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Effect of Long Term Manure and Fertilizer Addition on Sulphur Forms Under Rice Monoculture

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The effect of continuous application of manures and fertilizers to rice monoculture on chemical pools of different forms of sulphur was investigated in sandy clay loam soil. Among the major forms of S, organic S was the dominant one. Long term application of anyone of the organic manures and P fertilizer have increased the organic, water soluble, sulphate significantly but decreased the adsorbed and non sulphate forms of soil.

Key words : Manures, fertilizers, long-term sulphur forms

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Sulphur is one of the important secondary nutrient elements and its essentiality for plant growth has been recognized since the middle of 19^{th} century. Sulphur has been rated as fourth major nutrient element after N, P and K (Sarkar *et al.,* 1994). Sulphur nutrition to crops has not been fully realized during the past mainly because S deficiency was not a serious problem but with the use of high analysis fertilizers containing little or no S along with intensive cropping has led to depletion of S in many soils. Sulphur in the arable land would be in the form of soluble sulphate in solution, in organic matter adsorbed in the soil complex. Although studies have been conducted on the effect of S on various crops under various agro-climatic conditions, the information on the long term effects of different manures-fertilizers schedules on different forms of S in soil under rice monoculture is lacking. Keeping these points in view, the present investigation was taken up to evaluate the effect of the rice monoculture on different forms of sulphur under permanent manurial experiment which is in operation since 1975 with different manure-fertilizer schedules.

Materials and Methods

The permanent manurial experiment is in operation since 1975 at the Agricultural College and Research Institute, Madurai, Tamil Nadu in sandy clay loam soil (Typic Haplustalf). The experiment was laid out in split plot design with two replications (Main plot : M_1 - No manure, M_2 - Farm yard manure (FYM) @ 12.5 t ha^{-1}, M_3 - Green leaf manure (GLM) @ 12.5 t ha^{-1}, M4 - Urban compost (UC) @ 12.5 t ha^{-1}; Sub-plot - S_1 - Control (No, N, P and K); S_2 - N, S_3 - P, S_4-K,S_5-N+P,S_6-N+K,S_7-P+K,S_8-N+P+K. The organic manures viz., FYM, GLM and UC were applied and incorporated into the soil one week prior to planting. Nitrogen, P and K were applied @ 120 : 60 : 60 kg ha^{-1} respectively in the form of urea, single super phosphate and muriate of potash according to the treatments. Present study was taken up with the 45th and 46th rice crops raised in the experiments during 2005-06 and 2006-07 respectively.

Pre-planting and post harvest soil samples of 45th and 46th crops were collected at 0-15 cm depth, processed and analysed for organic S (Evans and Roast,1946), water soluble S (Williams and Steinbergs, 1959). Adsorbed S (Fox *et al.*,1964), Sulphate S (Williams and Steinbergs, 1959) and nonsulphae S (Chao *et al.,* 1964). Sulphur in the extract was determined turbidimetrically (Chesnin and Yien, 1951).

Results and Discussion

Organic S

The organic S ranged between 36 mg kg^{-1} in unmanured control and 365 mg kg^{-1} in UC and it varied from 163 to 280 mg kg^{-1} among the fertilizer schedules (Table 1). Continuous addition of organic manures had considerably improved the organic S while depletion was observed in the treatments receiving no manure. Among the organic sources, the highest organic S was registered with UC followed by GLM and FYM treatments. This might be due to the higher content of S and higher organic carbon content of UC treated plots. The positive relationship between organic carbon and organic S has been reported by Singh and Sharma (1993). Application of P either alone or in combination with N and K registered higher organic S status. Accumulation of organic S due to the long term annual application of superphosphate in pasture was reported by Nguyen and Goh (1992). Treatments receiving either alone or incombination with P or K recorded higher organic S than K added treatments or control. Since application of N would have caused development of more root biomass which upon decomposition could have enriched the

Table 1. Effect of manure-fertilizer schedules on organic S status of the soil (mg kg^{-1})

