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Site-specific nutrient management: impact on productivity, nutrient uptake and economics of rice-wheat system

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ABSTRACT

A field experiment was conducted on Typic Ustochrept soil at the Crop Research Centre of Sardar Vallabhbhai Patel University of Agriculture and Technology, Meerut, for two years (2014–15 to 2015–16) to evaluate site specific nutrient management (SSNM) against state recommendation (SR), integration of SSNM and SR with crop residue and farm yard manure. In terms of crop growth yield, nutrient uptake and economics, SSNM had significantly higher growth parameters, viz. number of tillers/m^2 and dry matter accumulation as compared to SR in both rice and wheat crops. Different yield attributes, viz. number of grains/panicle or spike, test weight of rice and wheat were also higher with SSNM. SSNM out yielded for rice, wheat and rice-wheat system (RWS) productivity by 10.3%, 14.1% and 11.9%. System N, P and K uptake under SSNM was also higher by 24.36, 9.55 and 36.01 kg/ha, respectively, compared to SR. An additional income of ₹12953/ha over SR and maximum return/rupee invested (₹2.50) was also recorded with SSNM. Recycling of 5 t/ha rice and wheat straw residue along with SSNM had added advantage.

Keywords: Economics, Nutrient uptake, Rice-wheat system, Site-specific nutrient management

Rice-wheat system (RWS) is one of the important sources of food security, income and employment in India covering 10.3 mha area (Dwivedi *et al.* 2003, Singh 2011). Fertilizer use in RWS is highly imbalanced and variable across the Indo-Gangetic Plains (IGP) and shows production fatigue (Singh *et al.* 2013). Fertilizer application is mostly confined to N followed by sub-optimal P use; other nutrients are almost ignored (Singh *et al.* 2005). Therefore, quantity of fertilizer applied to this cropping system cannot fulfil the amount of nutrients removed from the soil, which leads to soil and production inertia (Singh *et al.* 2014). The situation of nutrient drawing out is further more disturbing in the highly productive areas of the IGP of India, where widely adopted RWS is practised with inadequate and unbalanced nutrient management (Singh *et al.* 2015a). Therefore, balanced fertilization is indispensable to maintain the sustainability of RWS. Balanced nutrition increases a plant's ability to absorb requisite amount of desired nutrient thereby, improving crop productivity and input use efficiency. Site-specific nutrient management (SSNM) approach which deals with nutrient use as per crop demand and indigenous nutrient supply is a promising option to ensure balanced nutrient supply along with sustainable soil health (Singh *et al.* 2014). The present study was planned to assess effect of different SSNM options under RWS on crop productivity, nutrient uptake and economics in western IGP.

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MATERIALS AND METHODS

The study was carried out during 2014–15 and 2015–16 at the Crop Research Centre of Sardar Vallabhbhai Patel University of Agriculture and Technology, Meerut, Uttar Pradesh. The research site is geographically located at 29°08' N latitude and 77° 41' E longitude at an altitude of 237 meters amsl, and falls in Upper Gangetic Plains of IGP. Initial soil samples were analysed using standard procedure following Page *et al.* (1982). The soil was sandy loam in texture with *p*H 8.0, organic carbon 4.4 g/kg and available N, P and K (210, 10.9 and 231.4 kg/ha, respectively). The available S, Zn and B content of experimental field were 13.7, 0.95 and 0.62 mg/kg, respectively. Rice cultivar Pusa Basmati-1509 and wheat cultivar Raj-3765 were grown in sequence. The experiment was laid out in a randomized block design with 11 treatments comprising state recommended NPK, viz. (SR i.e.100 N, 60 P_2O_5 and 60 K_2O kg/ha in rice and 120 N, 60 P_2O_5 and 40 K_2O kg/ha in wheat (T_1), SR (-K) (T_2), SR (-P) (T_3), SR (-N) (T_4), SR + residue @5 t/ha to both crops (T_5), SR + FYM @10 t/ha to rice and recommended NPK to wheat (T_6), site specific nutrient management (SSNM) i.e. 100 kg N, 60 kg P_2O_5, 60 kg K_2O, 30 kg S, 5 kg Zn and 5 kg Borax/ha in rice and 150 kg N, 75 kg P_2O_5, 75 kg K_2O/ha in wheat) (T_7), SSNM (-K) (T_8), SSNM (-P) (T_9), SSNM + residue @5 t/ha to both rice and wheat (T_{10}), and SSNM (-K) + residue @5 t/ha to both rice and wheat (T_{11}) replicated thrice. Crop growth parameters were estimated at 90-days after establishment of rice and wheat crops. The leaf area index (LAI) was estimated by leaves of five plants taken from each penultimate rows and leaf area was recorded with a leaf area meter. At maturity, crops were harvested manually just above the ground, sun dried, the total biomass yield was measured; threshed with plot thresher and grain yield weighed. At harvest, yield attributes were also recorded. Representative grain and straw sample of rice and wheat were collected at harvest and dried at 70°C, ground in a stainless-steel Wiley mill, and then wet digested with concentrated H_2SO_4 for determining total N, digested with concentrated HNO_3 and $HClO_4$ (mixed in 1:4 ratio) for determining of total P and K. Total N, P and K uptake was assessed by multiplying their content in grain and straw with yield obtained. The cost of cultivation of rice and wheat, and overall RWS was calculated as per standard rate of material existing in particular year. Gross returns due to different nutrient management options were worked out using minimum support price fixed by the Government of India for rice and wheat. The results of the present study are based on pooled statistical analysis of data over two years, as per the procedure suggested by Gomez and Gomez (1984).

