Implementation of Improved Nitrogen Management Strategies Under Intense Wheat Cultivation

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Abstract

Wheat has been considered as the most important cereal after rice in India, contributing 1/3rd to total food nourishment. To feed the expanding population, there need to be increase in production of wheat. Expansion of land to increase the area under wheat is not possible. Development of land to build the zone under wheat is beyond the realm of imagination hence, production can be increased by higher productivity per unit land. Unseemly administration of nutrients causes poor yield of wheat in India. The most conventional way of applying fertilizers by farmers based on blanket recommendation, which does not examine the spatial and temporal variability of nutrients inside the field. In this way there is needed to adopt precision executive practices of nutrient supplements in wheat according to the crop demand and fluctuation within the field. Precision nutrient management helps in increasing yield and also the nutrient recovery as they are applied according to crop demand. Several tools are available for precise application of such as Leaf colour chart, optical sensor (Green Seeker), chlorophyll meter (SPAD), decision support system etc. The point specific nutrient availability also helps in protecting the environment by reducing the emission of harmful gases like N_2O.

Keywords: Decision support system, Green Seeker, LCC, SPAD, nitrogen management

Introduction

Food production in India is synonym of cereal production as it accounts for 90 per cent share to Indian food basket. For feeding a country having population of 1.25 billion, there is more stress imposed on more food production (Singh *et al.* 2017a). Being the second most valuable food crop after rice, it contributes 1/3rd to total food grain production (Kumari and Singh 2016) majorly cultivated in rice wheat cropping system belt. The area and production of wheat in India is 29.58 mha and 99.7 mt respectively and the average productivity is 3371 mt (**Agricultural statistics at a glance, 2018**). Currently India is producing sufficient amount of wheat. But according to the Indian Council of Agricultural Research with continuous increase in population the demand for wheat in country will reach 140 million tonnes by 2050. Due to least chance of land expansion under wheat production, this increase in wheat production has to come through increased yield per unit of production area. In India there is wide difference in the productivity of wheat in different states.

Table 1: Productivity of wheat in different states of India

State	Productivity (kg/ha)
Punjab	5090
Haryana	4412
UP	3269
Bengal	2667
Bihar	2816
Uttarakhand	2727
All India	3371

Source: (**Agricultural statistics at a glance 2018**)

Most challenging factors causing such yield gaps is improper nutrient management by the farmers (Majumdar *et al.*., 2013). In India blanket application as commerical practice by farmers is based on fixed-time fertilizer doses application at specified growth stages which do not combine the dynamic soil property for nutrient supply and crop requirements causing untimely application of fertilizer. The soil nutrient supplying capacity varies from plot to plot and even within the plot from year to year (Qureshi *et al.*., 2016). Blanket recommendation of fertilizer also causes many problems. Some of them are as follows:

1. **Possibility of over and under application of nutrients:** Due to Blanket fertilizer application soils remain under-fertilized in some cases while over-fertilization is done in other cases. Surveys conducted in the Indo-Gangatic plains revealed that farmers apply more Nitrogen and Phosphorus fertilizer than recommended, ignoring sufficient application of other nutrients to the rice-wheat system (Singh *et al.* 2013). The ideal NPK consumption ratio in India is 4: 2: 1. But the current consumption ratio of NPK in India is 6.8: 2.7:1. State wise the NPK dose consumption ratio is quite higher as compared to ideal ratio.

Table 2: NPK consumption ratio of different states (Agristatglance 2018).

State	NPK consumption ratio
Rajasthan	34.43 : 12.64 : 1
Punjab	25.79 : 5.8 : 1
Haryana	22.7 : 6.07 : 1
Uttar Pradesh	13.48 : 4.98 : 1
Uttarakhand	18.88 : 3.08 : 1

Source: (**Agricultural statistics at a glance 2018**)

2. **Low nutrient use efficiency:** In blanket recommendation of fertilizers nutrients are applied without considering spatial variability. Therefore there is no synchronisation between application of fertilizer and crop need which leads to loss of nutrients in various forms and low nutrient use efficiency.
3. **Absence of recommendations for secondary and micro nutrients leads to multi nutrients deficiency:** In India, most of the farmers only apply major nutrients like N, P and K and does not apply secondary and micronutrients which leads to deficiency in the crop and therefore the crop yield is reduced.
4. **Environmental risks:** Due to excess and untimely application of fertilizers, nutrients gets lost in form of leaching, volatilization etc. The leached nutrient accumulates near ground water and therefore contaminates it. Similarly the nutrient gets volatilized in harmful gases like N_2O, SO_2 etc. and contaminates the air. Therefore there is need to improve the nutrient management techniques in wheat.

