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Research article

EFFICACY OF SULPHUR SOURCES ON GREEN GRAM (*Vigna radiata* L.) IN RED AND LATERITIC SOIL OF WEST BENGAL

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ABSTRACT: Field experiment conducted on Green gram (*Vigna radiata* L.) during Pre-Kharif of 2012 in a typical red and lateritic soil of West Bengal, India revealed that sources of S viz. Gypsum, Magnesium sulphate and Single superphosphate and levels of sulphur (0, 20, 40, 60 and 80 kg S ha^{-1}) have significant influence on seed yield, total biological yield, sulphur content in seed and straw, total sulphur uptake, protein content, chlorophyll and carotenoids content. Although the seed yield and total biological yield increased with the increase of levels of sulphur, but higher levels failed to yield significant increase over 60 kg S ha^{-1} irrespective of sources under consideration. However, the maximum seed yield (949 kg ha^{-1}) was obtained with magnesium sulphate and single superphosphate followed by gypsum (827 kg ha^{-1}), respectively @ 60 kg S ha^{-1}. Over all best performance was recorded when sulphur was applied @ 60 kg S ha^{-1} either as magnesium sulphate, Single superphosphate or gypsum and if farmers apply magnesium sulphate, the possible deficiency of sulphur as well as magnesium whereas in case of application of single superphosphate and gypsum application, the possible deficiency of sulphur and calcium in soils and plants can be avoided.

Key words: Green gram, Sulphur, Magnesium sulphate, Single superphosphate, Gypsum

INTRODUCTION

Green gram (*Vigna radiata* L.) is an important legume of Asian origin, is widely cultivated in the countries of Asia, Australia and Africa continents [1]. It is an important summer pulse crop of many South Asian countries including India [2]. Green gram is used as whole or spilt seeds as Dal (Soup) but in other countries sprouted seeds are widely used as vegetables. It is considered as poor man meat containing almost triple amount of protein as compared to rice. The green plants are used as animal feed and residues as manure. It synthesizes nitrogen in symbiosis with rhizobia and enriches the soil. Total biomass of the soil is increased. Green gram also fixed nitrogen in soil by 15-210 kg ha^{-1} $season^{-1}$. It roots break the plough pan of puddle rice fields and go deep in search of water and nutrient. Sulphur has long been recognized as an essential major nutrient for plant and it ranks 4th after nitrogen, phosphorus and potassium because of its role in the synthesis of proteins, vitamins, enzyme and flavoured compounds in plant. About 90% of plant sulphur is present in amino acids viz. Methionine, Cystine, and Cysteine [3]. These amino acids are the building blocks of protein. Sulphur is also involved in the formation of chlorophyll, activation of enzymes etc. [4]. This is why adequate sulphur is so crucial for pulse crops. Sulphur is also a constituent of vitamins biotine and thiamine (B1) and also of iron sulphur proteins called ferrodoxins. Sulphur is associated with production of crops of superior nutritional and market quality. Sulphur deficiencies have been reported from over 70 countries worldwide including India. Deficiency of sulphur in Indian soils is on increase due to intensification of agriculture with high yielding verities and multiple cropping coupled with the use of high analysis sulphur free fertilizers along with the restricted or no use of organic manures have accrued in depletion of the soil sulphur reserve. In West Bengal, 28 per cent of geographical area occupied by red and lateristic soils, which are mainly, sulphur deficient. In fact, the re lateritic soils of eastern India are often deficient in sulphur [5].

Crops generally absorb sulphur and phosphorus in similar amounts. On average, the sulphur absorbed per tonne of grain production is 3-4 kilograms in cereals, 8 kilograms in pulses, and 12 kilograms in oilseeds [6](Tandon, 1991). Soils, which are deficient in sulphur, cannot on their own provide adequate sulphur to meet crop demand resulting in sulphur deficient crops and sub-optimal yields. India is the world's largest producer of pulses and occupies about 23 million ha area covering different soil types [7]. Sulphur deficiency in these soils is widespread and extended up to 60% of total pulse area [8]. Green gram leaves serve as a rich source of cattle feed and raw material for preparation of silage. Being a leguminous crop, green gram is also grown in crop rotation as it synthesizes atmospheric nitrogen and adds 100-210 kg of nitrogen in the fields per hectare per season. It maintains the fertility of soil and helps in reducing soil erosion. Sulphur requirement of pulse crops are more than cereals. Beneficial effect of sulphur application on increasing yield of several oilseeds, cereals, pulses and cash crops has been reported in sulphur deficient soils by several workers [9, 10.11].

