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Studies on Effect of Different Levels of Sulphur Application with Combined Use of Organic Manures on Nutrients Uptake, Nutrients-Relationships and Protein Content in Indian Mustard

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A B S T R A C T

An experiment was conducted to evaluate the direct effect of different level of sulphur (S) alone or in combination with organic manures on mustard in calcareous soil of north India. Sulphur application significantly increased the S concentration and its uptake by mustard (seed+stover). The optimum level of S was found to be 60 kg S ha^{-1} in conjoint with 5 t Bio Gas Slurry (BGS) ha^{-1} for mustard crop with respect to concentration and nutrient uptake. The maximum total N, P and K uptake of 69.5, 21.2 and 85.7 kg ha^{-1} respectively was recorded at 60 kg S ha^{-1} showing the synergistic behaviour at lower level of S-application with N, P and K content in seed and stover and antagonistic at higher level of S-application. The beneficial effect of organic manure was also apparent in increasing total N, P and K uptake from 51.9 to 56.6, 15.9 to 19.6 and 66.8 to 73.4 kg ha^{-1}, respectively. Biogas slurry (BGS) proved better as compared to FYM in increasing total N, P and K uptake by mustard. The optimum N: S ratios were worked out to be 3.57 and 1.72 in mustard seed and stover, respectively. The optimum P: S ratios for mustard seed and stover were 1.53 and 0.37, respectively. Sulphur application enhanced the protein content in mustard seed from 13.5 per cent to 18.2 per cent.

Introduction

The continuous mining of nutrients from soils coupled with inadequate and imbalanced fertilizer use has resulted in emergence of multi nutrient deficiencies. Sulphur (S) helps in the synthesis of cysteine, methionine, chlorophyll, vitamins (B, biotin and thiamine), metabolism of carbohydrates, especially by its effect on the protolytic enzymes (Najar *et al.*, 2011). It is also necessary for chlorophyll formation and helps in biosynthesis of oil and metabolism of carbohydrates, proteins and fats and thus now-a day sulphur is being considered as the fourth major nutrient element after NPK (Das *et al*., 2016). Nitrogen and sulphur both have important role in protein and oil production. Hence, the interaction between N and S is generally positive or sometimes additive (no interaction). In a field trials having 5.6 ppm available-S, 25% of total increase in oil yield of mustard due to N+S application could be attributed to their synergistic effect (Sachdev and Dev, 1990; Pasricha *et al.*, 1987). The combined application of N and S on Chinese cabbage and Fodder brassica gave 10% extra response than the sum of their individual effect in Chinese cabbage. Whereas, in case of fodder brassica, the response to N and S was about 7% less than the sum of their individual responses (Hazra, 1988). The effect of sulphur application on percent Nitrogen content of grain and stover of rapeseed had a marked effect on increasing N content of grain and stover. N application @ 60 and 90 kg ha^{-1} and S @ 30 and 45 kg ha^{-1} significantly increased N content over all other N and S levels of sulphur and nitrogen fertilization on N uptake by rapeseed. However, the highest level of S showed a decreasing trend of N content in rapeseed grain (Das and Das, 1994). Significant interaction effect of N and S was also observed in both seed and stover of gobhi sarson (Brassica napus L., ISN-706) by Biswas *et al.,* (1995). The yield of seed and stovercould be attributed to the synergistic effect of S on N for the formation of more metabolites. Also, the significant increase of mean uptake of N was observed with increasing level of S. The maximum total uptake of N was obtained with combined application of 120 kg N and 50 kg S ha^{-1} treatment. This may also be due to synergistic mechanism of N and S.

The nature of phosphorus and sulphur interaction may be positive or negative but recent research has shown that the nature of phosphorus and sulphur interaction depends on their rate of application. The synergistic effect of phosphorus and sulphur is reported at low-medium levels of P and antagonistic only at higher levels, usually at 60 kg P_2O_5 ha^{-1} or more for field crops (Pasricha *et al.,* 1987; Aulakh *et al.,* 1990). Similarly, Ali (1991) on a field experiment with pigeonpea at Kanke, Bihar showed that the P x S interaction was rate dependent. The P x S interaction was absent at 20-40 kg P_2O_5 with 20 kg S ha^{-1}, strongly synergistic at 40-60 kg P_2O_5 with 20-40 kg S and antagonistic at 60 kg P_2O_5 + 40 kg S ha^{-1}.

