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Direct and residual effect of organic manure amended sulphur on yield and nutrient uptake in mustard-rice cropping system

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Abstract
An experiment was conducted to evaluate the direct effect of different level of sulphur alone or in combination with organic manures on mustard and residual effect on rice crops in calcareous soil of north India. Sulphur application significantly increased the yield of mustard as well as rice, S concentration and its uptake by mustard (seed+stover) as well as available –S content in post- harvest soil samples after mustard and rice (grain+straw). The optimum level of S was worked out to be 60 kg S ha $^{-1}$ for mustard seed and stover production. However, with regards to total S uptake, the optimum dose appeared at 100 kg S ha^{-1}. The beneficial effect of organic manure was evident in enhancing the seed and stover production, S-c oncentration in seed, S-uptake (Seed+Stover) by mustard and available-S content in post-harvest soil samples from 9.8 to 10.7 q ha^{-1}, 37.5 to 40.5 q ha^{-1}, 0.779 to 0.821 per cent, 20.39 to 32.47 kg ha^{-1} and 25.7 to 86.5 mg kg^{-1}, respectively and the grain yield, S-content in grain, straw, total S-uptake (grain + straw) and available S content in post-harvest samples of rice from 47.2 to 49.8 q ha^{-1}, 0.088 to 0.098 per cent, 0.123 to 0.175 per cent, 13.83 to 17.98 kg ha^{-1} and 24.2 to 37.9 mg kg^{-1}, respectively. Among the organic manures, biogas slurry (BGS) proved to be better source in enhancing seed yield, stover/straw yield, S-uptake, and available-S in post-harvest soil samples after mustard and rice. The residual effect of higher level of S along with BGS proved more effective with respect to S nutrition to rice.

Keywords: Organic manures, mustard, residual effect, rice, sulphur

Introduction

Modernisation of agriculture involving high input and output activity necessitated the importance of sulphur, and now-a-days sulphur is called as the fourth major plant nutrient as most crops absorb sulphur in quantity equivalent to phosphorus. However, with the increased use of high analysis S-free fertilizers, lower use of organic manure and very low rate of application or practically no application of sulphur fertilizers, the reserves of sulphur in soil have started depleting and are limiting the soil productivity (Kour *et al*; 2007) [8]. Sulphur is best known for its role in balanced fertilization and consequently in crop production. It is essential nutrient for the formation of amino acid, synthesis of chlorophyll, oil in oilseeds and improvement in the nutritive quality of forage and fodder crops. Sulphur application increases the yield of mustard by 12 to 48% under irrigated and 17 to 24% under rainfed conditions (Aulakh and Pasricha; 1988) [2]. Pyrite, Pressmud and FYM application either alone or in combination significantly increased the lentil yield (Sinha and Sakal; 1993a) [14]. Increasing level of S increased S content of both grain and stover significantly over control. Sulphur content increased from 0.415 to 0.499 per cent in grain, 0.150 to 0.241 per cent in straw and consequently its uptake increased from 5.34 to 7.42 kg ha^{-1} with the application of 45 kg S ha^{-1}. Generally, sulphur application benefits more than one crop grown on sequence and produces a significant residual response. It was estimated that depending up on the systems, the directly fertilized crop contributed 33-82% to the rotational response and the crop raised to test the residual value, contributed 18-67% (Tandon, 1991) [18]. The residual effect of pyrites and organic manures (FYM and Pressmud) were evaluated with respect to S nutrition of crops in a field experiment on sandy loam calcareous soil (Sinha and Sakal; 1993b) [15].

Keeping in view the limited information available, the experiment was conducted to evaluate the effect of S nutrition on mustard and its residual effect on subsequent rice in calcareous soil of north Bihar.

