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On farm crop response to plant nutrients in rice-maize cropping system

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Abstract
An on farm research entitled "On Farm Crop Response to Plant Nutrients in Rice Maize Cropping System" was conducted during 2014-15 at farmers' field of Purnea in Zone II of Bihar. The seven treatments, *viz.*, T_1-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 were taken for study. $ZnSO_4$ was not applied in maize crop owing to observe its residual impact, applied in rice. 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} $ZnSO_4$ in rice recorded significantly higher grain (47.5q 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 recorded significantly higher grain (86.11 q ha^{-1}) yield. Similarly, the maximum system rice equivalent yield (173.22 q ha^{-1}) and productivity (47.46 kg ha^{-1} day^{-1}) were also achieved under (T_6) nutrient combination. Highest N, P and K uptake was observed in T_6 87.75, 32.05 and 110.0 kg ha^{-1} respectively, in both the crop in both season. Significantly highest gross return (1, 87,458 ha^{-1}), net return (1, 25,788 ha^{-1}) and B: C ratio (2.49) was also found in NPK+Zn.

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) [12]. 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) [15]. 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) [8]. Moreover, deficiency of Zn is very frequent in rice-based intensive system with no or little application of Zn fertilizer (Saha *et al.*, 2015) [17]. 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

An experiment was conducted in Purnea district, situated in Kosi Zone of Bihar on **"On Farm Crop Response to Plant Nutrients in Rice Maize Cropping''** to assess the response of major crops to different nutrients combinations during 2014-15 at farmers' field. The seven treatments, *viz.*, T_1-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 were taken for study. The experimental area comes under medium land situations. Soils of the experimental site was sandy clay loam with pH 6.84, EC 0.09 dS/m, organic carbon 0.45 and available N, P and K was 226.25, 17.09 and 207.16 kg ha^{-1} respectively. In T-6 (NPK+$ZnSO_4$), ZnSO4 was only applied to rice crop. Rice cultivar 'Sabour Ardhjal' and maize 'P-9637 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} while, for maize it was 120:75:50:0 kg ha^{-1} respectively. In farmers' practice 60:30 and 10 and 90, 50 and 20 kg ha^{-1} N, P_2O_5 and K_2O were applied in rice and maize respectively. Both the crops were raised with recommended package of practices under irrigated conditions. 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 analysed for various soil properties; pH and EC (described by Chopra and Kanwar, 1982) [1], organic carbon determined by Walkley and Black's rapid titration method (Jackson, 1973) [7]. The determination of available nitrogen was done by alkaline permanganate method (Subbiah and Asija, 1956) [19], available phosphorus by Olsen's (1954) [13] method (as described Houba *et al.*, 1988) [6], and potassium by flame photometer described by (Jackson, 1973) [7]. The data were analyzed as per the standard procedure for Analysis of Variance (ANOVA) as described by Gomez and Gomez (1984) [3]. 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

Results revealed that application of NPK along with $ZnSO_4$ recorded significantly higher grain (47.53 q ha^{-1}) and (86.11 q ha^{-1}) of rice and maize (Table 1). In rice and maize, grain yield with NPK along with $ZnSO_4$ (residual effect in maize), recorded to the tune of 8.17 and 8.04 per cent higher over NPK. With respect to system REY and system productivity, NPK along with $ZnSO_4$ recorded significantly higher value (173.22 q ha^{-1} and 47.46 kg ha^{-1} day^{-1} respectively) as compared to other nutrient combinations (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) [16, 14, 5, 20].