Treatment	Preplanting '05 (Stage I)					Postharvest '05 (Stage II)					Postharvest' 06 (Stage III)					Mean (Sub plot)
	M_1	M_2	M_3	M_4	Mean	M_1	M_2	M_3	M_4	Mean	M_1	M_2	M_3	M_4	Mean	
S_1	23	138	196	244	150	20	142	226	276	166	16	147	238	286	172	163
S_2	30	160	225	270	171	23	165	245	304	184	17	166	255	310	187	181
S_3	44	220	280	386	232	44	245	313	423	256	41	256	330	445	268	252
S_4	27	150	210	260	162	20	153	238	285	174	15	156	248	294	178	171
S_5	48	250	310	420	257	45	264	340	453	276	45	275	353	475	287	273
S_6	33	193	240	280	187	30	172	253	306	190	25	175	262	316	195	191
S_7	55	218	285	418	244	57	236	323	446	267	51	250	340	459	275	262
S_8	60	255	310	439	266	55	260	339	478	283	49	266	354	490	290	280
Mean	40	198	257	340	209	37	205	285	371	225	31	192	298	384	226	
Mean (Main Plot)	M_1=36					M_2 = 198					M_3 = 280				M_4 = 365	

	SEd	CD (p=0.05)		SEd	CD (p=0.05)
St	1.45	3.0	St x M	2.91	6.0
M	1.68	3.0	St x S	4.11	8.00
S	2.37	5.0	M x S	4.74	9.0
			St x M x S	8.22	NS

organic S pool. Overall an appreciable build up of organic S (17 mg kg^{-1}) was recorded from preplanting '05 to post harvest '06 stage due to the addition of manure - fertilizer.

Water soluble S

A significant increase in water soluble S was observed at the successive stages due to manure - fertilizer application (Table 2). The values were 17.1, 18.1, and 19.2 mg kg^{-1} in preplanting '05, post harvest '05 and post - harvest '06 stages respectively. Among the manurial treatments, it varied from 9.8 mg kg^{-1} in M_1 (Unmanured control) to 25.4 mg kg^{-1} in M_4 (UC) treatments. Among the organics, UC occupied the higher place than GLM and FYM in influencing the water soluble S status. Watwood and Fitegerald (1988) reported that continuous addition of organic residues enhanced the water soluble S status to the tune of 5 per cent than in the unmanured control. In the case of fertilizer schedules, the water soluble S content varied from 10.3 to 24.5, 9.4 to 27.7 and 9.0 to 30.0 mg kg^{-1} in preplanting '05, post harvest '05 and post harvest '06 stages respectively. The water soluble S content was found to be higher in the treatments receiving P than without P fertilizer. Similar to the individual effects, the interaction effect showed that the treatments receiving UC or GLM along with P application recorded higher water soluble S content.

Table 2. Effect of manure-fertilizer schedules on water soluble S status of the soil (mg kg^{-1})

Treatment	Preplanting '05 (Stage I)					Postharvest '05 (Stage II)					Postharvest' 06 (Stage III)					Mean (Sub plot)
	M_1	M_2	M_3	M_4	Mean	M_1	M_2	M_3	M_4	Mean	M_1	M_2	M_3	M_4	Mean	
S_1	4.8	12.4	10.0	16.4	10.9	4.0	10.8	10.0	19.0	10.5	4.0	10.0	11.2	21.4	10.0	10.5
S_2	4.4	12.0	10.0	14.6	10.3	3.7	10.0	10.0	13.8	9.4	3.5	10.0	10.0	12.4	9.0	9.6
S_3	11.8	24.8	21.8	34.2	23.2	12.8	27.5	27.4	39.4	26.8	14.0	28.6	30.0	41.4	28.5	26.2
S_4	6.3	13.6	14.0	19.4	13.3	4.4	11.0	13.2	19.4	12.0	4.0	10.4	13.0	19.8	11.8	12.4
S_5	12.0	22.8	21.8	27.4	21.0	10.4	24.5	24.4	31.2	22.6	12.2	27.0	27.8	32.2	24.8	22.8
S_6	4.0	12.6	13.1	16.0	11.4	4.0	10.0	11.4	16.1	10.4	4.0	9.8	10.8	16.0	10.2	10.7
S_7	17.1	22.8	26.4	31.8	24.5	19.0	24.2	31.0	36.5	27.7	21.2	26.4	33.4	39.0	30.0	27.4
S_8	16.8	19.8	24.2	26.2	21.8	17.2	21.4	29.0	32.0	24.9	18.4	24.8	31.8	34.0	27.3	24.7
Mean	9.7	17.5	17.7	23.3	17.1	9.4	17.5	19.6	25.9	18.1	10.2	18.4	21.0	27.0	19.2	
Mean (Main Plot)	M_1 = 9.8					M_2 = 17.8					M_3 = 19.4			M_4 = 25.4		

