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Original Research Article

Response of Nitrogen, Phosphorus, Potassium and Zinc Nutrition on Rice (*Oryza sativa* L.) – Maize (*Zea mays* L.) Cropping System

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A B S T R A C T

A field experiment entitled "Response of nitrogen, phosphorus, potassium and zinc nutrition on rice (*Oryza sativa* L.)-maize (*Zea mays* (L.) cropping system" was conducted during *kharif* and *rabi* season of 2013-14 at farmers' field of Jalalgarh and Kasba blocks of Purnea district in Zone II of Bihar, The experiment consisted of 7 treatment combinations, *viz.*, T_1-absolute control, T_{2-}Recommended N alone, T_{3-}Recommended N and P, T_{4-} Recommended N and K, T_5-Recommended N, P and K, T_{6-} Recommended NPK with $ZnSO_4$ and T_{7-}farmers' practice. $ZnSO_4$ was not applied in maize crop owing to observe is residual impact, applied in rice. This experiment replicated in 24 farmers' field. Application of 100 kg ha^{-1} N, 40 kg ha^{-1} P_2O_5 and 20 kg ha^{-1} K_2O along with 25 kg ha^{-1} $ZnSO_4$ to rice recorded significantly higher grain (46.7q ha^{-1}) yield, and in the same plot in succeeding maize, application of 120 kg ha^{-1} N, 75 kg ha^{-1} P_2O_5 and 20 kg ha^{-1} K_2O also recorded significantly higher grain (83.18 q ha^{-1}) yield. Similarly, the maximum system rice equivalent yield (163.01 q ha^{-1}) and productivity (44.7 kg ha^{-1} day^{-1}) were also achieved under (T_6) nutrient combination. Highest N, P and K uptake was observed in T_6 in both the crop in both season. After harvest of the crop, highest available N and P was found in T_3 whereas, highest available K and Org-c was found in T_6. Significantly higher cost of cultivation (61606 ha^{-1}), gross return (1, 70,897 ha^{-1}), net return (1, 09,291 ha^{-1}), B: C ratio (1.77) for rice-maize cropping system was also recorded with the same treatment combination.

Keywords

Balanced nutrition, economics, rice-maize cropping system, soil fertility, crop productivity, nutrient uptake

Introduction

Rice and maize are major cereals in the Kosi region of Bihar. They are the major crops contributing to the food security and income of the State. In this region, rice-maize can be grown as rotation with each other. However, with the decline of the agriculture land, rotation and intensive cropping are reasonable options (Mussnug *et al.*, 2006).

Rice and maize are popular and staple food in Bihar as well as in India due to its versatile characteristic of adaptability and suitability with good to very high fetching price. The Kosi river basin of Bihar spread over an area of 11410 Sq. Km and represents low-land agro ecosystem with medium textured sandy clay loam soils.

Farmers used to grow high yielding varieties of rice during wet season followed by maize/wheat and green gram/maize in *Rabi* and summer respectively. Among them rice-maize is the pre- dominant cropping system and greatly support the livelihood of the rural people. During the last 30 years as a result of intensified crop management involving improved germ plasm, greater use of fertilizer and irrigation, the yield has markedly increased in India in cereal-based cropping system. During the period 1950-51 to 2007-08, the cereal production in the country increased by 5 times, whereas the fertilizer consumption increased by 322 times, implying a very low fertilizer use efficiency (Rajendra Prasad, 2009). A decline in partial factor productivity of nitrogenous fertilizer is the most commonly observed effect of intensive cereal-based systems. Decline in soil N supply results in declining factor productivity of chemical nitrogen, because soil N is natural substitute for chemical nitrogen.

In addition to nitrogen, phosphorus and potassium are the most important nutrient elements required by the cereal-based systems. In post green revolution era multiple-nutrient deficiency including micronutrients is one of the important problems making system unsustainable (Jat *et al.,* 2016). Moreover, deficiency of Zn is very frequent in rice-based intensive system with no or little application of Zn fertilizer (Saha *et al.,* 2015). Therefore, balanced fertilization application paves the way for optimum plant nutrient supply to realize full yield potential of crop. However, continuous use of imbalance fertilizers causes decline in soil fertility and yield reduction. Considering this fact, a participatory research was carried out at farmers' field to quantify the productivity potential of rice-maize cropping system with set of nutrient combination treatments.

