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Effect of sulphur and zinc management on yield, nutrient uptake, changes in soil fertility and economics in rice (*Oryza sativa*)–lentil (*Lens culinaris)* cropping system

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ABSTRACT

Four levels of sulphur and zinc (total 16 treatment combinations) were evaluated for three years (2008–09 to 2010–11) under randomized block design replicated thrice. Both the nutrients were applied to rice (*Oryza sativa* L.) and their direct and residual response was ascertained to rice and lentil (*Lens culinaris* Medikus) in sequence. Pooled results indicate that maximum rice yield (7.72 tonnes/ha) was recorded with combined application of 30 kg sulphur and 6 kg zinc, whereas corresponding minimum rice yield (7.09 tonnes/ha) was recorded with control where no application of zinc and sulphur was done. Similarly maximum lentil seed yield (1 243 kg/ha) was recorded with combined application of 30 kg sulphur and 6 kg zinc whereas corresponding minimum lentil seed yield of 960 kg/ha was recorded with control. Highest N uptake (281.2 kg/ha) was recorded with 6 kg zinc application, whereas P and K uptake was highest with 40 kg sulphur application. Highest extra net return (₹ 6 611/ha) was recorded in the plots which received combined application of 30 kg sulphur and 6 kg Zn. Maximum B: C ratio was noticed in with 20 kg sulphur application.

Key words: B: C ratio, Cropping system, Indo Gangetic Plains, Lentil, Rice, Sulphur, Zinc

Rice (*Oryza sativa* L.) and lentil (*Lens culinaris* Medikus) are very important in the Indo-Gangetic Plain (IGP) for their contribution to human and animal nutrition, as components of indigenous cropping systems, and as restorers of soil fertility (Ali *et al*. 2012, Joshi 1998, Reddy 2009 and Ramakrishna *et al*. 2000). Rice is staple food of not only Bihar but also for India and South Asia. Lentil is the important legume crop mainly grown in residual soil moisture in Eastern part of India and prominent source of vegetable protein (Singh *et al*. 1997 and Singh *et al.* 2011). Rice–lentil cropping system is practised with no application of chemical fertilizers or only high analysis chemical fertilizers only to rice crops. There is stagnation and deterioration in productivity of both the crops in a cropping sequence as well as on individual basis because zinc and sulphur deficiency is very common in track of Eastern Indo-Gangetic alluvial plains, where high intensive cropping of rice–wheat is practised and oilseeds and pulses are raised (Singh and Singh 2008). Rice–lentil cropping system is important cropping system not only for Bihar but also for Eastern UP, West Bengal and Odisha. In Bihar it is second to rice –wheat. Some part of country and in pockets of Bihar especially in Tal and Diara region, which occupies 3.00 lakh ha where either rice-lentil cropping or mono-cropping of lentil is possible (Singh *et al*. 2011). In Indo Gangetic plains (IGP) of Bihar, there is tendency to use indiscriminate amount of nitrogenous fertilizers and very limited amount of other nutrients containing high analysis chemical fertilizers. In general in this part of country lentil is grown on residue of rice crop and have to survive on the leftover nutrients and moisture by the previous crop (Ali *et al*. 2012).On an average to produce one tonne of grain of high-yielding varieties of rice, remove about 22 kg N, 7 kg P_2O_5, 32 kg K_2O, 5 kg MgO, 4 kg CaO, 1 kg S and 40g Zn from the soil. Similarly for producing one tonne of biomass, lentil crop in general remove about 40 kg N, 3.9 kg P_2O_5, 85 kg K_2O, 8.0 kg S 7.0 kg Ca, 9.0 kg Mg, 35 g Zn from soil (Ahlawat and Ali 1993). There is a need to ascertain and promote the uses of types of fertilizers required to correct the deficiency of all these nutrients especially zinc and sulphur. Zn deficiency is the most widespread micronutrient disorder in lowland rice and application of Zn along with NPK fertilizer increases the grain yield dramatically in most cases (Singh and Singh 2008). Deficiency symptoms of Zn in rice crop and sulphur in lentil are frequent and reduction in yield of rice and lentil is often blamed to zinc sulphur deficiency. There is need to investigate role of zinc and sulphur in the sustainable production of rice and lentil and their effects on fertility and productivity status of soil (Ahlawat and Ali 1993 and Sahaa *et al.* 2007). Keeping in the view of the