Materials and Methods

A field experiment was conducted on calcareous soil under mustard-rice cropping system in the nursery Jhilley of Pusa farm, Bihar which was found deficient in available sulphur. Before sowing a composite sample was taken and was analysed for their general properties following standard methods. Soil pH was determined in a soil suspension in water with soil and water ratio of 1:2 by using glass electrode pH meter (Jackson,1978) [6] and electrical conductivity was determined with the help of conductivity bridge (Jackson, 1978) [6]. Organic carbon was was estimated by the wet digestion method as given by Walkley and Black (1934) [20]. Determination of micronutrients like Zn, Fe, Cu and Mn was done with the help of atomic absorption spectrophotometer in DTPA extract as suggested by Lindsay and Norvell (1978) [9]. Available sulphur was determined by turbidimetric method as given by Chesnine and Yien (1951) [4]. The experimental site was sandy loam in texture, slightly alkaline in reaction, low in organic carbon, available N, P, K and S (Table 1). The treatment consisted of seven level of sulphur (0, 20, 40, 60, 80, 100 and 120 kg S ha^{-1}) alone or along with organic manures and were replicated thrice in randomised block design. Source of S-Phosphogypsum (1% P_2O_5 and 14% S), Source of organic manure-FYM/ Biogas slurry (5.0 t ha^{-1}). Two test crops Mustard (var. Varuna) and rice (var. Rajshree) were grown successively to see the direct and residual effect of sulphur alone or along with organic manure.

The required quantity of two source of organic manure i.e FYM and Biogas slurry (BGS) were amended with different level of sulphur and incubated for one month before application in mustard (Table 2 and Table 3). The recommended dose of 80 kg N, 40 kg P_2O_5 and 40 kg K_2O ha^{-1} in mustard and 100 kg N, 60 Kg P_2O_5 and 40 kg K_2O ha^{-1} in rice as urea, DAP and Murate of Potash, respectively were added. Since the plot was deficient in available Zn, a basal application of 10 kg Zn as Zinc oxide was done uniformly to all plots. Both the test crops were grown till maturity to records yield. Grain and stover/straw samples of both crops were taken from each plot for their chemical analysis. Post-harvest soil samples were also taken after both crops for different studies. Plant samples were collected and dried in the oven at 65 $\pm$ 1 ^{0}C and ground in Willey mill fitted with stainless steel blades. The samples were digested in binary acid mixture of nitric and perchloric acid for extraction of total sulphur content as per the method of Tabatabai (1982) [16]. Sulphur in the extract was determined by turbidimetric method given by Chesnine and Yien (1951) [4].

Table 1: General properties of initial surface soil of experimental plot

S. No.	Soil properties	Content
1.	Sand (%)	76.0
	Silt (%)	12.0
	Clay (%)	12.0
	Textural class	Sandy loam
2.	pH (1:2)	8.4
3.	EC (dSm^{-1})	0.35
4.	Organic carbon (g kg^{-1})	4.10
5.	Free $CaCO_3$ (g kg^{-1})	334
6.	CEC [Cmol (P^+) kg^{-1}]	8.80
7.	Available N (kg ha^{-1})	240
	P_2O_5(kg ha^{-1})	14
	K_2O (kg ha^{-1})	78
8.	Available Zn (mg kg^{-1})	0.57
9.	Available Fe (mg kg^{-1})	20.55
10.	Available Cu (mg kg^{-1})	3.62
11.	Available Mn (mg kg^{-1})	9.92
12.	Total S	349.8
13.	Available S	8.26

Table 2: Chemical composition of untreated organic manures used in the experiment before incubation

Parameters	FYM	BGS
Organic C (g kg^{-1})	353	452
Total N (%)	0.84	1.29
P (%)	0.75	0.93
K (%)	0.69	1.12
S (%)	0.63	0.82
Zn (mg kg^{-1})	79	102
Fe (mg kg^{-1})	2421	2508
Cu (mg kg^{-1})	39	50
Mn (mg kg^{-1})	172	228

Table 3: $CaCl_2$ extractable sulphur in incubated organic matter at the time of application

S levels	FYM		BGS	
	S_{conc} (%)	Amount of S added (kg ha^{-1})	S_{conc} (%)	Amount of S added (kg ha^{-1})
S_0	0.138	7	0.40	20
S_{20}	0.729	37	1.092	55
S_{40}	1.362	68	2.045	102
S_{60}	2.174	109	2.554	128
S_{80}	2.679	134	3.250	163
S_{100}	3.291	165	4.008	200
S_{120}	3.866	193	4.601	230

