Maximizing Productivity and Profit through Site-Specific Nutrient Management in Rice-Based Cropping Systems

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More comprehensive nutrient use strategies are required to offset the rates of nutrient depletion and emergence of multi-nutrient deficiencies within the western Indo-Gangetic Plain (IGP) region. This study's site-specific nutrient management (SSNM) strategy increased crop yield, system productivity, and profitability within different rice-based systems compared with treatments based on existing recommendations or farm practice.

Depletion of native nutrient reserves, emergence of multi-nutrient deficiencies, and decline in factor productivity of applied nutrients – the latter a measure of nutrient use efficiency defined by Snyder and Bruulsema (2007) as yield of harvested portion divided by amount of fertilizer nutrient applied – are major reasons for productivity stagnation in rice-based systems in the Upper Gangetic Plain region of India (Yadav 2000; Tiwari et al., 2006). Surveys conducted by the Project Directorate for Cropping Systems Research (PDCSR) in different agro-climatic regions indicate that current N-based farmer fertilization practices are creating nutrient imbalance in soil-plant systems, besides increasing pest incidence, cost of production, and environmental problems (Dwivedi et al., 2001). On the other hand, long-term experiments and other studies indicate that crop productivity can be sustained with balanced fertilization. SSNM can take into account all nutrient deficiencies to ensure crop demands are met and soil fertility is improved, which in turn ensures higher nutrient use efficiency, higher crop productivity, and higher economic returns (Dobermann et al., 2004).

Field experiments were conducted during 2008-09 at PDCSR Modipuram, Meerut, to evaluate the agronomic performance of five nutrient management options: (1) Farmer fertilizer practice (FFP), (2) State fertilizer recommendation (SR), (3) Improved State recommendation (ISR) providing 25% more N and 50% more P and K than the SR, (4) State soil testing laboratory recommendation (STLR), and (5) SSNM in systems growing wheat-rice, potato-rice, garlic-rice, chickpea-rice, mustard-rice, and berseem-rice.

The experimental site was located at 29° 4' N latitude, 77° 46' E longitude in western Uttar Pradesh on a Typic Ustochrept (Sobhapur sandy loam) soil within the Upper Gangetic Plains Region. The region has a semi-arid and sub-tropical climate with dry, hot summers and cold winters. The average annual rainfall is 810 mm, 75% of which is received between July and September. Initial soil samples were collected randomly from the experimental field. Soil analyses were done by Agro Services International Inc., per methods described by Portch and Hunter (2002) and SSNM recommendations were developed from soil test values and nutrient uptake requirements for the expected yield of different crops. The experimental site was alkaline in reaction and low in organic carbon (0.48%), available K (166 kg/ha) and S (4 mg/kg), and high in P (30 mg/kg). Available micronutrient contents including: Zn, Mn, Cu, Fe, and B were low to medium at 0.6, 12, 2, 47, and 0.4 mg/kg, respectively.

Abbreviations: N = nitrogen; P = phosphorus; K = potassium; S = sulfur; Zn = zinc; Mn = manganese; Cu = copper; Fe = iron; B = boron; DAP = diammonium phosphate; KCl = potassium chloride; INR = Indian rupee.

Table 1. Treatment details of different winter season crops.

	Rate applied, kg/ha					
Treatments	N	P_2O_5	K_2O	S	$ZnSO_4$	Borax
Wheat						
FFP	150	60				
SR	120	60	40			
ISR	150	75	60			
STLR	150	45	50			
SSNM	150	75	90	30	25	5
Potato						
FFP	250	150	40		25	
SR	180	80	100			
ISR	225	100	150			
STLR	225	60	125			
SSNM	210	100	150	40	40	10
Garlic						
FFP	22.5	58				
SR	125	60	60			
ISR	156	75	90			
STLR	156	45	75			
SSNM	150	90	120	45	25	
Chickpea						
FFP	22.5	58				
SR	20	50	30			
ISR	25	62.5	45			
STLR	25	37.5	37.5			
SSNM	30	75	75	20	40	5
Mustard						
FFP	60	60				
SR	120	50	40			
ISR	150	62.5	60			
STLR	150	37.5	50			
SSNM	150	75	90	45	15	5
Berseem (fodder crop)						
FFP	75	50				
SR	30	60				
ISR	37.5	45				
STLR	37.5	45				
SSNM	40	100	100	20	20	5

Note: Rice was grown after each crop with same treatments structure following the general recommendation for rice.

The experiment used a split-plot design with three replications. The treatment details for winter season crops are given in **Table 1**. A succeeding rice crop was grown in the same

Table 2. Effect of nutrient management options on productivity (kg/ha) of different rice-based cropping systems.