The performance of various sulphur sources like gypsum (14–16% S), phosphogypsum (14-16% S), ammonium sulphate (24% S), single super phosphate (12%S), pyrites (22-24% S) and elemental sulphur (85-100% S) has been review by Sakal and Singh [12]. Single superphosphate is a multi-nutrient fertilizer containing 7% P, 12% S and 21% Ca accounts for about half of total S added through important fertilizers in India [13]. Although on elemental basis, there is more S than P in single superphosphate, the product is rarely recognized for its S content. Commercial agricultural grade gypsum contains 13 – 15 % S and 16 – 19% Ca. Gypsum has been a popular amendment for the reclamation of alkali soils and as a source of S for pulse crops particularly for groundnut. Only recently, magnesium sulphate has been included in the Fertilizer Control Order and given due recognition as a fertilizer. Magnesium sulphate, which is produced and used most commonly in India, is the Epson salt, $MgSO_4 . 7H_2O$ containing 16% MgO and 13% S. Generally, it is selected for application in situations where Mg application is also required in Mg-deficient soils [14]. Systematic research on crop responses to sulphur application, particularly on pulses is still lacking from West Bengal [15]. In the acute shortage of pulse in human diet in the country, sulphur can play key role in augmenting the production of pulses.

MATERIALS AND METHODS

The field experiment was conducted during the *pre-Kharif* season of 2012 at the Agricultural Farm of Palli Siksha Bhavana (Institute of Agriculture), Visva- Bharati, Sriniketan (23°39′ N and 87°42′ E), under sub humid semi-arid region of West Bengal, India. The soil properties of the experimental site is sandy in texture, acidic in soil reaction (pH 4.9); low in organic C (0.48%), available N (150.5 kg ha^{-1}), P (12 kg ha^{-1}), K (100.8 kg ha^{-1}) and S (3.2 kg ha^{-1}). The treatment comprises three sources of sulphur viz. single superphosphate, phosphogypsum and magnesium sulphate and five levels (0, 20, 40, 60 and 80 kg S ha^{-1}) were replicated thrice in a factorial randomized block design. The recommended package and practices were followed to raise the crop. The full dose of nitrogen (20 kg ha^{-1}) and full dose of phosphorus (80 kg P_2O_5 ha^{-1}) and potassium (80 kg K_2O ha^{-1}) were applied as basal. The recommended doses of nitrogen, phosphorus and potash were applied as urea, triple superphosphate and muriate of potash, respectively. Single superphosphate was used as a source of sulphur and its phosphorus content was also considered and adjusted with triple superphosphate as per treatments. Gypsum, magnesium sulphate and single superphosphate were applied at the time of sowing.

The soil samples were analyzed following standard procedures. Available sulphur in the soil was extracted using 0.15% $CaCl_2$ solution [16]. The total sulphur in the soil was extracted by perchloric acid ($HClO_4$) digestion [17]. Sulfur content in the digest of plant and soil extract was determined using turbidimetric method of Chesnin and Yien [18]. Chlorophyll a, chlorophyll b and total chlorophyll content in leaves were measured adopting the method of Sadasvam and Manikam [19].The amount of seed nitrogen content was estimated as per Jackson [20] and expressed the concentration in percentage. Crude protein was determined by multiplying percentage of nitrogen content in seeds of greengram with a factor of 6.25. The data collected from the experiment at different growth stages was subjected to statistical analysis as described by Gomez and Gomez [21].

