Madras Agric. J., 101 (4-6): 123-130, June 2014
https://doi.org/10.29321/MAJ.10.001165

Influence of Sulphur Conjoint with Organics on Hybrid Maize and Available Nutrient Status in Typic Haplustalf

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Field experiments were conducted during 2010 and 2011 in a farmer's field at Sivagangai district, Tamil Nadu to evaluate the effect of inorganic S alone and in combination with organic manures on hybrid maize. The results revealed a positive effect for the application of S alone and in combination with organic manures. The highest grain yields of 5980 and 6025 kg ha $^{-1}$ were registered with the application of vermicompost conjoint with 80 kg S ha^{-1}during the year 2010 and 2011, respectively. A marked improvement on uptake of N,P,K and S were observed with the increase in the level of S. Among the organics, application of vermicompost was better followed by press mud and FYM. Application of organics and inorganic S significantly improved the available P, K and S status of the soil .The available N content of the soil was not increased due to the application of organics and inorganic S.

Key words: Maize, Organics, Inorganic S.

Maize is the world's third most important cereal crop after wheat and rice. Maize is globally cultivated over an area of about 148.48 million hectares with a production of about 699.32 million tonnes and productivity of 4.71 t ha^{1}of grain. In India, it occupies third place among the cereals after rice and wheat. By 2020, the requirement of maize for various sectors will be around 100 mt, of which the poultry sector demand alone will be 31 mt. Out of the total maize produced in India, 50 per cent is used as cattle feed, 38 per cent as food grain for human consumption, 11 per cent in the manufacture of starch and one per cent as seed. Modern intensive farming has resulted in higher demand for fertilizers because of removal of all the essential nutrients in higher proportions by the crops. Most of our attention for fertilizer use has been restricted to the use of N, P, and K, the three primary nutrients required by the crops in large quantities. The reports of the deficiency of secondary and micro nutrients are increasingly appearing from intensively cropped regions. Sulphur is one of the important secondary nutrient elements and its essentiality for plant growth has been recognised since the middle of 19thcentury. Crops in general require as much sulphur as they need phosphorus.

It is indispensable for the synthesis of amino acids like cystine, cystyne and methionine besides being involved in various metabolic and enzymatic processes of plants. Sulphur nutrition to crops has not been fully realized during the past mainly, because of the fact that sulphur deficiency was not a serious problem. Recently, interest on sulphur as a plant nutrient has been increased dramatically. Sulphur being an anion gets adsorbed on the hydrous oxides of Fe, Al, and its availability get decreased. (*Borkotoki* and *Das*, 2008). Adsorption of sulphur is a major concern next to phosphorus in Alfisols. Our aim is increasing the availability of native and applied sulphur by the addition of organic substances. Organic substances chelate with Fe, Al and reduces the activities of Fe and Al and release the sulphur to the labile pool (Parfitt,1978; Evans, 1986). The cultivation of hybrid maize has become very popular among the farmers. The hybrid maize respond well to the application of nutrients. The recommendation of N, P, K and micronutrients are available, while the response study of sulphur on hybrid maize is lacking. Keeping these points in view, the present investigation was taken up to evaluate the effect of sulphur alone and in combination with organics on hybrid maize.

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Materials and Methods

Field experiments were conducted with maize hybrid (Syngenta NK 6240) during 2010 and 2011 in a farmer's field at Sivagangai district, Tamil Nadu. Taxonomically, the soils are grouped under Typic Haplustalf with sandy loam in texture. The available S status of the soils were 5.4 and 5.6 mg kg $^{-1}$in the experimental field selected during 2010 and 2011 respectively. The treatments consisted of 5 levels of inorganic sulphur (M_0- Control, M_1- 20 kg S ha^{-1}, M_2- 40 kg S ha^{1}, M_3- 60 kg S ha^{-1}, and M_4- 80 kg S ha^{-1}.) and 4 sources of organics (N_0 - Control, N_1– Press mud 5 t ha $^{-1}$, N_2– FYM 5 t ha $^{-1}$ and N_3– Vermi compost 5 t ha^{-1}). The experiments were conducted by following Factorial Randomised Block Design with two replications. Sulphur was applied through gypsum. Recommended dose of N, P_2O_5 and K_2O of 150, 75, 75 kg ha^{1}were applied as urea, DAP and

muriate of potash respectively. The soil samples were drawn from each treatment on 30 DAS, 60 DAS and after harvest of the crop and analysed for Alkaline $KMnO_4$ – N Olsen P, NH_4OAc-K and available S by following the standard procedures. The plant samples were collected on 30 DAS, 60 DAS and at harvest and dried in an oven at 65 ^{0}C for a constant weight. The leaves were cut into small pieces and the grains were also ground by using willey mill. The samples were analysed for N, P, K and S contents and their uptake were computed.

Results and Discussion

Effect of inorganic sulphur and organic manures on grain yield of maize.