	SEd	CD (p=0.05)		SEd	CD (p=0.05)
St	0.18	0.4	St x M	0.36	0.7
M	0.20	0.4	St x S	0.50	1.0
S	0.29	0.6	M x S	0.59	1.2
			St x M x S	1.02	2.0

Sulphate S

Both organic sources and fertilizer schedules significantly influenced the sulphate S and varied widely from 15.9 mg kg^{-1} in unmanured control (M_1) to 41.8 mg kg^{-1} in UC (M_4 treatment), whereas, among the fertilizer treatments, it ranged from 18.4 to 51.1 mg kg^{-1} (Table 3). The higher status of sulphate S was registered in the manured treatments than in the unmanured control. Similarly the treatments those received P fertilizer recorded higher sulphate S than the treatments without P. Among the organics, the UC and GLM performed better as compared to FYM in registering the sulphate S in all the three stages. Due to narrow C:S ratio and higher S content, the UC would have undergone mineralization relatively at a faster rate and added sulphate S to the labile pool. According to Schoenau and Bettany (1987), the green manure is enriched with ester sulphate a labile fraction of organic S which undergoes mineralization faster and releases the sulphate S to the labile pool. Considering the three stages, a rapid depletion of sulphate S was observed in N added treatments than in the control and K treatments. Due to the synergistic relationship between N and S, the uptake of S has been enhanced which would have led to the faster depletion of sulphate S. This has been confirmed earlier by Bettany *et al.* (1985).

Table 3. Effect of manure-fertilizer schedules on SO_4^{2-} status of the soil (mg kg^{-1})

Treatment	Preplanting '05 (Stage I)					Postharvest '05 (Stage II)					Postharvest' 06 (Stage III)					Mean (Sub plot)
	M_1	M_2	M_3	M_4	Mean	M_1	M_2	M_3	M_4	Mean	M_1	M_2	M_3	M_4	Mean	
S_1	8.2	24.5	28.2	35.6	24.1	6.4	22.0	25.0	37.0	22.6	5.0	19.0	26.4	37.8	22.1	22.9
S_2	5.4	26.0	25.0	25.4	20.5	5.0	22.0	23.0	23.2	18.3	4.8	20.0	21.4	19.8	16.5	18.4
S_3	24.6	46.4	52.0	44.4	41.9	25.2	50.2	58.5	51.4	46.3	28.0	52.4	61.8	56.4	49.7	46.0
S_4	8.0	23.5	33.8	32.6	24.5	6.2	22.0	31.4	32.0	22.9	5.5	20.0	32.6	33.0	22.8	23.4
S_5	22.0	52.4	42.0	45.0	40.4	23.0	58.2	49.8	48.5	44.9	27.4	61.4	54.5	53.8	49.3	44.9
S_6	7.6	22.8	23.0	27.8	20.3	4.8	20.0	23.8	27.0	18.9	4.5	18.2	21.4	28.4	18.1	19.1
S_7	25.0	51.8	57.8	51.4	46.5	27.0	54.0	64.6	59.4	51.2	31.4	58.0	69.0	63.8	55.6	51.1
S_8	22.8	46.5	52.5	48.4	42.6	24.0	51.4	57.2	56.0	47.2	29.0	56.4	62.5	61.4	52.3	47.4
Mean	15.5	36.7	38.8	39.3	32.6	15.2	37.5	41.6	41.8	34.0	17.0	38.2	43.7	44.3	35.8	

