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Efficacy of phosphogypsum and magnesium sulphate as sources of sulphur to sesame (*Sesamum indicum* L.) in red and lateritic soils of West Bengal

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Sulphur requirement of oilseed crops are more than cereals. Farmers grow oilseeds in upland soils of the red and lateritic soils of West Bengal. Systematic research on crop responses to sulphur application is still lacking from West Bengal (Mondal 1995). In the acute shortage of edible oils for human diet in the country, sulphur can play key role in augmenting the production of oilseeds. Since India is a net importer of sulphur for manufacturing some of the important nitrogenous, phosphatic and potassic fertilizers, alternative sulphur supply strategies must emphasize the use of indigenous sources of sulphur; the most dependable and cheaper such as magnesium sulphate and phosphogypsum. The phosphogypsum (16% S, 21% Ca and 0.2 - 1.2% P_2O_5) is the byproduct of gypsum obtained during the manufacture of wet process phosphoric acid. Therefore, phosphogypsum can thus serve as the source of sulphur and calcium for plant growth like mineral gypsum. On the other hand, magnesium sulphate which is produced and used most commonly in India, is the Epsom salt, $MgSO_4 .7H_2O$ containing 16% MgO and 13% S. Only recently, magnesium sulphate has been included in the Fertiliser Control Order and given due recognition as a fertilizer (Tandon *et al.* 1995). As attention has not been paid so far on the utility of these indigenous sulphur sources to crops in acidic red and lateritic soils of this region, therefore, an attempt to examine critically the phosphogypsum vis-a-vis magnesium sulphate as sources of sulphur on yield and upake of sulphur by sesame (*Sesamum indicum L.*) hopefully could contribute to future sulphur management strategies in these soils.

A field experiment was conducted at the Agricultural Research Farm, Institute of Agriculture, Visva -Bharati University, Sriniketan with sesame (*S. indicum* L. cv. Rama) during summer (March to June) of 2010 to evaluate the effects of different sources and levels of sulphur on the yield and uptake of sulphur. The experiment was conducted on a sandy clay loam textured red and lateritic soil of order Alfisol.

The major soil properties of the plot used were: pH 6.36, organic C 0.51%, CEC 10.2 Cmol (p^+) kg^{-1}, the available P 9.5 kg ha^{-1}, K 220 kg ha^{-1}, S 9.1 mg kg^{-1} and total sulphur 2800 mg kg^{-1}. The treatments comprised of two sources of sulphur viz. phosphogypsum and magnesium sulphate with seven levels (0, 15, 30, 45, 60, 75 and 90 kg S ha^{-1}) and replicated thrice in a Randomized Block Design. Half dose of nitrogen (40 kg ha^{-1}) and full dose of phosphorus (80 kg P_2O_5 ha^{-1}) and potassium (40 kg K_2O ha^{-1}) was applied to all treatments as basal and remaining dose of nitrogen (40 kg ha^{-1}) was applied after 21 days after sowing (DAS). The recommended doses of nitrogen, phosphorus and potash were applied as urea, triple superphosphate and muriate of potash, respectively. Phosphogypsum and magnesium sulphate were applied at the time of sowing. Sesame seeds were sown in rows 15 cm apart maintaining 10 cm plant- to-plant distance. Recommended packages of practices were followed to raise a good crop. After harvesting, yields of grain, stover and total dry matter were recorded. Soil properties were determined following standard procedures. Available sulphur in the soil was extracted using 0.15% $CaCl_2$ solution (Williams and Steinberg 1959). The total sulphur in the soil was extracted by $HClO_4$ digestion (Chapman and Pratt, 1961). Sulphur content in stover and grain sample was determined after wet digestion in diacid mixture (HNO_3:$HClO_4$:: 4:1). Sulphur content in the digest of plant and soil extract was determined using turbidimetric method of Chesnin and Yien (1951).

Grain, Stover and total biological yield of sesame

Significant response of sesame due to the application of S fertilizers irrespective of sulphur sources as evidenced by grain, stover and total dry matter yield was recorded (Table 1). The grain yield of sesame ranged from 2.34 to 4.25 q ha^{-1}. Grain yield of sesame increased significantly with increased levels of sulphur up to 60 kg S ha^{-1}, above which decreasing trend was observed. The maximum grain yield (4.25 q ha^{-1}) was obtained with magnesium sulphate at the rate of 60 kg S ha^{-1} followed by phosphogypsum (4.05 q ha^{-1}) at the same rate. The stover yield of sesame ranged from 16.00 to 27.00 q ha^{-1}. Among the sources, the maximum stover yield (27.00 q ha^{-1}) was obtained with magnesium sulphate @ 90 kg S ha^{-1}. It is interesting to note that stover yield and the total biological yield i.e. stover plus grain yield of sesame, however, continued to increase with increasing levels of sulphur irrespective of its sources. The increase in yield due to application of

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sulphur up to a level may be due to better metabolism and increased efficiency of other nutrients and the decrease in grain yield at some higher levels may be either due to toxicity or imbalance in ratio of sulphur with other nutrients within the plant.

