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Anand Prasad Rakesh
K.V.K. Jale, Darbhanga, Bihar, India

Vandana Kumari
Department of Soil Science, Dr. Rajendra Prasad Central Agricultural University, Pusa, Samastipur, Bihar, India

AP Singh
Department of Soil Science, Dr. Rajendra Prasad Central Agricultural University, Pusa, Samastipur, Bihar, India

Corresponding Author:
Vandana Kumari
Department of Soil Science, Dr. Rajendra Prasad Central Agricultural University, Pusa, Samastipur, Bihar, India

Residual effect of different levels of organic manures amended Sulphur on nutrients uptake, nutrients-relationships and protein content of rice in a mustard-rice cropping system

Anand Prasad Rakesh, Vandana Kumari and AP Singh

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Abstract
This study revealed that S application has definite residual effect on succeeding crop rice as evinced by significant increase in N, P and K uptake by rice grain and straw. The mean total uptake of N increased from 60.3 to 106.7 kg ha^{-1} at 80 kg S ha^{-1} whereas total P and K uptake increased from 20.2 to 33.5 kg ha^{-1} and 90.0 to 158.0 kg ha^{-1} upto 100 kg S ha^{-1} level. The residual effect of organic manure was apparent in enhancing the mean total uptake of N from 82.1 to 89.8 kg ha^{-1}, total P uptake from 24.7 to 31.1 kg ha^{-1} and total K uptake from 125.9 to 136.2 kg ha^{-1}. The FYM proved better as compared to BGS in increasing the total N, P and K uptake by rice. The N: S ratio in rice grain and straw was also increased upto 60 kg S ha^{-1} in grain and 80 kg S ha^{-1} in straw and beyond that level it decreased with lowest N: S ratio at highest level of S application (120 kg S ha^{-1}). No Significant residual effect of S levels was observed on P: S ratio in rice grain. The N: S ratio of 13.91 and 3.75 was considered as the optimum N: S ratio for rice grain and straw, respectively obtained at optimum treatment combination. The optimum P: S ratio 5.36 for grain and 0.84 for straw were obtained at optimum treatment combination. The mean protein content increased significantly from 5.80 to 8.04 per cent with increasing S levels upto 60 kg S ha^{-1} beyond which it decreased regularly. Between the organic manures, the residual effect of FYM was found superior over BGS in increasing protein content in rice.

Keywords: Organic manures, residual effect, biogas slurry, Sulphur, nutrients uptake

Introduction
Balanced nutrition with combined use of organic manures along with inorganic fertilizers based on soil test value is the key to sustain rice productivity and to improve soil productivity. A suitable combination of secondary nutrients is the most important single factor that affects the productivity of the crops. Rice removes approximately 20.4 kg N, 3.6 kg P and 20.4 kg K/ tonne of grain (Prasad *et al*. 2004) [14]. Sulphur application benefits more than one crop gown on sequence and produces a significant residual response. Hence, the study on residual effects of S deserves equal attention. It was estimated that depending upon 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) [24].
Sachdev and Deb (1990) [16] used radioactive S in the mustard-greengram-maize system showed that 1-3% initially added S was taken by succeeding crops. However, Pasricha and Aulakh (1986) [11]. Reported in the groundnut - wheat system that direct responses on groundnut was lower whereas residual effect on wheat was more pronounced. Similar observations were made by Pasricha *et al*. (1987) [12]. In lentil-greengram system. Tiwari (1989b) [25]. Showed that wheat following groundnut benefited more from residual S (22% yield increase) as compared to wheat after rice where the yield increase was 7%. Experiment conducted by Singh *et al* (1991) [20]. With oilseed-based cropping system i.e. groundnut-mustard indicated large direct effect as compared to residual response observed that total grain yield for rotation was 13% more and oil yield was 19% more when S was applied to groundnut instead of mustard. The interaction effect between organic manure and pyrites was positive and significant residual effect of pyrite was observed by Singh *et al*. (1992) [21]. In blackgram-lentil system.

