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PERFORMANCE OF SITE-SPECIFIC NUTRIENT MANAGEMENT IN RICE-WHEAT CROPPING SYSTEM

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ABSTRACT

A multi-location trial was conducted during 2008-09 to 2010-11 on farmers' field to assess the impact of site-specific nutrient management (SSNM) through soil test crop response (STCR) in rice-wheat cropping system (RWCS). The results revealed that the grain yield of RWCS was notably higher in SSNM over GRD (general recommended dose) and FP (farmers' practice) at all the locations averaged over the years. The SSNM generated a yield advantage of 0.96 (13.4%) and 3.05 t/ha (60%) respectively over GRD and FP plots. Further it was noted that 0.11 t/ha additional yield of rice-wheat was recorded over the targeted yields. The study reflected that the SSNM saved the significant quantity of nutrients (19 kg N and 8 kg P ha^{-1}) over GRD and 18 kg/ha of fertilizer P in comparison to FP. The feasibility computed in terms of kg grain kg^{-1} fertilizer use involved for NPK nutrients indicated that one kg N, P_2O_5 and K_2O gave 15.51 and 15.1 kg grain with SSNM in rice and wheat respectively over 10.81 and 10.29 kg grain kg^{-1} NPK fertilizer with GRD in rice and wheat crops. The study thus confirmed that the SSNM approach can be adopted by the farmers for increasing the rice-wheat productivity to the desired level and simultaneously to rectify the multiple nutrient deficiencies to sustain the soil health.

INTRODUCTION

Declining soil fertility and mismanagement of plant nutrients have made the task of providing food for the world's population in 2020 and beyond more difficult. Soil is a living organism that changes in space and in time, thereby affecting availability of plant available nutrients. The spatial variation in soil type, even within one to two ha paddocks, offers farmers scope to differentially manage nutrient applications to these contrasting areas. Rice, wheat, and maize are the major sources of calories for the rising human population in Asian countries. The production of these cereal staples must increase by 1.2% to 1.5% annually to meet rising demand and ensure food security (Buresh, 2010). The rice-wheat cropping system (RWCS) is India's most widely adopted system across the country. Rice based cropping systems are the major production systems contributing to food production. Wheat is the world's third most-produced cereal after maize and rice and India is the second largest wheat producer in the world (Meena *et al.*, 2013). In India, the productivity of both rice and wheat is relatively low which was recorded 2,410 and 3,290 kg/ha, respectively during 11th plan period (GOI, 2013), it was mainly due to poor soil fertility, inadequate, unbalanced, and inefficient use of fertilizers. Kymore Plateau and Satpura Hills zone of central India is also dominated by rice-wheat cropping system, where rice is grown in the summer months (July to October), followed by wheat in the winter months (November to mid-April). Continuous rice-wheat cropping without adequate and balanced nutrition has resulted in a widespread problem of multiple nutrient deficiencies which therefore results low crop yields (Timsina and Connor, 2001). The efficiency of fertilizers can be improved by fertigation instead surface application which can reduce the nutrient deficiencies (Vanitha and Mohandass, 2014).

The average rice and wheat productivity in Madhya Pradesh is 919 and 2,053 kg/ha respectively, which is comparatively quite low than the national average. As per GOI, 2013 estimates, the all-India average fertilizer consumption is much lower (144 kg per ha) than that in Pakistan (205) and China (396). Further, very high variability has been observed in fertilizer consumption across the states and crops. Among the states, the fertilizer consumption in Madhya Pradesh is 88.36 kg/ha, which is comparatively very low to that of Punjab (243.56 kg) and Andhra Pradesh (266.11 kg). Rice-wheat is cultivated in more than one lakh hectare with the average productivity of 1035 and 1184 kg/ha respectively in Katni district which falls in Kymore Plateau and Satpura Hills zone (Anonymous, 2011). Low production of rice-wheat is mainly attributed to imbalanced and insufficient nutrient use (47 kg NPK/ha) in the state. The NPK consumption in the study area is 48.45 kg /ha. The fertilizer nutrients use and removal by different crops in various agro-climatic zones of MP have shown that there is a negative balance of about 1.09 million tonnes of NPK and 0.05 million tonnes of sulphur in the state.

