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Yield and sulphur nutrition as influenced by direct and residual effect of sulphur in rice-rice sequence in vertisol of Karnataka*

Sulphur deficiency, caused by reduction of SO_4^{-2} to SO_3^{-2} and S^{-2} under anaerobic conditions has become an important growth limiting factor for wetland rice. In recent years, sulphur deficiency is occurring commonly in continuously submerged and continuously rice cropped areas with increased use of fertilizers, overstraining the sulphur supply reserves of the soil. The optimum dose of sulphur varied with crops and nature of the source. Sulphur application in general benefits more than one crop in sequence and produces a significant residual response. In view of the above, experiments were carried out to study the direct and residual effects of sulphur on rice yield and sulphur nutrition in rice-rice cropping sequence in Vertisol of Karnataka.

Field experiments were conducted at Agricultural Research Station, Gangavati, UAS, Dharwad during *rabi*/summer and *kharif* seasons in 2007 to investigate the direct and residual effect of applied sulphur on growth and yield of rice (var- IR 64). Composite soil sample from 0-20 cm was collected from experimental site before start of the experiment and analysed for physical and chemical characteristics by employing standard methods. The experimental soil was medium black clay, had organic carbon 4.78 g kg^{-1}, EC 0.18 dS m^{-1} and pH 8.12. The available N, P, K and S were 172.3, 14.9, 179.8 and 11.2 kg ha^{-1} , respectively. The DTPA extractable micronutrients were 0.58, 2.68, 7.67 and 9.85 mg kg^{-1} of Zn, Cu, Fe and Mn, respectively. The experiment was laid out in a randomized block design(RBD) with three replications and eight treatments, consisting of T_1:RDF, T_2: RDF + FYM (10 t/ha) + $ZnSO_4$ (20 kg/ha), T_3:T_2 + 25.0 kg sulphur ha^{-1} (Factomphos), T_4:T_2 + 37.5 kg sulphur ha^{-1} (Factomphos), T_5:T_2 + 50.0 kg sulphur ha^{-1} (Factomphos), T_6:T_2 + 25.0 kg sulphur ha^{-1} (Gypsum), T_7:T_2 + 37.5 kg sulphur ha^{-1} (Gypsum) and T_8:T_2 + 50.0 kg sulphur ha^{-1}(Gypsum). A common dose (RDF) of 150 kg N, 75 kg P_2O_5 and 75 kg K_2O was given for all treatments using urea, daimmonium phosphate, muriate of potash and factomphos where necessary. The entire amount of P_2O_5 and K_2O and half dose of N were applied at transplanting. The remaining N was applied in two equal splits, first at tillering and second at panicle initiation stage. One month old seedlings of rice (cv. IR-64) were transplanted at the rate of 2-3 seedlings per hill with a spacing of 20 x 10 cm. Irrigation (3-5 cm standing water) was given and water was drained from the field 15 days before harvesting. After harvest of first crop, field was kept undisturbed and residual crop (cv. IR-64) was raised. The residual crop did not receive S, but received FYM according to treatment and RDF applied through urea, diammonium phosphate and muriate of potash. In both direct and residual rice crops, grain and straw yields were recorded. Grain and straw were analysed for S content and their uptake was worked out. Sulphate–S was analysed in soil. All data recorded were statistically analyzed by the technique of analysis of variance and CD values were computed at 5% level of significance

Direct and residual effect of sulphur significantly increased rice yield, S uptake and sulphate-S over T_1 (RDF alone) (Table 1). In first rice crop, the highest grain and straw yield

Table 1. Yield of rice in cropping sequence as influenced by sulphur nutrition in vertisol of Karnataka

Treatments	Direct rice					Residual rice				
	Yield (kg ha^{-1})		Sulphur uptake (kg ha^{-1})		Soil Sulphate sulphur at harvest	Yield (kg ha^{-1})		Sulphur uptake (kg ha^{-1})		Soil Sulphate sulphur at harvest
	Grain	Straw	Grain	Straw	(mg kg^{-1})	Grain	Straw	Grain	Straw	(mg kg^{-1})
T_1 : RDF	44.63	49.92	5.03	5.28	10.81	40.02	46.06	4.55	4.27	8.29
T_2 : RDF + FYM + $ZnSO_4$	48.97	54.33	6.70	6.64	12.32	44.41	49.87	5.70	5.51	9.26
T_3 : T_2 + 25.0 kg sulphur/ha (Factomphos)	53.23	58.75	8.06	8.44	13.18	48.02	53.72	7.51	7.17	10.91
T_4 : T_2 + 37.5 kg sulphur/ha (Factomphos)	55.20	61.63	10.59	10.28	15.26	50.00	56.00	9.55	9.07	12.88
T_5 : T_2 + 50.0 kg sulphur/ha (Factomphos)	57.09	63.63	11.54	11.33	16.67	51.90	58.02	10.76	10.22	13.60
T_6: T_2 + 25.0 kg sulphur/ha (Gypsum)	50.05	55.98	6.93	7.37	12.92	46.03	51.75	6.56	6.29	10.22
T_7 : T_2 + 37.5 kg sulphur/ha (Gypsum)	52.15	58.10	7.98	8.30	13.52	48.29	54.28	8.34	7.77	11.18
T_8 : T_2 + 50.0 kg sulphur/ha (Gypsum)	53.05	59.23	8.26	8.76	13.68	50.02	56.86	9.88	9.51	12.95
S.Em±	0.987	1.422	0.609	0.495	0.883	1.097	0.916	0.628	0.345	0.508
C.D. (p=0.05)	2.99	4.31	1.85	1.50	2.68	3.33	2.78	1.91	1.05	1.54