Mean (Main Plot) M_1 = 15.9 M_2 = 37.5 M_3 = 41.4 M_4 = 41.8

	SEd	CD (p=0.05)		SEd	CD (p=0.05)
St	0.16	0.3	St x M	0.32	0.6
M	0.18	0.4	St x S	0.45	0.9
S	0.26	0.5	M x S	0.52	1.0
			St x M x S	0.90	1.8

Adsorbed S

On comparing the cropping stages, a depletion and build up of adsorbed form of S was recorded in the manured and unmanured treatments respectively (Table 4). The results further indicated that the highest adsorbed S was noted in FYM (51.2 mg kg^{-1}) followed by GLM (47.3 mg kg^{-1}) treatments. In unmanured control, a positive balance of 6 per cent of adsorbed S was recorded. The negative balance of S in manured treatments may be due to the prevailing competition between organic anions and sulphate ions for the same adsorption sites. Courchesne *et al.* (1995) demonstrated that the addition of organic manures decreased the

Table 4. Effect of manure-fertilizer schedules on adsorbed S status of the soil (mg kg^{-1})

Treatment	Preplanting '05 (Stage I)					Postharvest '05 (Stage II)					Postharvest' 06 (Stage III)					Mean (Sub plot)
	M_1	M_2	M_3	M_4	Mean	M_1	M_2	M_3	M_4	Mean	M_1	M_2	M_3	M_4	Mean	
S_1	23.8	47.5	39.6	46.4	39.3	21.6	43.0	35.0	38.0	34.4	21.6	32.2	29.4	30.6	29.9	34.5
S_2	18.6	45.0	45.8	47.6	39.3	18.0	38.0	43.0	35.8	33.7	15.0	27.5	41.1	29.2	28.5	33.8
S_3	62.4	60.6	62.8	61.6	61.9	65.8	61.8	57.5	50.6	58.9	73.0	56.6	52.4	37.1	54.3	58.4
S_4	28.0	38.5	32.8	46.4	36.4	27.8	38.0	22.6	36.0	31.1	22.3	38.0	18.0	30.0	27.2	31.6
S_5	60.0	53.6	70.2	52.0	59.0	62.0	53.8	55.2	44.5	55.4	63.3	48.5	53.1	31.2	48.7	54.4
S_6	29.4	21.2	41.0	25.2	29.2	28.2	25.0	34.2	23.0	27.6	20.1	15.8	31.4	19.4	21.9	26.2
S_7	60.0	71.2	76.2	65.6	68.3	59.0	77.0	60.6	54.6	62.8	69.6	70.5	53.5	49.2	60.4	63.8
S_8	72.2	81.5	78.5	54.6	71.7	75.0	78.6	68.8	45.0	66.9	87.6	71.6	58.5	36.2	63.7	67.4
Mean	44.3	55.9	52.4	49.9	50.6	44.7	51.9	47.1	40.9	46.2	47.0	45.8	42.3	32.7	42.0	

Mean (Main Plot) M_1 = 45.3 M_2 = 51.2 M_3 = 47.3 M_4 = 41.2

	SEd	CD (p=0.05)		SEd	CD (p=0.05)
St	0.24	0.5	St x M	0.49	1.0
M	0.28	0.6	St x S	0.69	1.4
S	0.39	0.8	M x S	0.80	1.6
			St x M x S	1.38	2.7

adsorbed S due to the chelation of Fe and Al by organic anions. The positive balance of adsorbed S (6%) in unmanured control might be due to the specific adsorption of sulphate ionsby the hydrous oxides of Fe and Al (Courchesne, 1992). The results further showed that a depletion of adsorbed S irrespective of the treatments in fertilizer schedules. Even in the treatments receiving P fertilizer a declining trend was noticed. This may be attributed to the prevailing competition between the H_2PO_4-and SO_4^{2-} ions for the same adsorption sites. As single super phosphate was used as P fertilizer in this experiment, the added H_2PO_4- would have competed with the SO_4^{2-} ions for adsorption sites.