Materials and Methods

The field experiment was conducted in Randomized Block Design, during *kharif* and *rabi* seasons of 2013-14, on farmers' field of Jalagarh (Chak, Kachnahar and Hansi villages) and Kasba (Sabdalpur, Dogachhi and Kulakhas villages) blocks of Purnea district, situated in Kosi Zone of Bihar. The soil of the experimental plot is sandy clay loam with soil pH 6.8, EC 0.09 dS/m, organic carbon 0.44, available N, P and K is 224.3, 17.07 and 207.08 kg ha^{-1} respectively. The experiment comprised of 7 treatments, *viz*. control (no fertilizer), recommended N, NP, NK, NPK, NPK+ZnSO4 and farmers' practice, applied to rice-maize cropping system. In case of NPK+ZnSO4, ZnSO4 was only applied to rice crop.

At each site/village, 4 farmers were selected thus making 24 farmers and all the 7 treatments were allotted in each of the farmers' field taking a block of 532 m^2 area (net plot) *i.e.* the area of treatment at every farmers' plot was 76 m^2. Rice cultivar 'Rajendra mahsuri' and maize 'P-3396 were taken as test crop. The recommended dose of N: P_2O_5: K_2O: $ZnSO_4$ in rice was 100:40:20:25 kg ha^{-1} respectively, while for maize it was 120:75:50:0 kg ha^{-1}. In farmers' practice 60:30 and 10 kg ha^{-1} N, P_2O_5 and K_2O were applied in rice, whereas in maize 90, 50 and 20 kg ha^{-1} N, P_2O_5 and K_2O were applied. Both the crops were raised with recommended package of practices under irrigated condition. Grain yield was considered as economic yield, in both the crops. The maize yield was converted into rice-equivalent yield (REY) based on prevailing market price in the respective year. Production efficiency in terms of kg ha^{-1} day^{-1} was calculated by dividing the total REY of rice-maize system with 365 days (Devsenapathy *et al.,* 2008).

The soil samples were processed and analyzed for various soil properties; pH and EC (described by Chopra and Kanwar, 1982), organic carbon determined by Walkley and Black's rapid titration method (Jackson, 1973). The determination of available nitrogen was done by alkaline permanganate method (Subbiah and Asija, 1956), available phosphorus by Olsen's (1954) method (as described Houba *et al.*, 1988), and potassium by flame photometer described by (Jackson, 1973). The data were analyzed as per the standard procedure for Analysis of Variance (ANOVA) as described by Gomez and Gomez (1984). The significance of treatments was tested by 'F' test (Variance ratio). The difference in the treatment mean was tested by using critical difference (CD) at 5% level of probability.

Results and Discussion

Yield of rice and maize

Application of recommended dose of NPK along with $ZnSO_4$ resulted significantly higher grain (46.7 q ha^{-1}) and (83.18 q ha^{-1}) of rice and maize (Table 1) respectively. The increase in grain yield of rice due to application of recommended doses of NPK along with $ZnSO_4$ was 143.1, 63.5, 28.1, 39.9, 6.1 and 32.4 per cent higher over the control, N, NP, NK, NPK and farmers' practice respectively. Further in succeeding maize, the increase in grain yield with NPK along with $ZnSO_4$ (residual effect), were to the tune of 134, 53.2, 19.7, 29.7, 6.4 and 22.6 per cent over control, N, NP, NK, NPK and farmers' practice respectively. Again with respect to system REY and system productivity, NPK along with $ZnSO_4$ recorded significantly higher value (163.01 q ha^{-1} and 44.7 kg ha^{-1} day^{-1} respectively) in comparison with other nutrient treatments (Table 1). Significant improvement in grain yield of rice and maize may be attributed to improvement of P that promote better root development and subsequently absorption of N, while K is involved in N metabolism in cereals. Further, soils of the experimental sites are deficient in Zn; the application of this deficit nutrient helped both the crops to record higher grain yield over NPK treatment alone. The results are in close conformity with (Ravisankar *et al.*, 2014; Preetha and Stalin, 2014 and Hiremath *et al.*, 2016; Chandrakar *et al.*, 2017)