RESULTS AND DISCUSSION

Growth attributes of rice and wheat: In rice maximum, number of tillers (343/m^2), dry matter accumulation (DMA) (286.3 g/m row) and LAI (4.98) were noticed with SSNM + residue (T_{10}) (Table 1). The results were statistically comparable to the effects of the treatment T_6 regarding number of tillers/m^2, with T_7 regarding DMA but significantly superior over rest of the treatments in case of LAI. In succeeding wheat, SSNM + residue (T_{10}) again showed its superiority with higher number of tillers (1032/m^2), DMA (239 g/m row) which were statistically at par with the treatments T_1, T_5, T_6 for number of tillers/m^2 and T_5, T_6 and T_7 for DMA. Almost similar variation was noticed with different fertility management options in case of LAI of wheat during the study. Optimized nutrient use under SSNM might have caused increased cell division, enlargement, photosynthesis and protein synthesis that are responsible for quantitative improvement in plant growth attributes like tillering (Singh *et al.* 2015b). Omission of N or P or K from fertilization schedule had apparent negative effect on different growth parameters and the magnitude of negative effect was more with N omission followed by K and P (Table 1). Incorporation of residue along with SSNM (-K) plots could not suffice the losses due to K omission indicating K supply through 5 t/ha residue to both rice and wheat crop was not sufficient to meet the K requirement as per crop demand (Singh *et al.* 2018).

Yield attributes of rice and wheat: In rice, maximum number of grain/panicle (79) and 1000-grain weight (34.57 g)

Table 1 Growth and yield parameters of rice, wheat and system rice equivalent productivity (SREP) as affected by different nutrient management options

Treatment	Rice							Wheat							SREP (t/ha)
	No. of tillers/m^2	Dry matter accumulation (g/m row)	Leaf area index	No. of grains/ panicle	1000- grain weight (g)	Grain yield (t/ha)	Harvest index	No. of tiller/m^2	Dry matter accumulation (g/m row)	Leaf area index	No. of grains/ spike	1000- grain weight (g)	Grain yield (t/ha)	Harvest index	
T_1	275	250.83	4.31	66	31.97	3.60	37.69	925	206.88	2.90	41	38.41	3.55	39.25	6.21
T_2	269	233.73	3.98	61	30.27	3.42	36.26	915	191.04	2.69	37	36.80	3.35	39.40	5.89
T_3	272	224.07	4.06	64	30.87	3.48	37.10	921	194.88	2.72	38	36.83	3.17	37.87	5.81
T_4	204	208.60	3.81	59	29.83	2.68	36.65	540	182.88	2.57	28	32.86	1.87	39.67	4.06
T_5	306	261.20	4.76	72	32.47	3.98	40.22	967	228.48	2.81	40	38.37	3.80	40.98	6.78
T_6	331	265.23	4.82	75	33.93	3.97	40.63	999	231.36	2.95	43	38.92	4.01	40.56	6.92
T_7	320	273.07	4.89	73	33.24	3.97	42.38	1021	234.72	2.99	43	39.54	4.05	41.54	6.95
T_8	279	250.07	4.26	65	31.17	3.60	37.56	940	204.48	2.75	37	37.63	3.67	40.70	6.30
T_9	289	244.60	4.58	67	31.52	3.73	38.75	948	219.84	2.71	38	37.93	3.74	41.42	6.48
T_{10}	343	286.27	4.98	79	34.57	4.25	42.54	1032	239.04	3.00	45	39.96	4.09	41.64	7.26
T_{11}	293	250.40	4.62	69	32.17	3.88	41.36	964	221.76	2.94	41	38.77	3.85	40.76	6.71
SEm±	5.2	4.95	0.02	1.8	0.52	0.07	0.40	23.5	1.54	0.11	1.5	1.43	0.06	0.61	0.14
CD at 5%	15.0	14.21	0.07	5.4	1.52	0.29	1.56	67.5	4.42	N.S.	4.4	4.26	0.22	2.37	0.45