The balance of NPK and sulphur is negative in all the agro-climatic zones except the Nimar Valley Zone of the state. Acute deficiencies of other nutrients in the future are expected if remedial measures are not taken to reduce the nutrient gap (Kauraw, 2012).

Current crop production systems are characterized by inadequate and imbalanced use of fertilizers; blanket fertilizer recommendations over large domains with least regard to the variability in soil fertility and productivity. Recent on farm research demonstrated existence of large field variability in terms of soil nutrient supply, nutrient use efficiency, crop responses etc. Managing this variability is a principal challenge for further increasing crop productivity of intensive rice crop systems (Rao, 2011). Existing fertilizer recommendations often consist of predetermined rates of N, P and K for vast areas. Such recommendations assume that the need of a crop for nutrients is constant over time and over large areas. But, the growth and needs of a crop for supplemental nutrients can vary greatly among fields, seasons, and years as a result of differences in crop-growing conditions, crop and soil management, and climate. Hence, the management of nutrients requires an approach that enables adjustments in N, P, and K applications to accommodate the field-specific needs of the crop for supplemental nutrients. Site specific nutrient management (SSNM) is the application of nutrients to meet the specific needs of plants within the pre-defined, spatially explicit land management units, by way of variable rate fertilizer application technologies (Haneklaus and Schnug, 2006). SSNM promotes agricultural sustainability through improved nutrient efficiency, higher net financial returns, protection of natural resources and minimization of nutrient emissions to the environment.

Keeping in view the above, a multi-location trial was conducted during 2008-09 to 2010-11 on farmers' field in rice-wheat cropping system (RWCS) with the objective to assess the performance of site specific management (SSNM) through soil test crop response (STCR) approach and other nutrient management options in rice and wheat.

MATERIALS AND METHODS

Trials were conducted in participatory mode at farmers' field for 3 years during to 2008-09 to 2010-11 to evaluate the effect of SSNM in rice-wheat cropping systems at 5 locations in Katni district falls under Kymore Plateau and Satpura Hills zone of Central India. The mixed red and black soils of the trial sites were generally silty clay loam in texture. Soils were very low to low in available N, medium in available P and K and low in available sulphur. The initial soil analysis was done as per the standard methods. These soil analyses were the basis for developing SSNM recommendations for yield targets of 4 t/ha for each crop. The SSNM nutrient packages were based on soil test crop response (STCR) approach for both crops and each locations included all macro and one secondary nutrient (Table 1). Fertilizer requirement for SSNM was computed through fertilizer adjustment equation given by All India Co-ordinated Research Project on soil test crop response (STCR) recommended for the study area which is as under-

Rice	Wheat
Fertilizer N = 4.25 TY-0.45 SN	Fertilizer N = 4.4 TY-0.40 SN
Fertilizer P_2O_5 = 3.55 TY-4.89 SP	Fertilizer P_2O_5 = 4.0 TY-5.73 SP
Fertilizer K_2O = 2.1 TY-0.18 SK	Fertilizer K_2O = 2.53TY-0.16 SK

Where

T = Target yield, q ha^{-1}; SN = Soil available N, kg ha^{-1}

SP = Soil available P, kg ha^{-1}; SK = Soil available K, kg ha^{-1}

Using the above fertilizer adjustment equations the quantity of fertilizer nutrients required for achieving 4 tone ha^{-1} grain yield of rice and wheat was worked out. The efficacy of SSNM was compared against a general fertilizer recommended dose (GRD) and farmers' fertilizer practice (FP). Fertilizer sources included urea (46% N), single super phosphate (16% P_2O_5 and 12% S) and potassium chloride (60% K_2O). Entire quantities of P, K and S and one-third of the total N were applied at planting. The remaining N was top-dressed in two equal splits. Rice cv. IR 36 and wheat cv. HD 2864 was grown at all the locations. Agronomic efficiency and feasibility was assessed on the individual crop and cropping system basis. Results reported here are year wise averages of the locations and average of 3 years of study.