Response of nutrients

The response (kg grain per kg nutrient applied) of N, P and K over control, was 9.34, 19.75 and 24.1 for rice and 15.62, 20.26 and17.40 for maize and 15.91, 25.16 and 26.13 kg for rice-maize system respectively (Table 2). Although, response of NP, NK and NPK over control was observed 12.3, 11.8 and 15.5 and 17.4, 16.8 and 17.4 kg grains obtained per kg nutrients applied in rice and maize crops respectively (Table 3). The response of P over N and NK was found 19.7 and 21.6 in rice and 20.2 and 18.8 in maize crops. The response of K over N and NP were observed 4.1 and 5.4 in rice and 4.0 and 4.5 in maize. The response of Zn over NPK recorded 1.7 in rice. Similar findings were also reported by Kumar *et al.*, (2006) and Hiremath *et al.*, (20 15).

Nutrient uptake and post-harvest nutrient status of soil

The highest total N (86.2 kg ha^{-1}) P (31.5 kg ha^{-1}) and K (108. kg ha^{-1}) uptake was observed in NPK+Zn treated plot by the rice crop (Table 4), and similar trend of N, P and K uptake (179.1, 48.8 and 206.9 kg ha^{-1}) respectively has been observed, by maize (Table 5), crop. Similar finding was also advocated by Kumar *et al.*, (2006) and Hiremath *et al.*, (20 15).

Table.1 Effect of various treatments on rice and Maize during 2013-14

Treatments	Grain Yield (q/ha)		|Rice equivalent yield (q/ha)	System Productivity (kg ha^{-1} day^{-1}
	Rice	Maize		
Control	19.21	35.55	68.60	18.8
N	28.55	54.30	103.60	28.4
NP	36.45	69.50	132.54	36.3
NK	33.37	64.11	121.89	33.4
NPK	44.02	78.20	153.42	42.0
NPK+Zn	46.70	83.18	163.01	44.7
Fp	35.26	67.85	128.92	35.3
CD (P=0.05)	1.84	3.43	4.78	1.3

Table.2 Response of plant nutrients as kg grains obtained per kg nutrient applied

Treatment	Kg grain kg^{-1} nutrient applied		Rice-Maize system
	Rice	Maize	
Nitrogen (N)	9.34	15.62	15.91
Phosphorus (P_2O_5)	19.75	20.26	25.16
Potash (K_2O)	24.1	17.40	26.13

Table.3 Response of plant nutrients as kg grains obtained per kg nutrient applied

Treatment	Response over control				Response of P		Response of K		$ZnSO_4$
	N	NP	NK	NPK	Over N	Over NK	Over N	Over NP	Over NPK
Rice	9.34	12.3	11.8	15.5	19.7	21.6	4.1	5.4	1.7
Maize	15.6	17.4	16.8	17.4	20.2	18.8	4.0	4.5	

Table.4 Nutrient uptake (kg/ha) by grain and straw of rice crop as influenced by various treatments

Treatments	Nitrogen uptake (kg/ha)			Phosphorus uptake (kg/ha)			Potassium uptake (kg/ha)		
	Grain	Straw	Total	Grain	Straw	Total	Grain	Straw	Total
Control	22.5	12.9	35.4	6.3	6.64	12.9	5.7	38.7	44.5
N	33.4	19.3	52.7	9.4	9.8	19.3	8.5	57.5	66.1
NP	42.6	24.6	67.3	11.9	12.6	24.6	10.8	73.5	84.4
NK	39.1	22.6	61.6	10.9	11.5	22.5	9.9	63.3	77.2
NPK	51.5	29.8	81.2	14.4	15.2	29.7	13.1	88.7	101.9
NPK+ Zn	54.6	31.6	86.2	15.3	16.1	31.5	13.9	94.2	108.1
FP	41.3	23.8	65.1	11.6	12.2	23.8	10.5	71.1	81.6
CD (P=0.05)	2.15	1.2	3.39	0.61	0.64	1.23	0.54	3.7	4.25

Table.5 Nutrient uptake (kg/ha) by grain and straw of maize crop as influenced by various treatments