There was consistent increase in P uptake with increasing levels of sulphur by grain. Application of S, on the other hand, did not affect phosphorus content of both grain and stover significantly (Das and Das, 1994). Total P uptake (seed + stover) increased significantly with increasing level of S proving positive interaction effects of these nutrients (Chaubey and Dwivedi, 1995). This increase in P concentration due to S incorporation might possibly be owing to the mobilization of soil P into available form for plant use.

Rauth and Ali (1985) reported a positive interaction between P and S in rapeseed and mustard. Sulphur increased seed yield by 41%, P by 49% and the remaining 10% was reported to their synergistic effect.

Brassica oil crops responded positively to the combined application of S and K resulting in maximum grain yield, concentration, uptake and recovery of each other (Pasricha *et al.,* 1987). The uptake of potassium and other major nutrients by blackgram due to S applied through different sources was significantly higher than control (Dwivedi *et al.,* 1996). It shows the positive interaction of sulphur with potassium, Kachhave *et al.,* (1997) advocated that the uptake of potassium and other major nutrients (N, P and S) increased significantly with increasing dose of sulphur. Keeping this in view of these aspects with respect to soils of Bihar in general and calcareous soils of north Bihar in particular prompted to undertake the present investigation.

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) and electrical conductivity was determined with the help of conductivity bridge (Jackson, 1978). Organic carbon was estimated by the wet digestion method as given by Walkley and Black (1934). 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). Available sulphur was determined by turbidimetric method as given by Chesnine and Yien (1951). 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}). Mustard (var. Varuna) was grown as test crop successively to see the direct 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 3). The recommended dose of 80 kg N, 40 kg P_2O_5 and 40 kg K_2O ha^{-1} in mustard 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. Crop was grown till maturity to records yield. Grain and stover samples of crop were taken from each plot for their chemical analysis. 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. Plant samples were digested as per procedure described by Piper (1966) in binary acid mixture of nitric and perchloric acid (10: 3)for extraction of total sulphur content as per the method of Tabatabai (1982). It was heated on hot plate till complete digestion. Residue in the flask was dissolved in distilled water and finally volume was made in 50 ml volumetric flask. The dissolved matter was filter with filter paper No. l and analysis of P, K and S was done as per the procedures described by Jackson (1978). Total N was analysed by Kjeldahl digestion distillation method as described by Piper (1966).Sulphur in the extract was determined by turbidimetric method given by Chesnine and Yien (1951). The average nitrogen (N) content of proteins was found to be 16 percent which led to use of calculation for protein content given as:protein content= Nx 6.25 (Food energy-methods of analysis and conversion factors FAO food and nutrition paper 77, 2002).

Results and Discussion

Direct effect of sulphur on nitrogen concentration and uptake on mustard crop

The nitrogen concentration in mustard seed and stover varied from 2.120 to 3.050 and 0.550 to 0.880 per cent, respectively which was found to be significantly increased with increasing S-levels upto 60 kg S ha^{-1} (Table 4). A favourable effect of S on N content in mustard was also reported by Das and Das (1994). Surprisingly, there was significant decrease in N concentration in mustard seed with the application of sulphur along with FYM and BGS. Although, there was significant improvement in the N concentration of mustard stover when sulphur was applied with organic manure. The decrease in seed N content might be due to dilution effect as the seed yield was significantly increased due to organic manure application. Secondly, the N applied through organic manure was compensated in treatments receiving no organic manure. The interaction effect of organic manure and S-levels in case of N concentration in mustard seed was significant. The data revealed that at lower S level, the N concentration was increased whereas at higher S level it was decreased irrespective of S application mode whether applied alone or along with organic manure.