The grain yields were from 4474 and 4438 kg ha^{-1} in unmanured control and 5359 and 5250 kg ha $^{-1}$ in vermicompost treatment (N_3) during the year 2010 and 2011, respectively (Table 1). The results showed that among the manurial treatments significantly higher and comparable yields were recorded in vermicompost and press mud 5 t ha $^{-1}$. The higher grain yield in the treatment receiving organic manures may be attributed to the overall positive influence of the manures on the properties and fertility status of the soil. The effect of vermicompost on maize grain yield was prominent. The narrow C:N, C:P and C:S ratio of vermicompost would have favoured for the better uptake of nutrients and growth of maize crop and augmented the grain yield. The positive influence of vermicompost on seed yield of green gram was reported by Rajkhowa *et a*l. (2000). The levels of S had a significant influence on the grain yield of maize. The yield increased with the concomittant increase in the level of S. Sulphur @ 80 kg ha $^{-1}$ recorded significantly higher grain yield in both the years of study. The data emphatically indicated that the higher response was observed for S application. Sinha *et al*. (1995) observed a positive response of S on maize grain yield. The conjoint incorporation of organics and inorganic S also had a prominent effect on grain yield. Significantly higher grain yield of 5980 and 6025 kg ha $^{-1}$ during the year 2010 and 2011 respectively were registered with the conjoint incorporation of 80 kg S ha $^{-1}$ with vermicompost. However, application of 60 kg S along with vermicompost also recorded comparable yield with 80 kg S incombination with vermicompost. Application of vermicompost with inorganic S would have created a better nutritional environment and thus promoted the growth and yield attributes which finally reflected on the grain yield.

Table 1. Effect of organic manures and inorganic S on maize grain yield (kg ha^{-1})

Organics / Inorganic S	2010					2011				
	N0	N1	N2	N3	Mean	N0	N1	N2	N3	Mean
M0	3465	3860	3740	4370	3859	3425	3945	3680	4265	3829
M1	4200	4568	4368	5005	4535	4165	4465	4290	5265	4546
M2	4685	5268	4864	5465	5071	4560	5465	5120	5680	5206
M3	4868	5645	5265	5975	5438	4775	5560	5355	6015	5426
M4	5152	5865	5428	5980	5606	5265	5765	5525	6025	5645
Mean	4474	5041	4733	5359		4438	5040	4794	5250	
SED	M	N	MxN	NxM		M	N	MxN	NxM	
CD(P= 0.05)	43	39	85	73		42	36	82	68	
	87	79	171	145		83	71	164	134	

Effect of organics and inorganic sulphur on uptake of nutrients

N uptake

A marked increase in N uptake of the maize was observed with the advancement of growth stages. Regarding the manurial treatments, the N uptake was significantly differed and it varied from 11.0 to 15.4, 79.6 to 122.6 and 121.5 to 165.2 kg ha^{-1} at 30 DAS, 60 DAS and at harvest stages respectively (Table 2). Application of any one of the organic manures such as pressmud, FYM and vermicompost showed a highest N uptake than unmanured control. Distinctly higher N uptake of 15.4, 122.6 and 165.2 kg ha^{-1} at 30 DAS, 60 DAS and harvest stage, respectively were observed with the application of vermicompost (N_3). It was followed by pressmud (N_1) and FYM (N_2). Due to narrow C:N ratio (24; 1), vermicompost would have undergone minerlization relatively at a faster rate and supplied N to the labile pool. The results showed that the S fertilization registered significantly higher N uptake than the treatment not receiving inorganic S. A continuous increasing trend of N uptake was registered at the successive stages. The N uptake varied from 11.4 to 15.2, 85.6 to 116.8 and 117.2 to 171.2 kg ha $^{-1}$ at 30 DAS, 60 DAS and harvest stages respectively among the S levels. Significantly higher N uptake of 15.2, 116.8 and 171.2 kg ha^{-1} at 30 DAS, 60 DAS and harvest stages respectively were recorded in the treatment receiving 80 kg S ha^{-1} (M_4) and was followed by 60 kg S ha $^{-1}$(14.7, 113.7 and 162.6 kg ha $^{-1}$). The increase in N uptake due to the application of S may be attributed to increase in N concentration of plant. The synergistic effect between S and N would have helped in greater N uptake. Such a synergistic relationship between N and S was

Table 2. Effect of organics and sulphur levels on nitrogen uptake (kg ha $^{-1}$) at different stages of crop growth (Mean of two years)

Organics / Inorganic S	Nitrogen uptake (kg ha^{-1})														
	30 DAS					60 DAS					At harvest				
	N0	N1	N2	N3	Mean	N0	N1	N2	N3	Mean	N0	N1	N2	N3	Mean
M0	8.9	12.2	11.1	13.2	11.4	64.9	90.2	82.7	104.4	85.6	98.7	121.1	113.6	135.5	117.2
M1	10.1	13.5	11.9	14.7	12.6	70.2	100.8	81.9	114.7	91.9	108.2	131.2	124.2	144.5	127.0
M2	11.4	14.8	13.1	15.9	13.8	78.7	110.0	99.6	124.6	103.2	118.2	149.2	140.5	161.2	142.3
M3	12.2	16.3	14.1	16.2	14.7	90.7	121.0	110.3	132.9	113.7	133.4	164.4	160.6	191.9	162.6
M4	12.6	16.9	14.5	16.9	15.2	93.6	123.2	113.9	136.5	116.8	149.0	174.4	168.3	193.1	171.2
Mean	11.0	14.7	12.9	15.4		79.6	109.4	97.7	122.6		121.5	148.1	141.4	165.2	
	M	N	MXN	NxM		M	N_1	MXN	NxM		M	N	MXN	NxM	
SEd	0.1	0.1	0.2	0.4		0.7	0.7	1.5	2.3		1.5	1.4	3.1	3.5	
CD (p=0.05)	0.2	0.2	0.4	0.8		1.6	1.4	3.3	4.7		3.3	2.9	6.6	7.0	

reported by Stewart *and* Porter (1969) and Bharathi and Poongothai (2008)

