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Effect of site specific nutrient management on yield and nutrient uptake in rice (*Oryza sativa*)-wheat (*Triticum aestivum*) cropping system

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ABSTRACT

On farm trials were conducted for two kharif and rabi seasons of 2014-15 and 2015-16 to study the effect of site specific nutrient management on yield and nutrient uptake in rice [Oryza sativa (L) R.Br]-wheat [Triticum aestivum (L) emend Paul & Flori] cropping system. The experiment was carried out with seven treatments and three replications. Recommended dose of NPK resulted in significantly higher grain and stover yield of rice and wheat as compared to FFP. Site specific nutrient management increased the rice grain and stover yield over FFP and state recommended dose by 43.5 and 49.6 and 34.0 and 42.9 %, respectively. FFP and state recommended dose of NPK fertilizers recorded 12.7 and 34.0 % lower wheat grain yield than the SSNM (N P K S B Zn) treatment. Application of zinc to rice crop had a significant effect on grain and straw yield over 100% NPK alone. The residual effect of B and zinc on succeeding wheat crop produced 10.2 % higher yield of grain over 100% NPK alone. Sulphur application proved significantly superior over 100% NPK in respect of yields of both rice and wheat crops. The mean uptake of N, P, K, S, B and Zn by rice under SSNM treatment was 86.7,78.4 ,53.1, 65.8, 40.6 and 89.0 % higher than that in FFP, respectively. The corresponding increases in uptake of N, P, K, S, B and Zn by wheat crop were 68.3, 86.2, 49.0, 90.5, 42.9 and 70.0 per cent.

Key words: Site specific nutrient management, farmer fertilizer practice, rice, wheat productivity nutrient uptake

INTRODUCTION

Rice-wheat cropping system is one of the most popular systems in India. It has played a major role for raising food grain production to make the country self sufficient. However, continuous cultivation of these crops caused decline in soil fertility, especially soil organic matter content. Rice-wheat being the cereal crops, the mining of nutrients is higher. Depletion of native nutrient reserves, emergence of multi nutrient deficiencies and decline in nutrient use efficiency are also the major reasons for stagnation in productivity of this crop sequence. Site specific nutrient management is an approach which takes in to account all nutrient deficiencies to ensure that crop demands are met and soil fertility is improved, which in turn ensures higher nutrient use efficiency crop productivity and economic returns. Sulphur has a key role in improving crop yield and produce quality which can only be performed in sulphur deficient areas by augmenting the supply of sulphur fertilizer. For optimum growth and production, plant tissue must contain sufficient concentrations of sulphur of sulphur, only then, the plants can produce carbohydrate, proteins to their full potential.. Boron plays a vital role in transport of carbohydrates as well as in cell wall metabolism, permeability and stability of cell membranes and phenol metabolism with primary role in lignin biosynthesis. Zinc is essential for promoting cartain metabolic reactions. It is necessary for the production of chlorophyll and carbohydrates. Zinc is directly or indirectly required by several enzymes, auxin and protein synthesis. However, little work has been done on this aspect on rice-wheat crop sequence in Agra region of Uttar Pradesh. In the light of above points, present study was carried out to evaluate the impact of site specific nutrient management on maximizing the productivity of rice-wheat cropping system in Agra region of Uttar Pradesh.

MATERIALS AND METHODS

On-farm trials were conducted with rice and wheat (CV PBW 343) during kharif and rabi seasons of 2014-15 and 2015-16 to evaluate the effect of seven nutrient management options (Table 1). All the treatments were replicated three times in a randomized block design. The

experimental soil was sandy loam in texture having pH, 8.0, EC, 0.28 dSm^{-1}, organic carbon, 3.3g kg^{-1} and available N, P, K and S, 156, 9.5, 105, 16 kg ha^{-1}, respectively. The DTPA-Zn was 0.52 mg kg^{-1}. Nitrogen in rice was applied in three splits, half was applied at the time of sowing and then remaining half was top dressed in two equal splits, first at the time of thinning and second at the ear formation stage. Wheat crop received nitrogen in two equal splits, half at the time of sowing and the remaining half at the first irrigation. Entire amount of P and K in both the crops and S, B and Zn were applied at the time of sowing through diammonium phosphate, muriate of potash, elemental S, borax and zinc oxide, respectively.

