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Nutrient management in high yield wheat system in Bihar using nutrient expert tool

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Abstract
The SSNM is need-based feeding of crops with nutrients in right source, right rate, right time and right place while, recognizing the inherent spatial variability which enhances crop productivity, profitability, NUE and avoids nutrient wastage. This paper deals with the SSNM technologies approaches and tools which are able to enhance NUE, crop productivity and profitability in wheat crop. The SSNM caters to help in improving NUE as it provides an approach for feeding crops like rice, maize and wheat, etc with nutrients as and when needed. It is based on the concept when and how much to feed. The main benefit for farmers from improved nutrient management strategy is an increase in the profitability and reducing the cost and environmental threats. The SSNM reduces the wastage of fertilizers by preventing excessive use of fertilizers and avoiding fertilizer application when the crop does not require nutrient inputs. It also assures that N, P and K are applied in that ratio required by the intended crop. It aims to achieve high yield and high efficiency of nutrient use, leading to high cash value of the harvest per unit of fertilizer invested. Results from 3 year data from 2014 to 2016, 173 on-farm sites in four districts of Bihar showed that NE significantly increased wheat yields and economic returns compared to the generalized Farmers' Fertilization Practice (FFP). NE's impact on fertilizer use in wheat shifted K application upwards while also minute upwards N and P application rates. We used recent advances in information and communication technology (ICT) and computer based application of "Nutrient Expert for Wheat, Maize and Rice", which transform the science of SSNM into guidelines matching the field-specific needs and conditions of a farmer. Across all sites, NE wheat increased to yield and economic benefit (i.e. gross return above fertilizer costs) over FFP (Table-4). Recommendations from NE wheat also increased yield (by 63 t/ha) over FFP with large increase in fertilizer K (+50.88 kg K_2O/ha) and N and P fertilizer was minute increase N (+ 4.32 Kg N/ha) and P (+ 6.21 Kg P_2O_5/ha).So result revealed that nutrient expert application significantly increase higher grain yields over farmer fertilizer practice (FFP). Average wheat grain yield in NE practice was 45.32 Kg ha-1, which was 13.9% more than the Farmer Fertilizer Practices, with NE recorded an additional net income of Rs.8434 ha-1 over FFP respectively.

Keywords: Site-specific nutrient management, real time N management, nutrient-use efficiency, factor productivity, nutrient expert decision support system

Introduction
Wheat (*Triticum aestivum* L.) is the staple food crop for the people of South Asia and contributes to more than 80% of the total cereal production in the region (Timsina and Connor, 2001) [8]. India is the second largest producer of wheat in the world, with production of almost 68–75 million tons for past few years. The latest estimated demand for wheat production for the year 2020 will be approximately 87.5 million tons, or about 13 million tons more than the record production of 75 million tons harvested in crop season 1999–2000. Since 2000, India has struggled to match that record production figure and thus faces a critical challenge in maintaining food security in the face of its growing population. Recent approaches like site-specific nutrient management (SSNM) provide an approach to "feeding crops" with nutrients as and when they are needed and hence making synergy for nutrient demand and supply under a certain production system. However, such an approach along with careful management of other crop production factors, allowed reaching yield targets and efficiency factors that are far higher than the current levels. But, soil testing has remained the major bottleneck to realize potential benefits of these new and improved approaches. We therefore attempted to develop a decision support system (DSS), based on the principles of SSNM (Nutrient Expert for wheat) that provides flexibility of using SSNM principles with and without soil testing and reaching large number of farmers. In this paper we therefore present the pros and cons of conventional as well as modern tools and techniques of nutrient management and comparing with Nutrient Expert (NE) results validated in in Bihar state in different district nearby Muzaffarpur, Samastipur, Vaishali and Begusarai provide alternate solution to soil test based nutrient management while capturing the variability. The Decision support systems (DSS) are now progressively used to facilitate application of improved nutrient management practices in

farmers' fields. The DSS developed in 2010-11 is an easy-to use, interactive computer-based decision tool that can rapidly provide nutrient recommendation for individual farmers' field in presence or absence of soil testing data. The results of farmers' field validation trials of NE based prescriptions in wheat across the Indo- Gangetic Plain region showed that the NE based recommendation significantly improved wheat yield and economics. This suggests that nutrient management strategies need to be higher production system of wheat.