Table 1: Yield (q ha^{-1}), S content (%) and total S uptake (kg ha^{-1}) of sesame as influenced by sources and levels of S application

Sources of S	S levels (kg ha^{-1})	Yield (q ha^{-1})			S content (%)		S uptake (kg ha^{-1})		
		Grain	Stover	Total dry matter	Grain	Stover	Grain	Stover	Total
Phosphogypsum	15	2.83	19.3	22.16	0.60	0.28	1.69	5.41	7.10
Magnesium sulphate	15	3.07	21.0	24.07	0.62	0.29	1.90	6.09	7.99
Phosphogypsum	30	3.22	21.3	24.55	0.58	0.27	1.86	5.76	7.60
Magnesium sulphate	30	3.52	22.3	25.85	0.60	0.27	2.10	6.03	8.13
Phosphogypsum	45	3.65	24.0	27.65	0.58	0.28	2.11	6.72	8.83
Magnesium sulphate	45	3.97	22.6	26.63	0.59	0.26	2.34	5.89	8.20
Phosphogypsum	60	4.05	24.0	28.03	0.63	0.24	2.53	5.76	8.29
Magnesium sulphate	60	4.25	25.0	29.25	0.64	0.26	2.71	6.50	9.20
Phosphogypsum	75	3.97	24.3	28.30	0.63	0.23	2.49	5.59	8.09
Magnesium sulphate	75	4.03	25.3	29.38	0.64	0.24	2.58	6.08	8.66
Phosphogypsum	90	3.70	26.0	29.70	0.62	0.23	2.35	5.98	8.33
Magnesium sulphate	90	3.88	27.0	30.88	0.63	0.24	2.42	6.48	8.90
Control	00	2.34	16.0	18.44	0.48	0.20	1.11	3.20	4.31
LSD(0.05)		**0.47**	**3.02**	**3.05**	**0.03**	**0.01**	**0.30**	**0.76**	**0.82**
CV (%)		**13.68**	**10.13**	**9.62**	**4.72**	**8.02**	**4.72**	**10.39**	**9.59**

Sulphur concentration in grain and stover and uptake of sulphur by sesame crop

Sulphur concentration in grain and stover of sesame increased significantly with increasing levels of sulphur (Table 1). This indicates that the crop responded to sulphur application since soil was deficient in available sulphur. Sulphur concentration in sesame grain and stover due to graded levels of sulphur ranged from 0.48 to 0.64 per cent and 0.20 to 0.29 per cent, respectively. The highest total sulphur uptake was observed at all levels of sulphur when magnesium sulphate was the sulphur sources followed by phosphogypsum, which was owing to the trend observed in grain and stover yield. The uptake of sulphur by sesame grain was higher than stover. The higher concentration in sesame grain than stover clearly indicates the mobilization of sulphur from plant parts to grain. Ghosh *et al.* (1999) also observed the similar results in mustard.

Available sulphur content in soil after sesame harvest

Available sulphur content in soil varied from 9.3 to 13.8 mg kg^{-1} after the harvest of sesame crop (Table 2). The increase in available sulphur content in soil, after harvest of sesame crop increased with increasing levels of sulphur application from 0 to 90 kg S ha^{-1}. An increase in available sulphur in soil over control was observed with all levels and sources of sulphur. Results indicate that graded levels and sources of sulphur application not only increase the available sulphur status over control, but also over initial soil status. This increase in available sulphur even in control plots may be due to mineralization of soil sulphur. Balangoudar *et al.* (1999) also reported that the available sulphur content in soils increased with increase in sulphur levels from 0 to 40 kg S ha^{-1} after harvests of moong.

Table 2: Effect of graded levels and sources of sulphur on available sulphur (mg kg^{-1}) and soil reaction (pH) in soil after harvest of sesame

Sources of S	Levels of S (kg ha^{-1})						Levels of S (kg ha^{-1})					
	15	30	45	60	75	90	15	30	45	60	75	90
	Available sulphur (mg kg^{-1})						P^{H}					
Phosphogypsum	10.2	10.9	12.3	13.4	13.1	13.7	4.31	4.47	4.54	4.39	4.20	4.50
Magnesium Sulphate	10.6	12.1	11.9	13.9	13.5	13.9	4.53	4.51	4.35	4.72	4.48	4.75
Control	**9.3**						**4.48**					
Initial	**8.2**						**6.36**					

Changes of pH in soils after sesame harvest

Results (Table 2) clearly indicate that all the sources of sulphur have acidifying effect on soil pH indicating the need of liming along with the application of sulphur to soils which will not only neutralizes the soil acidity but favours the availability of sulphur (Fox *et al.*, 1964). The lowering of pH in soils of even at control plots may be due to mineralogical make up of the soil and interactions of soil, crop and environment.

Both sulphur fertilizers i.e. magnesium sulphate and phosphogypsum under consideration are *at par* with respect to grain yield, stover yield and S uptake of sesamum and 60 kg S per hectare is the most suitable dose for red and lateritic soils. Based on the out come of the present study it can strongly be recommended to apply sulphur fertilizers, lime and organic matter along with other fertilizers in red and lateritic soils on regular basis to cope up with widespread sulphur deficiency and maintenance of balanced plant nutrition.

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