Also, nitrogen as well as Sulphur applied singly and in combination increased the sugar and starch contents of grain. Effect of nitrogen and Sulphur application singly or in combination showed that the grain yield, rice/husk ratio and the content of nitrogen and Sulphur of grains increased significantly (Paliwal *et al*., 1992) [10].

The effect of phosphorus and Sulphur on yield of rice and uptake of P and S by rice were reported by Sarkunan *et al*. (1998) [17]. The grain yield increased significantly with S addition upto 25 mg kg^{-1} rate, in the absence of added P. Application of P upto 50 mg kg^{-1} enhanced S uptake by grain, while the combined application of 100 mg P and 50 mg S kg^{-1} depressed S uptake by grain. The interaction between P and S upto 100 mg P and 25 mg S kg^{-1} rates and an adverse effect at higher levels on rice was recorded. Sulphur and phosphorus nutrition of winter maize in calcareous soil of north Bihar was reported by Sinha *et al.* (1995) [22]. Grain and stover yield increased with S and P application and the highest grain yield was obtained when 40 kg S was applied in conjunction with 60 kg P_20_5 ha^{-1}. Phosphorus application progressively increased its concentration in maize shoot. Addition of S increased fill-there the P content, showing a synergistic effect of applied Sulphur on P concentration of tissue. Synergistic effect was also reported by Paliwal *et al.* (1992) [10] in an experiment with rice var. cauvery, nitrogen application decreased while Sulphur application increased the phosphorus content of rice grain significantly. 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) [5]. It shows the positive interaction of Sulphur with potassium, Kachhave *et al*. (1997) [7] 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, general and calcareous soils with mustard-rice cropping system 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) [6] and electrical conductivity was determined with the help of conductivity bridge (Jackson, 1978) [6]. Organic carbon was estimated by the wet digestion method as given by Walkley and Black (1934) [26]. 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) [8]. Available Sulphur was determined by turbidimetric method as given by Chesnine and Yien (1951) [2]. The experimental site was sandy loam in texture, slightly alkaline in reaction, low in organic carbon, available N, P, K and S. General properties of initial surface soil of experimental plot are Sandy loam in texture (Sand-76%, Silt-12% and Clay-12%), pH (1:2) 8.4, EC 0.35 ds/m, Organic Carbon 4.10 g kg^{-1}, Free calcium carbonate 334 g kg^{-1}, CEC 8.80 Cmol(P^+)kg^{-1}, Available N 240.0 kg ha^{-1}, P_2O_5 14.0 kg ha^{-1}, K_2O 78.0 kg ha^{-1}, Available Zn 0.57 mg kg^{-1}, Available Fe 20.55 mg kg^{-1}, Available Cu 3.62 mg kg^{-1}, Available Mn 9.92 mg kg^{-1}, Total S 349.8 mg kg^{-1} and Available S 8.26 mg kg^{-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 residual effect of Sulphur alone or along with organic manure on rice crop. 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. $CaCl_2$ extractable Sulphur concentration in incubated organic matter at the time of application has been shown in Table 1. 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) [13] in binary acid mixture of nitric and perchloric acid (10: 3) for extraction of total Sulphur content as per the method of Tabatabai (1982) [23]. 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) [6]. Total N was analysed by Kjeldahl digestion distillation method as described by Piper (1966) [13]. Sulphur in the extract was determined by turbidimetric method given by Chesnine and Yien (1951) [2]. The average nitrogen (N) content of protein was found to be 16 percent which led to use of calculation for protein content given as: protein content= N x 6.25 (Food energy-methods of analysis and conversion factors FAO food and nutrition paper 77, 2002).

Table 1: $CaCl_2$ 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}

Result and discussions

Residual effect of Sulphur on Nitrogen concentration and uptake on Rice crop

A perusal of data in table 2 indicated that the residual effect of Sulphur application significantly increased N concentration in rice grain and straw. The mean N content in grain was highest (1.29%) at 60 kg S ha^{-1} and in straw the highest N content (0.54%) was observed at 80 kg ha^{-1}, and thereafter N content decreased showing antagonistic effect at higher level of Sulphur. A favourable effect of S on N content at lower level of S application and antagonistic at higher level of S was also observed by Das and Das (1994) [3]. The effect of BGS was not apparent in increasing N content in rice grain although it significantly increased N content in rice straw.