Attaining Food Security had been a major challenge for the nation since independence. India has achieved self-sufficiency in food production at present, but the realistic demand for food has been estimated at 235 million tons (Mt) for 2015, which will reach 265 Mt by the year 2030. Looking at the rapid growth of population in the country, the slow growth rate in food grain production necessitates special initiatives to meet the increasing demands. Wheat has to play an important role in this direction considering the vast scope of increasing productivity of this crop through bridging the management yield gaps by the newly emerging technologies. Cereals, especially wheat, constitute the staple food in India and meet about 61% of the protein requirement of the country. The current wheat production of India is about 80 Mt and the country has to produce 105 Mt by 2025, demanding an average growth rate of 4% per annum (Prasad, 2011) [5]. Expansion of the area sown to wheat has long ceased to be a major source of increased wheat output and most of the increase in production has to result from greater yield per hectare. As we look at further opportunities to improve production, it becomes evident that there still exist substantial yield gaps within wheat growing regions of the country, as well as between on-station and on-farm yields. Inappropriate nutrient management is one of the major factors causing such yield gaps (Majumdar *et al.*, 2012; Nagarajan *et al.*, 2005) [3, 4]. The current paper aims to analyze the nutrient management related constraints for such yields gaps and possible ways of improving productivity through appropriate nutrient management strategies.

Wheat production scenario in India: Wheat (*Triticum aestivum* L) is the most important cereal crop in the World and stands next to rice in India. The share of wheat to total food grain production in India is around 37% and occupies about 24% of the total area under food grains. Wheat is grown in India over an area of about 29 million hectares (M ha). Nearly 82-85% of the wheat grown in India is under irrigated conditions while the rest is grown under rain-fed ecology. Nearly 90% of the wheat growing area is in the North Western Plain Zone (NWPZ), North Eastern Plain Zone (NEPZ) and Central Zone (CZ). At the current production level, NWPZ alone produces over 50% of the total wheat followed by NEPZ (less than half of NWPZ) and Central zone. The average productivity of wheat in the country is 2839 kg ha-1 with the highest yield recorded in Punjab (4307 kg ha-1) followed by Haryana (4213 kg ha-1), Rajasthan (3133 kg ha-1), Uttar Pradesh (2846 kg ha-1), West Bengal (2680 kg ha-1) and Bihar (2084 kg ha-1) indicating wide yield differences between the major wheat growing states of the country (Fertilizer Statistics, 2010-11) [1].

Yield gaps: Review of current statistics shows that there are considerable yield gaps between the major wheat growing states in the country (Fertilizer Statistics, 2010-11) [1]. For example, productivity in Bihar and Madhya Pradesh are less than 50% of Punjab. Similarly, Uttar Pradesh, with the highest acreage among the states (9.7 M ha), has a productivity of 2846 kg ha-1, which is about 65% of Punjab. Such yield gaps can be partially related to the nutrient ($N+P_2O_5+K_2O$) consumption per unit of gross cropped area in a particular state. The productivity data of seven major wheat producing states (Punjab, Haryana, Rajasthan, Uttar Pradesh, Bihar, Madhya Pradesh and West Bengal). Area, production and productivity trend of wheat in Bengal, Jharkhand and Madhya Pradesh) were correlated with the latest nutrient consumption data for these states and has revealed a good linear correlation (R_2=0.78). It must be understood, however, that besides nutrient use, there are several other important factors, including climate and management issues that influence yield gap between these states. Pathak *et al.* (2005) [7] while working on on-farm situation also observed large yield gaps between potential and farmers' field yield of wheat in the Trans-Gangetic alluvial tract of Delhi. They attributed such yield gaps to a large extent to inappropriate nutrient management. Recently, Gupta *et al.*, (2010) [2] suggested that the management yield gaps in wheat in Punjab, Haryana, Eastern UP and Bihar were 17, 14, 47 and 48 %, respectively. However, existence of such yield gaps are also opportunities in disguise as bridging these gaps provides the avenues for future food security in the country. It is interesting to note that an average wheat yield increase of .63 t ha-1through NE tool recommendation in Bihar (Table - 4).

Improved nutrient management for wheat: Site-specific nutrient management (SSNM) provides an approach to "feeding" crops with nutrients as and when they are needed. It ensures that all the required nutrients are applied at the proper rate and in proper ratio based on the crop's nutrient needs. The principles of SSNM are well established and have produced yield and quality improvement in wheat across soils and regions. All the experiments shown here ensured that all limiting nutrients were applied in each location after carefully determining the nutrient supplying capacity of the soil and the nutrient requirement of wheat based on a specified yield target. IPNI work on rice-wheat cropping sequence across four district of Bihar showed that SSNM improved yield of wheat in nutrient expert over farmers' practice (FP).