Due to higher bonding strength of H_2PO_4- it would have been adsorbed preferentially and tenaciously on the colloidal constituents than the sulphate. This would have led to the depletion of adsorbed S at the successive stage. A negative correlation between the sulphate adsorption potential and Bray and Kurtz P_1(r=-0.80) and P_2(r = -0.72) were observed by Barrow (1970).

Non sulphate S

The results reflected that the non sulphate S status was significantly decreased (from 37.0 to 34.8 mg kg^{-1}) at the successive stages (Table 5). Among the manured treatments, the non-sulphate S ranged

Table 5. Effect of manure-fertilizer schedules on non SO_4^{2-} S status of the soil (mg kg^{-1})

Treatment	Preplanting '05 (Stage I)					Postharvest '05 (Stage II)					Postharvest' 06 (Stage III)					Mean (Sub plot)
	M_1	M_2	M_3	M_4	Mean	M_1	M_2	M_3	M_4	Mean	M_1	M_2	M_3	M_4	Mean	
S_1	37.0	29.6	26.2	23.8	29.2	37.0	23.0	24.0	21.0	26.3	32.4	19.4	21.2	20.0	23.3	26.3
S_2	56.0	23.8	24.2	27.0	32.8	54.2	19.1	19.2	23.4	28.9	51.2	18.4	17.5	21.0	27.0	29.6
S_3	46.2	33.4	35.2	35.8	37.7	48.0	35.0	36.4	35.0	38.5	48.0	33.0	31.8	33.5	36.6	37.6
S_4	37.4	36.0	33.4	21.0	32.0	36.0	35.0	32.2	21.0	31.0	35.2	31.0	29.4	21.0	29.2	30.7
S_5	60.4	29.8	42.8	34.8	42.0	65.4	32.2	41.4	33.0	42.8	62.3	30.0	37.4	30.0	39.9	41.6
S_6	55.0	46.5	36.0	32.5	42.5	52.5	44.2	35.6	30.0	40.4	48.4	41.0	33.2	28.2	37.7	40.2
S_7	74.5	44.6	36.0	30.0	46.3	78.4	43.0	34.0	30.0	46.2	73.4	40.5	32.5	30.0	44.1	45.5
S_8	80.5	29.0	34.5	28.0	43.0	84.0	28.2	33.8	27.5	43.4	75.4	27.0	33.0	26.4	40.4	42.3
Mean	51.3	34.1	33.5	29.1	37.0	56.8	28.4	31.9	27.6	36.2	53.3	30.0	29.5	26.3	34.8	
Mean (Main Plot)	M_1 = 53.8					M_2 = 30.8					M_3 = 31.6				M_4 = 27.7	

	SEd	CD (p=0.05)		SEd	CD (p=0.05)
St	0.18	0.4	St x M	0.35	0.7
M	0.20	0.4	St x S	0.50	1.0
S	0.29	0.6	M x S	0.57	1.1
			St x M x S	0.99	2.0

from 27.7 to 53.8 mg kg^{-1} and the highest amount of 53.8 mg kg^{-1} was recorded in unmanured control (M_1) and the lowest value was noted in the UC (M_4) treatment (27.7 mg kg^{-1}). This may be attributed to accumulation of higher organic matter in UC added treatment (1.51%). Johnson and Henderson (1979) observed a significant negative relationship between the organic carbon and non-sulphate S in the surface soils of hardwood forest. Generally, the non sulphate S content was significantly lower in the treatments receiving any one of the manures than in the unmanured control (M_1). This may be due to the solubilization of occluded sulphate by the organic acids released during the decomposition of organic manures. Similar to the organics, the fertilizer schedules also significantly altered the non-sulphate S and it ranged from 29.2 5 to 46.3, 26.3 to 46.2 and 23.3 to 44.1 mg kg^{-1}. The non-sulphate S followed the similar trend in the individual stages as that of the pooled averages.

From this study, it is concluded that long term application of any one of the organic manures and P fertilizers containing S have increased significantly the organic, water soluble and sulphate S but decreased the adsorbed and nonsulphate S status of the soil. Thus to increase the availability of S to the labile pool for absorption of S by the rice crop, application of organic manures has become inevitable in Typic Haplustalf soils.

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