N.B. Dose of organic manure application=50 q ha^{-1}

Results and Discussion

Direct effect of Sulphur on mustard crop

Seed and stover yield of mustard as influenced by different levels of sulphur application alone or along with organic manure varied from 8.3 to 12.7 and 33.7 to 44.2 q ha^{-1} in different treatments (Table 4). Seed and stover yields were significantly increased with increasing S levels up to 60 kg S ha^{-1} beyond which there was sharp decline in yield. The highest seed and stover yields were found to be 11.6 and 42.6 q ha^{-1}, respectively at 60 kg ha^{-1}. The increase in mustard yield due to sulphur application were also reported by Sakal *et al.* (1996) [11] in Bihar soils and Kour *et al* (2014) [7] in sub-tropical Inceptisol of Jammu, North India. The response data were fitted significantly in to quadratic equations which were as below;

Seed yield (without O.M) = 8.38 + 0.55 X – 0.00037 X^2 (R^2 =0.881**)
$X_{max.}$ = 62.3 kg S ha-1, $Y_{max.}$ =10.97 q ha^{-1}
Seed yield (with FYM) = 9.15 + 0.059 X – 0.00047 X^2 (R^2 =0.872 **)
$X_{max.}$ = 62.3 kg S ha^{-1}, $Y_{max.}$ = 10.97 q ha^{-1}
Seed yield (with BGS) = 9.63 + 0.066 X – 0.00056 X^2 (R^2 =0.686 **)
$X_{max.}$ = 59.5 kg S ha^{-1}, $Y_{max.}$ = 11.60 q ha^{-1}
Mean seed yield = 9.06 + 0.061 X -0.00047 X^2 (R^2 =0.823 **)
$X_{max.}$ = 64.8 kg S ha^{-1}, $Y_{max.}$ = 11.02 q ha^{-1}

Table 4: Direct effect of sulphur application alone or along with organic manure on yield (q ha^{-1}) of mustard

Sulphur levels (kg ha^{-1})	Seed yield				Straw yield			
	Organic manures				Organic manures			
	Control	FYM	BGS	Mean	Control	FYM	BGS	Mean
0	8.3	9.0	9.7	9.0	33.7	36.5	38.7	36.3
20	9.5	10.3	10.7	10.2	35.2	38.2	39.8	37.7
40	9.7	10.7	10.8	10.4	39.0	39.5	41.5	40.0
60	10.8	11.2	12.7	11.6	41.5	42.2	44.2	42.6
80	10.2	10.8	11.0	10.7	38.3	38.2	41.0	39.2
100	10.0	9.8	10.3	10.1	37.8	37.8	40.0	38.5
120	9.8	9.7	9.8	9.8	36.7	36.3	38.5	37.2
Mean	9.8	10.2	10.7		37.5	38.4	40.0	

Sources	S.Em±	CD (P=0.05)	S.Em±	CD (P=0.05)
Organic manures	0.1	0.4	0.3	0.8
S levels	0.2	0.6	0.4	1.3
Interactions	0.4	-	0.8	-

The optimum sulphur level whether it was applied alone or along with organic manure for mustard seed production as obtained from quadratic equation was 64.8 kg S ha^{-1}. The optimum rate of S application as reported by Ankineedu *et al.* (1985) [1] and Tandon (1990) [17] was 30 and 75 kg S ha^{-1}, respectively for mustard crop. The difference in optimum rate might be due to differences in soil characters as well as variety of the crop. The beneficial effect of organic manure was evident in enhancing seed and stover yield from 9.8 to 10.7 and 37.5 to 40.5 q ha^{-1}, respectively. However, BGS was found superior to FYM in increasing the seed and stover yield of mustard. The superiority of BGS over FYM might be due to more sulphur content in BGS than FYM and was well decomposed. Similarly, Sinha and Sakal (1993a) [14] found that efficiency of pyrite was remarkably enhanced when applied in combination with FYM and inferred that pyrite should be applied in combination with FYM for maximum yield of lentil in sulphur deficient soil.