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Table 1 Effect of sulphur and zinc nutrition on rice seed yield (kg/ha) during 2010

Treatment	S_1(0kg)	S_2(20kg)	S_3(30kg)	S_4(40kg)	Mean of Zn
Zn_1(0kg)	7.09	7.17	7.23	7.27	7.19
Zn_2(4kg)	7.22	7.31	7.36	7.39	7.32
Zn_3(5kg)	7.29	7.46	7.52	7.53	7.45
Zn_4(6kg)	7.31	7.58	7.63	7.53	7.51
Mean of S	7.23	7.38	7.435	7.43	
CD (±5%)	Mean effects 0.12		Interaction 0.27		

Table 2 Effect of sulphur and zinc nutrition on seed yield (kg/ha) yield of lentil

Treatment	S_1(0kg)	S_2(20kg)	S_3(30kg)	S_4(40kg)	Mean of Zn
Zn_1(0kg)	960	1 003	1 073	1 103	1 035
Zn_2(4kg)	1 038	1 138	1 118	1 125	1 105
Zn_3(5kg)	1 070	1 125	1 153	1 131	1 120
Zn_4(6kg)	992	1 143	1 183	1 112	1 108
Mean of S	1 015	1 102	1 132	1 118	
CD (±5%)	Mean effects 34.7		Interaction (69.3)		

importance of rice–lentil cropping system in the IGP and role of sulphur and zinc nutrient in their crop physiology and ultimately in the economic yield this experiment was undertaken.

MATERIALS AND METHODS

A field experiment was conducted at ICAR Research Complex for Eastern Region, Patna during 2008–09 to 2010–11 in randomized block design (RBD) replicated thrice to evolve suitable nutrient management system with respect to one secondary nutrient (sulphur) and one micronutrient (zinc) under rice–lentil cropping system for Indo–Gangetic plains of Bihar. Total 16 treatment combination was tested, i e four level of sulphur S_1(0kg), S_2(20kg), S_3(30kg), and S_4(40kg) and zinc Zn_1(0kg), Zn_2(4kg), Zn_3(5kg) and Zn_4(6kg) were applied in combination, respectively, on hectare basis. Both sulphur and zinc applied to rice crop and their direct effects on rice and residual effect on lentil were investigated. Different sources were used for sulphur and zinc. Other nutrients especially NPK and agronomic management practices were as per recommended practices and were same for all treatments. No major incidence of pests and disease were noticed during the course of experimentation. The texture of soil of experimental field was silty clay loam with mean pH value of 6.8, electrical conductivity 0.16 dS/m in 1:2 soils: water solution, organic carbon 0.68%, with available nitrogen 244.7 kg/ha, available phosphorus 28.6 kg/ha, available potash 185.8 kg/ha, sulphur 8.3 kg/ha and zinc 0.8 kg/ha. The plot size was kept 10.0 m × 5.0 m. Seed yield (kg/ha) was estimated based on seed weight per plot adjusted to 12% moisture. Though only seed yield recorded has been given and discussed in this paper. Nutrient content on whole plant basis for both the crop was analysed at harvest and uptake was also calculated accordingly. Physical and chemical parameters of soils were recorded on pH, EC (dS/m), OC (%), available P (kg/ha) and available K (kg/ha) before sowing and after harvest crop. The soil samples were analysed following the procedure described by AOAC (1980). Regular analysis of variance was performed for each trait for all three seasons and the combined (Pooled) analysis over seasons after testing error variance homogeneity was carried out according to the procedure outlined by Gomez and Gomez (1984), using the MSTATC version 2.1 (Michigan State University, USA) statistical package design. Significant differences between the treatments were compared with the critical difference at (± 5%) probability by LSD.

