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Full Length Research Paper

Interaction Effect of Nitrogen, Phosphorus, Potassium with Sulphur, Boron and Zinc on Yield and Nutrient Uptake by Rice Under Rice - Rice Cropping System in Inceptisol of Coastal Odisha

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Abstract

A replicated field experiment was conducted for two years in Inceptisol of coastal Odisha to investigate the integrated effect of major (N, P, K), secondary (S) and micronutrient (B and Zn) on yield, nutrient accumulation and uptake by rice. The results revealed that highest significant grain yield of 76.70 q ha^{-1} was recorded when the crop received all the nutrients (N, P, K, S, B and Zn). The yield was decreased by 19.4 – 27% due to omission of N, P, K or P,K and by 17.1 – 32.6 % in absence of S, B, Zn individually or in combination. Combined application of all the nutrients increased nutrient accumulation and uptake. Omission of N, P, K or N&P from the fertilizer schedule decreased the N, P and K uptake by 40.7 – 50.5, 13.9 - -20.4 and 33.0- 46.9% respectively. Among the micro and secondary nutrients, deletion of B greatly affect the N, P and K uptake as compared to Zn and S. Integrated use of N, P and K with S, B and Zn recorded highest grain yield response (37.23 kg grain per kg of the fertilizer applied). It was reduced by 44-49 % in absence of P or K and by 8% in absence of B, Zn, S.

Keywords: Integrated nutrient management, nutrient accumulation, grain yield response, interaction effect.

INTRODUCTION

Inceptisols occupy about 48 per cent of the total geographical area of Odisha and represent older alluvial and mixed red and yellow soils. These soils in general are neutral to slightly alkaline in reaction and have high base saturation capacity with Ca^{++} and Mg^{++} dominating in the exchange complex. Rice is the principal food grain of the state and occupies about 0.40 m. ha during kharif and 0.03 m. ha during rabi season in irrigated command areas covering Alfisols and Inceptisols. In irrigated command areas intensive cultivation of rice after rice for several years has depleted the available nutrients of the soil considerably and rice yield declined.

Recent studies indicated that about 44 percent of soils of Odisha are deficient in B, 28percent in Zn and 18 percent in S. Further the soils are low in available N and P but medium in available K (Jena *et al.,* 2008).

Balanced nutrition based on soil test value is the key to sustain rice productivity and to improve soil productivity. A suitable combination of secondary and micronutrients is the most important single factor that affects the productivity of the crops. With these information, the present study was undertaken to evaluate the integrated effect of N, P and K with S, Zn and B on productivity and nutrient uptake by rice grown in an highly intensive cultivated alluvial tract of coastal Odisha.

MATERIAL AND METHODS

A field experiment as conducted on alluvial soil representing an Inceptisol (Typic Ustocrept) during kharif

2011 and 2012 in farmers field, village Singarkeri in Delang block of Puri district. The experimental soil (0-15 cm) was loamy in texture with sand, silt and clay content of 56.6, 26.0 and 18.4 %, respectively. It was mild acidic in reaction (pH-6.14), non-saline (EC – 0.19 ds m^{-1}), low in available N (176 kg ha^{-1}), high in P (26 kg ha^{-1}) and medium in K (174 kg ha^{-1}). The soil was high in available S (30 mg Kg^{-1}), Zn (1.0 mg Kg^{-1}) and B (0.8 mg Kg^{-1}). Organic carbon content of the soil was 6.5 g Kg^{-1}. In general, the fertility status of the experimental site was optimum with few limitations. The experiment was laid out in a randomized block design (RBD) with three replications and nine treatments consists of T_1: N+P+K+S+ Zn+ B; T_2 : T_1 – B; T_3 : T_1 – Zn; T_4 : T_1 – S; T_5 : T_1 – K; T_6 : T_1 – P; T_7 : T_1 – N; T_8 : T_1 – S,Zn,B; T_9 : T_1 – P & K. Twenty days old rice seedlings (Cv.- Kranti) was transplanted during second week of July. The crop received fertilizer @ 80:40:40 Kg N: P_2O_5: K_2O per hectare as per the treatments. Full dose of P and K and 25% of N was applied at the time of planting through diammonium phosphate and muriate of potash. Rest of the nitrogen was applied through Urea i.e. 50% at peak tillering and 25% at panicle initiation stage. In case of secondary and micronutrient treated plots sulphur was applied @ 40 Kg S ha^{-1} through phosphogypsum (16% S), Zn @ 25Kg ha^{-1} as $ZnSO_4$, and B @ 10Kg ha^{-1} as borax. Other agronomic practices were followed as per the crop requirements. Biometric observations were recorded before harvest of the crop. The crop was harvested at full mature stage. The grain and straw yield were recorded at proper moisture content. Grain and straw samples were processed and digested with di-acid mixture (HNO_3: $HClO_4$ in 9:1 ratio). Phosphorus was determined by Vanadomolybdo Phosphoric acid yellow colour method (Jackson, 1973), S by turbidometric method (Chesnin and Yien, 1951), K by Flame photometer, Zn by Atomic Absorption Spectrophotometer (Lindsay and Norwell, 1978) and B by Azomethine-H method (Page *et al.*, 1982). Nitrogen in grain and straw were determined by modified micro-Kjeldhal method (Jackson, 1973). The nutrient uptake was calculated by multiplying the concentration values with respective grain and straw yield data.