Table 2: Residual effect of Sulphur application alone or along with organic manure on nitrogen concentration (%) in rice

Sulphur levels (kg ha^{-1})	N concentration in grain				N concentration in straw			
	Organic manures				Organic manures			
	Control	FYM	BGS	Mean	Control	FYM	BGS	Mean
0	0.87	0.95	0.96	0.93	0.25	0.29	0.31	0.28
20	0.95	1.12	1.02	1.06	0.29	0.35	0.41	0.35
40	1.10	1.33	1.08	1.17	0.36	0.38	0.46	0.40
60	1.29	1.36	1.22	1.29	0.45	0.46	0.51	0.47
80	1.36	1.25	1.15	1.25	0.51	0.55	0.55	0.54
100	1.11	1.12	1.08	1.10	0.41	0.48	0.47	0.45
120	1.03	1.07	0.94	1.01	0.34	0.46	0.42	0.41
Mean	1.12	1.17	1.06		0.37	0.42	0.45	

Sources	S.Em±	CD (P=O.05)	S.Em ±	CD (P=O.05)
Organic manures	0.008	0.024	0.006	0.018
S levels	0.013	0.037	0.010	0.028
Interactions	0.022	0.064	0.017	0.049

The residual effect of organic manures and levels of Sulphur was found to significantly affect the N-uptake by grain and straw which varied from 36.5 to 70.2 and 16.8 to 45.2 kg ha^{-1}, respectively (Table 3). A synergistic effect of S on N was observed upto 80 kg S ha^{-1} and thereafter the decline in N uptake by rice grain and straw and also the total uptake was observed showing the antagonistic effect.

The reduction in N-uptake by grain and straw due to S-application suggested that increased concentration of N interacted with S and altered N availability causing reduction in uptake. The significant increase of N uptake by grain and stover with increasing levels of S was also observed by several workers (Das and Das, 1994; Dwivedi and Chaubey, 1995; Kachhave *et al*., 1997) [3, 4, 7]. The FYM significantly increased the mean uptake of N by 7.7 kg ha^{-1}. The effect of BGS did not reach to the significant level in increasing the mean uptake of N. The interaction of organic manures and S levels was found positive and significant which indicated that the residual effect of 80 kg S ha^{-1} + FYM was the best treatment combination with respect to N-uptake.

Table 3: Residual effect of Sulphur application alone or along with organic manure on nitrogen uptake (kg ha^{-1}) by rice

Sulphur levels (kg ha^{-1})	N uptake by rice grain				N uptake by rice straw				Total nitrogen uptake by rice			
	Organic manures				Organic manures				Organic manures			
	Control	FYM	BGS	Mean	Control	FYM	BGS	Mean	Control	FYM	BGS	Mean
0	36.5	40.7	45.8	41.0	16.8	19.7	21.5	19.3	53.3	60.3	67.2	60.3
20	47.5	50.0	49.0	48.8	21.7	25.2	29.5	25.4	69.1	75.1	78.4	74.2
40	50.1	62.8	53.1	55.3	27.6	28.8	33.2	29.9	77.7	91.6	86.3	85.2
60	65.4	70.2	60.1	65.2	35.3	35.4	38.0	36.2	100.7	105.6	98.1	101.4
80	68.5	63.0	60.2	63.9	40.7	45.2	42.6	42.8	109.2	108.1	102.8	106.7
100	54.0	56.7	56.2	55.6	34.2	41.2	36.7	37.4	88.1	97.9	92.9	93.0
120	49.7	51.5	47.2	49.5	27.2	38.5	33	32.9	76.9	90.0	80.2	82.4
Mean	53.1	56.4	53.1	-	29.1	33.4	33.5	-	82.1	89.8	86.6	-

Sources	S.Em ±	CD (P=0.05)	S.Em ±	CD (P=0.05)	S.Em ±	CD(P=0.05)
Organic manures	0.7	2.0	0.5	1.5	0.9	2.5
S levels	1.1	3.1	0.8	2.2	1.3	3.8
Interaction	1.9	5.4	1.4	3.9	2.3	6.6