The SSNM approach used in this study focused on managing spatial variation in indigenous N, P, and K supplies among individual sites. The approach mainly involved (a) prediction of site specific optimal fertilizer NPK rates using indigenous nutrient supplies and (b) development and implementation of a site-specific N management scheme that accounted for real-time variation in crop N demand at major wheat growth stages. Recommendations from NE wheat also increased yield (by 63 t/ha) over FFP with large increase in fertilizer K (+50.88 kg K_2O /ha) and N and P fertilizer was minute increase N (+ 4.32 Kg N/ha) and P (+ 6.21 Kg P_2O_5 /ha).So revealed that nutrient expert application resulted in significantly higher grain yields over farmer fertilizer practice (FFP). Average wheat grain yield in NE practice was 45.32 Kg ha-1, which was 13.9% more than the Farmer Fertilizer Practices, with NE recorded an additional net income of Rs.8434 ha-1 over FFP respectively. NE wheat recommendations were also tested against FFP in 173 locations in four districts in Bihar. The above SSNM studies in wheat highlights that a combined approach of real-time N management along with application of nutrients based on indigenous nutrient supply and yield target has the potential to improve productivity of wheat, far beyond achievable by the current general recommendations. Such approaches not only have the capability to reverse the yield stagnation in wheat but also can improve farmers' profit and lessen the environmental impact of imbalanced fertilization promoted by generalized

nutrient recommendation. Decision support systems (DSS) are now progressively used to facilitate application of improved nutrient management practices in farmers' fields. A recently developed DSS, Nutrient Expert for Wheat, synthesized the wheat on-farm research data into a simple delivery system that enables wheat farmers to rapidly implement SSNM for their individual fields. The decision support system developed in 2010-11 is an easy-to-use, interactive computer-based decision tool that can rapidly provide nutrient recommendation for individual farmers' field in presence or absence of soil testing data (Pampolino *et al.*, 2012) [6]. The tool estimates the attainable yield for a farmer's field based on the growing conditions determines the nutrient balance in the cropping system based on yield and fertilizer/manure applied in the previous crop and combines such information with expected N, P and K response in the concerned field to generate a location specific nutrient recommendation for wheat. It utilizes information provided by a farmer or a local expert to suggest a meaningful yield goal for his location and formulates a fertilizer management strategy required to attain the yield goal. The software also does a simple profit analysis comparing costs and benefits between the farmer's current practice and the recommended alternative improved practice. First year farmers' field validation of Nutrient Expert decision support tool in wheat (Table-1) across the Indo-Gangetic Plains region showed that the tool-based recommendation significantly improved yield and economics of production.

Future research needs on nutrient management in wheat systems: Until recent past, the nutrient management research was primarily focused on developing generalized prescriptions for larger domains and for conventional crop management practices. However, in recent past significant attempts have been made to develop precise approaches based on the principles of site-specific nutrient management (SSNM) so as to capture the spatial and temporal variability in soil fertility. This approach (SSNM) has been able to address many of the issues of adhoc nutrient prescriptions. However, large-scale implementation of SSNM in farmers' field still remains a challenge due to the knowledge requirement. Recent development and validation of the Nutrient Expert DSS for wheat provides a great opportunity to easily implement SSNM in farmers' fields. However, there are several other areas of research that has potential to help in implementing improved nutrient management practices at different scales: During past decade or so, alternate crop establishment techniques, zero tillage with or without surface retention of residues, have emerged as one of the potential alternate to conventional tillage based wheat production. However, most nutrient management research caters to conventional tillage based crop management systems. Therefore, there is a need to develop recommendation and application strategies in line with the 4R principles (right source, right rate, right time and right place) for wheat cultivation.