RESULTS AND DISCUSSIONS

With integrated application of N, P, K and S, B, Zn the grain yield of rice increased significantly during both the years (Table 1). The highest grain yield of 69.3 q ha^{-1} and 76.7 q ha^{-1} was recorded during 2011 and 2012, respectively. In general, the grain yield was higher during 2012 than that of 2011 due to well distributed rainfall and more bright sun shine hour without any severe calamities. With omission of N, P, K and PK from the fertilizer schedule, the yield was declined over best treatment (T_1: N+P+K+S+ Zn+ B) by 5.6, 8.4, 18.6 and 30.0% during 2011 and 27.0, 25.3, 21.1 and 19.4% during 2012 respectively (Figure 1). The omission effect of major nutrients on the grain yield was in the order of N<P<K<PK during first year and PK<K<P<N during second year. Although the omission effect of during first year was lower than P and K, but in the second year it became the limiting nutrient to influence the grain yield since the inherent soil status could not meet the crop N requirement.

The deletion effect of K during second year was lower than the first year might be due to incorporation and decomposition of left over straw (about 15 cm height) that build up the K status of the soil to meet crop K requirement. Since the soil was high in available P, the deletion effect of P from the schedule did not affect the grain yield too much and remained in between N and K. However, deletion of PK from the fertilizer schedule influenced the grain yield significantly during both the years. Deletion of PK reduced the grain yield by 30.0 and 19.4% during first and second year respectively.

Among the secondary and micronutrients, omission of individual element such as S, Zn, B or combination of S, Zn, B reduced grain yield over T_1 (N+P+K+S+ Zn+ B) by 25.1, 2.3,14.4 and18.6% during first year and 19.8, 17.1, 32.6 and 19.4% during second year respectively (Figure 1). The extent of limiting nutrients was in the order of Zn<B<S< B,Zn,S during first year and Zn<S<S,B,Zn<B during second year. Among the micronutrients, effect of B was higher than Zn. Generally the farmers of the region apply $ZnSO_4$ to rice and the response to Zn application was not observed during both the years might be due to high soil Zn status. However, based on this observation, Zn application should not be skipped from the fertilizer schedule.

Boron is very much essential for flowering and grain formation in rice. In absence of B, there was reduction in grain yield from 69.3 to 59.6 q ha^{-1} during first year and 76.7 to 51.7 q ha^{-1} during second year. Reduction of yield by 14.4-32.6 % is a great concern in rice production. However, the effect of S remained in between B and Zn.

Straw Yield in best treatment (T_1) was 76.7 and 81.0 q ha^{-1} during first and second year respectively (Table 1). Potassium was found to be limiting during first year where as N was limiting during second year. The effect of P remained in between N and K as observed in grain yield. Harvest index of rice in all treatments remained in between 0.47 to 0.48 during first year but during second year it was higher in T_1 (0.49) and varied between 0.47 to 0.48 in other treatments.