Residual effect of Sulphur on Phosphorus concentration and uptake on Rice crop

The concentration of phosphorus in rice grain and straw increased with increasing level of Sulphur added to the first crop (Table 4), although the significant effect was not obtained at lower dose of Sulphur application. Phosphorus content in rice grain and straw varied from 0.28 to 0.57 and 0.06 to 0.17 per cent, respectively. The maximum mean P content in rice grain was obtained at 60 kg and in straw at 80 kg S ha^{-1}, beyond that the increase in Sulphur application did not show significant effect. Among the organic manure, FYM was more effective than BGS with respect to their residual effect on P content. The interaction of S-levels and organic manure was found significant.

Table 4: Residual effect of Sulphur application alone or along with organic manure on phosphorus concentration (%) in rice

Sulphur levels (kg ha^{-1})	P concentration in grain				P concentration in straw			
	Organic manures				Organic manures			
	Control	FYM	BGS	Mean	Control	FYM	BGS	Mean
0	0.28	0.37	0.39	0.35	0.06	0.07	0.09	0.07
20	0.31	0.42	0.41	0.38	0.06	0.09	0.07	0.07
40	0.34	0.42	0.44	0.40	0.06	0.09	0.08	0.08
60	0.49	0.47	0.45	0.47	0.09	0.10	0.09	0.09
80	0.45	0.48	0.46	0.46	0.10	0.12	0.13	0.12
100	0.43	0.51	0.45	0.46	0.10	0.17	0.09	0.12
120	0.42	0.57	0.41	0.47	0.07	0.15	0.07	0.10
Mean	0.39	0.46	0.43		0.08	0.11	0.09	

Sources	S.Em±	CD (P=O.05)	S.Em ±	CD (P=O.05)
Organic manures	0.008	0.022	0.002	0.007
S levels	0.012	0.034	0.004	0.010
Interactions	0.020	0.059	0.006	0.018

Phosphorus uptake by rice grain and straw varied from 11.7 to 27.5 and 3.6 to 14.5 kg ha^{-1}, respectively due to the residual effect of Sulphur application alone or along with organic manure (Table 5). Mean P uptake increased significantly with increasing level of S both in grain and straw upto 60 and 80 kg S ha respectively. The total P uptake varied from 15.3 to 40.1 kg ha^{-1} showing the residual effect at higher dose of S-application. The antagonistic effect of Sulphur on P-uptake was observed only at very high rate of Sulphur application i.e. after l00 kg S ha^{-1}. Several workers have reported the synergistic effect of P x S interaction at lower S application and antagonistic effect at higher level (Ali, 1991; Randhawa, 1995; Sarkunan *et al*., 1998) [1, 15, 17]. Organic manures also increased mean P-uptake by rice grain and straw as well as total P uptake significantly. The interaction between organic manure and Sulphur levels was found positive and significant.

Residual effect of Sulphur on Potassium concentration and uptake on Rice crop

The residual effect of Sulphur application was apparent on potassium concentration in rice grain as well as straw as appeared from the data in table 6. The data revealed that K concentration in rice grain varied from 0.17 to 0.34 per cent and in straw from 1.19 to 1.88 per cent. The mean K content in rice grain and straw increased significantly with increasing Sulphur levels upto 80 and 100 kg ha^{-1} showing the synergistic residual effect of Sulphur on K-content upto that level and antagonistic effect beyond that level. Farm yard manure was proved more effective in increasing K-content in rice grain by increasing mean K-content from 0.23 to 0.27 per cent, whereas BGS was more efficient in increasing K-content in rice straw by increasing the concentration from 1.48 to 1.65 per cent. The interaction effect of organic manure and S-levels was found significant on rice grain.