P uptake

The P uptake was significantly higher in the treatments receiving any one of the manures than in control (Table 3). The P uptake of 3.3, 24.2 kg ha $^{-1}$ at 30 DAS and 60 DAS, respectively in the treatment receiving vermicompost (N_3) was substantially higher than other manurial treatments. While at harvest stage significantly higher P uptake of 35.3 kg ha^{-1} was recorded in the treatment receiving pressmud (N_1) followed by vermicompost (33.3 kg ha^{-1}). The higher P uptake in organic manure added treatments might be

Table 3. Effect of organics and sulphur levels on phosphorus uptake (kg ha^{-1}) at different stages of crop growth (Mean of two years)

Organics / Inorganic S	Phosphorus uptake (kg ha $^{-1}$)														
	30 DAS					60 DAS					At harvest				
	N0	N1	N2	N3	Mean	N0	N1	N2	N3	Mean	N0	N1	N2	N3	Mean
M_0	1.5	2.3	1.9	2.3	2.0	10.2	16.9	13.4	18.4	14.7	15.5	23.0	18.6	22.9	20.0
M_1	1.8	2.7	2.1	3.1	2.4	12.1	20.4	17.4	20.8	17.6	18.6	28.7	22.0	26.2	23.8
M_2	2.2	3.1	2.4	3.3	2.7	14.4	23.2	20.4	24.9	20.7	24.0	34.4	26.5	31.5	29.1
M_3	2.5	3.6	3.0	3.9	3.2	15.3	27.2	23.0	27.7	23.3	31.1	45.2	35.4	42.9	38.6
M_4	2.6	3.9	3.2	4.1	3.4	18.0	28.0	25.1	29.6	25.1	36.6	45.6	39.5	43.2	41.2
Mean	2.1	3.1	2.5	3.3		14.0	23.14	19.8	24.2		25.1	35.3	28.3	33.3	
	M	N	MXN	NxM		M	N	MXN	NxM		M	N	MXN	NxM	
SEd	0.1	0.1	0.1	0.1		0.2	0.2	0.4	0.5		0.2	0.2	0.4	0.3	
CD (p=0.05)	0.1	0.2	NS	0.2		0.4	0.4	0.9	1.1		0.4	0.4	0.9	0.7	

due to the release of organic acids and organic anions during the decomposition of organic manure, which would have chelated the Fe and Al and released the H_2PO_4- to the labile pool in turn favoured in the higher uptake of P. The positive effect of organic manures on release of P to the labile pool was reported by several Researchers (Bahl and Avatar Singh (1992) and Sharma *et al*.(1995). In the case of inorganic S, the P uptake ranged from 2.0 to 3.4, 14.7 to 25.0 and 20.0 to 41.2 kg ha $^{-1}$ at 30 DAS, 60 DAS and harvest stages, respectively. A progressive increase in the P uptake with the increase in S level was observed. Due to the addition of S, the SO_4^{2-} would have replaced the $H_2PO_4^-$ from the sesquioxide through anion exchange mechanism and released to the labile pool which would have favoured for the higher P uptake by the crop. Such a mechanism of desorption of P to the labile pool due to the addition of S was reported by Palaskar *et al*. (1981) and Pandey *et al*.(2000). Conjoint application of organic manures with inorganic S also had a prominent effect on the uptake of P. Distinctly higher P uptake of 4.1 and 29.6 kg ha^{-1} at 30 DAS and 60 DAS were registered in the combined application of vermicompost with 80 kg S ha^{-1}, while at harvest stage, significantly higher P uptake of 35.3 kg ha^{-1} was recorded in the treatment receiving 80 kg S ha^{-1} with press mud.

K uptake

The K uptake by the maize crop ranged from 3.7 to 5.8, 27.0 to 46.6 and 54.4 to 76.9 kg ha $^{-1}$ at 30 DAS, 60 DAS and harvest stages, respectively among the manurial treatments (Table 4). Application of vermicompost and press mud registered comparable K uptake at all the three stages. This may be due to the higher drymatter production. Higher K uptake due to the application of organic manures were reported earlier by Maskina *et al* .(1984). Among the inorganic S treatments, the K uptake extended from 4.1 to 5.7, 30.3 to 46.5 and 45.8 to 83.8 kg ha^{-1}at 30 DAS, 60

Table 4. Effect of organics and sulphur levels on potassium uptake (kg ha $^{-1}$) at different stages of crop growth (Mean of two years)