Biometric observations

Biometric observations like plant height (102.80 cm), no. of effective tillers per hill (16.33) and panicle length (23 cm) was higher in best treatment (T_1) (Table 2). However, omission of N, P, K or PK from the schedule had marginal

Table 1. Effects of multinutrients on rice yield (q ha^{-1})

Treatments	Kharif 2011			Kharif 2012		
	Grain	Straw	HI	Grain	Straw	HI
T_1 : N P K + S B Zn	69.3	76.7	0.47	76.7	81.0	0.49
T_2 : T_1 – B	59.6	66.0	0.47	51.7	58.2	0.47
T_3 : T_1 – Zn	67.7	75.0	0.47	63.6	68.7	0.48
T_4 : T_1 – S	51.9	57.0	0.48	61.5	67.3	0.48
T_5 : T_1 – K	56.4	63.0	0.47	60.6	67.7	0.47
T_6 : T_1 – P	63.4	70.0	0.48	57.3	64.3	0.47
T_7 : T_1 – N	65.4	72.7	0.47	56.0	63.3	0.47
T_8 : T_1 – S Zn B	56.4	63.7	0.47	54.9	62.2	0.47
T_9 : T_1 – P K	48.5	54.7	0.47	61.8	70.0	0.47
CD (0.05)	3.04	3.13		2.03	1.95	