- Scientific basis of attainable yield targets need to be established under contrasting management practices for tillage and residues in various cropping systems under diverse ecologies (rainfed, irrigated).
- Crop physiological processes and efficiency under contrasting management practices will be variable that will lead to variable nutrient responses. Basic understanding of such processes will allow designing appropriate nutrient management decision tools/prescriptions.
- Nutrient availability under enhanced moisture availability under zero-till and residue retention scenarios needs to be understood properly to determine appropriate rate and time of nutrient application.
- Development of appropriate machinery for nutrient application (surface application, drilling, band placement, fertigation) under different management scenarios (no-till with and without surface residues, conventional till with and without residue incorporations) is urgently required. Repeated foliar application of N-P-K fertilizer grades (19:19:19 or 20:20:20) at flowering is also gaining momentum in farmer fields especially in areas where wheat is subjected to severe incidence of frost damage. Therefore the relationship between foliar feeding of nutrients and crop damage to frost has to be well established and there is a need to quantify the contribution of such foliar application of nutrients to the final crop removal. Developing Expert Systems/mobile apps for identification of nutrient deficiency symptoms in wheat is a critical area of research. Timely identification of deficiency symptoms and their early rectification can save farmers from major economic losses.

Wheat is the most widely grown cereal crop in the world. It is cultivated on almost 215 million ha out of 670 million ha under cereals. Wheat grain contains 70 percent starch and 12–18 percent protein. The highest grain yields are obtained with winter wheat. These range from 1 ton/ha to more than 12 ton/ha, with a world average of about 3 ton/ha. High yields (up to 14 ton/ha) can be obtained from highly productive varieties with appropriate nutrient and crop protection management on fertile soils with adequate water supply. Globally, wheat yields have increased considerably as a result of breeding programmes that have incorporated the short-straw trait from Mexican varieties. Such varieties are more responsive to applied nutrients and are also more resistant to lodging as compared with the local wheat varieties. Wheat can grow on almost any soil, but for good growth it needs a fertile soil with good structure and a porous subsoil for deep roots. The optimal soil reaction is slightly acid to neutral although it can be grown successfully in alkaline calcareous soils under irrigation. The water supply should not be restrictive and rains should be well distributed.

Nutrient decision support systems Nutrient expert®: *Nutrient Expert*® is an interactive, computer based decision-support tool that enables smallholder farmers to rapidly implement SSNM in their individual fields with or without soil test data. The software estimates the attainable yield for a farmer's field based on the growing conditions, determines the nutrient balance in the cropping system based on yield and fertilizer/manure applied in the previous crop and combines such information with expected N, phosphorus (P) and potassium (K) response in target fields to generate location-specific nutrient recommendations. The software also does a simple profit analysis comparing costs and benefits between farmers' current practice and recommended alternative practices. The algorithm for calculating fertilizer requirements was developed from on-farm research data and validated over 5 years of testing. The software is currently available without charge for wheat & maize systems in South Asia.

Site-specific nutrient management parameters in NE: NE estimates the attainable yield and yield response to fertilizer from site information using decision rules developed from on-farmer field trials (Table 2). Specifically, NE uses characteristics of the growing environment to water availability (irrigated, fully rain-fed and rain-fed with

supplemental irrigation) and any occurrence of flooding or drought; soil fertility indicators including soil texture, soil color 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 specific geographic regions are required in developing the decision rules for NE. The datasets must represent diverse conditions in the growing environment characterized by variations in the amount and distribution of rainfall, crop cultivars and growth durations, soils and cropping systems. Fertilizer application recommendations are often based on crop response data averaged over large areas, though farmers' fields show large variability in terms of nutrient-supplying capacity and crop response to nutrients. Thus, blanket fertilizer application recommendations may lead farmers to over-fertilize in some areas and under-fertilize in others, or apply an improper balance of nutrients for their soil or crop. An alternative to blanket guidance, Site- Specific Nutrient Management (SSNM) aims to optimize the supply of soil nutrients over time and space to match the requirements of crops through four key principles. The principles, called the "4 Rs", date back to at least 1988 and are attributed to the International Plant Nutrition Institute (Bruulselma *et al*. 2012) [1]. They are:

Right product: Match the fertilizer product or nutrient source to crop needs and soil type to ensure balanced supply of nutrients.

Right rate: Match the quantity of fertilizer applied to crop needs, taking into account the current supply of nutrients in the soil. Too much fertilizer leads to environmental losses, including runoff, leaching and gaseous emissions, as well as wasting money. Too little fertilizer exhausts soils, leading to soil degradation.

Right time: Ensure nutrients are available when crops need them by assessing crop nutrient dynamics. This may mean using split applications of mineral fertilizers or combining organic and mineral nutrient sources to provide slow-releasing sources of nutrients.