RESULTS AND DISCUSSION

Seed, straw and total yield of green gram

Significant response of green gram due to application of S fertilizers irrespective of sulphur sources as evidenced by grain, straw and total biological yield during 2012 (Table 1). The seed yield of green gram ranged from 437 kg ha^{-1} to 949 kg ha^{-1}. Through increase in seed yield was significant in sulphur treated plots over control but higher sulphur level i.e.60 and 80 kg ha^{-1}failed to register higher yield increase over that of 40 kg S ha^{-1}. The maximum seed yield (949 kg ha^{-1}) was obtained with magnesium sulphate and single superphosphate at the rate of 60 kg S ha^{-1} followed by gypsum (827 kg ha^{-1}) at the same rate. More or less similar trend was observed in case of straw yield and total biological yield. Straw yield ranged from 984 kg ha^{-1} to 1294 kg ha^{-1}. The maximum straw yield (1354 kg ha^{-1}) was recorded with Magnesium sulphate @ 60 kg S ha^{-1} followed by 1294 kg ha^{-1} with Gypsum @80 kg S ha^{-1} and 1210 kg ha^{-1} @ 80 kg S ha^{-1}.

The total biological yield ranged from 1421 kg ha^{-1} to 2303 kg ha^{-1}. The maximum dry matter yield (2303 kg ha^{-1}) was recorded with Magnesium sulphate @ 60 kg S ha^{-1} followed by Gypsum (2119 kg ha^{-1}) @ 80 kg S ha^{-1} and Single superphosphate (2080 kg ha^{-1}). Interaction of levels and sources of S revealed that the levels of S have significant effect on seed yield, straw yield and total biological yield of green gram (Table 1). The increase in yield due to application of sulphur may be due to better metabolism and increased efficiency of other nutrients. Application of S has been reported to markedly affect green gram yield [10, 22, 23].

Sulphur concentration in seed and straw of green gram

Sulphur concentration in seed and straw of green gram increased significantly with increasing levels of sulphur irrespective of sources of sulphur (Table 2). This indicates that the crop responded to sulphur application since soil was deficient in available sulphur. Sulphur concentration in green gram seed and straw due to graded levels of sulphur ranged from 0.23 to 0.29 and 0.06 to 0.09 per cent. It is interesting to note that in spite of increasing levels of S, the S per cent in seed or straw has not increased accordingly. Results revealed that levels of S have significant effect on per cent content of S in seeds and straw of green gram.

Table-1: Effect of different sources and levels of S on seed, straw and total biological yield (kg ha^{-1}) of green gram

Level of S	2012											
	Seed yield (kg/ha)				Straw yield (kg/ha)				Total biological yield			
	Sources of S			Mean	Sources of S			Mean	Sources of S			Mean
	Gypsum	Mag-Sulph	Single supper phosphate		Gypsum	Mag-Sulph	Single supper phosphate		Gypsum	Mag-Sulph	Single supper phosphate	
20	651	693	685	677	950	1154	996	1033	1601	1847	1681	1710
40	765	864	802	810	1055	1095	1176	1108	1820	1959	1978	1919
60	827	949	949	908	1161	1354	1030	1182	1987	2303	1979	2090
80	825	945	870	880	1294	1237	1210	1247	2119	2182	2080	2127
Mean	701	778	749	742	1089	1165	1079	1111	1790	1942	1828	1853
Control	437				984		1421					
	Source	Level	Source × Level		Source	Level	Source × Level		Source	Level	Source × Level	
S. Em.±	26.1	33.7	58.3		53	68.5	118.6		69.9	90.2	156.3	
C.D.(P=0.05)	75.5	97.5	168.9		153.6	198.3	343.5		202.4	261.3	452.5	
C.V. %	13.6				18.5		14.6					
FRBD(0.05)	NS	S	NS		NS	S	NS		NS	S	NS	

Table-2: Effect of different sources and levels of sulphur on S content (%) in seed and straw of green gram

Level of S (kg ha^{-1})	S content (%) in Seed				S content (%) in Straw			
	Sources of S			Mean	Sources of S			Mean
	Gypsum	Mag-Sulph	Single supper phosphate		Gypsum	Mag-Sulph	Single supper phosphate	
20	0.26	0.27	0.27	0.27	0.077	0.08	0.07	0.08
40	0.29	0.29	0.28	0.29	0.09	0.09	0.09	0.09
60	0.28	0.29	0.28	0.28	0.087	0.09	0.09	0.09
80	0.28	0.28	0.28	0.28	0.083	0.09	0.08	0.08
Mean	0.27	0.27	0.27	0.27	0.08	0.08	0.08	0.08
Control	0.23				0.06			
	Source	Level	Source × Level		Source	Level	Source × Level	
S. Em±	0.003	0.003	0.006		0.003	0.004	0.006	
C.D.(P=0.05)	0.007	0.01	0.017		0.008	0.011	0.018	
C.V. %	3.65				13.33			
FRBD(0.05)	NS	S	NS		NS	S	NS	