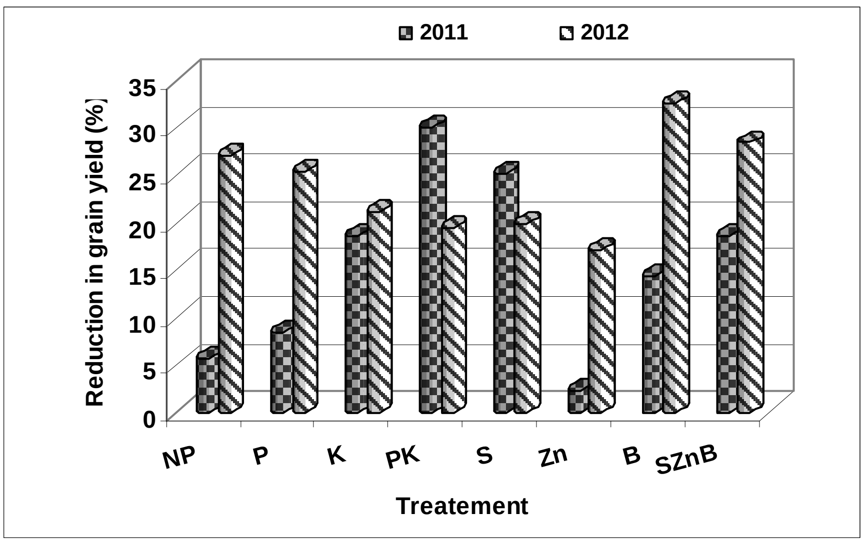

Figure 1. Percent reduction in rice yield in absence of different nutrients

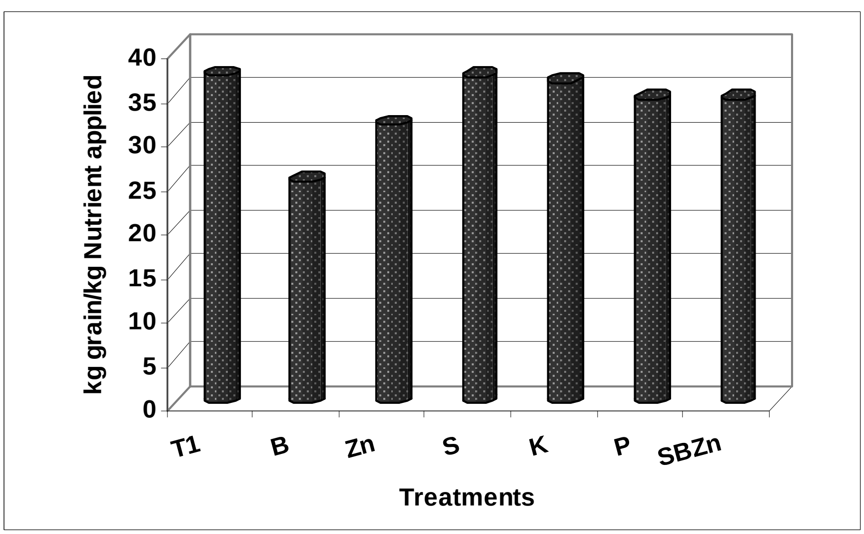

Figure 2. Omission effect of nutrients on nutrients use efficiency

Table 2. Effects of multinutrients on growth and yield attributes of rice (mean of two years)

Treatments	Plant height (Cm)	No. of effective tillers /hill	Panicle length (Cm)	Chaff (%)	1000 grain weight (gm)
T_1	102.8	16.3	23.0	13.0	17.5
T_1	99.9	12.7	22.2	19.2	15.6
T_3	101.3	13.3	22.6	15.7	16.1
T_4	102.3	13.3	23.0	14.3	15.4
T_5	102.3	13.3	21.9	15.3	16.1
T_6	101.3	13.7	22.6	12.5	16.2
T_7	98.5	12.0	22.5	12.7	15.7
T_8	101.5	15.3	21.5	16.0	17.2
T_9	101.9	13.0	22.8	15.0	15.5
CD (0.05)	NS	1.3	NS	1.6	1.04

effect on biometric characters. Skipping B from the fertilizer schedule decreased the plant height, tiller number and panicle length by 3.4, 22.3 and 2.5% over T_1. Omission of Zn, S or S Zn B had no significant effect on biometric characters.

Grain filling and chaff percent in rice were significantly influenced by micro and secondary nutrients as compared to major nutrients. Chaff percent in best treatment (T_1) was 13% and increased by 21.2 – 47.4% in absence of S, B, Zn or SBZn and 2.6 – 17.9% in absence of N, P, K, or PK. Highest significant chaff content was recorded in absence of B (47.4%) followed by S B Zn treatment (23.1%). Among the major nutrients, the role of K in grain filling was higher than N or P.

The effect of major, secondary or micronutrients on test weight was not clearly observed. It was 17.5 gm in T_1 and decreased by 7.5 to 10.4 % in absence of N, P, K or PK and 8.2 to 12.5% in absence of S, B, Zn or SB Zn treatments.

Nutrient accumulation

Accumulation of N, P and K

Highest accumulation of N in grain (2.06%) and straw (0.70%) was recorded in T_1 treatment. Omission of N fertilizer from the schedule decreased the N accumulation by 34.95% in grain and 21.43% in straw. On the other hand, K plays a vital role in N accumulation and in absence of K, the N content decreased by 41.75% in grain and 28.57% in straw. The role of P application on N accumulation was not so significant as compared to N or K. This might have happened due to increase in solubility of fixed P in soil at neutral soil pH in rice ecosystem (Table 3).

Nitrogen accumulation was greatly declined in absence of S application although the crop received recommended dose of N. In absence of Zn addition, the N content declined by 32% as against 23.8% for B.

Content of P varied between 0.22 to 0.28% in grain and 0.12 to 0.18% in straw, respectively and highest accumulation was recorded in T_1 treatment. Although the soil is rich in available P, skipping the P application greatly influence its accumulation as compared to N or K. Reduction in P accumulation in absence of B and Zn was higher as compared to S.

Accumulation of K in straw was higher than grain. It varied between 0.29 to 0.39% in grain and 1.54 to 1.93% in straw. Highest significant K accumulation was recorded in T_1 treatment.

With omission of N, P, K or PK from the fertilizer schedule, content of K was decreased over T_1 by 12.8 – 23% in grain and 12.4-16.6% in straw. The rate of decrease was in the order of K<P<N<PK indicating that maximum reduction in K accumulation was observed when P and K was omitted from the schedule.

The omission effect of micro and secondary nutrients from the fertilizer schedule was similar to major nutrients indicating that the efficiency of major nutrients could not be achieved in absence of these nutrients.