Table 5: Residual effect of Sulphur application alone or along with organic manure on phosphorus uptake (kg ha^{-1}) by rice

Sulphur levels (kg ha^{-1})	P uptake by rice grain				P uptake by rice straw				Total phosphorus uptake by rice			
	Organic manures				Organic manures				Organic manures			
	Control	FYM	BGS	Mean	Control	FYM	BGS	Mean	Control	FYM	BGS	Mean
0	11.7	16.0	18.6	15.4	3.6	4.6	6.1	4.8	15.3	20.6	24.6	20.2
20	14.0	18.5	19.7	17.4	4.2	6.2	5.3	5.3	18.2	24.8	25.0	22.7
40	15.3	20.0	21.7	19.0	4.5	6.5	5.7	5.6	19.8	26.6	27.4	24.6
60	25.1	24.1	22.2	23.8	7.4	7.7	6.3	7.1	32.5	31.8	28.6	30.9
80	22.7	24.4	23.9	23.6	8.3	9.7	9.9	9.3	30.9	34.1	33.8	32.9
100	21.1	25.8	23.4	23.4	8.5	14.5	7.3	10.1	29.7	40.1	30.7	33.5
120	20.5	27.5	20.7	22.9	5.9	12.3	5.1	7.8	26.3	39.8	25.8	30.6
Mean	18.6	22.3	21.5		6.1	8.8	6.5		24.7	31.1	28.0	

Sources	S.Em ±	CD (P=0.05)	S.Em ±	CD (P=0.05)	S.Em ±	CD(P=0.05)
Organic manures	0.4	1.2	0.2	0.6	0.4	1.2
S levels	0.7	1.9	0.3	0.8	0.7	1.9
Interaction	1.1	3.2	0.5	1.5	1.2	3.3

Table 6: Residual effect of Sulphur application alone or along with organic manure on potassium concentration (%) in rice

Sulphur levels (kg ha^{-1})	K concentration in grain				K concentration in straw			
	Organic manures				Organic manures			
	Control	FYM	BGS	Mean	Control	FYM	BGS	Mean
0	0.17	0.21	0.22	0.20	0.19	1.24	1.17	1.20
20	0.20	0.23	0.23	0.22	1.32	1.51	1.57	1.47
40	0.22	0.30	0.26	0.26	1.35	1.60	1.62	1.52
60	0.32	0.31	0.27	0.30	1.46	1.63	1.63	1.57
80	0.25	0.34	0.27	0.29	1.68	1.64	1.66	1.73
100	0.24	0.29	0.26	0.26	1.74	1.69	1.86	1.76
120	0.23	0.24	0.21	0.23	1.61	1.77	1.88	1.75
Mean	0.23	0.27	0.25		1.48	1.58	1.65	

Sources	S.Em±	CD (P=O.05)	S.Em ±	CD (P=O.05)
Organic manures	0.004	0.012	0.020	0.059

S levels	0.007	0.019	0.032	0.091
Interactions	0.011	0.032	0.055	

Residual effect of Sulphur application was found to affect the K-uptake significantly which varied from 7.2 to 17.0, 78.6 to 146.8 and 85.8 to 158.5 kg ha^{-1} in grain, straw as well as total K uptake, respectively (Table 7). The mean maximum K uptake was obtained at 60 and 100 kg Sulphur levels in case of grain and straw, respectively beyond that no improvement of K-uptake was recorded. The mean total K-uptake was also found to increase continuously upto 100 kg ha^{-1} S level showing synergistic effect of S with K upto that level. The residual effect of organic manures on K-uptake was found significant where FYM proved Superior to BGS in increasing K-uptake by rice grain, straw as well as total K uptake. The mean K-uptake increased from 11.1 to 13.3 and 12.2, from 114.9 to 123.0 and 121.8 and from 125.9 to 136.2 and 134.0 kg ha^{-1} due to FYM and BGS application in rice grain, straw as well as total K-uptake, respectively. The Interaction effect between S-levels and organic manure was found significant only in case of K-uptake by rice grain, however, the results of K-uptake by straw and total uptake also indicated the superiority of inorganic S in combination with organic manure preferably FYM.