Organics	Potassium uptake (kg ha^{-1})														
Inorganic S	30 DAS					60 DAS					At harvest				
	N0	N1	N2	N3	Mean	N0	N1	N2	N3	Mean	N0	N1	N2	N3	Mean
M0	2.9	4.9	3.9	4.9	4.1	20.1	36.0	28.4	36.8	30.3	34.6	48.0	46.5	54.1	45.8
M1	3.4	5.5	4.2	5.6	4.6	25.2	42.0	32.7	42.3	35.3	46.6	61.5	59.1	60.8	57.0
M2	4.0	5.9	4.7	6.0	5.1	27.8	47.8	36.0	48.4	40.0	59.6	75.7	55.3	77.5	67.0
M3	4.1	6.3	5.2	6.2	5.4	30.2	50.3	41.0	51.1	43.1	66.5	93.1	75.8	94.5	82.4
M4	4.3	6.8	5.2	6.6	5.7	31.9	53.2	46.3	54.8	46.5	64.7	93.9	78.9	97.9	83.8
Mean	3.7	5.8	4.6	5.8		27.0	45.8	36.8	46.6		54.4	74.4	63.1	76.9	
	M	N	MXN	NxM		M	N	MXN	NxM		M	N	MXN	NxM	
SEd	0.1	0.1	0.06	0.07		0.5	0.4	0.1	0.2		1.7	1.5	3.4	3.7	
CD (p=0.05)	0.1	0.1.	0.1	0.2		1.1	1.0	2.3	1.0		3.6	3.2	7.2	7.5	

Table 5. Effect of organics and sulphur levels on sulphur uptake (kg ha $^{-1}$) at different stages of crop growth (Mean of two years)

Organics	Sulphur uptake (kg ha^{-1})														
Inorganic S	30 DAS					60 DAS					At harvest				
	N0	N1	N2	N3	Mean	N0	N1	N2	N3	Mean	N0	N1	N2	N3	Mean
M0	0.88	1.40	1.17	1.48	1.23	5.67	9.59	8.27	9.82	8.33	8.66	13.46	12.10	14.59	12.20
M1	1.20	1.65	1.49	1.58	1.48	8.42	11.40	9.83	12.39	10.51	13.06	16.40	14.01	16.43	14.97
M2	1.42	2.04	1.74	2.08	1.82	9.60	15.50	13.20	15.93	13.55	16.03	22.95	19.93	21.81	20.18
M3	1.62	2.52	2.00	2.30	2.11	11.47	18.40	15.40	18.25	15.88	20.00	33.25	27.83	32.94	28.50
M4	1.66	2.75	2.03	2.61	2.26	11.70	21.00	15.90	20.77	17.34	24.44	34.88	31.56	34.90	31.44
Mean	1.35	2.07	1.68	2.01		9.37	15.17	12.52	15.42		16.43	24.18	21.08	24.13	
	M	N	MXN	NxM		M	N	MXN	NxM		M	N	MXN	NxM	
SEd	0.03	0.02	0.06	0.08		0.37	0.33	0.75	0.84		0.69	0.62	1.39	1.42	
CD (p=0.05)	0.06	0.05	0.13	0.16		0.49	0.71	1.58	1.72		1.45	1.30	2.91	2.86	

DAS and harvest stages respectively. A liner relationship of K uptake was observed with the advancement of stage of growth. Significantly higher K uptake was registered with the application of 80 kg S ha $^{-1}$. This could be attributed to the adsorption of $SO_4^{2-}$by the Fe and Al oxides and reduced the activity of the Fe and Al which inturn would have favoured for the exchange of K^+ between soil solution and colloidal complexes. Significant increase in the K uptake due to S application was reported by Biswas *et al.* (1995). The interaction effect was that the application of any one of the organic manures with inorganic S recorded higher K uptake than control. It ranged from 2.9 to 6.8, 20.1 to 54.8 and 34.6 to 97.9 kg ha^{-1}at 30 DAS, 60 DAS and at harvest stages, respectively. At 30 DAS, application of press mud with 80 kg S ha $^{-1}$ (M_4N_1) recorded significantly higher K uptake, while at 60 DAS and harvest stages, the distinctly higher K uptake of 54.8 and 97.9 kg ha $^{-1}$, respectively were registered with the conjoint incorporation of vermicompost with 80 kg S ha $^{-1}$ (M_4N_3).

S uptake

The sources of organics had a significant effect on S uptake. Considering the stages, the S uptake ranged from 1.35 to 2.01, 9.37 to 15.42 and 16.43 to 24.13 kg ha $^{-1}$ at 30 DAS, 60 DAS and harvest stages, respectively (Table 5). Application of organic manures resulted in higher S uptake than control. The organic acids released during the decomposition of organic manures would have chelated the Fe