Sulphur concentration and uptake

Sulphur concentration in seed varied from 0.705 to 0.906 per cent and in stover it ranged from 0.364 to 0.670 per cent (Table 5). The higher concentration of S in seeds as compared to stover of mustard gave support to findings of Aulakh *et al.* (1988) [2]. The concentration of sulphur in seed and stover increased significantly with increase in the levels of S over control with highest sulphur concentration at 120 kg S ha^{-1}. The increase in S concentration due to S application in soil has also been reported by Tripathi *et al.* (1997) [19]. FYM was found significantly superior to BGS in increasing S concentration in mustard seed although their effect was at par in case of stover. The result confirms the findings of Sinha and Sakal (1993a) [14], who observed increase in S concentration by the addition of organic manure. Organic manure might have immobilized soluble S and reduced the leaching loss. Organic sulphur on mineralization with lapses of time was made available to crop. Data on S uptake revealed that akin to yield and S concentration, S application also increased S uptake by mustard (Table 6). Sulphur uptake by seed and stover varied from 5.88 to 10.29 and 12.27 to 25.78 kg ha^{-1}, respectively. Sulphur uptake by mustard was lower when S was applied alone through inorganic fertilizer (Phosphogypsum) as compared to those of S application in conjoint with organic manure. Total sulphur uptake by mustard crop ranged between 18.15 to 34.44 kg ha^{-1} (Table 6). Increasing levels of S significantly increased S uptake by seed up to 60 kg S ha^{-1}, the same by stover up to 120 kg S ha^{-1}. These results are in accordance with the findings of Sakal *et al.* (1996) [11] and Mishra (2001) [10] who also reported increase in sulphur uptake due to sulphur application. Increase in S uptake seems to be associated with increased S availability from applied S with a concomitant increase in S concentration and dry matter production. Among sources of organic manure BGS performed well as compared to FYM in increasing sulphur uptake by seed and stover of mustard. Both BGS and FYM were significantly superior to control in boosting sulphur uptake by seed, stover and total sulphur uptake. Similar observations were also recorded by Sinha and Sakal (1993a) [14].

Table 5: Direct effect of sulphur application alone or along with organic manure on sulphur concentration (%) in mustard

Sulphur levels (kg ha^{-1})	S concentration in seed				S concentration in stover			
	Organic manures				Organic manures			
	Control	FYM	BGS	Mean	Control	FYM	BGS	Mean
0	0.705	0.771	0.766	0.747	0.364	0.364	0.401	0.377
20	0.735	0.837	0.780	0.784	0.387	0.476	0.478	0.447
40	0.769	0.842	0.817	0.809	0.477	0.558	0.478	0.504
60	0.794	0.861	0.813	0.823	0.522	0.573	0.509	0.534
80	0.800	0.859	0.836	0.832	0.571	0.579	0.530	0.560
100	0.814	0.870	0.852	0.845	0.594	0.581	0.610	0.595
120	0.839	0.906	0.880	0.875	0.622	0.637	0.670	0.643
Mean	0.779	0.849	0.821		0.505	0.538	0.525	

Sources	S.Em±	CD (P=0.05)	S.Em±	CD (P=0.05)
Organic manures	0.005	0.015	0.006	0.017
S levels	0.008	0.023	0.009	0.027
Interactions	0.014	-	0.016	0.046

Table 6: Direct effect of sulphur application alone or along with organic manure on sulphur uptake (kg ha^{-1}) by mustard

Sulphur levels (kg ha^{-1})	S uptake by mustard seed				S uptake by mustard straw				Total sulphur uptake by mustard			
	Organic manures				Organic manures				Organic manures			
	Control	FYM	BGS	Mean	Control	FYM	BGS	Mean	Control	FYM	BGS	Mean
0	5.88	6.94	7.40	6.74	12.27	13.30	15.52	13.70	18.15	20.11	22.92	20.39
20	6.98	8.65	8.32	7.98	13.62	18.15	19.01	16.93	20.59	26.80	27.34	24.91
40	7.42	8.98	8.84	8.41	18.62	22.06	19.83	20.17	26.04	31.04	28.67	28.58
60	8.60	9.61	10.29	9.50	21.64	24.12	22.48	22.75	30.24	33.73	32.77	32.25
80	8.14	9.31	9.20	8.88	21.87	22.13	21.72	21.91	30.00	31.45	30.92	30.79
100	8.14	8.55	8.81	8.50	22.45	21.96	24.41	22.94	30.59	30.51	33.22	31.44
120	8.27	8.77	8.66	8.57	22.81	23.11	25.78	23.90	31.08	31.89	34.44	32.47
Mean	7.63	8.69	8.79	-	19.04	20.69	21.25	-	26.67	29.36	30.04	-

Sources	S.Em ±	CD (P=0.05)	S.Em ±	CD (P=0.05)	S.Em ±	CD (P=0.05)
Organic manures	0.14	0.40	0.27	0.76	0.32	0.91
S levels	0.21	0.61	10.41	1.16	0.49	1.40
Interaction	0.37	-	0.70	2.01	0.85	2.42