Nutrient management options	Mustard	Chickpea	Garlic clover	Berseem green (fodder)	Potato tuber	Wheat
FFP	1,688	1,970	4,512	75,050	17,900	5,029
SR	2,090	2,188	6,575	85,101	22,600	5,610
ISR	2,240	2,442	7,022	87,772	24,200	6,071
STLR	2,105	2,210	6,640	80,029	21,800	5,658
SSNM	2,312	2,652	7,534	92,219	27,500	6,255
CD<0.05	126	214	512	-	2,010	416
	------------------------------ Residual rice yield ------------------------------					
FFP	6,745	6,839	7,070	7,161	7,248	6,790
SR	7,276	7,903	7,329	8,071	8,115	7,237
ISR	8,145	8,111	8,023	8,524	8,456	7,745
STLR	7,771	8,042	8,469	8,386	8,310	7,027
SSNM	9,041	9,250	9,025	9,338	9,542	8,836
CD<0.05	772	823	664	938	734	543

CD denotes critical difference, which is similar to the least significant difference.

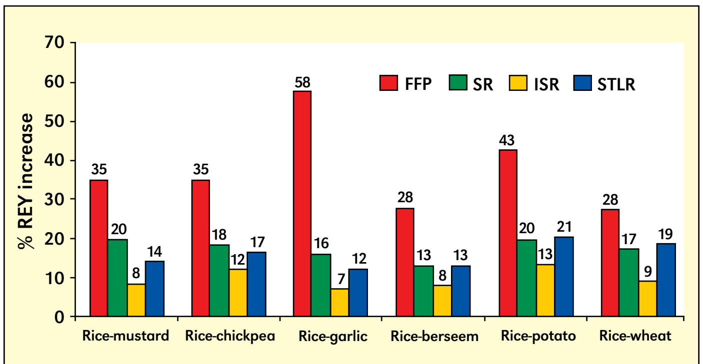

Figure 1. Percent increase in system productivity (Rice equivalent yield) generated by the SSNM treatment over other nutrient management options applied in different cropping systems.

layout, using NPK fertilizer only, to assess the carry-over effect of secondary and micronutrient applications. Fertilizer sources included urea, DAP, KCl, gypsum, zinc sulphate ($ZnSO_4$), and sodium tetra-borate (Borax).

Application of the ISR and SSNM treatments both had a significant influence on mustard productivity. However, significant gains over FFP, the SR, and the STLR were only generated with SSNM **(Table 2)**. In chickpea, SSNM produced the highest grain yield followed by ISR, STLR, SR, and FFP. The effect of SSNM on garlic was more pronounced than in other crops as about 67% more clove yield was obtained in SSNM than with FFP. Clove yield with ISR was 56% higher than with FFP. Number of cloves/bunch and weight of clove bunch/plant were the important yield contributing parameters, when considering the effect of SSNM on crop growth and development (data not shown). Use of either the ISR or SSNM not only enhanced potato tuber yield, but also had pronounced effect on total dry matter content, tuber size, and specific gravity (data not shown). Tuber yields resulting from SSNM and the ISR were 54% and 35%, 22% and 7%, and 26% and 11% higher than FFP, the SR, and STLR, respectively. Berseem fodder yield increased up to the third cutting and thereafter it declined with age. Green fodder yield from SSNM, the ISR, the SR, and the STLR were 23%, 17%, 13%, and 7% higher yield than FFP. Wheat yield under SSNM and the ISR were 24% and 21% higher than FFP. This increase was ascribed to greater head length, higher grains/head, and higher numbers of effective tillers per m^2. Application of fertilizer according to the SR or STLR certainly out-yielded FFP, but these treatments generated 0.6 t/ha less grain compared to SSNM.

Rice grown on the same layout after different winter season crops was markedly influenced by the different nutrient management options **(Table 2)**. Averaged across the cropping system, yield gain over FFP was 0.68 t/ha, 1.19 t/ha, 1.03 t/ha, and 2.20 t/ha due to the SR, ISR, STLR, or SSNM, respectively. The significant difference between SSNM and other nutrient management options may be ascribed to the residual effect of nutrients applied to previous winter crops, particularly secondary and micronutrients. Among the various cropping systems (averaged over the nutrient management options), the higher rice yield was recorded under rice-potato (8.33 t/ha) followed by rice-berseem (8.3 t/ha), rice-chickpea (8.0 t/ha), rice-garlic (8.0 t/ha), and rice-mustard (7.8 t/ha). It was lowest under rice-wheat. Lower productivity with the rice-wheat system was probably due to adverse effects of biotic and abiotic stresses associated with growing two cereal crops in sequence. On the other hand, component crops like potato and chickpea have different root feeding zones within the soil profile and can leave sufficient residual nutrient to a succeeding rice crop. The necessity for crop diversification along with appropriate nutrient management options is highlighted by this result.