Response of nutrients and nutrient uptake

Data presented in table 2 revealed the response (kg grain per kg nutrient applied) of N, P and K over control, was 8.18, 15.75 and 15.50 for rice and 15.25, 17.64 and 15.92 for maize and 15.48, 21.89 and 20.24 kg for rice-maize system respectively. Although, response of NP, NK and NPK over control was observed 10.34, 9.4 and 12.34 and 16.15, 15.44 and 14.85 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 15.75 and 21.17 in rice and 17.64 and 13.52 in maize. The response of K over N and NP were observed 15.5 and 26.35 in rice and 15.92 and 7.74 in maize. The response of Zn over NPK recorded 14.36 in rice. Similar findings were also reported by Kumar *et al.*, (2006) [9] and Hiremath *et al.*, (2015) [4]. The highest total N, P and K (87.75, 32.05 and 110.0 and 195.82, 53.35 and 226.30) uptake kg ha^{-1} by rice and maize respectively was observed in NPK+Zn treated plot. Likewise the highest N, P and K uptake (283.57, 85.4 and 336.3 kg ha^{-1}) was observed in NPK+Zn treated plot in rice maize system (Table 4). Similar finding was also advocated by Kumar *et al.*, (2006) [9], Hiremath *et al.*, (2015) [4] and Mahto *et al.*, (2017) [11].

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. 61670 ha^{-1}), gross return (Rs. 187458 ha^{-1}), net return (Rs.125788 ha^{-1}) and benefit: cost ratio (2.47) of the rice-maize system over the remaining nutrient combinations (Table 5). Whereas, the control treatment recorded the significantly lower cost of cultivation of the system (Rs.51850 ha^{-1}), system gross return (Rs.94630 ha^{-1}), system net return (Rs. 42781.0 ha^{-1}) and benefit-cost ratio (1.03). 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 close conformity with Sharma *et al.* (2011) [18] and Mahto *et al.*, (2017) [11]. 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 cropping system under Kosi region of Bihar.

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	24.19	43.30	87.51	23.98
N	32.37	61.60	121.57	33.31
NP	38.67	74.83	146.75	40.21
NK	35.47	69.56	135.74	37.19
NPK	43.94	79.70	160.24	43.90
NPK+Zn	47.53	86.11	173.22	47.46
Fp	36.43	71.78	139.83	38.31
CD (P=0.05)	1.94	2.85	4.87	1.33

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)	8.18	15.25	15.48
Phosphorus (P_2O_5)	15.75	17.64	21.89
Potash (K_2O)	15.50	15.92	20.24

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

Treatment	Response over control			NPK	Response of P		Response of K		$ZnSO_4$
	N	NP	NK		Over N	Over NK	Over N	Over NP	Over NPK
Rice	8.18	10.34	9.4	12.34	15.75	21.17	15.5	26.35	14.36
Maize	15.25	16.15	15.44	14.85	17.64	13.52	15.92	7.74	

Table 4: Total N P and K uptake (kg ha^{-1}) by rice, maize and rice-maize cropping system as influenced by various treatments

Treatments	Rice			Maize			Rice-maize system		
	N	P	K	N	P	K	N	P	K
Control	44.66	16.31	55.97	98.47	26.83	113.79	143.13	43.14	169.76
N	59.76	21.83	74.92	140.07	38.16	161.87	199.83	59.99	236.79
NP	71.39	26.07	89.48	170.17	46.36	196.64	241.56	72.43	286.12
NK	65.49	23.92	82.09	158.19	43.09	182.80	223.68	67.01	264.89
NPK	81.12	29.63	101.68	181.24	49.38	209.44	262.36	79.01	311.12
NPK+ Zn	87.75	32.05	110.00	195.82	53.35	226.30	283.57	85.4	336.30
FP	67.25	24.56	84.30	163.24	44.47	188.64	230.49	69.03	272.94
CD (P=0.05)	3.58	1.31	4.49	6.48	1.76	7.48	-	-	-

Table 5: 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	94630	51850	42781	1.03
N	131996	54624	77372	1.76
NP	159507	58784	100723	2.11
NK	147670	56010	91661	2.03
NPK	173431	60170	113261	2.50
NPK + $ZnSO_4$	187458	61670	125788	2.49
Farmers' practice	152158	57382	94776	2.11
	5281.3		5281.3	0.12

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