RESULTS AND DISCUSSION

Effects of sulphur and zinc

Grain yield of rice was also affected significantly with the levels of both the factors/nutrients (S and Zn). Maximum (7.57 tonnes/ha) and minimum (7.20 tonnes/ha) grain yield was obtained with 6 and 0 kg/ha (Mondal *et al.* 2004, Sahaa *et al*. 2007, Singh and Gupta 1986 and Singh *et al*. 1997). To get clear-cut response of both the factors on rice yield, combined two way data is presented in Table 2. Perusal of data revealed that minimum rice yield (7.09 tonnes/ha) was recorded with absolute control plots where no application of zinc and sulphur was done during entire experimentation period. Whereas corresponding maximum (7.72 tonnes/ha) rice yield was recorded with combined application of 30 kg sulphur and 6 kg zinc (Mondal *et al.* 2004 and Singh *et al.* 2011). This combined analysis suggests that for better output and for balanced nutrition combined application is advocated.

Similarly highest lentil seed yield (1 147 kg/ha) was recorded with 30 kg sulphur treatment, whereas lowest yield (1 015 kg/ha) was noticed with no application of sulphur (Singh *et al.* 2002, Singh and Singh 2008 and Thiyagarajan

Table 3 Effect of sulphur and zinc nutrition on NPK concentration (%) in rice (grain + straw) and lentil (grain + straw) under rice–lentil cropping systems

Treatments	N (%)		P (%)		K (%)	
	Rice	Lentil	Rice	Lentil	Rice	Lentil
S_1(0kg)	1.10	1.85	0.42	0.74	0.73	0.91
S_2(20kg)	1.17	1.89	0.48	0.76	0.75	0.93
S_3(30kg)	1.21	1.91	0.46	0.79	0.74	0.87
S_4(40kg)	1.23	1.98	0.52	0.85	0.83	0.98
Zn_1(0kg)	1.09	1.83	0.57	0.71	0.78	0.93
Zn_2(4kg)	1.19	1.84	0.51	0.73	0.76	0.95
Zn_3(5kg)	1.23	1.92	0.48	0.66	0.78	0.76
Zn_4(6kg)	1.25	1.96	0.44	0.57	0.76	0.94
CD (±5%)	0.08	0.11	0.05	0.07	0.03	0.06

Table 4 Effect of sulphur and zinc nutrition on NPK uptake (kg/ha) in rice (grain + straw) and lentil (grain + straw) under rice–lentil cropping systems

Treatment	Nitrogen (kg/ha)			Phosphorus (kg/ha)			Potash (kg/ha)		
	Rice	Lentil	Total	Rice	Lentil	Total	Rice	Lentil	Total
S_1(0kg)	194.0	46.9	240.9	74.1	18.8	92.8	128.7	23.1	151.8
S_2(20kg)	205.6	53.4	259.0	84.3	21.5	105.8	131.8	26.3	158.1
S_3(30kg)	214.3	55.4	269.8	81.5	22.9	104.4	131.1	25.3	156.3
S_4(40kg)	222.9	58.3	281.2	94.2	25.0	119.2	150.4	28.8	179.2
Zn_1(0kg)	190.0	50.1	236.7	97.6	19.3	116.9	133.5	25.3	158.9
Zn_2(4kg)	212.5	51.9	264.3	91.1	20.7	111.7	135.7	26.9	162.6
Zn_3(5kg)	218.2	53.8	271.9	85.1	18.5	103.6	138.4	21.3	159.6
Zn_4(6kg)	223.5	55.7	279.2	78.7	16.2	94.9	135.9	26.7	162.6
CD (±5%)	11.7	4.9	18.3	6.7	3.1	8.3	13.1	3.6	15.2

et al. 2003). To get comprehensive and combined residual response of both the nutrients on lentil seed yield two data are presented in Table 4. Results of interaction of both the nutrient was synergistic in manner up to extant possible except at highest level. Results revealed that minimum lentil seed yield of 960 kg/ha was recorded with control, where nothing has been applied, whereas corresponding maximum lentil seed yield (1 243 kg/ha) was recorded with combined application of 30 kg sulphur and 6 kg zinc (Singh and Gupta 1986, Singh *et al*. 2011 and Thiyagarajan *et al.* 2003).