In absence of B, Zn, S or B Zn S addition, K accumulation was decrease over T_1 by 12.8 – 25.6% in grain and 14.0 – 17.1% in straw. The reduction was in the order of Zn<B<S< ZnBS indicating that deletion of ZnBS from the schedule significantly decreased K accumulation.

Accumulation of B, Zn and S

Accumulation of S in straw was higher than grain and it varied between 0.08- 0.11% in grain and 0.16 to 0.50% in straw. Among the major nutrients, N plays an important role in S accumulation and its omission decreased S content by 36.4% in grain and 48% in straw. The combined effect of PK was higher than individual effect of P or K. On the other hand, deletion of S addition reduced the S accumulation over T_1 by 27.3% in grain and 38% in straw.

Table 3. Effects of multinutrients on nutrient content in rice (Mean of two years)

Treatments	N (%)		P (%)		K (%)		S (%)		Zn (mg kg^{-1})		B (mg kg^{-1})	
	Grain	Straw	grain	Straw	grain	Straw	grain	Straw	grain	Straw	grain	straw
T_1	2.06	0.70	0.28	0.18	0.39	1.93	0.11	0.50	73	94	45.6	39.0
T_2	1.57	0.70	0.24	0.14	0.33	1.61	0.10	0.34	65	90	36.5	32.4
T_3	1.45	0.65	0.24	0.13	0.34	1.61	0.10	0.30	60	71	41.2	23.0
T_4	1.40	0.62	0.26	0.14	0.32	1.60	0.08	0.31	66	90	26.0	30.8
T_5	1.20	0.50	0.26	0.13	0.34	1.65	0.10	0.23	45	91	25.7	23.5
T_6	1.60	0.57	0.23	0.13	0.32	1.69	0.10	0.27	44	83	27.1	20.5
T_7	1.34	0.55	0.26	0.14	0.33	1.68	0.07	0.26	46	88	24.0	31.6
T_8	1.36	0.60	0.26	0.14	0.29	1.66	0.05	0.46	48	66	31.2	24.5
T_9	1.30	0.50	0.25	0.12	0.30	1.61	0.08	0.16	44	74	41.4	28.6
CD (0.05)	NS	NS	NS	NS	0.05	0.09	0.02	0.08	7.26	7.4	6.9	5.6

Accumulation of Zn in straw was higher than grain and it varied between 40-74 mg kg^{-1} in grain and 51-94 mg kg^{-1} in straw. Combined application of NPK along with SB Zn recorded highest Zn content of 73 mg kg^{-1} in grain and 94 mg kg^{-1} in straw.

Deletion of N, P, K or PK from the fertilizer schedule decreased the Zn accumulation over T_1 by 37.0 – 39.7% in grain and 3.2 – 21.3% in straw. Highest reduction was recorded in absence of PK followed by P, K, or N. Similarly, with deletion of B Zn S from the schedule, Zn content was decreased over T_1 by 34.3% in grain and 29.8% in straw.

Boron content in grain and straw varied between 21.3 – 45.6 and 20.5 – 39.0 mg kg^{-1}, respectively. Combined application of N, P and K along with S, B and Zn recorded significantly higher B content in grain (45.6 mg kg^{-1}) and straw (39.0 mg kg^{-1}) as compared to other treatment combinations. Deletion of N, P, K or PK decreased the B content over T_1 by 40.6 – 47.4% in grain and 19.1 – 47.5% in straw and highest reduction was observed when N fertilizer was omitted from the schedule.

Nutrient uptake

Significantly higher N uptake by grain (158.3 kg ha^{-1}) and straw (56.7 kg ha^{-1}) was observed in T_1 treatment. Omission of N, P, K or PK from the fertilizer schedule decreased N uptake over T_1 by 40.7-50.5%. Nitrogen uptake was significantly decreased in absence of N or K as compared to P. In case of micro and secondary nutrient treatments, omission of B, Zn or S decreased the N uptake by 43.3, 36.2 and 40.5%, respectively over T_1, Maximum decreased was observed (47.0%) when the crop received only NPK (Table 4).