The average system productivity across the treatments, in terms of rice equivalent yield (REY) [(kg yield x unit price/unit price of rice) + rice yield], was highest in rice-garlic (40.34 t/ha) followed by rice-potato (17.55 t/ha), rice-berseem (15.52 t/ha), rice-wheat (13.70 t/ha), and rice-chickpea (12.0 t/ha). It was lowest in rice-mustard (11.62 t/ha). SSNM out-yielded the other nutrient management options and had 28 to 58% extra REY when compared to FFP **(Figure 1)**. The second most promising option was ISR, which gave 5 to 10% additional yield over the SR, 4 to 10% yield over the STLR, and 17 to 47% over FFP. The advantage of SSNM over the ISR is mainly attributed to better balance and adequate application of all yield-limiting nutrients. These results corroborated earlier work done under rice-wheat and rice-rice system by Singh et al. (2008, 2009) and Gill and Singh (2009).

Implementation of SSNM involved an added expense, which ranged between INR 1,210 in rice-potato to INR 4,488 in rice-garlic **(Table 3)**. SSNM was most beneficial within the rice-potato system through its highest additional return over FFP as well as its lowest extra cost. INR return per INR invested in SSNM were calculated at 13.3 in rice-wheat, 50.2 in rice-potato, 37.1 in rice-garlic, 10.2 in rice-chickpea, 10.3 in rice-mustard, and 9.8 in rice-berseem.

Table 3. Extra cost and returns due to fertilization (INR/ha) over farmer fertilizer practice.

Nutrient management options	Rice-wheat	Rice-potato	Rice-garlic	Rice-chickpea	Rice-mustard	Rice-berseem
			Extra cost			
SR	285	-1,840	1,418	739	345	831
ISR	698	-662	2,219	1,110	1,016	1,157
STLR	128	-1,510	1,611	642	529	662
SSNM	2,388	1,210	4,488	3,224	3,110	2,876
			Extra return			
SR	10,985	29,518	104,196	14,204	12,610	13,547
ISR	20,178	38,093	137,717	19,955	23,804	19,195
STLR	8,541	27,950	118,861	15,539	17,210	14,260
SSNM	31,946	60,765	166,478	33,034	31,904	28,163

Notes: The prices (INR per kg) for input materials were: N = 11.15; P = 46.11, when applied with SSP and 47.46 when applied with DAP; S = 26.43; Zn = 76.19; and B = 76.19. The cost of N supplied through DAP was subtracted from the cost of N supplied through urea. The prices (INR per kg) of produce were 10 for rice, 18.3 for mustard, 17.3 for chickpea, 50 for garlic clove, 0.50 for berseem fodder, 4 for potato, and 10.8 for wheat. 1 USD is approximately 45 INR.

Widespread multinutrient deficiencies (K, S, Zn, and B) within the soils of the intensively cultivated IGP, owing to constant depletion, have become major constraints to improving productivity. These results underline the significance of soil test-based SSNM in augumenting crop yields, system productivity, and net returns. Generalized recommendations prove to be suboptimal and insufficient for high yielding varieties grown under intensive cropping systems. Such recommendations require an upward revision as well as more inclusive consideration of all yield-limiting nutrients.

Although implementation of SSNM involved added expense, it was offset by substantial yield responses (direct as well as residual) to secondary and micronutrients (S, Zn, and B in this present study). This suggests that balanced fertilization within the region no longer means application of NP or NPK. There is further need to study the impact of each primary, secondary, and micronutrient included within the SSNM recommendation to establish their individual significance in balanced fertilization. BC

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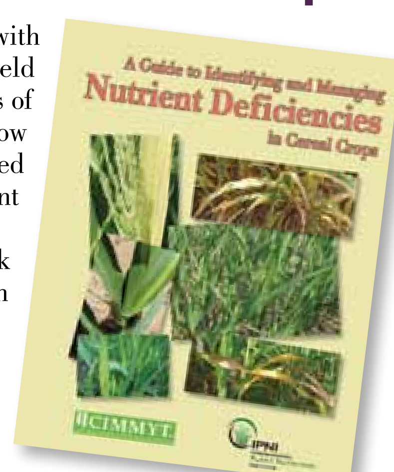
A Guide to Identifying and Managing Nutrient Deficiencies in Cereal Crops



A new booklet has been developed by the IPNI South Asia Program in cooperation with the International Maize and Wheat Improvement Center (CIMMYT). It is a 50-page field guide (8 1/2 x 11 in. size, wire-o bound) designed to describe the underlying causes of nutrient deficiencies in maize, wheat, rice, sorghum, pearlmillet, and barley, with tips on how they might be prevented or remedied. Hundreds of excellent deficiency photographs provided by the authors and IPNI will allow the user of this field guide to understand the development of nutrient deficiency symptoms through the growth stages of the crop.

Titled *A Guide to Identifying and Managing Nutrient Deficiencies in Cereal Crops*, this book should be a useful reference for researchers and extension staff involved in cereal production and knowledge dissemination. It will help minimize cereal yield losses.

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