Effects of sulphur and zinc nutrition on content and uptake of NPK

To know the effect of sulphur and zinc on NPK concentration (%) and uptake (kg/ha) in rice (grain + straw) and lentil (grain + straw) under rice–lentil cropping systems, samples were analyses for above purpose. Data presented in Table 5 and 6, indicates that concentration and uptake of nitrogen, phosphorus and potassium due to application of sulphur and zinc, influenced significantly. Highest concentration (1.25 and 1.96%) of nitrogen in rice and lentil was recorded in plots fertilized with zinc 6 kg. The lowest concentration (1.10 and 1.83%) of nitrogen was noticed in case of rice and lentil plots treated with 0 kg sulphur and 0 kg zinc. Likewise response was also obtained in case of phosphorus and potassium concentrations in both the crops. Highest (0.57%) and lowest (0.42%) P concentration in rice recorded with 0 kg zinc application and 0 kg sulphur application. This is clear-cut indication of sulphur induced P deficiency and antagonistic relation of P and Zn (Islam *et al.* 2009, Singh and Singh 2008 and Thiyagarajan *et al.* 2003). K concentration in rice and lentil had been influenced by both the tested nutrients. Sulphur influenced rice greatly, whereas in case of lentil K concentration gets improved with increasing doses of Zn (Table 5). It was noticed that the concentration of all the three major nutrients (NPK) across the treatment was higher side in case of lentil in compression to rice (Singh *et al.* 2001, Sahaa *et al.* 2007).

Uptake of NPK by rice and lentil is accordingly to the content and their above ground biomass they produced. Since biomass produced by the respective crops and contents of NPK are influenced significantly, similar trend was also repeated in case of uptake. In general maximum uptake of all three nutrients was recorded in case of rice (Table 6). Highest N uptake 281.2 kg/ha was recorded with 6 kg zinc application, corresponding maximum uptake of P (119.2 kg/ha) and K

Table 5 Effect of sulphur and zinc nutrition on soil fertility status

Treatment	pH	EC ds/m	OC (%)	N (kg/ha)	P (kg/ha)	K (kg/ha)	S (ppm)	Zn (ppm)
Initial Value	6.80	0.19	0.71	244.7	28.6	185.8	0.81	8.3
Status (I)	Normal	Normal	Medium	Low	High	Medium	Low	Low
S_2 (20kg)	6.85	0.19	0.72	257.3	33.1	190.6	0.94	9.2
S_3 (30kg)	6.91	0.20	0.73	268.9	30.1	193.7	0.99	9.7
S_4 (40kg)	6.95	0.20	0.74	286.5	27.3	189.9	1.07	9.8
Zn_1 (0kg)	6.86	0.18	0.70	242.9	28.5	183.4	0.83	8.1
Zn_2 (4kg)	6.84	0.19	0.71	254.3	30.7	185.9	0.91	8.7
Zn_3 (5kg)	6.84	0.19	0.74	271.4	32.9	187.3	0.96	9.7
Zn_4 (6kg)	6.83	0.20	0.76	289.4	34.2	193.2	0.98	1.1
Status (F)	Normal	Normal	Medium	Low	High	Medium	Normal	Normal
CD (±5%)	NS	NS	NS	27.6	2.6	NS	0.07	0.6

Table 5 Effect of sulphur and zinc nutrition on economics of developed technology