Right place: Placing and keeping nutrients at the optimal distance from the crop and soil depth so that crops can use them is key to minimizing nutrient losses. Generally, incorporating nutrients into the soil is recommended over applying them to the surface. The ideal method depends on characteristics of the soil, crop, tillage regime and type of fertilizer.

Materials and methods

Bihar is located in the eastern part of the country (between 83°30'E to 88°00'E longitude). We are conducting 173 Nutrient Expert with farmer fertilizer practices trials during *Rabi* season 2014 and 2016. Last 3 year data the performance of Nutrient Expert (NE) was evaluated in Muzafarpur (Binda, Narauli, davarikanagar, Jaya, Unsar, Bhelaepur, Sundarpur ratwara, Lohsari, Thegharari), Vaishali (Bathadasi, Habipur, Suarthi), Samastipur (Dalsinghsarai, Manda, Sakhamohan), Begusarai (Simaria, Bhawanandpur, Birpur, Badiagh, Lalunagar, Pipradevash), districts in Bihar State by comparing its results against the farmer fertilizer practices during 2014 and 2016. Three year data for field evaluation of Nutrient Expert for wheat was conducted at 173 locations across four districts in Bihar. The seed rate for all treatments was same. Similar water management and plant protection measures were adopted for all treatments at each site. At harvest, the sampling area (located within the middle part of the plot) was selected randomly in each treatment plot to determine grain yield. Grain yields from all treatment plots were calculated at 15.5% moisture content. At each site, nutrient Management recommendations from NE maize were tested against farmers' fertilizer practice (FFP). The selected four districts include Muzaffarpur, Vaishali, Samastipur, Begusarai. At each location, plot sizes of at least more than 100 square metres. The actual fertilizer application rates applied are detailed in table 1.

Table 1: District wise NPK fertilizer application variance range of NE and FFP.

Treatment	District wise NPK fertilizer application variance range of NE and FFP			
	Muzaffarpur (n=73)	Vaishali (n=32)	Samastipur (n=22)	Begusarai (n=46)
Farmer Fertilizer Practices				
N	80-119	84-168	96-158	100-165
P_20_5	62-73	43-62	37-69	62-69
K_20	22-60	21-66	13-33	0-30
Nutrient Expert				
N	95-140	95-140	110 - 155	110 - 155
P_20_5	48-65	48-75	50-78	52-78
K_20	72-83	72-88	73-102	65-102

Table 2: District wise Average maize Grain yield q/ha (n= 173).

Treatment	District wise Average maize Grain yield q/ha (n= 173)			
	Muzaffarpur (n=73)	Vaishali (n=32)	Samastipur (n=22)	Begusarai (n=46)
FFP	36.65	36.71	42.09	40.63
NE	42.5	43.31	49.04	46.88
Mean	39.35	40.01	45.56	43.75
CD (0.05)	.848	1.06	1.14	.89
CV	6.46	4.91	3.90	4.76

Table 3: District wise average yield and fertilizer recommendation variance of NE and FFP treatment.

Parameter	Unit	District wise average yield and fertilizer recommendation variance of NE and FFP treatment											
		Muzaffarpur (n=73)			Vaishali (n=32)			Samastipur (n=22)			Begusarai (n=46)		
		FFP	NE	NE-FFP	FFP	NE	NE-FFP	FFP	NE	NE-FFP	FFP	NE	NE-FFP
Grain Yield	Q/ha	36.65	42.05	5.4**	36.71	43.31	6.6**	42.09	49.04	6.95**	40.63	46.88	6.25**
Fertilizer N	Kg/ha	100.83	116.5	15.67 ns	121.33	125	3.67 ns	138.12	140.62	2.5 ns	149.28	144.72	-4.56*
Fertilizer P_20_5	Kg/ha	69.38	56.91	-12.47*	52	66	14 ns	47.55	67.76	20.21 ns	68.62	71.69	3.07 ns
Fertilizer K_20	Kg/ha	44.76	77.83	33.07 ns	42	82.66	40.66 ns	24.88	88.65	63.77 ns	27.29	93.33	66.04 ns

**,* Significant at P<0.05 level, ns- non significant

Table 4: Effect of Nutrient Expert and farmer fertilizer practices trial variance on Economics