RESULTS AND DISCUSSION

Across the locations and over the years, the panicles per plant and rice grain yield were remarkably higher with SSNM followed by GRD and FP (Table 2). It was observed from the data that panicle per plant with SSNM was 35 and 163% higher over GRD and FP treatments respectively. The grain yield of rice (unhusked) obtained with the SSNM was 4.03 t/ha as compared to 3.49 t/ha under the GRD and 2.46 t/ha under FP. Averaged over the locations, the panicles per plant and grain yield of the succeeding wheat crop was significantly higher with SSNM followed by GRD and FP (Table 2). The panicle per plant with SSNM was 10 and 59% higher over GRD and FP treatments respectively. The grain yield of wheat was 4.08 t/ha with SSNM against 3.66 and 2.60 t/ha under GRD and FP plots respectively. It was observed that on an average, an additional yield of 0.03 and 0.08 t/ha was recorded respectively in both crops over the target yield of 4 t/ha. An additional grain yield of 0.11 t/ha was recorded in RWCS over the target yields, which indicates that SSNM out-yielded in excess to the target yield due to higher nutrient uptake as a consequence of précised application of nutrients which fulfilled the need of the crop due to improved nutrient use efficiency. The average grain yield with GRD was more than 1.0 t/ha over FP in both crops. The low grain yield of FP may be attributed to imbalanced fertilizer application resulted restricted nutrient uptake by the plants. Many researchers have worked on SSNM approach and its application in various crops. It has been reported by Witt *et al*., 1999 that the SSNM approach provides the scientific principles for determining the amounts of N, P, and K that best match the field-specific needs of a cereal crop for supplemental nutrients. The approach originated from the direct relationship between crop yield and the need of the crop for a nutrient, as determined from the total amount of the nutrient in the crop at maturity. Khurana *et al*., 2008 conducted research experiments on SSNM in rice-wheat cropping system and they observed that on average, SSNM produced a yield gain of at least 17% and 12% in rice and wheat crops, respectively, compared with farmers' field practice. It was reported by Singh *et al.*, 2008 that the productivity of the entire rice-wheat system was highest under SSNM, which was 35% more than farmers' practice. The findings are also in conformity with those of Singh *et al.*, 2015 who observed that fertilizer application through STCR technology in transplanted rice resulted in 3.792 tone ha^{-1} grain yield which was nearly 95% of the established target (4 tone ha^{-1}) and it was appreciably higher than that of the GRD plot yield.

On the whole, the yield response of SSNM in rice, wheat and RWCS was significantly higher over GRD and FP plots over the locations and across the years during the study. Averaged across the years, the rice SSNM plot out-yielded GRD by 0.54

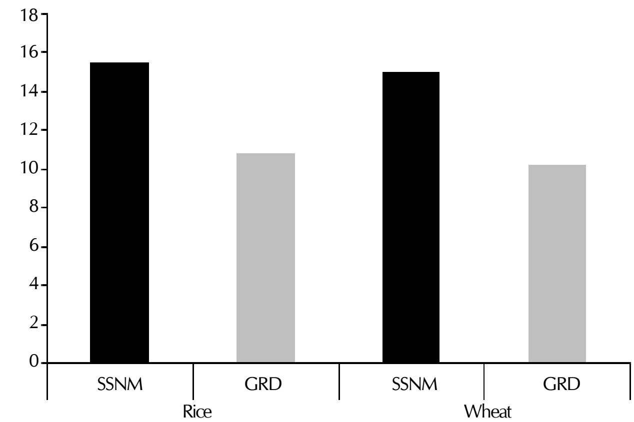

Figure 1: Yield response (kg) kg^{-1} fertilizer nutrient use in rice-wheat

Table 1: Nutrients applied in rice-wheat cropping system

Nutrient management options	Nutrients applied (Kg/ha) Rice	Wheat	Rice-wheat cropping system
SSNM	$N_{111}P_{50}K_{38}S_{38}$	$N_{114}P_{46}K_{63}S_{35}$	$N_{225}P_{96}K_{101}S_{73}$
GRD	$N_{116}P_{44}K_{33}S_{0}$	$N_{128}P_{60}K_{40}S_{0}$	$N_{244}P_{104}K_{73}S_{0}$
FP	$N_{41}P_{57}K_{0}S_{0}$	$N_{68}P_{57}K_{0}S_{0}$	$N_{109}P_{114}K_{0}S_{0}$