Available sulphur in post- harvest soil

The changes in available sulphur and organic carbon content due to application of different levels of sulphur alone or along with organic manure in post- harvest soil of mustard showed that sulphur applied either alone or in combination with organic manure significantly increased soil available sulphur from 18.1 to 91.2 mg kg^{-1} (Table 7). BGS performed superior over FYM in increasing available sulphur content at all level of sulphur application. Build-up in available sulphur was noted to be 353.0 per cent when applied without organic manure, whereas it increased by 377.3 and 403.9 per cent when applied with FYM and BGS, respectively. Increase in the availability of sulphur in soil with increasing level of S application alone or in combination with organic manure has also been reported by Sinha and Sakal (1993a) [14]. Increased availability of sulphur in soil due to organic manure might be attributed to the mineralization of organic sulphur as well as holding water soluble S to minimise leaching loss.

Table 7: Available sulphur (mg kg^{-1}) and organic carbon content (g kg^{-1}) in post- harvest surface soil of mustard

Sulphur levels (kg ha^{-1})	Available sulphur				Organic carbon			
	Organic manures				Organic manures			
	Control	FYM	BGS	Mean	Control	FYM	BGS	Mean
0	18.1	29.5	29.6	25.7	3.8	4.2	4.3	4.1
20	20.9	32.9	46.0	33.3	3.5	4.3	4.5	4.1
40	27.8	44.8	48.8	40.5	3.9	4.4	4.9	4.4
60	40.0	55.1	59.5	51.5	4.0	4.3	5.2	4.5
80	53.7	68.4	72.8	65.0	4.1	4.4	4.8	4.4
100	67.3	70.0	81.7	73.0	3.6	4.2	4.7	4.2
120	82.0	86.4	91.2	86.5	3.9	4.2	4.8	4.3
Mean	44.3	55.3	61.4	-	3.8	4.3	4.7	-

Sources	S. Em ±	CD (P=0.05)	S. Em ±	CD (P=0.05)
Organic manures	0.38	1.08	0.002	0.008
S levels	0.57	1.64	0.004	0.011
Interactions	1.00	2.85	0.007	0.019

Biogas slurry was significantly superior in this respect owing to differences in its S content and level of decomposition. The higher value of available-S in control treatment than initial value suggested upward movement of SO_4-S during summer, the harvesting time of mustard. Organic carbon content varied from 3.5 to 5.2 g kg^{-1} with application of sulphur alone or along with organic manure. Organic manure was found to enhance the level of organic carbon in the soil 7significantly where BGS was more effective than FYM.

Residual effect of sulphur on rice

Sulphur research during recent years indicated that sulphur leaves its residual effect on succeeding crop, hence deserves equal attention as direct one. The recent researches also indicated that wherever the direct response was relatively lower, the succeeding crop benefited more from the residual S. Keeping this idea in view, the residual effect of S was studied on rice.

Grain and straw yield

The grain and straw yield of rice varied from 41.8 to 52.3 and 66.0 to 85.3 q ha^{-1}, respectively due to residual effect of sulphur alone or along with organic manure (Table 8). The residual value of sulphur increased the grain and straw yield from 44.1 to 51.0 and 66.7 to 82.3 q ha^{-1}, respectively at 80 and 100 kg S ha^{-1} levels, respectively. However, the residual effect of lowest level of sulphur (20 kg ha^{-1}) was non-significant. The results are in accordance with the findings of Singh *et al.* (1991) [12] and Sinha and Sakal (1993b) [15] who found more pronounced residual effect at higher level of pyrite application. A crop usually takes up only a small fraction of fertilizer applied to the soil and very often a remarkable residual effect is observed in succeeding crop (Aulakh *et al*; 1977) [3]. The significant effect of S level was recorded up to 60 kg ha^{-1} in case of grain. However, the residual effect up to 80 kg S ha^{-1} was found significant in case of rice straw. The residual effect of BGS was found significant in increasing the grain yield of rice from 47.2 to 49.8 q ha^{-1}. This might be due to differences in their S content and production of organic acid on decomposition to make complexes.