Table 1: Treatment details for rice and wheat

Treatment	Nutrients (kg ha^{-1})					
	N	P_2O_5	K_2O	S	B	Zn
	Pearl Millet					
T_1 Farmer Fertilizer Practice (FFP)	100	50				
T_2 FFP + K	100	50	40			
T_3 State recommended dose of NPK	150.	60	40			
T_4 T3 + S + B	150	60	40	20		
T_5 T3 + S + Mn	150	60	40	20	1.0	
T_6 T3 + S + B + Zn (SSNM)	150	60	40	20	1.0	2.5
	Wheat					
T_1 Farmer Fertilizer Practice (FFP)	100	50				
T_2 FFP + K	100	50	40			
T_3 State recommended dose of NPK	150	60	40			
T_4 T3 + S	150	60	40	20		
T_5 T3 + S + B	150	60	40	20	1.0	
T_6 T3 + S + B + Zn (SSNM)	150	60	40	20	1.0	2.5

The yields of both the crops were recorded at maturity. Grain and straw samples after preparation were digested in a diacid mixture of HNO_3 and $HClO_4$ (4:1) for all the nutrients except N. Sample digests were analysed for P, K, S, B and Zn using standard procedures (Jackson,1973). Nitrogen in grain and straw was determined by following modified Kjeldahl method. The uptake of nutrients by the crops was worked out by multiplying their content values with corresponding yield data. Statistical analysis of data was carried out by ANOVA technique in randomized block design.

RESULTS AND DISCUSSION

Yield of rice

The grain and stover yields of rice were 6.96 and 9.67t ha^{-1}, respectively under T_6 (SSNM) compared to 6.01 and 8.05 t ha^{-1} obtained under the state recommended dose of NPK (T_3) and 4.85 and 6.45 t ha^{-1} under FFP (T_1), respectively (Table 1). On an average, SSNM (T_6), wherein nutrients were applied not only to meet the crop demands but also to avoid any mining from soil reserve, out yielded state recommended dose of NPK and FFP by 24.0 and 43.5 %, respectively. The mean yield difference of 0.95t ha^{-1} between 100% NPK (SR) and SSNM (T_6) was partly ascribed to inclusion of S, B and Zn. The low available K content of the experimental soil was very much reflected in crop performance and also in yield response to K fertilizer. Inclusion of 40 kg K_2O ha^{-1} alone in FFP (T_2) produced an additional grain yield of 0.78 t ha^{-1}. Singh *et al.* (2012) also reported a significant response of potassium to rice. Like grain yield, stover yield was also significantly affected by the different treatments under study. The higher yield of rice seems to be cumulative effect of yield attributes which were boosted by SSNM. These results clearly indicate that the highest crop response in terms of yield was found with SSNM practice. These findings are supported by Kumar *et al.* (2017). Inclusion of soil application of S in SSNM significantly increased grain and stover yield of rice over FFP, FFP + K and state recommended NPK dose. The marked effect of S on yields of rice may be attributed to low status of S in experimental soil. Similar results were reported

by Singh *et al.* (2014) and Ram Bharose *et al.* (2018). Application of S + B along with 100% NPK (T_5) was more beneficial for enhanced crop production. These elements (S + B) produced higher yield (6.58 and 8.87 t ha^{-1}) of crop over NPK + S alone. The increase in yield due to B application may be attributed to increased availability of B in soil (Singh *et al.* 2015).

Yield of wheat

The grain yield of wheat ranged from 4.46 t ha^{-1} under farmers fertilizer practice to as high as 5.98 t ha^{-1} under SSNM treatment (Table 1). The SSNM treatment out yielded by 15.6 and 34.0 per cent over state recommended dose of NPK fertilizer and FFP, respectively. Application of NPK fertilizers according to the state recommendation certainly outyielded FFP. However, grain yield of wheat was significantly lower under FFP, FFP + K and state recommended NPK dose compared to SSNM. Like grain yield, straw yield of wheat was also affected significantly by different treatments under study. The highest straw yield of 9.15 t ha^{-1} was recorded with SSNM and lowest (6.40 t ha^{-1}) in FFP. Singh and Singh (2018) and Singh (2018) reported that SSNM treatment wherein nutrients were applied not only to meet the crop demands but also to avoid over-mining of the soil, outyielded SR treatment (T_3). This increase in yield was attributed partly to inclusion of secondary and micronutrient (S, B and Zn) in SSNM. Soil application of S in wheat crop exerted significant effect on grain and straw yield and increased the grain and straw yields by 7.3 and 6.2 per cent over 100% NPK alone, respectively (Pandey and Kumar 2017). Application of S and B along with 100% NPK fertilizers increased the grain and straw yields of wheat significantly 100% NPK alone (Singh *et al.* 2015). Inclusion of 40 kg K_2O ha^{-1} in FFP produced an additional wheat grain and straw yield of 0.40 and 0.85 t ha^{-1}, respectively. Beneficial effect of K fertilization in FFP dose was greater (0.40 t ha^{-1}) than FFP. Thus, the K-exhaustive crops like rice and wheat should be supplemented with K fertilizer to avoid yield loss and also arrest the mining of soil K reserves. These results corroborate the findings of Pandey and Singh (2017).