and Al and released the SO_4^{2-} to the labile pool which inturn would have favoured for the higher uptake of S in the manured treatments. An inverse relationship between the S adsorption and organic matter of soil was reported by Mc Donald and Hart (1990). Johnson and Todd (1983) and Courchesne *et al.* (1995) also demonstrated that the addition of organic manures decreased the S adsorption and increased the concentration of SO_4^{2-}-S into the labile pool. At 30 DAS, significantly higher S uptake of 2.0 kg ha^{-1} was registered with the incorporation of press mud followed by vermicompost, while at 60 DAS and harvest stage, application of press mud and vermicompost registered comparable S uptake. As observed in organic manures, application of inorganic S also significantly influenced the S uptake at all the three stages. Among the fertilizer S treatments, substantially higher S uptake was recorded in the treatment receiving 80 kg S ha^{-1} The increase in S uptake with increase in S levels might be due to increased surface area exposed to sulphur oxidizing microorganisms which in turn might have released S to the plant. These results are in conformity with the findings of Tripathy and Tripathi (1993). Significant increase in S uptake with the increase in S levels was already reported by Pandey *et al* .(2000), who attributed that higher S uptake by the crop may be due to the increased availability of SO_4^{2-}-S in solution. The combined effect of manures and fertilizer S also significantly influenced the S uptake at all the three stages. It varied from 0.88 to 2.75, 5.67 to 21.00 and 8.66 to 34.90 kg ha^{-1} at 30 DAS, 60 DAS and harvest stages, respectively. Significantly higher S uptake of 2.75 and 21.00 kg ha^{-1} at 30 DAS and 60 DAS, respectively were recorded in the treatment receiving conjoint incorporation of press mud and 80 kg S ha^{-1}(M_4N_1), while at harvest stage, distinctly higher S uptake of 34.90 kg ha^{-1} was registered with the application of vermicompost with 80 kg S ha^{-1} (M_4N_3), which was statistically on par with the application of press mud with 80 kg S ha^{-1} (M_4N_1). Similarly, application of 60 kg S ha^{-1} separately with press mud and vermicompost produced comparable S uptake.

Table 6. Effect of organics and sulphur on soil available N status (kg ha^{-1}) at different stages of crop growth (Mean of two Years)

Organics / Inorganic S	Available N (kg ha^{-1})														
	30 DAS					60 DAS					Post Harvest Stage				
	N0	N1	N2	N3	Mean	N0	N1	N2	N3	Mean	N0	N1	N2	N3	Mean
M0	250	268	280	295	273	235	275	285	305	275	210	275	280	285	263
M1	235	250	268	280	258	228	268	272	290	265	200	268	270	280	255
M2	225	230	250	265	243	215	255	265	278	253	190	255	250	265	240
M3	210	220	230	252	228	200	240	250	268	240	185	240	235	260	230
M4	198	210	216	241	216	195	220	230	255	225	180	232	230	252	224
Mean	224	236	249	267		215	252	260	279		193	254	253	268	
	M	N	MXN	NxM		M	N	MXN	NxM		M	N	MXN	NxM	
SEd	5.	4.	10.	11.		6.	5.	13.	12.		8.	7.	16.	14.	
CD (p=0.05)	11.	10.	22.	24.		13.	12.	NS	23.		17.	15.	NS	29.0	

Both inorganic S and organic manures had a significant influence on the available N status at 30 DAS, 60 DAS and post harvest stages. In the case of organic sources, the mean available N status ranged from 224 to 267, 215 to 279 and 193 to 268 kg ha^{-1} at 30 DAS, 60 DAS and post harvest stages, respectively (Table 6). Significantly higher N status was observed with the treatment receiving vermicompost (N_3) at all the three stages (267; 279; 268 kg ha^{-1}) followed by FYM and press mud. This may be due to narrow C:N ratio (24:1) of vermicompost, which would have released the N easily. Beneficial effect of vermicompost on available N status on greengram cropping system was reported by Rajkhowa *et al.* (2000). Blair *et al*. (1996) also reported that an increase in available N status and retentive capacity of nutrients due to the application of vermicompost. Application of inorganic S also significantly influenced the available N status. It ranged from 216 to 273, 225 to 275 and 224 to 263 kg ha^{-1} at 30 DAS, 60 DAS and post harvest stages, respectively. A declining trend of available N status was observed with the increase in the level of S at all the growth stages of crop. This may be due to the synergistic effect of S on N, which would have favoured for the increased uptake of N and depleted the available N status of the soil. Considering the three stages, those treatments which have received any one of the organics, a slight improvement in available N status was observed from 30 DAS to 60 DAS beyond which, it got declined. Tiwari *et al*. (2002) reported that a reduction in available N status at harvest stages of the crop growth. Due to the mineralization process, the organic N might have been released slowly into the labile pool. In addition, the decomposition of organic manures also releases some of the organic acids and thus forming chelating

Effect of S levels and organic manures on nutrient status of soil

Available N

agents there by loss of N would have been reduced. The available N status in the treatment receiving FYM is lower than vermicompost and press mud. This might be due to low N content of FYM as compared to vermicompost and press mud.