Residual effect of Sulphur application alone or along with organic manure on N: S ratio in Rice crop

Increasing content of residual S enhanced the N: S ratio upto 60 kg ha^{-1} in grain and 80 kg ha^{-1} in straw and after that gradual decrease in the N: S ratio was observed (Table 8). The N: S ratio ranged from 9.42 to 14.54 and 2.00 to 4.14 in grain and straw, respectively. Mean N: S ratio was found lowest 9.63 and 2.28 in grain and straw, respectively with highest dose of residual S i.e. 120 kg ha^{-1}. The maximum N : S ratio was achieved at 60 kg S level in rice grain (13.49) and at 80 kg S ha^{-1} in rice straw (3.64) which was supported by Singh *et al*. (1988) [19], however, Sharma *et al*. (1991) [18] and Das and Das (1994) [3] in mustard crop observed continuous decrease in this ratio with increasing S levels. Relatively higher uptake of N with addition of S upto a certain level showing synergistic effect might have resulted in such increase of N: S ratio in the grain and straw. At high level of S, such synergistic effect did not appear but caused decrease in N: S ratio.

Organic manure was found to decrease the N: S ratio in both rice grain and straw where the effect of BGS was found to be significant. The interaction effect was non-significant in grain.

Table 7: Residual effect of Sulphur application alone or along with organic manure on potassium uptake (kg ha^{-1}) by rice

Sulphur levels (kg ha^{-1})	K uptake by rice grain				K uptake by rice straw				Total potassium uptake by rice			
	Organic manures				Organic manures				Organic manures			
	Control	FYM	BGS	Mean	Control	FYM	BGS	Mean	Control	FYM	BGS	Mean
0	7.2	9.0	10.3	8.8	78.6	83.2	81.7	81.2	85.8	92.2	92.0	90.0
20	8.9	10.4	10.9	10.1	98.7	108.4	113.6	107.0	107.6	118.9	124.5	117.0
40	9.9	14.4	12.9	12.4	103.8	120.3	117.4	113.9	113.7	134.6	130.3	126.2
60	16.1	16.0	13.5	15.2	115.0	124.6	120.2	119.9	131.1	140.6	133.7	135.1
80	12.7	17.0	13.9	14.6	134.2	133.5	128.8	132.2	146.9	150.5	142.8	146.7
100	11.8	14.8	13.7	13.4	145.2	143.8	144.8	144.6	156.9	158.5	158.5	158.0
120	11.2	11.6	10.3	11.1	128.4	146.8	146.1	140.5	139.6	158.4	156.5	151.5
Mean	11.1	13.3	12.2		114.9	123.0	121.8		125.9	136.2	134.0	

Sources	S.Em ±	CD (P=0.05)	S.Em ±	CD (P=0.05)	S.Em ±	CD (P=0.05)
Organic manures	0.2	0.7	1.8	5.1	1.8	5.2
S levels	0.4	1.1	2.7	7.7	2.8	7.9
Interaction	0.6	1.8	4.7		4.8	

Table 8: Residual effect of Sulphur application alone or along with organic manure on N:S ratio in rice

Sulphur levels (kg ha^{-1})	N:S ratio in rice grain				N:S ratio in rice straw			
	Organic manures				Organic manures			
	Control	FYM	BGS	Mean	Control	FYM	BGS	Mean
0	12.53	11.64	10.34	11.50	2.57	2.94	2.37	2.63
20	13.40	13.00	10.93	12.40	2.91	2.95	2.43	2.76
40	13.16	14.54	11.34	13.01	3.13	2.77	2.76	2.89
60	13.85	13.91	12.72	13.49	3.80	3.16	2.96	3.31
80	14.34	12.05	11.74	12.71	4.14	3.75	3.04	3.64
100	11.89	10.07	10.86	10.94	2.86	3.09	2.37	2.77
120	9.91	9.57	9.42	9.63	2.14	2.70	2.00	2.28
Mean	12.73	12.11	11.05		3.08	3.05	2.56	

Sources	S.Em±	CD (P=O.05)	S.Em ±	CD (P=O.05)
Organic manures	0.25	0.70	0.07	0.19
S levels	0.38	1.07	810	0.29
Interactions	0.65	-	0.18	0.51

but it was significant in straw. Since, the optimum treatment combination for rice grain and straw production was found to be 60 kg S ha^{-1} + FYM and 80 kg S ha^{-1} + FYM, respectively, the N : S ratio obtained at these treatment combination i.e. 13.91 for grain and 3.75 for straw may be treated as the optimum N : S ratio.