Table 8: Residual effect of sulphur application alone or along with organic manure on yield (q ha^{-1}) of rice

Sulphur levels (kg ha^{-1})	Grain yield				Straw yield			
	Organic manures				Organic manures			
	Control	FYM	BGS	Mean	Control	FYM	BGS	Mean
0	41.8	42.7	47.7	44.1	66.0	67.2	70.0	67.7
20	45.2	44.5	48.0	45.9	74.8	72.0	72.3	73.0
40	45.5	47.3	49.0	47.3	76.8	75.5	72.7	75.0
60	50.8	51.7	49.3	50.6	79.0	76.5	74.0	76.5
80	50.3	50.5	52.3	51.0	79.8	81.8	77.8	79.8
100	48.8	50.5	52.0	50.4	83.5	85.3	78.0	82.3
120	48.2	48.2	50.2	48.9	79.8	83.2	78.0	80.3
Mean	47.2	47.9	49.8	-	77.1	77.4	74.7	-

Sources	S.Em±	CD (P=0.05)	S.Em±	CD (P=0.05)
Organic manures	0.5	1.3	0.8	-
S levels	0.7	2.1	1.0	2.9
Interactions	1.2	-	1.8	-

Sulphur concentration and uptake

The concentration of sulphur increased in rice grain with increasing level of sulphur added to the first crop of mustard (Table 9). Sulphur content showed variations from 0.070 to 0.112 per cent in grain and 0.098 to 0.213 per cent in straw due to residual effect of sulphur. The effect of sulphur on sulphur content in rice grain was found non-significant at lower dose of sulphur application, however, the significant effect was observed at higher dose of sulphur application. Sulphur content in rice straw increased significantly at all the levels of sulphur application. The effect of organic manures was highly significant in enhancing the S content in rice grain and straw. The superiority of BGS was observed in increasing the sulphur content in rice straw, where it increased the mean sulphur content from 0.123 per cent to 0.175 per cent. The interaction effect of organic manure and sulphur level was found significant in rice grain. Higher levels of sulphur in combination with organic manure proved very effective with respect to sulphur nutrition to rice supporting the earlier observations of Sinha and Sakal (1993b) [15] in groundnut and wheat in calcareous soil of north Bihar.

Table 9: Residual effect of sulphur application alone or along with organic manure on sulphur concentration (%) in rice

Sulphur levels (kg ha^{-1})	S concentration in rice grain				S concentration in rice straw			
	Organic manures				Organic manures			
	Control	FYM	BGS	Mean	Control	FYM	BGS	Mean
0	0.070	0.082	0.093	0.082	0.098	0.100	0.130	0.109
20	0.071	0.087	0.094	0.084	0.100	0.120	0.163	0.128
40	0.084	0.091	0.096	0.090	0.117	0.140	0.167	0141
60	0.095	0.098	0.096	0.096	0.123	0.147	0.173	0.148
80	0.095	0.104	0.098	0.099	0.123	0.150	0.180	0.151
100	0.094	0.112	0.100	0.102	0.143	0.157	0.200	0.167
120	0.107	0.112	0.101	0.107	0.160	0.173	0.213	0.182
Mean	0.088	0.098	0.097	-	0.123	0.141	0.175	-

Sources	S. Em ±	CD (P=0.05)	S. Em ±	CD (P=0.05)
Organic manures	0.002	0.005	0.003	0.010
S levels	0.002	0.007	0.005	0.015
Interactions	0.004	0.012	0.009	-

Sulphur uptake by rice grain, straw and total S uptake ranged from 2.92 to 5.64, 6.48 to 16.68 and 9.40 to 21.72 kg ha^{-1}, respectively due to residual effect of different levels of sulphur applied alone or along with organic manures (Table **10)**. Organic manures significantly increased the uptake of S by by rice grain and straw. The mean S uptake by rice grain increased from 4.22 to 4.76 and 4.82 kg ha $^{-1}$ due to FYM and BGS application respectively. Such observations were also recorded by Sinha and Sakal (1993b) [15] on groundnut crop in calcareous soil of north Bihar and by Singh *et al.* (1992) [13] for lentil crop on alluvial soils of Varanasi.