Tandon [6] and Mehta and Singh [24] reported an increase in sulphur concentration of green gram along with the increase in doses of sulphur. It is interesting to note that seed sulphur content was higher as compared to straw in green gram. The higher concentration of S in green gram seed than straw clearly indicates the mobilization of sulphur from plant parts to grain. About 40 to 80 per cent of S absorbed by oilseed crops is being translocated to seed grains [25]. Ghosh *et al.* [26] also observed the similar results in mustard crop.

Sulphur uptake by green gram

Significant differences of the sulphur sources and levels for sulphur uptake by seed and straw over control were noticed. The total sulphur uptake continued to increase with the increase in levels of sulphur irrespective of its source. The highest total sulphur uptake was observed with magnesium sulphate (3.90 kg ha^{-1}). However higher doses i.e.80 kg S ha^{-1} failed to register higher total uptake of S over 60 kg S ha^{-1}. Total sulphur uptake was found to be highest in seed than the straw of green gram.

The uptake of sulphur by green gram seed was higher than haulm. This might be due to the mobilization of sulphur from plant parts to seed. The S uptake by pulse crops ranges from 5 to 13 kg S depending on crops, soil conditions, S fertility level and agronomic management conditions. Majority of S absorbed by pulses is being translocated to seed grains [6]. Results revealed that levels of S have significant effect than sources in uptake of S by greengram.

Table-3: Effect of different sources and levels of Sulphur on uptake of S (kg ha^{-1}) by seed, straw and total biological matter of green gram

Level of S	2012											
	S uptake by seed (kg ha-1)				S uptake by straw (kg/ha-1)				S uptake by total biologiocal matter(kg/ha-1)			
	Sources of S			Mean	Sources of S			Mean	Sources of S			Mean
	Gypsum	Mag-Sulph	Single supper phosphate		Gypsum	Mag-Sulph	Single supper phosphate		Gypsum	Mag-Sulph	Single supper phosphate	
20	1.7	1.9	1.9	1.8	0.72	1	0.77	0.83	2.4	2.9	2.6	2.7
40	2.2	2.5	2.3	2.3	0.96	1.06	1.07	1.03	3.2	3.6	3.3	3.4
60	2.3	2.7	2.7	2.6	1.02	1.23	0.98	1.07	3.3	3.9	3.6	3.6
80	2.3	2.6	2.4	2.5	1.07	1.11	0.87	1.02	3.4	3.8	3.3	3.5
Mean	1.9	2.2	2	2	0.88	1.01	0.86	0.92	2.8	3.2	2.9	3
Control	1				0.63				1.6			
	Source	Level	Source × Level		Source	Level	Source × Level		Source	Level	Source × Level	
S. Em±	0.07	0.09	0.15		0.05	0.07	0.12		0.1	0.1	0.2	
C.D.(P=0.05)	0.2	0.25	0.44		0.16	0.21	0.36		0.3	0.4	0.7	
C.V. %	12.9				23.26				13.4			
FRBD(0.05)	NS	S	NS		NS	S	NS		S	S	NS	

Chlorophyll content

Results (Table 4) revealed that levels and sources of sulphur has the significant effect on chlorophyll content in leaves before and after flowering of green gram. Sulphur is involved in the formation of chlorophyll [6].

Protein content

Results (Table 5) revealed that sources as well as levels of sulphur have significant effect on the protein content in green gram. The protein content of green gram seed increased over control with increasing levels of sulphur irrespective of sulphur source. The protein content of green gram ranged from 15 to 24 per cent. It is interesting to note that increased levels of S beyond 60 kg S ha^{-1} decreased the per cent protein content irrespective of sources. The decreasing trend of protein content due to higher levels of sulphur might be due to the dilution effect of increased seed yield. The highest protein content (24.00 %) was observed in case of single super phosphate @60 kg S ha^{-1} followed by single magnesium sulphate and gypsum.