Parameter	Comprarison with FFP (n= 173) during 2014 to 2016				
	Unit	FFP	NE	(NE-FFP)	Remarks
Grain Yield	Q/ha	39.02	45.32	6.3	**
Fertilizer N	Kg/ha	127.39	131.71	4.32	ns
Fertilizer P_20_5	Kg/ha	59.38	65.59	6.21	ns
Fertilizer K_20	Kg/ha	34.73	85.61	50.88	ns
Fertilizer Cost	INR/ha	3440.6	4457.46	1016	ns
Grain yield Cost	INR/ha	58530	67980	9450	**
GRF	INR/ha	55089.4	63522.54	8434	**

**,* Significant at P<0.05 level, ns- non significant
GRF: grass return above fertilizer cost
FFP, NE: Farmer fertilizer practices and Nutrient expert,
Price (in Rs/kg): Wheat-15, N-11, P_20_5- 25, K_20- 16

Results and discussion

Results suggested that both grain yield in NE-based fertilizer recommendation plots were significantly higher at and 0.05 levels (Table-2). Across all sites, NE wheat increased yield and economic benefit (i.e. gross return above fertilizer costs) over FFP (Table-4). Results from 3 year data from 2014 to 2016, 173 on-farm sites in four districts of Bihar showed that NE significantly increased wheat yields and economic returns compared to the generalized Farmers' Fertilization Practice (FFP). NE's impact on fertilizer use in wheat shifte K application upwards while also minute upwards N and P application rates. We used recent advances in information and communication technology (ICT) and computer base applications of "Nutrient Expert for Wheat, Maize and Rice", which transform the science of SSNM into guidelines matching the field-specific needs and conditions of a farmer. Across all sites, NE wheat increased yield and economic benefit (i.e. gross return above fertilizer costs) over FFP (Table-4). Recommendations from NE wheat also increased yield (by .63 t/ha) over FFP with large increase in fertilizer K (+50.88 kg K_20/ha) and N and P fertilizer was minute increase N (+ 4.32 Kg N/ha) and P (+ 6.21 Kg P_2O_5/ha).So revealed that nutrient expert application resulted in significantly higher grain yields over farmer fertilizer practice (FFP). Average wheat grain yield in NE practice was 45.32 Kg ha-1, which was 13.9% more than the Farmer Fertilizer Practices, with NE recorded an additional net income of Rs.8434 ha-1 over FFP respectively. NE wheat recommendations were also tested against FFP in 173 locations in four districts in Bihar. This suggested that NE was able to better manage the variability in growing environments in Bihar and can therefore be a reliable tool for site-specific fertilizer application.

Conclusion

Site specific nutrient management (SSNM) is a new and useful concept. This concept is fundamental to precision nutrient applications in different crops. 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. Crop yields increase by over 13.9%, while amount of nutrients applied mostly balance fertilizer application. Farm profitability and NUE increase convincingly by using this novel concept. For efficient and effective SSNM, the use of soil and plant nutrient status sensing devices, remote sensing, GIS, decision support systems, simulation models and machines for variable application of nutrients play an important role.

References

1. Bruulselma TW, Fixen PE, Sulewski GD (Eds). 4R Plant Nutrition Manual: A Manual for Improving the Management of Plant Nutrition. International Plant Nutrition Institute (IPNI), Norcross, GA, USA. Fertilizer Statistics, 2012, 2010-11.
2. Gupta Raj, Jat ML, Gopal R, Kumar R. In: Souvenir, National Symposium on Resource management approached towards livelihood security, 2-4 Dec, Bengaluru, Karnataka, India, 2010, 1-10.
3. Majumdar K, Jat ML, Pampolino M, Kumar A, Shahi V, Gupta N *et al*. Economics of potassium fertilizer application in rice, wheat and maize grown in the Indo-Gangetic Plains. Indian Journal of Fertiliser, 2012; 8(5):44-53.
4. Nagarajan S. Can India produce enough wheat even by 2020? Current Science. 2005; 89(9):1467-1471.
5. Prasad R. Nitrogen and foodgrain production in India. Indian Journal of Fertiliser. 2011; 7(12):66-76.
6. Pampolino MF, Witt C, Pasuquin JM, Johnston A, Fisher MJ. Development approach and evaluation of the Nutrient Expert software for nutrient management in cereal crops. Computers and Electronics in Agriculture (in press), 2012.
7. Pathak H, Patra AK, Kalra N. Information technology based nutrient management for higher and sustainable crop yields. Indian Journal of Fertiliser. 2005; 1(4):27-28, 31-37.
8. Timsina J, Connor DJ. Productivity and Management of Rice-Wheat Cropping Systems: Issues and Challenges. Journal of Field Crops Research. 2001; 59:93-132.