Phosphorous uptake varied between 13.2-21.5 kg ha^{-1} in grain and 8.4-9.3 kg ha^{-1} in straw and total uptake 20.44-30.74 kg ha^{-1}. There is not much difference in P uptake per quintal of grain which varied between 0.38 – 0.42 kg q^{-1} grain. In absence of P application the uptake was reduced by 30% over the best treatment (T_1). In absence of N, K or NP application the uptake was reduced by 13.9 to 20.40%. Boron plays an important role in translocation and absorption of P by rice. In absence of this vital nutrient the uptake was reduced by 33.5% over T_1. However in absence of Zn or S, the P uptake was reduced by 21.43 and 17.50% respectively over T_1.

Potassium keeps the plant erect, avoid lodging, reduces chaff percent and increase the resistance power of the plant. Absorption of K in plant is influenced by N and P. Highest K uptake was recorded (110.02 kg ha^{-1}) in T_1 treatment. Skipping N or P from this fertilizer schedule, the K uptake was reduced over T_1 by 33 and 31.8%, respectively.

Boron plays a vital role or even better than N and K in K translocation and absorption. Omission of B decreased the K uptake by 40.6% over T_1. In absence of Zn or S, the decline was 29.0 and 31.7%, respectively over T_1.

The magnitude of S uptake was similar to P uptake which varied between 20.37–49.52 kg ha^{-1}.

Table 4. Effects of multinutrients on nutrient uptake by rice (mean of two years)

Treatment	N uptake (kg ha^{-1})		Kg N uptake q^{-1} grain	P uptake (kg ha^{-1})		Kg P uptake q^{-1} grain	K uptake (kg ha^{-1})		Kg K uptake q^{-1} grain	S uptake (kg ha^{-1})		Kg S uptake q^{-1} grain	Zn uptake (g ha^{-1})		g Zn uptake q^{-1} grain	B uptake (g ha^{-1})		g B uptake q^{-1} grain
	G	S		G	S		G	S		G	S		G	S		G	S	
T^1	158.3	56.7	2.80	21.5	9.3	0.40	30.1	156.2	2.43	8.4	41.1	0.64	560.4	759.7	17	350.0	316.0	8.0
T_2	81.2	40.7	2.36	12.4	8.0	0.39	17.1	93.6	2.14	5.4	19.8	0.50	336.3	523.2	16	188.9	187.7	7.0
T_3	92.6	44.6	2.15	15.3	8.9	0.38	21.6	110.8	2.08	6.6	20.6	0.34	381.5	487.7	13	262.1	157.7	6.0
T_4	86.2	41.8	2.07	16.0	9.4	0.41	19.6	107.7	1.75	4.9	20.9	0.41	406.2	429.3	13	159.5	205.4	5.0
T_5	72.6	33.9	1.75	15.8	10.7	0.43	20.6	78.4	1.63	6.1	15.6	0.36	271.5	616.1	14	155.6	157.1	5.0
T_6	91.8	36.7	2.24	13.2	8.4	0.38	18.4	108.7	2.21	5.9	16.1	0.38	252.4	533.7	13	155.2	130.2	4.0
T_7	75.0	34.8	2.00	14.6	8.9	0.42	18.5	106.4	2.23	3.9	16.5	0.36	258.0	554.2	14	134.4	198.7	4.0
T_8	74.6	37.3	2.07	14.3	8.7	0.41	16.3	102.9	2.17	3.1	28.6	0.57	263.7	291.9	10	171.2	152.0	5.0
T_9	80.4	34.8	1.86	15.4	9.1	0.40	18.5	112.3	2.12	5.2	17.6	0.36	270.7	508.6	12	255.8	199.3	7.0
CD (0.05)	11.11	6.25		2.63	NS		3.17	31.60		1.38	4.62		49.1	225.3		98.93	35.74	

G = Grain, S = Straw

Highest significant uptake was recorded in T_1. Skipping K, P, N or PK application, the S uptake was decreased by 54.0 – 58.9% over T_1. Zinc plays an important role in S absorption as compared to B and S. In absence of Zn, S uptake was decreased by 56.32 % over T_1 whereas, the magnitude of reduction in absence of B and S was 49.30 and 48.0%, respectively.