Treatment	S_1(0kg)			S_2(20kg)			S_3(30kg)			S_4(40kg)			Mean of Zn		
	Expenditure	Extra incomes	Net extra returns	Expenditure	Extra incomes	Net extra returns	Expenditure	Extra incomes	Net extra returns	Expenditure	Extra incomes	Net extra returns	Expenditure	Extra incomes	Net extra returns
Zn_1(0kg)	0	0	0	200	1 451	1 251	300	3 426	3 126	400	4 351	3 951	225	2 307	2 082
Zn_2(4kg)	1 000	2 548	2 548	1 200	5 393	4 193	1 300	5 198	3 898	1 400	5 528	4 128	1 225	4 667	3 691
Zn_3(5kg)	1 200	3 685	3 685	1 400	5 913	4 513	1 500	6 901	5 401	1 600	6439	4 839	1 425	5 734	4 609
Zn_4(6kg)	1 400	1 962	1 962	1 600	6 996	5 396	1 600	8 211	6 611	1 800	5 992	4192	1 600	5 790	4 540
Mean of S	900	2 049	2 049	1 100	4 938	3 838	1 175	5 934	4 759	1 300	5 577	4 277			

Table 6 Effect of sulphur and zinc nutrition on economics of extra cost of cultivation v/s excess return

Treatments	Extra gross income (₹/ha)		Gross extra income (₹/ha)	Extra cost of cultivation (₹/ha)	Net profit (₹/ha)	BC ratio*
	Rice	Lentil				
S_1(0kg)	0	0	0	0	0	0
S_2(20kg)	753	2 446	3 199	200	2 999	15.9
S_3(30kg)	1 075	3 293	4 368	300	4 068	14.6
S_4(40kg)	1 230	2 994	4 224	400	3 824	10.6
Zn_1(0kg)	0	0	0	0	0	0
Zn_2(4kg)	1 032	1 715	2 747	1 000	1 747	2.7
Zn_3(5kg)	1 603	1 968	3 571	1 200	2 371	3.0
Zn_4(6kg)	2 015	1 842	3 857	1 400	2 457	2.8

*Note: Benefits cost ratio (B: C ratio) was calculated based on gross extra income and extra cost of cultivation involved.

(179.2 kg/ha) was recorded in the plot supplemented with sulphur @40 kg/ha in the cropping system (Islam *et al.* 2009, Sahaa *et al.* 2007, Singh and Gupta 1986 and Singh and Singh 2008).

Effects of sulphur and zinc nutrition on fertility status of soil

Perusal of data presented in Table 5 Vindicate that the initial value of pH and EC was recorded normal, however organic carbon (%) and K was in medium category. Phosphorus is the only mineral whose content was recorded and classified as high (28.6 kg/ha). Sulphur and zinc content was recorded below benchmark level. After the end of three years crop cycle, pH and EC value were recorded normal. There are gradual build-up of organic carbon (%), N, P and K due to application of sulphur and zinc; however significant build-up was noticed in case of sulphur and zinc content in the soil of experimental plots and it crossed the critical limits and categorized as normal. This data shows that every parameter was improved with the application of the minerals, this not only improved overall productivity of cropping system but also improved fertility status of soils as well.

Feasibility of developed technology

To test the feasibility of developed technology, i e sulphur and zinc nutrition in rice–lentil cropping system in the Indo–Gangetic plains of Bihar, input and output relation was worked out based on extra investment incurred for added inputs as other cost of cultivation remain same and also to stay away from detailed explanation. Extra expenditure, extra incomes and net extra returns were calculated and presented in Table 5. Highest extra net returned (₹ 6611/ha) was noticed in case of combined application of 30 kg sulphur and 6 kg zinc. Likewise extra benefits cost ratio (B: C ratio) of added inputs and corresponding output is presented in the Table 6. It is interesting to note that B: C ratio has followed different fashion for different added nutrients. With increasing dose sulphur the response ratio in terms of per rupee investment is decreasing in order with maximum B: C ratio (16.0) in case of plot treated with 20 kg sulphur and minimum (10.6) with 40 kg sulphur. In case of zinc application, the response ratio recorded increasing in trend up to 5 kg (B: C ratio of 3.0) and then starts decreasing (Bastia *et al.* 2008, Singh *et al.* 2001 and Singh and Singh 2008).

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