Residual effect of Sulphur application alone or along with organic manure on P: S ratio in Rice crop

The P: S ratio in rice grain varied from 3.96 to 5.36 and in straw from 0.31 to 1.09 with variation in S-levels alone or along with organic manures (Table 9). The effect of S-levels on P: S ratio in rice grain was found non-significant whereas in case of rice straw it was found significant, however, no definite trend was recorded. Sharma *et al*. (1991) [18] found decreasing trend of P: S ratio with increasing S-levels in mustard crop. Organic manure also did not show any significant effect on P: S ratio in rice grain. Interaction of organic manures and S levels was found significant in rice straw. The optimum P: S ratio may be regarded as 5.36 for grain and 0.84 for straw which were obtained at optimum treatment combination.

Table 9: Residual effect of Sulphur application alone or along with organic manure on P:S ratio in rice

Sulphur levels (kg ha^{-1})	P:S ratio in rice grain				P:S ratio in rice straw			
	Organic manures				Organic manures			
	Control	FYM	BGS	Mean	Control	FYM	BGS	Mean
0	4.00	4.58	4.19	4.26	0.56	0.69	0.67	0.64
20	4.49	4.82	4.39	4.57	0.56	0.74	0.45	0.58
40	4.03	4.65	4.65	4.44	0.51	0.63	0.47	0.54
60	5.36	4.79	4.70	4.95	0.76	0.68	0.49	0.64
80	4.75	4.67	4.66	4.69	0.84	0.82	0.65	0.77
100	4.64	4.58	4.53	4.58	0.71	1.09	0.47	0.76
120	3.96	5.08	4.13	4.39	0.46	0.86	0.31	0.54
Mean	4.46	4.74	4.46		0.63	0.79	0.50	

Sources	S.Em±	CD (P=O.05)	S.Em ±	CD (P=O.05)
Organic manures	0.13	-	0.03	0.07
S levels	0.20	-	0.04	0.11
Interactions	0.35	-	0.07	0.19

Residual effect of Sulphur application alone or along with organic manure on Protein content in Rice crop

Protein content in rice grain was found to vary from 5.46 to 8.50 per cent as influenced by the residual effect of S-levels and organic manure individually or in combination (Table 10). Increasing S-levels significantly increased the mean protein content from 5.80 to 8.04 per cent upto 60 kg S ha^{-1} level and beyond that level it decreased. The increase in protein content may be due to higher nitrogen utilization by the crop with adequate supply of Sulphur. Similarly, Malarvizhi *et al*. (1990) [9] observed the increase in protein content from 5.2 to 6.2 per cent with S application in rice. The protein content was significantly increased with the application of FYM, however, the effect of BGS was negative. The interaction effect was found to be significant which showed that FYM application increased the protein content in rice grain at almost all levels of S whereas BGS was able to increase the protein content at lower levels of S, and at higher S-levels it was decreased. This might be due to higher exploiting power of BGS for S as compared to FYM at higher S levels.

Table 10: Residual effect of Sulphur application alone or along with organic manure on protein content in rice

Sulphur levels (kg ha^{-1})	Organic manures			
	Control	FYM	BGS	Mean
0	5.46	5.95	6.00	5.80
20	5.94	7.02	6.37	6.44
40	6.87	8.29	6.77	7.31
60	8.04	8.48	7.60	8.04
80	8.50	7.79	7.19	7.83
100	6.92	7.02	6.75	6.90
120	6.46	6.69	5.87	6.34
Mean	6.88	7.32	6.65	
Sources	S.Em±		CD (P=O.05)	
Organic manures	0.05		0.15	
S levels	0.08		0.23	
Interactions	0.14		0.4	

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 grain and straw 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. Thus, the residual effect of higher level of S along with FYM proved more effective with respect to S nutrition to rice. The N: S ratio in rice grain and straw was also increased upto 60 kg S ha in grain and 80 kg S ha^{-1} in straw and beyond that level it decreased with lowest N: S ratio at highest level of S application (120 kg S ha^{-1}). No Significant residual effect of S levels was observed on P: S ratio in rice grain. Among the organic manures, the residual effect of FYM was found superior over BGS in increasing protein content in rice.

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