Precision nutrient management in wheat

Precision nutrient management or Site Specific Nutrient Management (SSNM) means the application of nutrients to the soil over time and space in such a manner that it matches the requirements of crops through four key principles known as "4 Rs" Right Product, Right Rate, Right Time, Right Place.(Richards et al.., 2015)

Right product: Right product means the use of fertilizer according to the type of soil and crop to ensure balanced supply of nutrients.

Right rate: Right rate means the correct amount of fertilizer that applied on the basis of indigenous nutrient supplying capacity of soil and demand of the crop. Too much fertilizer application causes environmental losses, including leaching, runoff and gaseous emissions. Similarly application of less fertilizer exhausts soils and degrades the soil.

Right time: Right time means applying the nutrients to the crop when crop demand is maximum. It will help in better uptake by plants therefore reduce the loss of nutrients.

Right place: Right place means applying the nutrients according to the spatial variability that noticed within the field.

The SSNM approach (Shinde et al.., 2013)

Step 1: Establish an approach for attainable yieldt*:* Crop yield differs according to the location, season, climate, variety and crop management. The target yield at a local site and season is the maximum estimated grain yield that a farmer can attain when all the growing conditions are favourable and all the constraints are overcome. The amount of nutrients consumption by a crop is directly proportional to yield. Therefore cumulative amount of nutrient required to produce a target yield is calculated.

Step 2: Effective use of existing nutrients*:* The SSNM approach facilitates the optimal uses of existing nutrients which are generated from the soil, manure, crop residue, organic amendments and also through irrigation water. The indigenous supply of nutrients can be well estimated by omission plot technique in which the crop is remain deficient with the nutrient of interest, but with all other nutrients to ensure they do not limit yield.

Step 3: Fertilizer application to fill the deficit generated between crop requirement and indigenous supply: The quantity of fertilizer to be applied is determined by the difference between the crop's total need for nutrients and their supply from indigenous sources. In order to see the effect of SSNM on productivity of important crops of Northern Karnataka, and to disseminate the knowledge to surrounding farming communities, Biradar *et al.* (2006) initiated a research project during 2003-04. Research and demonstration trials were undertaken on farmers' fields. Five trials each on rice, wheat, and chickpea were conducted with three treatments comparing yields and economics of SSNM over recommended rates of fertilizers (RDF) and farmers' practice (FP). The trials were located at Siruguppa, Bijapur, and Navalgund Talukas of Karnataka. SSNM nutrient requirements were identified based on soil tests and the treatments were imposed considering set crop yield goals and available soil nutrients.

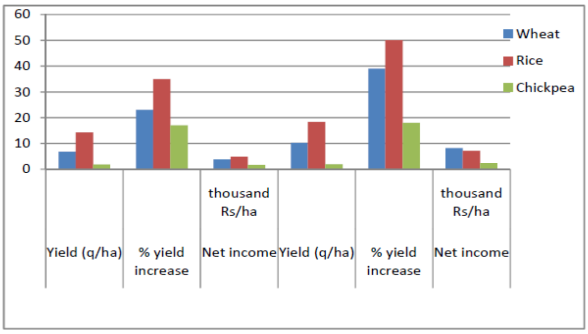

Figure 1: Yield increase and economic advantage due to SSNM (Source: Biradar et al.., 2006)

Nutrient application based on SSNM principles resulted in significantly higher grain yields over FP and RDF in all three crops under investigation. Wheat yields ranged from 3.5 to 3.8 t/ha under SSNM, 2.8 to 3.2 t/ha under RDF, and 2.6 to 2.7 t/ha in FP. Average wheat yields were 3.66, 2.98, and 2.64 t/ha in the respective practices, signifying 23% higher productivity due to SSNM over RDF and 39% over FP. Yield increases under SSNM resulted in a vast improvement in the economic feasibility of food crop production. The average additional net income under SSNM in rice, wheat, and chickpea was RS 4845, 3776, and 1638 /ha over RDF, and RS7196, 8194, and 2430/ha over FP. (Table 3)

SSNM proved to be advantageous over RDF and FP both in yields and net returns in wheat, rice, and chickpea. The results also suggested that there is opportunity to improve the RDF for these crops.