Significant increase in mean N-uptake by seed, stover and total uptake was observed with increasing level of sulphur upto 60 kg S ha^{-1} where the values were 33.7, 35.9 and 69.5 kg ha^{-1}, respectively (Table 5). Beyond this level there was decline in uptake and lowest was observed at 120 kg S ha^{-1}. This may be due to synergistic uptake mechanism of N and S upto 60 kg S ha^{-1}. This increase can again be attributed to increase in dry matter yield and higher nutrient demand for plant growth. Similar observations were recorded by Das and Das (1994) and Biswas *et al.*, (1995). Biogas slurry proved to be superior source of organic matter for increasing the N uptake by both seed and stover. This may be attributed to the readily available nature of nutrients in BGS compared to FYM did not exhibit any increase in the mean N uptake by mustard seed. Although, it produced significant effect in case of N uptake by mustard stover.

Direct effect of sulphur on phosphorus concentration and uptake on mustard crop

Data presented in Table 6 showed the variation in P content in mustard seed and stover from 0.993 to 1.247 and 0.090 to 0.203 per cent, respectively due to various S treatments. The mean P-concentration in seed and stover was increased progressively from 1.048 to 1.194 and 0.116 to 0.173 per cent, respectively due to increasing levels of S upto 60 kg S ha^{-1}. Similar increase in P content by S-application in winter maize in calcareous soil of Bihar was also reported by Sinha *et al.*, (1995). Organic manure application significantly increased the P-concentration in seed and stover except with FYM in seed which might be due to immobilization of available P by microbes during the decomposition of FYM. The interaction of organic manure and S-levels was significant and positive in influencing the P-content in mustard seed and stover, although FYM has negative influence in increasing the P-content in seed. This shows the more degradable nature of BGS in soil owing to the mobilization of soil P into available form for plant uptake. The interaction effect suggested the superiority of 60 kg S ha^{-1} level along with BGS in mobilizing soil-P.

The P uptake by mustard seed, stover and total uptake as influenced by organic manures and different sulphur levels alone or in combination was found to vary from 8.3 to 15.7, 3.0 to 8.3 and 11.3 to 24.0 kg ha^{-1}, respectively (Table 7). Sulphur application upto 60 kg ha^{-1} level progressively increased the P uptake by seed and stover from 9.5 to 13.8 and 4.2 to 7.7 kg ha^{-1}, respectively. Beyond this level the P uptake was significantly decreased progressively suggesting thereby synergistic effect of S on P at lower level of S application but antagonistic effect at higher level of S application. This result confirmed the findings of many workers like Patel and Patel (1994), Randhawa (1995), Sinha *et al.*, (1995) and

Sarkunan *et al.,* (1998) who had reported such results for crops like lucern, wheat, winter maize and rice, respectively. The effect of organic manure on P uptake followed the trend of concentration in mustard. The interaction effect between organic manures and S-levels was also significant which indicated that 60 kg S ha^{-1} in combination with 50 q ha^{-1} BGS was the best treatment combination with respect to P uptake by mustard.

Direct effect of sulphur on potassium concentration and uptake on mustard crop

Potassium concentration in mustard seed and stover varied from 0.547 to 0.790 per cent and 1.413 to 1.920 per cent, respectively with the application of sulphur alone or along with organic manure (Table 8). The mean K concentration in seed and stover increased progressively from 0.629 to 0.790 and 1.419 to 1.796 per cent, respectively with increasing levels of S upto 60 kg ha^{-1} Beyond this level, there was decline in K-content and lowest being observed with 120 kg S ha^{-1} The synergistic effect of S on K concentration at lower level of S and antagonistic effect at higher levels of S was also observed by Jaggi *et al.,* (1995) in linseed crop. There was significant positive effect of FYM and BGS in increasing the K-content in mustard seed. The FYM was found to significantly decrease the K-content in mustard stover but BGS did not change the K-concentration. The interaction effect of S levels and organic manures was significant only in case of stover which again indicated the superiority of BGS over FYM with respect to K-nutrition.