Treatments	Nitrogen uptake (kg/ha)			Phosphorus uptake (kg/ha)			Potassium uptake (kg/ha)		
	Grain	Straw	Total	Grain	Straw	Total	Grain	Straw	Total
Control	48.4	28.1	76.5	10.0	10.8	20.8	20.8	73.6	88.4
N	74.0	42.9	116.9	15.3	16.5	31.8	31.8	112.5	133.1
NP	94.7	54.9	149.6	19.6	21.1	40.8	40.7	143.9	172.9
NK	87.4	50.6	138.0	18.1	19.5	37.6	37.6	132.8	159.5
NPK	106.6	61.7	168.4	22.1	23.8	45.9	45.8	162.0	194.5
NPK+ Zn	113.4	65.6	179.1	23.4	25.3	48.8	48.8	172.3	206.9
FP	92.5	53.7	146.1	19.1	20.6	39.8	39.8	140.6	168.8
CD (P=0.05)	4.9	2.8	7.8	1.0	1.1	2.1	2.12	7.5	9.0

Table.6 Post-harvest soil-nutrient status as influenced by nutrient combinations in rice-maize cropping system

Treatments	OC (%)	Available N (kg ha^{-1})	Available P (kg ha^{-1})	Available K (kg ha^{-1})
Control	0.399	216.333	15.263	196.917
N	0.443	232.375	15.001	198.375
NP	0.447	233.667	18.808	201.292
NK	0.434	228.125	15.208	204.167
NPK	0.452	229.833	17.371	200.375
NPK + $ZnSO_4$	0.470	233.583	17.363	205.083
Farmers' practice	0.445	226.167	15.236	200.250
SEm(±)	0.004	2.698	0.239	1.179
LSD (0.05%)	0.012	7.552	0.669	3.300

Table.7 Economics of rice-maize cropping system as influenced by nutrient combinations

Treatments	Gross return (Rs.)	Cost of cultivation (Rs.)	Net return (Rs.)	B: C ratio
Control	72149	51275	20874	0.41
N	109264	54049	55215	1.02
NP	139757	58209	81548	1.40
NK	128609	55435	73174	1.32
NPK	160812	60856	99956	1.64
NPK + $ZnSO_4$	170897	61606	109291	1.77
Farmers' practice	136041	56456	79585	1.41

The maximum value (Table 6) of organic carbon (.47%) and available K (205.08) were observed with the application of 100 kg N, 40 kg P_2O5, 20 kg K_2O, and 25 kg $ZnSO_4$ to rice and 120 kg N, 75 kg P_2O_5, 50 kg K_2O to the succeeding maize, while highest available N and P (233.667 and 18.808 kg ha^{-1}) respectively, were observed in NP applied treatments in rice-maize system. It might be due to balanced fertilizer application.

Economic analysis

Application of 100 kg N, 40 kg P_2O_5, 20 kg K_2O along with $ZnSO_4$ @ 25 kg ha^{-1} in rice and 120 kg N, 75 kg P_2O_5, 50 kg K_2O in maize in same plot resulted in significantly higher cost of cultivation (Rs. 61606 ha^{-1}), gross return (Rs. 170897 ha^{-1}), net return (Rs.109291 ha^{-1}) and benefit: cost ratio (1.77) of the rice-maize system over the remaining nutrient combinations (Table 7). Whereas, the control treatment recorded the significantly lower cost of cultivation of the system (Rs.51275 ha^{-1}), system gross return (Rs.72149.0 ha^{-1}), system net return (Rs. 20874.0 ha^{-1}) and benefit-cost ratio (0.41). Though, recommended NPK along with $ZnSO_4$ recorded the highest cost of cultivation due to highest level of fertilizer application, at the same time this treatment recorded the highest level of yield for both the crops and the marginal gain is higher than any of the treatments. Similarly, in control treatments, the cost of cultivation is the lowest owing to no fertilizer application, at the same time this treatment recorded the minimum level of yield for both the crops and marginal gain was also the lowest. These findings are in line with those of Sharma *et al.,* (2011). It may be concluded that the application of 100 kg N, 40 kg P_2O_5, 20 kg K_2O, 25 kg $ZnSO_4$ to rice and 120 kg N, 75 kg P_2O_5, 50 kg K_2O in succeeding maize with the residual effect of $ZnSO_4$ applied in rice are required to harvest optimum crop yield, maintaining soil fertility and economic returns in rice-maize crop sequence under Kosi region of Bihar.

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