Tools used for Precision nutrient management in wheat

Leaf colour chart

LCC was jointly developed by IRRI (International rice research institute) and Philippines Rice Research Institute for measuring the required quantity of N to be applied in rice. Later it was also developed for other crops like wheat and maize. LCC for wheat is standardized for a number of varieties by PAU, Ludhiana. LCC is a cost effective tool for real time or crop need based N management. It is a visual indicator of deficiency of nitrogen in plants. The colour panels of LCC are matched with the leaf colour of wheat to know whether plants are hungry or over-fed by N fertilizer. LCC can help the farmers to decide right time and amount of application of N fertilizer.

Guidelines for Using LCC

- The topmost fully expanded leaf should be used for colour measurement because it is highly related to the N status of wheat plants.
- The leaf should not be detached or destroyed.
- The leaf in which reading to be recorded is to be shielded with our body as the leaf colour chart reading is affected by sun's angle and light intensity.
- Readings are taken between 8-10 am when there is not much glare from the sun.
- Readings should not be taken very early in the morning since dew drops can make reading difficult.
- Every time the same person should take colour measurement at the same time of the day.
- Readings are taken from ten leaves at random for each plot and then the average score is compared to determine the need for nitrogen top dressing.

SPAD (Soil Plant Analysis Development)

SPAD was released in 1984 by Minolta Co. ltd. Japan. The SPAD-502 chlorophyll meter (Minolta Camera Co., Japan) is a simple, portable, diagnostic and non- destructive device which is used to estimate the leaf chlorophyll content (Minolta, 1989). Chlorophyll absorbs maximum light in the blue (400-500nm) and red (600-700nm) regions, with no or little absorbance in the near- infrared region. Using absorbances in red and near infrared regions, the meter provides numerical set values of SPAD which indicates the amount of chlorophyll of the leaf. A higher SPAD value means a healthier plant. Chlorophyll meter helps in saving time and resources (Netto *et al.*., 2005) and it offers strategy for synchronization between crop demand and application of N (Babu *et al.*., 2000). The chlorophyll meter readings shows positively correlation with destructive chlorophyll amount in a number of crop species (Zhu *et al.*., 2012) and it is considered to be very useful indicator of N topdressing demand in plant during the crop growth (Naderi *et al.*. 2012; Singh *et al.*., 2010). For SPAD measurement, the new fully expanded leaf of a plant should be used. 10-15 readings per field or plot are taken and their mean is calculated. Whenever the mean SPAD value fall below critical ranges, N fertilizer should be applied to avoid any yield loss.

Reena *et al.*(2017) conducted a field experiment at G.B. Pant University of Agriculture and Technology, Pantnagar, Uttarkahand, during the winter (*rabi*) season of 2014–15. The study aimed to investigate the effect of LCC and chlorophyll meter (SPAD meter) based nitrogen management on wheat crop. Application of nitrogen at lower rate of 105 kg /ha based on LCC value (4 and 5) and SPAD (30 and 40) resulted statistically similar growth, yield attributes viz., plant height, shoot density, leaf area index, dry matter, number of grains per spike and 1000 grains weight compared with recommended practice (150 kg/ha). Higher numerical value of nitrogen use efficiency in terms of agronomic efficiency, recovery efficiency obtained from SPAD and LCC based treatments of 105 kg/ha than recommended nitrogen management.