Pooled Data of 2 years.

were attributed to the treatment T_{10} (SSNM + 5 t/ha residue) which was statistically at par with T_6 and T_7 in respect of number of grain/panicle and 1000-grain weight. Similarly, in wheat, treatment T_{10} again resulted in increased number of grain/panicle (45) and 1000-grain weight (39.06 g) which was at par with T_1, T_6, T_7 and T_{11} in respect of number of grain/panicle, whereas, the results on 1000-grain weight did not show much contrast (Table 1). The increase in yield contributing traits under SSNM based treatments might be due to improved supply of nutrients during active growth and development stages of rice and wheat (Singh *et al.* 2014). Among nutrient omission plots, maximum reduction in different yield parameters was caused due to absence of N followed by K and P use. Similarly, reduction in yield attributing parameters under SSNM (-K) plots could not offset even by using 5 t/ha crop residue (Table 1). Such reduction in yield attributing parameters may be ascribed to "Liebig's law of minimum" wherein crop productivity is decided by the nutrient in question if all other nutrients are sufficiently made available.

Yield of rice and wheat: In both rice and wheat, the treatment T_{10} (SSNM + 5 t/ha residue) resulted in highest grain yield (4.25 t/ha and 4.09 t/ha, respectively) which was statistically at par with T_6 and T_7. Further, harvest index was also higher under these treatments. These results clearly reveal that balanced nutrient supply either through SSNM or integrated use of FYM/residue and inorganics improves sink capacity, resultantly higher yield was obtained. Compared to recommended NPK use (T_1), SSNM had 10.3 and 14.2% higher yield gain of rice and wheat, respectively. Residue incorporation along with SSNM had further added advantage on productivity of both rice and wheat crop. More productive tillers, photosynthetic rate of the flag leaves, root activity, and ATPase activity during grain filling under SSNM had also been reported by Xu *et al.* (2009). A greater yield loss due to K omission as compared to P in both rice and wheat is contrary to the earlier belief that release of native K from illitic clay minerals of the IGP soils is sufficient to meet the K needs of the crops. The increase in yield from added K is however consistent with reports that application of K has become essential for sustaining higher yields in the IGP (Singh *et al.* 2018).

System productivity: Comparing system productivity, in terms of rice equivalent yield (SREP) indicated that SSNM out yielded SR across the year (Table 2). The significantly higher system productivity in SSNM over SR may partially be ascribed to the inclusion of all deficient nutrients (S, Zn and B) in fertilization schedule. Further, high yielding cultivars of rice and wheat were grown in this study; their nutrient uptake demands are comparatively higher than the commonly grown cultivars in the region. Theoretically, as yield targets move up, not only nutrient demand increases but it also becomes more varied and complex leading to multiple nutrient deficiencies (Singh *et al.* 2014) implying that balanced nutrient supply of major and micronutrients through SSNM lead to higher nutrient utilization and finally yield improved. Addition of 5 t/ha crop residue with SSNM

Table 2 Total NPK uptake (kg/ha) and relative economics as influenced by different nutrient management options

Treatment	Total NPK uptake									Relative economics					
	Rice			Wheat			RWS uptake			RWS cost of cultivation (₹/ha)	RWS gross returns (₹/ha)	Returns invested in RWS (₹)	Change in RWS economics due to nutrient omission (₹/ha)		
	N	P	K	N	P	K	N	P	K				N	P	K
T_1	90.63	9.11	115.31	96.15	17.37	100.14	186.78	26.48	215.45	75245	163757	2.18	-	-	-
T_2	74.50	8.06	89.33	83.47	14.55	70.79	157.97	22.61	160.12	72411	152540	2.11	-	-	11217
T_3	81.19	7.31	102.22	87.38	10.61	93.42	168.57	17.92	195.64	69545	147629	2.12	-	16128	-
T_4	50.24	5.32	74.28	37.81	7.88	49.50	88.05	13.2	123.78	71316	98767	1.39	64990	-	-
T_5	94.86	9.83	141.89	99.48	21.09	104.55	194.34	30.92	246.44	86495	166065	1.92	-	-	-
T_6	102.08	10.37	140.86	107.06	20.77	109.87	209.14	31.14	250.73	90745	170198	1.88	-	-	-
T_7	93.50	9.65	145.05	117.64	26.38	117.41	211.14	36.03	251.46	80653	176710	2.50	-	-	-
T_8	86.67	8.10	126.14	103.73	22.38	75.70	190.4	30.48	201.84	76828	158282	2.06	-	-	18428
T_9	86.16	8.62	107.11	101.3	12.01	104.33	187.46	20.63	211.44	74203	155700	2.10	-	21010	-
T_{10}	110.07	11.27	150.43	122.8	28.96	120.37	232.87	40.23	270.80	88903	187238	2.11	-	-	-
T_{11}	91.75	9.42	146.94	107.99	26.32	118.90	199.74	35.74	235.96	80078	164814	2.06	-	-	22424
SEm±	2.36	0.28	2.01	2.35	0.90	1.47	3.05	1.39	2.30	-	4026	0.02	-	-	-
CD at 5%	6.79	0.82	5.77	6.75	2.59	4.22	8.76	3.99	8.96	-	12122	0.07	-	-	-