Integrated use of both major and micronutrient recorded highest Zn absorption (1.32 Kgha^{-1}). The interaction effect of P and Zn is synergistic. Omission of P from the fertilizer schedule, significantly decreased Zn uptake over T_1 by 40.44% as against 41.0% in absence of PK. Contribution of S was higher than Zn or B. In absence of S, Zn uptake of Zn was reduced by 36.10% over T_1 as against 34.9% for B and 34.15% for Zn. However, the integrated effect of S, B and Zn was maximum as compared to their individual effect since omission of SB Zn from the fertilizer schedule decreased the Zn uptake by 57.9% over T_1.

Boron uptake by rice varied between 247.56 to 665.96 g ha^{-1} and highest uptake was recorded in T_1 treatment. Among the major nutrients, the contribution of N was higher than P or K, since maximum reduction was recorded (62.85%) in this treatment (T_7). Among the secondary and micronutrients, the degree of reduction was highest (45.20%) in absence of S followed by B (43.44%) and Zn (36.95%). However, maximum reduction (51.46%) was recorded when all these three elements (S, B, Zn) was deleted from the fertilizers schedule.

Nutrient use efficiency and interaction effects

Interactions among the nutrients are a standard feature of biological system. These interaction effects have significance in crop productivity and returns from investments made by farmers on fertilizers. Interaction between two or more nutrients may be positive (synergistic), negative (antagonistic) or even absent (additive effect). Both the positive and negative ones is equally important because of the ability to maximize the returns from positive interaction and also to minimize the losses from antagonistic effects. Available research results revealed that N and P interaction is often synergistic, occasionally additive and in some cases can be antagonistic (Biswas and Prasad, 1991). Chakravorti (1982) reported that K application increased the N content in grain and K uptake by rice in alluvial, black, red and lateritic soils of India. The N and K interaction showed synergistic effect on rice yield.

The results of the present study indicated that

Table 5. Percent reduction in nutrient uptake by rice in absence of different nutrients

Treatment	Percent reduction in nutrient uptake					
	N	P	K	S	Zn	B
-N(T_7)	48.9	23.7	30.0	58.9	38.5	62.9
-P(T_6)	40.5	30.0	31.8	55.6	40.4	57.1
- K(T_5)	50.5	13.9	46.9	56.3	32.8	53.0
-PK(T_9)	46.4	20.4	29.8	54.0	41.0	31.7
-S(T_4)	40.5	17.5	31.7	48.0	36.7	45.2
-Zn(T_3)	36.2	24.4	29.0	56.3	34.2	37.0
-B(T_2)	43.3	33.5	40.6	49.3	34.9	43.4
-S Zn B(T_8)	47.0	25.4	36.0	36.0	57.9	51.5

about 126 to 206 kg of plant nutrients per hectare (N + P + K + S + Zn+ B) was applied to rice as per the treatments. Highest grain yield response of 37.23 kg grain kg^{-1} nutrient applied was recorded when rice received balance package of all nutrients. The grain yield response decreased to 34.53-36.48 kg grain kg^{-1} nutrient applied when P or K was omitted from the schedule. This showed that the interaction effect of P or K alone with other nutrients is synergistic but the combined effect was negligible when P and K were applied together.

In absence of secondary and micronutrients, the grain yield response decreased from 37.23 (T_1) to B –25.23, Zn – 31.64, S – 37.06 and B Zn S 34.33 kg grain kg^{-1} nutrient applied indicating that interaction effect of B or Zn with other nutrients is synergistic and higher than S. However, the combined effect of B Zn S was additive since there was no change in nutrient use efficiency in this treatment.

Several studies showed that the crop yield and nutrient uptake in N + P treated plots was higher than N or P alone (Bhusan and Singh 1979, Tandon 1987). Chandrakar *et al.* (1978) reported that the N and P interaction in rice at Raipur was almost additive and weakly synergistic. But system became highly synergistic when adequate K supply was ensured in all plots. The results of the present study showed that the contribution of P and K interaction (-N) in N accumulation and uptake was maximum as compared to N and P as well as N and K interaction. Since the soil has optimum N and O.C. content, interaction of N with P or K was negligible or additive in nature. On the other hand, the contribution of N and P towards N and K uptake was highly synergistic in presence of optimum supply of K (Table 5).