Table 3: Treatment details of experiment conducted by Reena *et al.*(2017)

Treatments	Control (no N)	Recomme-nded N	30 kg at LCC 4	40 kg at LCC 4	30 kg at LCC 5	40 kg at LCC 5	30 kg at SPAD 40	40 kg at SPAD 40	30 kg at SPAD 35	40 kg at SPAD 35
Total dose of N(kg/ha)	0	150	85	105	85	105	85	105	85	105

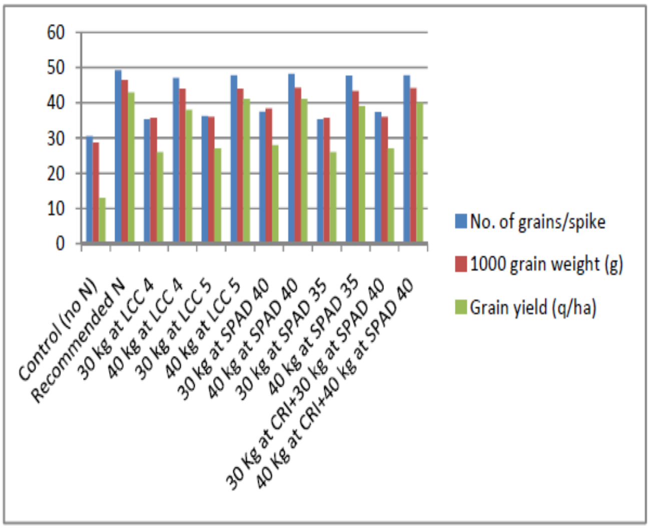

Figure 2: Effect of different nitrogen management treatments on yield attributes and grain yield of wheat. (Source: Reena *et al.*(2017))

Thus study concluded that LCC and SPAD are the effective tools which help to uptake applied nitrogen more efficiently rather than subjected to losses and make economical use of absorbed N and showing saving of 30 per cent or 45 kg /ha nitrogen without any significant yield decrement.

Green seeker (optical sensor)

Green seeker is an integrated optical sensing, variable rate application and mapping system that measures crop's N demand. Yield potential of any crop is identified while using a vegetative index known as NDVI (Normalized Difference Vegetation Index).

How does the sensor works

The sensor uses light emitting diodes (LED) to generate red (660nm) and near infrared (780nm) light. During photosynthesis plant absorbs red light as an energy source. Healthy plants reflect larger amounts of NIR light and absorb more amount of red light.

$$\text{NDVI} = \frac{NIR\ reflected\ - Red\ reflected}{NIR\ reflected\ + Red\ reflected}$$

NDVI readings range from 0 – 0.99.The higher the reading, the healthier the plant. The value 0 represents an absence of vegetation. Nutrient management on the basis of optical sensor requires local calibration of sensor for a given crop, nutrient and region. After calibration, theoptical sensor requires:

1. Establishment of a N rich strip that will receive a non-limiting amount of nitrogen.
2. NDVI readings from the N rich strip and NDVI readings from the test plot where farmer wants to apply N.
3. NDVI readings of both the plots along with date of planting and date of sensing are entered in a mathematical model developed for each region.

Decision support system
DSS is a computer systems which collect information, process information and provide information based on computer systems (Sheng and Zhang 2009). Various DSSs have been introduced in agriculture to monitor and assist the farmers to make decisions regarding farm management.

Examples of DSS for precision nutrient management in wheat: Nutrient Expert, DSS4ag (Decision Support System for Agriculture), QUEFTS (Quantitative Evaluation of the Fertility of Tropical Soils), Crop manager.

Nutrient Expert

Nutrient Expert is a simple computer based decision support system developed by IPNI [International Plant Nutrition Institute] and (International Maize and Wheat Improvement Centre) for providing 4R fertilizer recommendations to farmers in the presence or absence of soil testing. It takes the user through simple working modules, gathers information on farmers crop yield and fertilizer application practices, suggest an optimum plant density and finally develops an individual farmer specific fertilizer recommendation through responding to a series of simple questions.
Following information is needed to be processed to estimate the required nutrient doses under NE (Majumdar *et al.* 2013):

i. Farmers" fertilization practices – amount of fertilizers, scheduling, organic/inorganic sources
ii. Estimation of the attainable yield at the particular location by considering environment situations (irrigated/ rainfed/flooding/drought, presence of soil problems like soil salinity/alkalinity/acidity).
iii. Yield responses to fertilizer N, P and K (if available)
iv. Soil fertility parameters (soil colour, texture and use of organic manures)
v. History of preceding crop (yield, fertilizer inputs, crop residue management)
vi. Crop residue management and use of organic inputs.
vii. Price of wheat grain produce as well as cost of seeds and fertilizers.