Available sulphur status in post-harvest soil

Maximum increase in available-S (50.4 mg kg^{-1}) was noted at 120 kg S ha^{-1} level and ranged from 8.1 to 43.6 mg kg^{-1} due to S application without organic manures and from 19.7 to 57.2 mg kg^{-1} in organic manure treated plot after harvest of rice crop in mustard- rice sequence (Table 11). The increase in available sulphur status after harvest of rice crop is due to the fact that uptake of sulphur by mustard and rice was much lower as compared to the amount of sulphur applied hence, supporting the findings of Islam *et al.* (1997) [5] in rice-mustard cropping system. The effect of organic manure was apparent after harvest of rice crop as available sulphur status was increased significantly from 24.2 to 32.9 and 37.9 mg kg^{-1} in FYM and BGS treated plot, respectively. The interaction of organic manure and S-levels was found positive and significant, which showed the superiority of BGS over FYM at all levels of S application.

Table 10: Residual effect of sulphur application alone or along with organic manure on sulphur uptake (kg ha^{-1}) by rice

Sulphur levels (kg ha^{-1})	S uptake by rice grain				S uptake by rice straw				Total S uptake by rice			
	Organic manures				Organic manures				Organic manures			
	Control	FYM	BGS	Mean	Control	FYM	BGS	Mean	Control	FYM	BGS	Mean
0	2.92	3.49	4.43	3.61	6.48	6.70	9.09	7.42	9.40	10.19	13.52	11.04
20	3.19	3.87	4.49	3.85	7.48	8.63	11.80	9.30	10.68	12.50	16.29	13.16
40	3.82	4.32	4.69	4.28	8.97	10.55	12.15	10.56	12.79	14.87	16.84	14.83
60	4.78	5.34	4.74	4.95	9.74	11.22	12.81	11.26	14.52	16.56	17.56	16.21
80	4.80	5.25	5.15	5.07	9.84	12.32	14.01	12.06	14.64	17.58	19.16	17.13
100	4.88	5.64	5.19	5.24	11.95	13.35	15.61	13.64	16.84	18.99	20.80	17.88
120	5.15	5.40	5.04	5.20	12.78	14.38	16.68	14.61	17.92	19.78	21.72	19.81
Mean	4.22	4.76	4.82	-	9.61	11.02	13.16	-	13.83	15.78	17.98	-

Sources	S.Em ±	CD (P=0.05)	S.Em ±	CD (P=0.05)	S.Em ±	CD (P=0.05)
Organic manures	0.10	0.28	0.30	0.85	0.30	0.86
S levels	0.15	0.43	0.45	1.30	0.46	1.32
Interaction	0.26	-	0.79	-	0.80	-

Table 11: Available sulphur (mg kg^{-1}) in post- harvest surface soil (0-15cm depth) of rice

Sulphur Levels (kg ha^{-1})	Organic manures			
	Control	FYM	BGS	Mean
0	8.1	19.7	20.8	16.2
20	15.0	21.4	23.9	20.1
40	17.8	24.1	29.2	23.7
60	20.1	31.7	36.1	29.3
80	29.5	40.8	48.7	39.7
100	35.6	42.2	49.2	42.3
120	43.6	50.3	57.2	50.4
Mean	24.2	32.9	37.9	-
Sources		S. $E_m \pm$	CD (P=0.05)	
Organic manures		0.4	1.0	
S levels		0.6	1.6	
Interactions		1.0	2.8	

Conclusions
It was revealed in this study that sulphur application significantly increased the yield of mustard, S concentration and its uptake by mustard (seed + straw) and rice (grain+ straw) as well as available S content in post-harvest soil samples after mustard and after rice crop. The beneficial effect of organic manure was evident in enhancing the seed and stover/straw production, S-concentration in seed, S-uptake (seed + straw) by mustard and rice and available-S content in post-harvest soil samples. Mean available sulphur in post-harvest soil after mustard and rice increased significantly from 25.7 to 86.5 mg kg^{-1} and 16.2 to 50.4 mg kg^{-1} respectively with increasing S levels, i.e. S application at higher rates left sufficient available-S in soil after one complete cycle of rotation. It was observed that S application has definite residual effect on succeeding crop rice as evinced by significant increase in yield, S-content and its uptake by subsequent rice crop as well as available sulphur content in post-harvest soil. The contribution of organic manure was apparent in increasing the grain yield, S-content in grain, straw, total S-uptake (grain + straw) and available S content in post-harvest samples of mustard and rice crop. Biogas slurry proved superior to FYM in improving the above plant and soil characters. Thus, the residual effect of higher level of S along with BGS proved more effective with respect to S nutrition to rice. Still after two crops, the influence of BGS was found superior over FYM in enhancing available-S status of soil.

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