Available P

Both organic and inorganic S significantly influenced the available P status at all the three stages and it varied from 13.2 to 17.7,13.3 to 18.2 and 13.1 to 18.5 kg ha^{-1} at 30 DAS, 60 DAS and post harvest stages, respectively (Table 7). The higher status of available P was registered in the manured treatments than in the unmanured control. As the experimental soil contained 12.8 per cent sesquioxide, which would have retained the P in the non labile pool. During the decomposition of organic manures, many organic acids would have been released for chelating the Fe and Al and released the $H_2PO_4^-$ into the labile pool. Damodar Reddy *et al.* (1999) stated that due to ligand exchange mechanism, the organic anions make chelation with Fe and Al and release the $H_2PO_4^-$ to the labile pool. With regard to the organic manures, the press mud performed better in registering the higher available P status followed by vermicompost. This may be due to higher P content of press mud. More (1994) reported that application of press mud recorded the highest available P status among the various organic residues. A linear relationship between S levels and available P status of the soil was observed. Significantly higher available P status of 16.1, 16.5 and 16.8 kg ha^{-1} at 30 DAS, 60 DAS and post harvest stages, respectively were recorded with the treatment receiving 80 kg S ha^{-1}. This may be attributed to the release of $H_2PO_4^-$ from the adsorption sites due to the adsorption of SO_4^{2-}. The results envisaged that a progressive build up of available P in the treatments receiving either organic manures or S fertilizer was observed. The reason might be due to slow releasing nature of organics. Tandon (1993) reported that humic acid has the capacity to form phospho humic complex with anion replacement of the phosphate by humate anion, and the coating of sesquioxides by humus to form a protective cover and thus reducing the phosphate fixing capacity of the soil.

Available K

The available K status of the soil was significantly influenced by the inorganic S and organic manures. With regard to the organic manures, a build up of available K status was observed with the advancement of growth stages. The available K status ranged from 271 to 300 , 277 to 304 and 262 to 307 kg ha^{-1} at 30 DAS, 60 DAS and post harvest stages, respectively (Table 8). Significantly higher available K status in all the three stages was registered in the treatment receiving press mud (N_1) (300,304, and 304 kg ha^{1}) followed by vermicompost (N_3).This may be due to the higher K content of press mud. More (1994) recorded higher available K status due to the application of press mud among the various organic residues. The unmanured control recorded the negative balance of available K at all the three stages.

Table 7. Effect of organics and sulphur on soil available P status (kg ha^{-1}) at different stages of crop growth (Mean of two years)

Organics / Inorganic S	Available P (kg ha^{-1})														
	30 DAS					60 DAS					Post harvest stage				
	N0	N1	N2	N3	Mean	N0	N1	N2	N3	Mean	N0	N1	N2	N3	Mean
M0	11.4	15.8	12.6	14.0	13.5	9.0	16.4	14.0	14.6	13.5	8.0	17.0	14.0	14.8	13.5
M1	13.0	17.4	13.4	14.8	14.7	13.8	17.8	14.2	15.6	15.4	13.8	18.4	14.4	16.0	15.7
M2	13.8	18.0	14.0	15.0	15.2	14.4	18.8	14.8	15.8	16.0	14.2	18.6	14.8	16.0	15.9
M3	13.8	18.6	14.8	15.4	15.7	14.6	19.0	15.6	16.0	16.3	14.6	19.0	15.6	16.6	16.5
M4	14.2	18.6	15.4	16.0	16.1	14.8	19.2	15.6	16.4	16.5	14.8	19.4	16.0	16.8	16.8
Mean	13.2	17.7	16.0	15.0		13.3	18.2	14.8	15.7		13.1	18.5	15.0	16.0	
	M	N	MXN	NxM		M	N	MXN	NxM		M	N	MXN	NxM	
SEd	0.5	0.5	1.1	1.2		0.9	0.8	1.9	1.4		0.5	0.4	1.0	0.9	
CD (p=0.05)	1.2	1.0	NS	2.5		1.9	1.7	NS	3.6		1.1	1.0	NS	1.9	

By increasing the S levels, the available K status was also increased at all the three stages. Distinctly higher available K status of 297, 303, and 295 kg ha^{-1} at 30 DAS, 60 DAS and post harvest stages respectively were registered with the application of 80 kg S ha^{-1} (M_4) followed by 60 kg S ha^{-1}(M_3). However, they were statistically on par with each other. The conjoint application of inorganic S and organic manures did not significantly influence the available K status at all the three stages. However, significantly higher available K status was registered with the combined application of press mud with 80 kg S ha^{-1} at all the three stages.

Available S

The available S status was significantly higher in the treatments that received manures than in the control. In the case of sources of organic manures, the press mud recorded higher available S status than vermicompost followed by FYM. Besides an increase in the available S status was observed with the advancement of stages of growth. The mean

available S status varied from 8.4 to 11.9, 8.9 to 12.6 and 7.9 to 12.9 mg kg^{1}at 30 DAS, 60 DAS and post harvest stages, respectively (Table 9) . Applicaton of press mud recorded higher available S status than the vermicompost followed by FYM. This might be due to higher S and carbon content of press mud. The positive relationship between organic carbon and available S was reported by Kher and Singh (1993) and Saravana Pandian (2003). The inorganic S had a significant effect on the available S status. A linear relationship between available S and S levels were observed. The mean available S status ranged from 7.7 to 11.7, 7.8 to 12.1 and 6.9 to 12.1 mg kg^{-1} at 30 DAS, 60 DAS and post harvest stages, respectively. The available S was found to be higher in the treatments receiving S than without S fertilizer. Dikshit *et al.* (1995) reported that application of S fertilizer increased the SO_4^{2-}-S in soybean-wheat cropping

Table 8. Effect of organics and sulphur on soil available K status (kg ha^{-1}) at different stages of crop growth (Mean of two years)