Direct effect of sulphur application alone or along with organic manure on Potassium uptake by mustard has been presented in Table 9. Potassium uptake by mustard seed, stover and total uptake varied from 4.6 to 10.5, 47.6 to 84.8 and 52.1 to 95.2 kg ha^{-1}, respectively. The mean K-uptake in seed and stover increased progressively from 5.7 to 9.2 and 51.5 to 76.6 kg ha^{-1}, respectively with mean total K-uptake from 57.2 to 85.7 kg ha^{-1} with increasing S levels upto 60 kg ha^{-1} beyond which the K-uptake was significantly reduced. The synergistic effect of sulphur on K-uptake at lower levels of sulphur and antagonistic effect at its higher level confirm the findings of Jaggi *et al.,* (1995). The significant positive effect of BGS in increasing K-uptake by seed and stover is apparent, however, FYM did not produce its significant effect in increasing the K-uptake by stover and total Kuptake by mustard. The first order interaction was also found to be significant in affecting K-uptake by mustard. This suggested that S application either alone or in combination with organic manures especially BGS was able to dissolve native K to make it available for plants.

Direct effect of sulphur application alone or along with organic manure on N: S ratio

The data on N: S ratio in mustard seed and stover as influenced by different levels of S alone or along with organic manure have been portrayed in Table 10 which varied from 2.51 to 3.80 and 1.10 to 1.72, respectively. The mean N: S ratio in mustard seed was increased from 2.57 to 3.54 with increasing S levels upto 60 kg ha^{-1} beyond which it was decreased. However, in case of stover though the effect of S levels was irregular initially but at higher levels this ratio decreased. The reduction of N: S ratio due to S application has also been reported by Sharma *et al.,* (1991); Das and Das (1994); Patel and Patel (1994). The effect of organic manures was non-significant in case of N : S ratio in stover but N : S ratio in mustard seed was reduced significantly and the higher reduction was noted in case of FYM This suggested that organic manure not only stabilized the added S but also solubilized the native S and the extent of dissolution was more for S as compared to N. The interaction effect was also significant in changing N: S ratio in mustard. Since previous results suggested 60 kg S ha^{-1} along with BGS as the Optimum treatment combination for mustard, hence, N: S ratio at this treatment combination i.e. 3.57 for mustard seed and 1.72 for mustard stover may be treated as optimum N: S ratio for mustard production.

Direct effect of sulphur on P: S ratio

Both N: S and P: S ratio are good indices for differentiating the normal plant from sulphur deficient one. P: S ratio in mustard seed and stover as affected by different S-levels alone or along with organic manures have been presented in Table 11. The P: S ratio in mustard seed and stover varied from 1.06 to 1.56 and0.15 to 0.39, respectively. The highest mean P: S ratio was recorded at 60 kg S ha^{-1} level which significantly decreased with further increase in S levels. The effect of organic manure and interaction effect on P: S ratio was very much similar to N: S ratio.

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}

Table.4 Direct effect of sulphur application alone or along with organic manure on nitrogen concentration (%) in mustard

Sulphur levels (kg ha^{-1})	N concentration in seed				N concentration in stover			
	Organic manures				Organic manures			
	Control	FYM	BGS	Mean	Control	FYM	BGS	Mean
0	2.193	2.120	2.177	2.163	0.550	0.60	0.653	0.601
20	2.297	2.230	2.270	2.266	0.650	0.677	0.707	0.678
40	2.540	2.467	2.450	2.486	0.713	0.750	0.743	0.735
60	3.050	2.793	2.900	2.914	0.787	0.860	0.877	0.841
80	2.907	2.540	2.423	2.623	0.850	0.880	0.810	0.847
100	2.330	2.360	2.300	2.330	0.800	0.800	0.750	0.783
120	2.177	2.270	2.290	2.246	0.733	0.723	0.736	0.731
Mean	2.499	2.397	2.401		0.726	0.756	0.754	

Sources	S.Em±	CD (P=O.05)	S.Em ±	CD (P=O.05)
Organic manures	0.014	0.041	0.01	0.027
S levels	0.022	0.063	0.015	0.042
Interactions	0.038	0.109	0.025	

Table.5 Direct effect of sulphur application alone or along with organic manure on nitrogen uptake (kg ha^{-1}) by mustard

