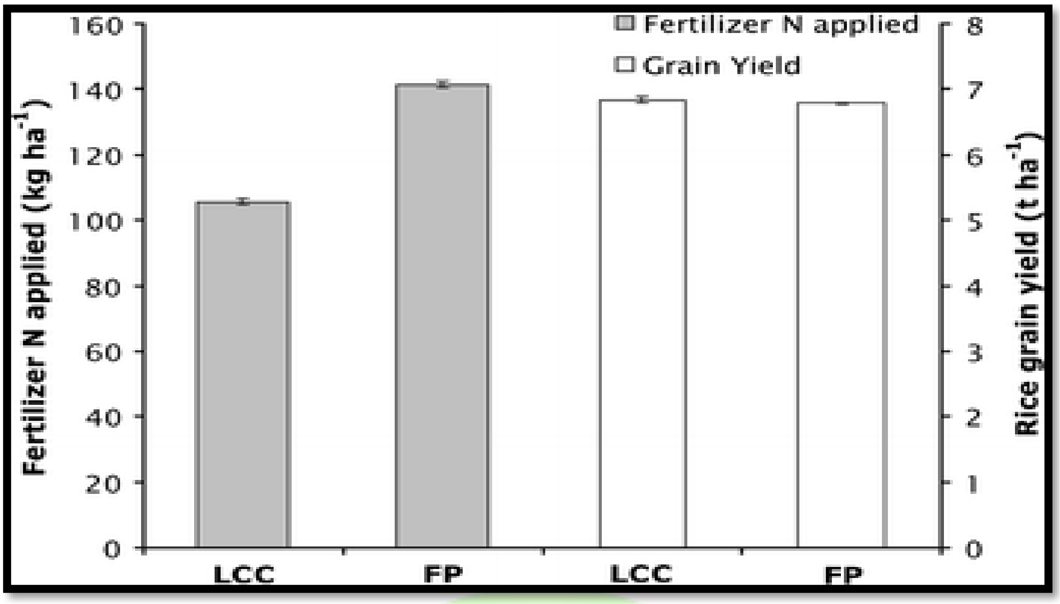

Fig. 1: Average fertilizer N applied and grain yield of rice in 350 on-farm trials comparing LCC based N management (LCC) with farmer's practice (FP) (Varinderpal-Singh et al. 2007)

Omission Plot Technique

Omission plot technique is used to estimate fertilizer requirements for attaining a yield target. All the major nutrients are applied except the nutrient of interest that *is* omitted nutrient. It provides estimate of indigenous nutrient supply of the soil. For example, if all the nutrients except phosphorus are applied in phosphorus omission plot, then the yield will be limited by the indigenous supply of phosphorus. The yield gap between the maximum achievable yield and the yield in the omission plot technique is then used to calculate the requirement of fertilizer.

Nutrient Management Models

Nutrient Expert (NE) and QUEFTS model are basically used computer-based systems for precision nutrient management in crop production. The models are designed in order to consider spatial and temporal variability in nutrient supply and to ensure need-based nutrient management. The nutrient expert (NE) develops farmers' specific fertilizer recommendation based on yield of previous 3 to 5 years, organic and inorganic fertilizers applied, achievable yield, soil fertility indicators, residue content. It takes care of the availability of resources to evaluate their yield target. The algorithm for estimating fertilizer requirements in Nutrient Expert is developed from a set of on-farm trial data using the guidelines of site-specific nutrient management (SSNM). It is a highly interactive computer-based tool that quickly talks about fertilizer requirement of a particular field.

Limitations and Future Research Strategies

Precision nutrient management strategies are mainly based on estimation of leaf greenness using LCC or SPAD meter, crop biomass and soil properties using optical sensors. Many factors influence leaf greenness, biomass and reflectance of light from the soil surfaces. Insufficient or excessive supply of water or other nutrients, soil moisture, organic matter and climatic conditions impede with the measurements and may lead to wrong decision in the nutrient management. Thus, optimum supply of water and nutrients other than nitrogen should be ensured when device such as SPAD meter, LCC or optical sensors are used for precision nitrogen management. The device-based precision nitrogen management may also be affected by certain stress conditions like presence of excessive salts in soil or water, untimely and prolonged rainfall etc. Although LCC and SPAD meter can guide in-season need-based N management even under unfavorable conditions, it is expected that P and K deficiencies will interfere with leaf greenness and affect SPAD meter or LCC measurements. There is a need to define the stress conditions when need-based N management will not be practicable. It seems that amount of solar radiation received in a region will affect the threshold SPAD or LCC values. More data need to be collected to solve this problem.

Conclusion

Precision nutrient management practices includes use of optical sensors, chlorophyll meter, leaf colour chart, omission plot technique and crop models for facilitating need- based nutrient applications and thus improving nutrient use efficiencies while achieving high yield. The real-time nitrogen management approach works well in rice and maize, however fixed time variable rate approach that combines preventive (applying fertilizer nitrogen as basal or at earlier fixed growth stages to prevent fertilizer nitrogen deficiency) fertilizer nitrogen application schedule with LCC, SPAD or optical sensor-guided corrective nitrogen management seems to be more effective in wheat. The management of nutrients other than nitrogen can be done using omission plot technique and crop models.

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