Organics / Inorganic S	Available K (kg ha^{-1})														
	30 DAS					60 DAS					Post harvest stage				
	N0	N1	N2	N3	Mean	N0	N1	N2	N3	Mean	N0	N1	N2	N3	Mean
M0	260	288	280	280	277	268	295	286	290	285	250	298	280	290	280
M1	270	295	285	290	285	276	295	290	295	289	260	305	280	296	285
M2	273	302	288	295	290	280	308	296	305	297	265	305	285	300	289
M3	275	305	292	298	293	280	310	300	305	299	270	310	288	305	293
M4	275	312	296	304	297	283	314	305	308	303	265	315	290	308	295
Mean	271	300	288	293		277	304	295	300		262	307	285	300	
	M	N	MxN	NxM		M	N	MxN	NxM		M	N	MxN	NxM	
SEd	4.97	4.45	9.95	10.05		4.78	4.2	9.57	9.84		4.78	4.28	9.57	9.68	
CD (p=0.05)	10.4	9.31	NS	20.1		10.02	8.9	NS	19.60		10.02	8.96	NS	19.21	

system. The interaction effect of organic manures and inorganic S exhibited a marked effect on available S. It varied from 5.6 to 14.0, 4.8 to 14.8 and 4.0 to 14.8 mg kg^{-1}at 30 DAS, 60 DAS and post harvest stages, respectively. Significantly higher available S content was registered with the conjoint incorporation

Table 9. Effect of organics and sulphur on soil available S status (kg ha^{-1}) at different stages of crop growth (Mean of two years)

Organics / Inorganic S	Available S (kg ha^{-1})														
	30 DAS					60 DAS					Post harvest stage				
	N0	N1	N2	N3	Mean	N0	N1	N2	N3	Mean	N0	N1	N2	N3	Mean
M0	5.6	9.4	7.3	8.4	7.7	4.8	9.8	7.6	8.8	7.8	4.0	9.8	6.0	8.0	6.9
M1	7.4	10.8	9.2	9.8	9.3	7.0	11.8	9.6	10.0	9.6	6.0	12.4	8.6	10.4	9.4
M2	8.6	12.0	9.4	10.8	10.2	9.1	12.4	9.6	11.2	10.6	8.5	13.8	9.0	11.4	10.7
M3	9.8	13.4	9.6	11.6	11.1	10.2	14.0	10.0	12.4	11.7	10.2	14.2	9.2	12.2	11.5
M4	10.4	14.0	9.8	12.4	11.7	10.8	14.8	10.0	12.8	12.1	11.0	14.8	9.4	13.2	12.1
Mean	8.4	11.9	9.1	10.6		8.9	12.6	9.4	11.0		7.9	12.9	8.4	11.0	
	M	N	MXN	NXM		M	N	MXN	NxM		M	N	MXN	NxM	
SEd	0.10	0.09	0.21	0.24		0.21	0.19	0.43	0.48		0.31	0.28	0.63	0.72	
CD (p=0.05)	0.22	0.20	0.45	0.47		0.45	0.41	0.91	0.95		0.66	0.59	1.32	1.41	

of 80 kg S ha^{-1}with press mud. An increasing trend of available S was observed, while applying all the organic manures upto 60 DAS. However, at post harvest stage, the available S status got declined in the treatment receiving FYM. This might be due to the low S content of FYM . On the other hand, in the case of press mud and vermicompost, an increasing trend of available S status was recorded. This might be due to replacement of SO_4^{2-} by the organic anions from the adsorption sites of soil colloidal complexes. Fuller *et al*. (1985) reported that the incorporation of organic manures considerably increased SO_4^{2-}- S and decreased the adsorbed SO_4^{2-} . The lower available S in unmanured control might be due to the specific adsorption of SO_4^{2-} by the hydrous oxides of Fe and Al (Bolon and Barrow, 1984; Courchesne, 1992). Singh (1984) reported that the removal of organic matter had a little effect on SO_4^{2-} adsorption, but the removal of Fe and Al oxides had a marked reduction of SO_4^{2-}adsorption.

Conclusion

The results have shown that maize crop responds positively for the application of sulphur. Application of S fertilizer with or without the organic manures have become imperative to maintain the reserve S status of the soil. Due to the continuous mining without the application of either organic manures or S fertilizer, the soil have become deficient in available S (less than 10 mg kg^{-1}), which may lead to occurrence of S deficiency in maize crop.

References

Bahl, G.S. and Avtarsingh.1992. The inorganic soil phosphorus fractions and available P as influenced by green manuring, cropping and P fertilization. *J. Indian Soc. Soil. Sci.,* **47***:*19-23*.*

Bharathi, C. and Poongothai. S. 2008. Direct and residual effect of S on growth, nutrient uptake, yield and its use efficiency in maize and subsequent greengram, Res. *J. Agric. Bio Sci.,* **4***:* 368-392.

Biswas, D.R., Ali, S.A. and Khanna, M.S. 1995. Nitrogen – sulphur interaction on the uptake of P,K,Zn, Cu, Fe and Mn by Gobhi season. *J. Indian Soc. Soil Sci*., **43:** 280-281.