Table 2: Effect of nutrient management practices on growth and grain yield (mean over locations)

Nutrient management options	Panicles/Plant		Grain Yield (t/ha)		Per cent deviation in grain yield from the target		
	Rice	Wheat	Rice	Wheat	Rice	Wheat	R-W System
SSNM	41.5	3.30	4.03	4.08	(+) 0.03	(+) 0.08	(+) 0.11
GRD	30.8	3.00	3.49	3.66	-	-	-
FP	15.8	2.07	2.46	2.60	-	-	-
CD (0.05)	1.25	0.21	1.09	0.70	-	-	-

Table 3: Grain yield response to SSNM and general recommended fertilizer doses over farmers' practice (mean over locations)

Nutrient management options	Rice			Wheat			Rice-wheat system		
	Yield (t/ha)	Response (t/ha)	%	Yield (t/ha)	Response (t/ha)	%	Yield (t/ha)	Response (t/ha)	%
SSNM	4.03	1.57	64	4.08	1.48	57	8.11	3.05	60
GRD	3.49	1.03	42	3.66	1.06	41	7.15	2.09	41
FP	2.46	-	-	2.60	-	-	5.06	-	-
CD (0.05)	1.09	-	-	0.70	-	-	1.03	-	-

Table 4: Major nutrients' saving and cost economics# in site specific nutrient management *vs* other nutrient management approaches

Year	Nutrient saving in SSNM over GRD (kg/ha)			Nutrient saving in SSNM over FP (kg/ha)			Cost saving in SSNM over GRD(Rs./ha)		Total Saving over GRD(Rs./ha)	Additional cost incurred in K (SSNMover GRD)	Net saving in SSNM over GRD(Rs./ha)
	N	P	K	N	P	K	N	P			
Rice	5	(-)6	(-)5	(-)70	7	(-)38	50	(-) 138	(-)88	35	(-)123
Wheat	14	14	(-)23	(-)46	11	(-)63	140	322	462	161	301
RCWS	19	8	(-)28	(-)116	18	(-)101	190	184	374	196	178

#Cost economics based on 2008-09 and 2009-10 costs of nutrients. Fertilizer (Rs./kg): N, 10; P_2O_5, 23; K_2O, 7.

Table 5: Agronomic efficiency (AE) articulated as kg grain/kg of K_2O and S application through SSNM and GRD in the rice-wheat cropping system

Nutrient management options	AE_K			AE_S		
	Rice	Wheat	RWCS	Rice	Wheat	RWCS
SSNM	41.3	23.5	30.2	41.3	42.3	41.8
GRD	31.2	26.5	28.6	-	-	-

t/ha (+15.5%) and FP by 1.57 t/ha (+64%), however, in succeeding wheat crop, the SSNM plot out-yielded GRD by 0.42 t/ha (+11.5%) and FP by 1.48 t/ha (+57%) over the years (Table 3). In RWCS, it was observed that the yield advantage with SSNM plots was 0.96 t/ha (+13.4%) over GRD and 3.05 t/ha (+60%) over FP across the years. A significant yield response for GRD was also obtained in rice and wheat crops and the magnitude of yield increase over FP was 1.03 t/ha (+42%) and 1.06 t/ha (+41%) respectively with a cumulative yield enhancement of 2.09 t/ha (+41%) in RWCS across the locations during the trial period. The low yield in FP was mainly attributed to imbalanced application of N and P nutrients and no use of K and other essential nutrients. Based on the study conducted on site-specific nutrient management, Dobermann *et al.*, 2004 reported that existing N or NP-driven agriculture cannot sustain high yield agriculture; hence, adequate supply of P, K and other deficient secondary and micronutrients is essential.It has been reported by the researchers (Fairhurst *et al.*, 2007; IRRI, 2010b) that remarkable response of SSNM in rice was observed due to effectively supplying nutrients to the crop as and when needed and has consistently increased the yield under on-farm evaluation conducted across Asia.