Quality

Rice

There was significantly higher percentage of protein in rice grain under all the treatments as compared to FFP. The protein content in grain ranged from 10.0 to 11.1 per cent. Application of 100% NPK dose proved significantly superior to FFP and FFP + K treatments in respect of protein content. This may be due to accumulation of more nitrogen with 100% NPK dose and ultimately showing more protein content in rice grain (Pandey 2018). Application of S along with 100% NPK dose (T_4) further improved the protein content over 100% NPK (Singh *et al.* 2017). Application of 100% NPK + S + B (T_5) also improved the protein content in grain but the effect of B application proved inferior to that of S. The SSNM (100%NPK + S + B + Zn) resulted in highest protein content (11.1%) in rice grain Singh *et al.* (2015) also reported similar results.

Table 2: Effect of different nutrient management practices on grain and straw yield (t ha^{-1}) of rice and wheat

Treatments	Rice			Wheat		
	Grain Yield	Straw yield	Protein (%)	Grain Yield	Straw yield	Protein (%)
T_1 Farmer Fertilizer Practice (FFP)	4.85	6.45	10.0	4.46	6.40	11.2
T_2 FFP + K	5.63	7.55	10.5	4.86	7.25	11.3
T_3 State recommended dose of NPK	6.01	8.05	10.4	5.17	8.00	11.8
T_4 T3 + S	6.25	8.49	10.8	5.55	8.50	12.0
T_5 T3 + S + B	6.58	8.87	11.1	5.70	8.90	12.2
T_6 T3 + S + B + Zn (SSNM)	6.96	9.67	11.3	5.98	9.15	12.3
CD (P = 0.05)	0.57	0.64	0.20	0.37	0.51	0.12

Wheat

The protein content in wheat grain ranged from 11.2 % at FFP to 12.3 % with SSNM treatment. The minimum protein content was noted under FFP, which may be attributed to lower status of available N in soil. Protein content significantly increased with 100% NPK dose over FFP and FFP + K treatments. Addition of 100% NPK + S further enhanced the protein content in wheat grain over 100% NPK. Similar increase in protein content with S application was also reported by Pandey and Kumar (2017). Application of S and B coupled with 100% NPK also improved the protein content (Pandey 2018). The maximum value of protein content in wheat grain was recorded under SSNM (T_6) treatment showing the beneficial effect of SSNM treatment. Similar results were reported by Singh (2018) and Singh (2018).

Table 3: Effect of different nutrient management practices on uptake of N, P and K (kg ha^{-1}) by rice crop

Treatments	Nitrogen		Phosphorus		Potassium	
	Grain	Straw	Grain	Straw	Grain	Straw
T_1 Farmer Fertilizer Practice (FFP)	73.1	34.1	8.2	5.7	27.6	35.3
T_2 FFP + K	91.0	41.4	9.5	7.5	36.5	166.3
T_3 State recommended dose of NPK	102.1	48.1	10.4	1.0	39.6	179.5
T_4 T3 + S	116.0	56.2	12.1	10.2	42.5	182.6
T_5 T3 + S + B	126.0	64.0	12.7	10.5	46.7	190.0
T_6 T3 + S + B + Zn (SSNM)	131.1	67.6	13.3	11.5	48.5	200.8
CD (P = 0.05)	4.83	2.28	1.35	1.12	2.45	7.43

Uptake studies

Rice

The nutrient removal pattern by rice crop depended upon the nutrient management options (Table 3 and 4). Nitrogen, P and K removal by rice grain and straw was highest in SSNM-plot and lowest in FFP plot. Nitrogen uptake by rice grain and stover increased from 73.4 and 34.1 kg ha^{-1} at FFP to 131.1 and 67.6 kg ha^{-1}, respectively with SSNM.Compared to the FFP, mean uptake of P and K by grain and stover increased by 7.1 and 5.8 kg ha^{-1} and 19.9 and 135.2 kg ha^{-1}, respectively. The mean uptake of N, P and K by grain and stover in SSNM treatment was significantly higher than that under state recommended dose of NPK, Ganai *et al.,* (2013) and Singh *et al.* (2015) also reported similar results.

Table 4: Effect of different nutrient management practices on uptake of S (kg ha^{-1}), Mn and Zn (g ha^{-1}) by rice crop

Treatments	Sulphur		Boron		Zinc	
	Grain	Straw	Grain	Straw	Grain	Straw
T_1 Farmer Fertilizer Practice (FFP)	7.2	5.7	119.0	66.1	100.6	135.0
T_2 FFP + K	8.0	7.1	122.3	68.8	112.5	160.2
T_3 State recommended dose of NPK	9.3	8.0	139.0	75.3	130.3	182.5
T_4 T3 + S	10.8	9.0	153.5	79.8	139.5	205.3
T_5 T3 + S + B	11.2	9.4	168.9	84.8	144.5	219.9
T_6 T3 + S + B + Zn (SSNM)	11.6	9.8	172.3	88.0	173.5	272.0
CD (P = 0.05)	0.95	0.66	8.46	5.40	8.75	14.05