Blair, J.M., Pamelee, R.W., Allan, M.F., Mc Cartney, D.A. and Stinner, B.R. 1996. Changes in soil N pools in responses to earthworm population manipulation in agro ecosystems with different N sources. *Soil Biol. Biochem*., **29**: 361-367.

Bolan, N.S. and Barrow, N.J. 1984. Modelling the effect of adsorption of phosphate and other anions on the surface charge variable oxides. *J. Soil Sci*., **35**: 379- 388.

Borkotoki, B. and Das, K.N. 2008. Forms of sulphur and their relationship with soil properties in Entisols, Inceptisols and Alfisols of Assam. *J. Indian Soc. Soil Sci.*, **56**: 186-191.

Courchesne, F. 1992. Relationship between soil chemical properties and sulphate sorption kinetics in Podzolic soils from Quebec. *Candian J. Soil Sci*., **72**:467- 480.

Courchesne, F., Gobran, G.R. and Dufresne, A. 1995. The role of humic acid on sulphate retention and release in podzol. *Water Air Soil Pollution*, **85**:1813-1818.

Damodar Reddy, D., Subba Rao, A. and Takkar, P.N. 1999, Phosphate adsorption behaviour of a Typic Haplustalf in relation to long term use of fertilizer phosphorus and manure under soybean-wheat rotation. *J. Indian Soc. Soil Sci*., **47**: 425-430.

Dikshit, P.R., Gautam, S.K., Turker, O.R. and Khatik, S.K. 1995. Effect of long-term fertilizer application under multiple cropping system on the forms and content of potassium and sulphur in Jabalpur Chromusterts . *Indian J. Agric.Res.,* **29:** 29-35.

Evans, A. 1986. Effect of dissolved organic carbon and sulphate on aluminium mobilization in forest soil columns. *Soil Science Soc. Am. J*., **50:** 1576-1578.

Fuller, R.D .,David, M.B. and Driscoll, C.T. 1985. Sulphate adsorption relationship in forested Spodosol of north eastern USA. *Soil Sci. Soc. Am. J* .,**49**: 1934-1040.

Johnson, D.W. and Todd, D.E. 1983. Relationship among iron, aluminium, carbon and sulphate in a variety of forest soils. *Soil Sci. Soc. Am. J.,* **47**: 792-800.

Kher, D. and Singh, N. 1993. Different forms of sulphur in mustard growing soils of North Kashmir. *J. Indian Soc. Soil Sci.,* **41**: 164-165.

Maskina, M. S., Meelu, O.P. and Morris, R.A. 1984. FYM in rice wheat rotation. *Int. Rice. Res Newsl.,* **9**:24.

Mc Donald, N.W. and Hart, J.B. 1990, Relating sulphate adsorption to soil properties to Michigan forest soils. *Soil Sci. Soc. Am. J*., **54:** 238-245.

More, S.D. 1994. Effect of farm wastes and organic manures on soil properties. *J. Indian Soc. Soil Sci*., **43**: 280-281.

Palaskar, M.S., Babrakar, P.G. and Ghosh, A.B. 1981. Availability of sulphur and phosphorus in major series of Uttarpradesh. *J. Indian Soc. Soil Sci.,* **29**: 249-253.

Pandey, S.P., Singh, R.S. and Minhas, S.K. 2000. Availability of phosphorus and sulphur in Inceptisols of Central Uttar Pradesh. *J. Indian Soc.Soil Sc*i., **48**;118- 181.

Parfitt, R.L. 1978. Anion adsorption by soil materials. *Adv. Agron*., **30**:1-50.

Rajkhowa, D.J., Gogoi, A.K., Kandal, P. and Rajkhowa, K.M. 2000. Effect of vermicompost on green gram. *J. Indian Soc.Soil Sci*., **48**: 207-208.

Saravana Pandian, P. 2003. Status and availability of sulphur in soils as influenced by long-term manure-fertilizer schedules under rice monoculture. Ph.D., Thesis, Tamil Nadu Agricultural University, Coimbatore.

Sharma, S.P., Dhayani, B.P. and Minhas R.S. 1995. Inorganic phosphorus fractions in an Alfisol under long term fertilization experimentation*. J. Indian Soc. Soil Sci.*, **43**: 466-468.

Singh, B.R. 1984. Sulphate sorption by acid forest soils: Sulphate adsorption isotherms with and without organic matter and oxides of aluminium and iron. *Soil. Sci*., **138**; 294-297.

Sinha, R.B., Sarkar, R. and Kumar, S. 1995. Sulphur and phosphorus nutrition of winter maize in calcareous soil. *J. Indian. Soc. Soil Sci*., **43**: 413-417.

Stewart. B.A. and Porter, L.K. 1969. Nitrogen sulphur relationships in wheat, corn and beans. *Agron. J*., **61:** 267-271.

Tandon, H.L.S. 1993. Phosphorus Research and Agricultural Production in India. Fertilizer Development and Consultation Organisation, New Delhi

Tripathy, S.B. and Tripathi, R.K. 1993. Effect of sulphur levels and sources on yield and nutrient content of cowpea. *Forage Res.,* **19**: 141-147.

Received: May 24, 2013; Accepted: March 19, 2014