RDF – Recommended dose of fertilizer (150:75:75 kg N, P_2O_5 and K_2O ha^{-1}) - common for all treatments
FYM – Farmyard manure, FYM (10 t/ha) + $ZnSO_4$ (20 kg/ha)-common for T_2, T_3, T_4, T_5, T_6, T_7 and T_8

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(57.09 and 63.63 q ha^{-1}) were noticed with T_5 [RDF + FYM (10 t/ha) + $ZnSO_4$ (20 kg/ha) +50 kg sulphur ha^{-1} (Factomphos)] , followed by T_4 [RDF + FYM (10 t/ha^{-1}) + $ZnSO_4$ (20 kg/ha) + 37.5 kg sulphur ha^{-1} (Factomphos)] (55.20 and 61.63 q ha^{-1}, T_5 respectively gave 27.9 and 27.5 percent increase in grain and straw yield over T_1 (RDF alone), whereas T_4 recorded 23.7 and 23.5 per cent increase in grain and straw yield, respectively. Increase in rice yield due to sulphur could be attributed to stimulating effect of applied sulphur in the synthesis of chloroplast protein resulting in greater photosynthetic efficiency, which in turn resulted in increased yield. In residual rice crop, T_5 recorded the highest grain and straw yield (51.90 and 58.02 q ha^{-1}, respectively followed by T_8 [RDF + FYM (10 t/ha) + $ZnSO_4$ (20 kg/ha) + 50 kg sulphur ha^{-1} (gypsum)] (50.02 and 56.86 q ha^{-1}, respectively and T_4 [RDF + FYM (10 t/ha) + $ZnSO_4$ (20 kg /ha) + 37.5 kg sulphur ha^{-1} (Factomphos)] (50.0 and 56.0 q ha^{-1}, respectively (Table 1). The treatment T_5 gave 29.7 and 26.0 per cent increase in grain and straw yield respectively over T_1 (RDF alone). Similarly, T_8 and T_4 respectively recorded 25.0 and 23.4 per cent and 24.9 and 21.5 per cent increase in grain and straw yields, respectively. Sakal *et al.* (2001) reported that 45 kg S ha^{-1} applied to first rice crop supported two crops grown in succession.

Application of sulphur significantly influenced the sulphur uptake of first rice crop (Table 1). T_5 registered markedly increased sulphur uptake over T_1 (RDF alone) in grain and straw (129.4 and 114.5%, respectively). Increased uptake of sulphur can be ascribed to the increased available sulphur in soil. Increase in sulphur uptake might be due to integrated use of farmyard manure with sulphur. Sriramachandrasekharn *et al.* (2007) reported increase of sulphur uptake in first rice crop (67.3% in gain and 69.7% in straw) over control due to direct effect of sulphur applied @ 60 kg per ha. The results of this investigation are consonance with the finding of Sriramachandrasekharn *et al.* (2005). Residual effect of application of T_5 registered the highest per cent increase in sulphur uptake by 155.1 and 145.1 per cent over T_1 in grain and straw, respectively. Addition of sulphur to previous crop and farmyard manure might have caused the higher sulphur uptake over T_1. Sriramachandrasekharn *et al.* (2007) reported increase of sulphur uptake in succeeding rice crop (202.7 % in grain and 110.4% in straw) over control due to residual effect of sulphur applied to previous rice crop @ 60 kg per ha.

Among the treatments for first rice crop, T_5 and T_4 significantly increased sulphate sulphur in soil by 54.2 and 41.2 per centrespectively as compared to T_1 at harvest. Under flooded conditions, in addition to plant uptake of sulphate, it is reduced by two genera of bacteria, *viz.*, Desulfovibrio and Desulfotomaculam and converted into organic forms. The sulphate sulphur content increased markedly by residual effect of sulphur application (Table 1). Residual effect of application of T_5 registered the highest increase (64.1 %) in sulphate sulphur over T_1 at harvest, followed by T_8 (56.2 %) and T_4 (55.4 %). Sriramachandrasekharn *et al*. (2007), reported 168.6 per cent increase in available sulphur over control due to residual effect of application of 60 kg S per ha.

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