The contribution of N and P, N and K and P and K interaction becomes negligible in S uptake, since N alone contribute 58.9% to words S uptake. Similar trend was observed in Zn uptake. The contribution of (-) PK was 41 % as against N and P – 32.8%, N and K – 40.4% and P and K – 38.5%.

Boron uptake was greatly influenced due to P and K interaction rather than N alone. Addition of N (in – PK treatment) contributes only 31.7% towards B uptake where as a synergistic interaction effect was observed in N and P, N and K and P and K treatments. The positive effects of N and K interaction was reported by several workers (Umar et al 1986, Chandrakar *et al.,* 1978).

Among the secondary and micronutrients, the contribution of B towards yield and nutrient uptake was maximum. Omission of this nutrient from the fertilizer schedule, reduced the grain yield, straw yield, N, P, K, S, Zn and B uptake by 32.6, 28.3, 43.3, 33.5, 40.6, 49.3, 34.9, and 43.4%, respectively. The individual effect of S and Zn was lower than B. The combined interaction effect of B Zn S does not indicate synergistic in yield and N, P, K uptake because the response in this treatment was lower than the individual effect of B. However synergistic interaction effect (of S x B x Zn) was observed in B and Zn uptake.

Post harvest soil properties

The initial soil pH was 6.14 and varied between 6.14 – 6.43 in treatments after harvest of two rice crops. In all the treatments, the pH remained above the initial value. However higher pH was maintained in best treatment (T_1) due to maintenance of soil fertility at optimum level. The role of micro and secondary nutrients on soil pH in puddled rice field could not be realized under present study. The O.C. content of initial soil was 0.65% and remained between 0.58 – 0.83% in treatments. There was a declined trend in available N which varied between 115.4 – 177.0 kg ha^{-1} as against an initial value of 175.8 kg ha^{-1}. The decline trend in the best treatment (T_1) suggests to be rescheduled the N dose for rice in rice-rice cropping system (Table 6).

Maintenance of soil P and K status after two crops showed a positive impact on nutrient management strategy. Build up of S and Zn status in soil suggested that these two nutrients can be skipped from the schedule for one –two seasons without any adverse impact on crop yield. Although the hot water soluble B content in soil

Table 6. Nutrient status of soil after harvest of two rice crops (mean of three applications)

Treatments	pH	O.C. (%)	N	P	K	S	Zn	B
			(Kg ha^{-1})				(mg kg^{-1})	
T_1	6.43	0.62	119.0	21.6	160.4	89.8	2.7	0.8
T_2	6.39	0.58	115.0	23.1	249.9	38.8	3.0	0.6
T_3	6.30	0.64	146.7	32.2	164.6	74.0	2.8	0.7
T_4	6.19	0.65	115.4	29.8	166.8	42.3	3.0	0.7
T_5	6.19	0.70	117.0	25.1	167.4	79.3	3.2	0.8
T_6	6.15	0.83	119.8	33.9	190.3	69.0	3.1	0.6
T_7	6.17	0.64	123.2	30.4	168.8	80.0	2.8	0.7
T_8	6.28	0.68	116.5	27.5	201.5	53.0	3.0	0.5
T_9	6.14	0.65	175.8	25.7	173.6	100.0	3.0	0.8
Initial	**6.14**	**0.65**	**175.8**	**25.7**	**173.6**	**60.0**	**1.0**	**0.8**

remained in medium to high range, but its application to each crop is recommended to maintain higher productivity.

CONCLUSION

The result of the study revealed that combined application of NPK with S, B and Zn recorded higher yield, nutrient accumulation as well as uptake and maintained soil fertility. Omission of N, P or K from the fertilizer scheduled reduced the rice yield by 19.4 – 27.0%. Yield reduction in absence of B was higher (32%) as compared to N, P or K alone or in combination. Combined application of B Zn S increased the use efficiency of N, P and K. The grain yield response decreased by 44-49% in absence of P or K and by 8% in absence of B Zn S.

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