Sulphur levels (kg ha^{-1})	N uptake by mustard seed				N uptake by mustard stover				Total nitrogen uptake by mustard			
	Organic manures				Organic manures				Organic manures			
	Control	FYM	BGS	Mean	Control	FYM	BGS	Mean	Control	FYM	BGS	Mean
0	18.3	19.1	21.0	19.5	18.5	21.9	25.3	21.9	36.8	41.0	46.3	41.4
20	21.8	23.0	24.2	23.0	22.8	25.8	28.2	25.6	44.7	48.8	52.3	48.6
40	24.6	26.3	26.6	25.8	27.8	29.6	30.8	29.4	52.4	56.0	57.4	55.2
60	33.1	31.2	36.7	33.7	32.7	36.3	38.7	35.9	65.7	67.4	75.5	69.5
80	29.5	27.5	26.7	27.9	32.6	33.6	33.2	33.1	62.1	61.1	59.8	61.0
100	23.3	23.2	23.8	23.4	30.3	30.2	30	30.2	53.5	53.4	53.8	53.6
120	21.5	22.0	22.5	22.0	26.9	26.2	28.4	27.2	48.5	48.2	50.9	49.2
Mean	24.6	24.6	25.9		27.4	29.1	30.7		51.9	53.7	56.6	

Sources	S.Em ±	CD (P=0.05)	S.Em ±	CD (P=0.05)	S.Em ±	CD (P=0.05)
Organic manures	0.4	1.1	0.4	1.2	0.5	1.5
S levels	0.6	1.7	0.6	1.8	0.8	2.3
Interaction	1		1.1		1.4	3.9

Table.6 Direct effect of sulphur application alone or along with organic manure on phosphorus concentration (%) in mustard

Sulphur levels (kg ha^{-1})	**P concentration in seed**				**P concentration in stover**			
	Organic manures				Organic manures			
	Control	FYM	BGS	Mean	Control	FYM	BGS	Mean
0	0.993	1.017	1.133	1.048	0.090	0.107	0.150	0.116
20	1.083	1.083	1.163	1.110	0.093	0.123	0.157	0.124
40	1.153	1.123	1.173	1.150	0.120	0.133	0.170	0.141
60	1.197	1.143	1.243	1.194	0.193	0.140	0.187	0.173
80	1.250	1.077	1.247	1.191	0.143	0.153	0.203	0.167
100	1.250	1.057	1.23	1.178	0.100	0.143	0.180	0.141
120	1.147	0.960	1.136	1.081	0.097	0.117	0.130	0.114
Mean	1.153	1.066	1.190		0.120	0.131	0.168	

Sources	S.Em±	CD (P=O.05)	S.Em ±	CD (P=O.05)
Organic manures	0.011	0.03	0.002	0.006
S levels	0.016	0.046	0.003	0.009
Interactions	0.028	0.079	0.006	0.016

Table.7 Direct effect of sulphur application alone or along with organic manure on phosphorus uptake (kg ha^{-1}) by mustard

Sulphur levels (kg ha^{-1})	P uptake by mustard seed				P uptake by mustard stover				Total phosphorus uptake by mustard			
	Organic manures				Organic manures				Organic manures			
	Control	FYM	BGS	Mean	Control	FYM	BGS	Mean	Control	FYM	BGS	Mean
0	8.3	9.2	11.0	9.5	3	3.9	5.8	4.2	11.3	13	16.8	13.7
20	10.3	11.2	12.4	11.3	3.3	4.7	6.2	4.7	13.6	15.9	18.6	16.0
40	11.1	12.0	12.7	11.9	4.7	5.3	7.1	5.7	15.8	17.2	19.8	17.6
60	13.0	12.8	15.7	13.8	8.0	5.9	8.2	7.4	21.0	18.7	24.0	21.2
80	12.7	11.7	13.7	12.7	5.5	5.9	8.3	6.6	18.2	17.6	22.0	19.3
100	12.5	10.4	12.7	11.9	3.8	5.4	7.2	5.5	16.3	15.8	19.9	17.3
120	11.3	9.3	11.2	10.6	3.6	4.2	5.0	4.3	14.8	13.5	16.2	14.8
Mean	11.3	10.9	12.8		4.6	5.0	6.8		15.9	16	19.6	