Application of 100% NPK significantly increased N, P and K uptake by rice grain and stover over FFP and FFP + K treatments. Addition of 100% NPK also improved the utilization of S, B and Zn by rice grain and straw over FFP. Sulphur uptake by grain and stover exhibited an increase of 4.4 and 4.1 kg ha^{-1} in SSNM treatment over FFP, which may be due to increased availability of sulphur as a result of its addition (Singh *et al.* 2014). The SSNM treatment including application of Zn increased the Zn uptake of rice grain and stover by 72.9

and 13.7 g ha^{-1} over FFP, respectively. This increase in Zn uptake may be ascribed to increased grain and stover yield and improvement in Zn content (Singh *et al.* 2015, Sabina *et al.* 2014). Application of B was associated with higher B uptake by rice grain and stover over FFP. This increase in B uptake may be attributed to increased availability of B as a result of its addition (Singh *et al.*2015).

Table 5: Effect of different nutrient management practices on uptake of N, P and K (kg ha^{-1}) by wheat crop

Treatments	Nitrogen		Phosphorus		Potassium	
	Grain	Straw	Grain	Straw	Grain	Straw
T_1 Farmer Fertilizer Practice (FFP)	85.7	37.5	8.8	7.2	25.8	123.2
T_2 FFP + K	90.3	42.0	10.0	8.8	29.4	140.0
T_3 State recommended dose of NPK	105.1	52.1	12.6	11.2	32.1	156.5
T_4 T3 + S	113.5	56.5	14.0	13.0	35.0	170.2
T_5 T3 + S + B	117.2	61.6	15.6	13.5	37.1	176.8
T_6 T3 + S + B + Zn (SSNM)	125.6	65.0	15.8	14.0	39.4	182.3
CD (P = 0.05)	5.85	3.63	0.78	1.10	1.90	9.95

Wheat

Removal 0f N, P, K and S by wheat crop varied markedly depending upon the nutrient management practices (Table 5 and 6). The uptake of N, P, K and S was lowest in FFP treatment and highest in SSNM treatment. The mean N, P, K and S uptake by wheat grain varied from 85.9 to 125.6, 8.8 to 15.8.,25.8 to 39.4 and 8.6 to 15.4 kg ha^{-1}, respectively. The corresponding ranges of increase in N, P, K and S were from 37.5 to 65.0, 7.2 to 14.0, 123.2 to 182.3 and 6.9 to 14.2 kg ha^{-1}. The increase in uptake of these nutrients with SSNM may be attributed to increased grain and stover yield of rice. Similar results were reported by Pandey and Singh (2017). Inclusion of S in SSNM significantly increased the S uptake by wheat grain and straw over FFP. This increase in S uptake may be attributed to increased grain and straw yield and improvement in S content in crop (Pandey and Kumar, 2017). The mean Zn uptake by grain and straw was significantly higher in SSNM treatment compared to FFP and state recommended dose of N, P and K. The minimum uptake of Zn by the crop was recorded in FFP (Singh and Singh 2018). Application of B increased its uptake by grain and straw of wheat over FFP, On the other hand, minimum value of B uptake in grain and straw of wheat was recorded in FFP treatment due to lower crop yield. Similar results were reported by Singh *et al.* (2015).

Table 6: Effect of different nutrient management practices on uptake of S (kg ha^{-1}), B and Zn (g ha^{-1}) by wheat crop

Treatments	Sulphur		Boron		Zinc	
	Grain	Straw	Grain	Straw	Grain	Straw
T_1 Farmer Fertilizer Practice (FFP)	8.6	6.9	116.4	64.8	117.3	136.0
T_2 FFP + K	9.8	8.0	131.0	70.5	123.7	150.0
T_3 State recommended dose of NPK	10.6	9.7	141.6	76.5	158.0	200.0
T_4 T3 + S	15.0	14.0	150.7	78.4	166.5	208.5
T_5 T3 + S + B	15.2	14.1	165.6	80.0	170.0	215.5
T_6 T3 + S + B + Zn (SSNM)	15.4	14.2	170.0	89.0	190.8	242.5
CD (P = 0.05)	1.01	1.12	10.81	4.60	8.05	11.87

It may be concluded from the results that grain and stover/straw yields of both rice and wheat crops were significantly lower under FFP as compared to SSNM. Inclusion of 40 kg K_2O ha^{-1} in FFP resulted in more grain and straw yields of rice and wheat. Inclusion of S, Zn and B significantly increased the yields of rice and wheat. The quality and uptake of nutrients by

rice and wheat crop were significantly higher in SSNM treatment as compared to FFP and state recommendation of NPK fertilizers. Inclusion of S, Zn and B also enhanced their uptake by both the crops.

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