Nutrient saving and cost economics

Averaged over the years, shifting from FP to SSNM in rice involved an additional consumption of 70 kg N and 38 kg K/ha, however, 7 kg P/ha saved with SSNM plots (Table 4). The cost statistics of nutrients confirmed that an additional expenditure of Rs. 805 incurred in SSNM over FP in rice cultivation, whereas, this figure was Rs. 123 when compared to GRD as an additional consumption of 6 kg P and 5 kg K/ha implicated in SSNM and 5 kg N/ha saved over GRD plots. In the succeeding wheat crop, moving from FP to SSNM involved an additional consumption of 46kg N and 63kg K/ha, however, 11kg P/ha saved with SSNM plots. The cost statistics indicated that an additional investment of Rs. 648 incurred as excess fertilizer nutrient cost of major nutrients in SSNM over FP plots; however, in comparison to GRD net saving of Rs. 301 was recorded in nutrient cost with SSNM plots due to saving of 14kg N and 14kg P/ha averaged over the years in wheat cultivation.

The statistics of RWCS cultivation indicated that the SSNM plots involved an additional consumption of 116kg N and 101kg K/ha, however, 18 kg P/ha saved during cultivation. The nutrient cost analysis confirmed that an additional investment of Rs. 1453 incurred as excess fertilizer nutrient cost of major nutrients in SSNM over FP plots; however, in comparison to GRD net saving of Rs. 178 was recorded in nutrient cost with SSNM plots due to saving of 19 kg N and 8 kg P/ha in rice-wheat cultivation.These results thus suggest that use of NPK is inadequate in FP, whereas, GRD involves higher nutrients' consumption to that of SSNM; however, the effect of the additional fertilizer nutrients in GRD seems unresponsive with respect to the grain yields of rice-wheat. Singh *et al.*, 2008 mentioned in their study conducted on SSNM in rice-wheat cropping system which showed that despite of extra cost involvement in SSNM, the technology was found reasonable as it out-yielded higher grain yields. Houshmandfar and Kimaro, 2011 found in their study that LCC based N management in rice can save 25 percent excess nitrogen application with no yield lose by appropriately revising the fertilizer recommendation, thus, there is considerable opportunity to increase farmers yield and N recovery efficiency levels through improved N management with the LCC. Khurana *et al.*, 2008 reported that SSNM saved a significant amount (8 and 10% for rice and wheat, respectively) of fertilizer N compared with farmers' field practice.

Agronomic efficiency

Agronomic efficiency (AE) calculated for K_2O and S in SSNM and GRD plots only as these nutrients were not applied in FP plots which treated as unfertilized. The agronomic efficiency expressed as kg grain/kg was greater with SSNM plots in rice and rice-wheat cultivation compared to the GRD for K_2O and it was noted to be 41.3 and 30.2 respectively. The agronomic efficiency in wheat was 23.5 kg grain/kg K_2O which was lower to that of GRD (26.5 kg/kg K_2O) over FP plots. The corresponding increase in AE was 10.6 kg rice/kg and 1.6 kg rice-wheat/kg for K_2O (Table 5). Average AE for S was 42.3 in wheat followed by RWCS (41.8) and 41.3 kg in rice/kg/S respectively. The feasibility computed in terms of kg grain kg^{-1} fertilizer use involved for NPK nutrients indicated that one kg N, $P_2O_5$and K_2O gave 15.51 and15.1 kg grain with SSNM in rice and wheat respectively (Fig. 1), while, 10.81 and 10.29 kg grain kg^{-1} nutrient was recorded with GRD in rice and wheat crops. These findings thus suggest that SSNM is the superlative option with respect to grain yields and technology is appropriate for rice-wheat cultivation.

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