Sources	S.Em ±	CD (P=0.05)	S.Em ±	CD (P=0.05)	S.Em ±	CD (P=0.05)
Organic manures	0.2	0.6	0.1	0.3	0.2	0.7
S levels	0.3	0.9	0.1	0.4	0.4	1.0
Interaction	0.5	1.5	0.3	0.7	0.6	1.8

Table.8 Direct effect of sulphur application alone or along with organic manure on potassium concentration (%) in mustard

Sulphur levels (kg ha^{-1})	**K concentration in seed**				**K concentration in stover**			
	Organic manures				Organic manures			
	Control	FYM	BGS	Mean	Control	FYM	BGS	Mean
0	0.547	0.640	0.700	0.629	1.413	1.407	1.437	1.419
20	0.59	0.660	0.783	0.678	1.553	1.497	1.507	1.519
40	0.643	0.690	0.807	0.713	1.793	1.530	1.633	1.652
60	0.757	0.783	0.830	0.790	1.853	1.613	1.920	1.796
80	0.730	0.797	0.813	0.780	1.65	1.747	1.660	1.686
100	0.677	0.740	0.780	0.732	1.547	1.597	1.603	1.582
120	0.643	0.697	0.753	0.698	1.413	1.473	1.430	1.439
Mean	0.655	0.715	0.781		1.603	1.552	1.599	

Sources	S.Em±	CD (P=O.05)	S.Em ±	CD (P=O.05)
Organic manures	0.008	0.25	0.014	0.039
S levels	0.013	0.038	0.021	0.059
Interactions	0.023		0.036	0.103

Table.9 Direct effect of sulphur application alone or along with organic manure on potassium uptake (kg ha^{-1}) by mustard

Sulphur levels (kg ha^{-1})	K uptake by mustard seed				K uptake by mustard stover				Total potassium uptake by mustard			
	Organic manures				Organic manures				Organic manures			
	Control	FYM	BGS	Mean	Control	FYM	BGS	Mean	Control	FYM	BGS	Mean
0	4.6	5.8	6.8	5.7	47.6	51.3	55.6	51.5	52.1	57.1	62.3	57.2
20	5.6	6.8	8.4	6.9	54.6	57.1	60	57.2	60.2	63.9	68.4	64.2
40	6.2	7.4	8.7	7.4	69.9	60.5	67.8	66.1	76.1	67.8	76.5	73.5
60	8.2	8.8	10.5	9.2	76.9	68.1	84.8	76.6	85.1	76.9	95.2	85.7
80	7.4	8.7	9.0	8.4	63.3	66.7	68.1	66.0	70.7	75.3	77.1	74.4
100	6.8	7.3	8.1	7.4	58.6	60.4	64.1	61.0	65.3	67.7	72.2	68.4
120	6.4	6.7	7.4	6.8	51.8	53.6	55.0	53.5	58.2	60.4	62.4	60.3
Mean	6.5	7.4	8.4		60.4	59.7	65.0		66.8	67.0	73.4	

Sources	S.Em ±	CD (P=0.05)	S.Em ±	CD (P=0.05)	S.Em ±	CD (P=0.05)
Organic manures	0.15	0.43	0.7	2.1	0.7	2.1
S levels	0.23	0.65	1.1	3.2	1.1	3.1
Interaction	0.39		1.9	5.5	1.9	5.5

Table.10 Direct effect of sulphur application alone or along with organic manure on N:S ratio in mustard

Sulphur levels (kg ha^{-1})	N:S ratio in mustard seed				N:S ratio in mustard stover			
	Organic manures				Organic manures			
	Control	FYM	BGS	Mean	Control	FYM	BGS	Mean
0	3.28	2.75	2.84	2.96	1.51	1.65	1.63	1.60
20	3.14	2.66	2.91	2.90	1.68	1.42	1.48	1.53
40	3.30	2.93	3.00	3.08	1.50	1.35	1.55	1.47
60	3.80	3.25	3.57	3.54	1.52	1.50	1.72	1.58
80	3.64	2.96	2.90	3.17	1.49	1.52	1.53	1.51
100	2.86	2.71	2.70	2.76	1.35	1.37	1.23	1.32
120	2.60	2.51	2.60	2.57	1.18	1.21	1.10	1.16
Mean	3.23	2.82	2.93		1.46	1.43	1.46	