Pooled Data of 2 years.

to both rice and wheat (T_{10}) had added gain of 0.31 t/ha over SSNM alone (T_7). On the other hand, addition of 5 t/ha crop residue recycling to both the crops, under SSNM (-K) plots had SREP reduction of 0.24 t/ha. These results clearly demonstrate that continuous neglect of K from fertilization schedule and non-recycling of crop residue in the system, which is a common practice in IGP, is a major constraint to achieve sustainable high yield of RWS in the region (Singh *et al.* 2014).

NPK uptake: In case of rice, the highest N and P uptake (110.07 and 11.27 kg/ha) was recorded with T_{10} (SSNM + 5 t/ha residue) which was significantly superior over rest of the fertilizer management options (Table 2). Similarly, K uptake was higher (150.43 kg/ha) with treatment T_{10} being statistically at par with the treatment T_{11}. The non-significant effect of K use under SSNM, SSNM along with 5 t/ha residue used plots on K uptake reveals that excessive K supply from both fertilizer as well as from residue might have either lost through leaching beyond root zone or fixed as non-exchangeable pool of K. Recent study in IGP by Singh *et al.* (2018) suggested that only 15% of the applied K was recycled in the soil available K and a major portion of the remaining K input is utilized as K uptake by the crops or fixed as non-exchangeable K (NE_K). In case of wheat, maximum N, P and K uptake (122.80, 28.96, 120.37 kg/ha, respectively) in treatment T_{10} (SSNM + 5 t/ha residue) was noticed which was statistically at par with the treatment T_7 and significantly superior over other treatments. Combining rice and wheat, systems N, P and K uptake values were also higher with T_{10} (SSNM + 5 t/ha residue) followed by SSNM (T_7). This further strengthens the hypothesis that consistent and balanced nutrient supply to both rice and wheat crop might have helped in augmenting deficient nutrient supply and ultimately resulted in higher yield and uptake (Xu *et al.* 2008, Singh *et al.* 2014).

Relative economics: Total cost of cultivation of RWS ranged from ₹69545–90745/ha, being highest with SR along with 10 t/ha FYM in rice and SR in wheat closely followed by 5 t/ha crop residue recycled along with SR in both rice and wheat (Table 2). Higher cost with integrated organic and inorganic use may be seen as additional cost of residue (₹10750/ha) and FYM (₹15000/ha) involved in these treatments. In general, higher cost of cultivation with SSNM as compared to recommended NPK use may be ascribed to the higher rate of fertilizer N, P, K used along with all deficient nutrients (S, Zn and B). Therefore, higher cost of cultivation with SSNM was noticed. SSNM option had higher RWS gross returns (₹155700–187238/ha) as compared to SR (₹163757/ha). Fertilizer use as per SR + crop residue or FYM also had added advantages of ₹2308–6441/ha over SR. Higher gross returns under SSNM option was mainly due to increased RWS productivity (Table 2) and optimized fertilizer used as per crop demand. On analyzing return per rupee invested in RWS, the maximum values were obtained under SSNM (₹2.50/₹ invested). Magnitude of economic loss due to P and K omission was more under SSNM plots as compared to SR. These results clearly show that optimized use of all deficient nutrients must be ensured for attaining maximum economic gain under RWS. RWS economic loss due to K omission under SSNM option was further more (₹3996/ha) when 5 t/ha residue of both rice and wheat was recycled to the system. Such high losses due to K neglect may be attributed to additional cost (₹10750/ha) involved for residue recycling, and insufficient K supply through crop residue to meet the crop requirement in absence of fertilizer K use. These results clearly suggest the need of optimized K use when crop residue is being recycled under RWS to attain maximum economic gain.

Foregoing results clearly reveal that existing nutrient management practices (SR) in RWS pose a constant threat of production fatigue. Insufficient and imbalanced fertilizer use not only hinders attaining the potential yield but also leads to drastic loss on economic front. The SSNM based on indigenous soil nutrient supplying capacity and targeted yield, is a promising option for attaining higher productivity and improved economics. Future research must be focussed on evolving SSNM option combining integrated use of organics to attain sustainable yield and profits.

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