After putting these details, the output file is obtained which contains the fertilizer doses and their application schedule along with the economics.

On-farm trials were conducted by Sapkota *et al*.., (2014) in seven districts of Haryana for two consecutive years (2010–11and 2011–12). The aim of study was to evaluate nutrient recommendations based on decision support system Nutrient Expert (NE) in wheat production systems under conventional tillage (CT) and no tillage (NT). There were 3 SSNM treatments based on NE based recommendation viz. (1) 'NE80:20' with 80% N applied at planting and 20% at second irrigation (2)'NE33:33:33' with N split as 33% basal, 33% at Crown Root Initiation (CRI) and 33% at second irrigation; and (3) 'NE80:GS' with N split as 80% basal and further application of N based on optical sensor (Green Seeker TM)-guided recommendations.

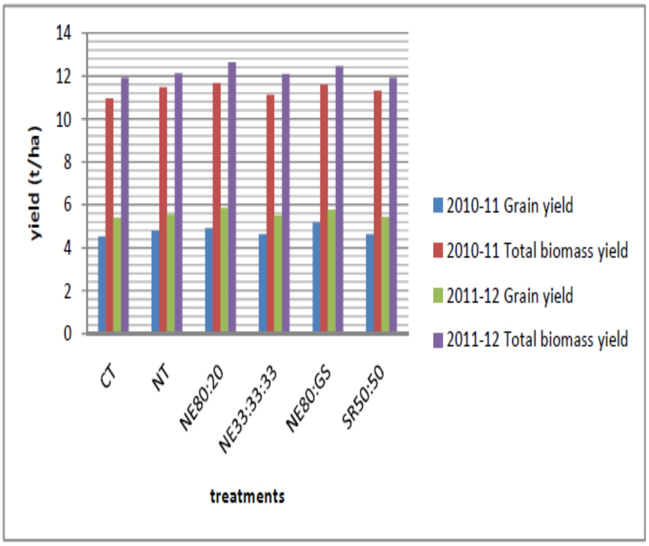

Figure 3: Effects of tillage systems and nutrient management strategies on grain and total biomass yield (t ha−1) (*Source:* Sapkota *et al.*, 2014)

The result shown the higher grain and biomass yield of wheat under NT during study of 2010–11 but no significant difference was observed in 2011–12. Nutrient use efficiency and yield as well as net return were increased under the NE-based plant nutrient management strategies as compared to state recommendation and farmers' fertilization practice.

SSNM also helps in the protection of environment because under SSNM the quantity of N applied is reduced therefore the total reactive N (NH_3, NH_4+, NO_3-, NO_2-, NO, N_2O) losses to the environment (through leaching or volatilization, for example) and N2O emissions are also reduced. In In a study conducted in wheat it was seen that N_2O emissions was less by 50% (Matson *et al.*, 1998) and leaching losses were reduced by 90% (Riley *et al.*, 2001) by the use of SSNM. SSNM may prescribe more amount of N application in places where soils reported nutrient-depleted (Dobermann *et al.*, 2002), but it does not necessarily increases emissions of harmful gases. A research suggested that the emission response for every increment in N input is exponential rather than linear, with very low emissions until plant needs are met (Shcherbak *et al.*. 2014)..

Constraints of Precision nutrient management in India

Precision farming is at its beginning level in many developing countries including India but there are many opportunities for adoption (Shanwad *et al.*, 2004).There are many obstacles which are responsible for low adoption of precision farming in India.

- Small and fragmented land holding
- Lack of success stories
- Complexity of technology usage
- High initial and operational cost of the instruments
- Lack of awareness among farmers
- Lack of training to the farmers
- Rigidity to adopt changes

Conclusion

The use of blanket nutrient management recommendations in India has led to low nutrient use efficiencies, increased environmental problems and lowered profits. Optimized nutrient management strategies via site-specific approaches would increase yield, higher nutrient use efficiency and enhance the profitability of wheat production. LCC and Nutrient Expert are the cheapest tools for precision nutrient management which Indian farmers can easily use for precise application of nutrients in their field. There are many constraints which leads to low adoption of precision nutrient management techniques in India, therefore proper research and fine tuning of instruments is necessary for easier adaptation by farmers.

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