Sources	S.Em±	CD (P=O.05)	S.Em ±	CD (P=O.05)
Organic manures	0.03	0.09	0.02	-
S levels	0.05	0.14	0.04	0.10
Interactions	0.08	0.24	0.06	0.18

Table.11 Direct effect of sulphur application alone or along with organic manure on P:S ratio in mustard

Sulphur levels (kg ha^{-1})	P:S ratio in mustard seed				P:S ratio in mustard stover			
	Organic manures				Organic manures			
	Control	FYM	BGS	Mean	Control	FYM	BGS	Mean
0	1.41	1.32	1.48	1.40	0.25	0.29	0.37	0.30
20	1.47	1.29	1.49	1.42	0.24	0.26	0.33	0.28
40	1.50	1.33	1.44	1.42	0.23	0.24	0.35	0.27
60	1.51	1.33	1.53	1.46	0.37	0.24	0.37	0.33
80	1.56	1.25	1.49	1.43	0.25	0.26	0.39	0.30
100	1.54	1.21	1.44	1.40	0.17	0.25	0.29	0.24
120	1.37	1.06	1.29	1.24	0.15	0.18	0.20	0.18
Mean	1.48	1.26	1.45		0.24	0.25	0.33	

Sources	S.Em±	CD (P=O.05)	S.Em ±	CD (P=O.05)
Organic manures	0.02	0.04	0.01	0.02
S levels	0.02	0.06	0.01	0.02
Interactions	0.04		0.01	0.04

Table.12 Direct effect of sulphur application alone or along with organic manure on protein content in mustard

Sulphur levels (kg ha^{-1})	Organic manures			
	Control	FYM	BGS	Mean
0	13.52	13.25	13.61	13.46
20	14.35	13.93	14.19	14.16
40	15.87	15.42	15.31	15.53
60	19.06	17.46	18.12	18.21
80	18.17	15.87	15.14	16.39
100	14.56	14.75	14.37	14.56
120	13.6	14.19	14.31	14.03
Mean	15.59	14.98	15.01	
Sources	S.Em±		CD (P=O.05)	
Organic manures	0.09		0.21	
S levels	0.14		0.40	
Interactions	0.24		0.69	

Direct effect of Sulphur on Protein content

Effect of sulphur application alone or along with organic manure on protein content in mustard seed has been presented in Table 12. Protein content mustard seed varied from 13.25 to 19.06 per cent. The mean protein content in increased progressively from 13.46 to 18.21 per cent with the application of S upto 60 kg ha^{-1}. It is conspicuous that increase in each S dose increased the contents of protein significantly. The mean protein content was found maximum at 60 kg S ha^{-1} and thereafter declined linearly upto 120 kg S ha^{-1} level. The increase in protein content might be due to increase in N-content of mustard which ultimately increased aminoacid and protein content of mustard. The result confirms the findings of Singh *et al.*, (1991) and Singh *et al.*, (1998). Application of 60 kg S ha^{-1} gave significantly higher seed yield, economics, oil yield, protein yield and nutrients uptake (kg ha^{-1}) than control, 20 and 40 kg S ha^{-1} during experimental years (Verma *et al*., 2012). Both the organic manures were equally effective in reducing the protein content in seed which might be due to reduction in N content as a result of immobilization of soil N by microbes activated by organic manure during their decomposition. The interaction effect was also significant which indicated that inorganic S application upto 60 kg S ha^{-1} level was most suitable for increasing protein content in seed.

In conclusion, the maximum total N, P and K uptake showed the synergistic behaviour at lower level of S-application with N, P and K content in seed and stover and antagonistic at higher level of S-application. The beneficial effect of organic manure was also apparent in increasing total N, P and K uptake. Biogas slurry (BGS) proved better as compared to FYM in increasing total N, P and K uptake by mustard. The N: S ratio in mustard seed and stover was found highest at 60 kg S ha^{-1}, and the lowest N: S ratio was observed at highest level of S application (120 kg ha^{-1}) in both seed and stover. Sulphur application enhanced the protein content significantly in mustard seed.

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