Fertiliser S has been reported to increase per cent protein and per cent amino acids in green gram [27]. Adequate supply of sulphur to oilseed crops promotes the synthesis of sulphur containing amino acids and proteins [28].

Table-4: Effect of different sources and levels of Sulphur on Chlorophyll content (mg g^{-1} leaf) before and after flowering of green gram

Level of S (kg ha-1)	S (kg ha-1)	2012					
		Chlorophyll content (mg g-1 leaf) before flowering			Chlorophyll content (mg g-1 leaf) after flowering		
		Chlorophyll a	Chlorophyll b	Total chlorophyll	Chlorophyll a	Chlorophyll b	Total chlorophyll
Gypsum	20	0.681	0.300	0.980	0.718	0.228	0.945
Mag-Sulph	20	0.732	0.310	1.042	0.675	0.235	0.909
Single superphosphate	20	0.689	0.279	0.968	0.614	0.196	0.810
Gypsum	40	0.660	0.251	0.910	0.541	0.205	0.746
Mag-Sulph	40	0.727	0.289	1.015	0.700	0.243	0.943
Single superphosphate	40	0.692	0.278	0.970	0.575	0.216	0.791
Gypsum	60	0.665	0.243	0.907	0.598	0.209	0.807
Mag-Sulph	60	0.745	0.302	1.047	0.765	0.232	0.997
Single superphosphate	60	0.675	0.256	0.932	0.573	0.223	0.796
Gypsum	80	0.705	0.291	0.996	0.549	0.170	0.719
Mag-Sulph	80	0.630	0.257	0.887	0.537	0.191	0.728
Single superphosphate	80	0.689	0.257	0.946	0.623	0.188	0.811
Control	0	0.653	0.258	0.910	0.625	0.186	0.810

Table-5: Effect of different sources and levels of sulphur on crude protein content (%) in seeds of green gram

Level of S (kg ha^{-1})	Crude protein content (%) in seed			
	Sources of S			
	Gypsum	Mag-Sulph	Single supper phosphate	Mean
20	19	15	22	19
40	21	18	21	20
60	20	16	24	20
80	20	16	22	19
Mean	19	16	21	19
Control	15			
	Source	Level	Source × Level	
S. Em±	0.2	0.3	0.4	
C.D.(P=0.05)	0.6	0.7	1.3	
C.V. (%)	4.1			
FRBD(0.05)	S	S	S	

Apparent sulphur recovery (%) and sulphur response by green gram

Significant amount of applied sulphur was recovered by the green gram crop, which ranged from 2.1 to 6.2 % and sulphur response 4.8 to 12.8 during pre-Kharif 2012 (Table 6). Among the sources, Magnsium sulphate showed the highest recovery of sulphur followed by single superphosphate and gypsum. It was interesting to note that the recovery of sulphur was higher at lower levels of sulphur application, which decreases with increasing sulphur levels irrespective of sulphur sources. Crop response in terms of kg grain per kg sulphur ranged from 4.8 to 12.8. Among the sulphur sources, crop response was more with magnesium sulphate followed by single superphosphate and gypsum at all the corresponding levels under consideration (Table 6). The greater recovery of sulphur with lower levels of added sulphur in green gram crop was noticed. The higher recovery of sulphur with lower levels of added sulphur was also reported by Ghosh *et al*. [26] in mustard and Singh *et al*. [29] in niger crop. It is interesting to note that the absolute uptake of added sulphur decreased with increasing rate of application. A higher recovery is indicative of a more efficient uptake while higher yield is necessary for a more efficient utilization of the sulphur taken up by the plants.

Table-6: Apparent sulphur recovery (%) and sulphur response by green gram

Level of S (kg ha^{-1})	Apparent S recovery (%)			Response of S (kg grain kg^{-1} S)		
	Sources of S			Sources of S		
	Gypsum	Mag-Sulph	Single supper phosphate	Gypsum	Mag-Sulph	Single supper phosphate
20	4.0	6.2	4.9	10.7	12.8	12.4
40	3.8	4.9	4.2	8.2	10.6	9.1
60	2.8	3.8	3.3	6.4	8.5	8.5
80	2.2	2.6	2.1	4.8	6.3	5.4

Available sulphur content in soil after green gram harvest

Available sulphur (sulphate sulphur) content varied from 8.6 to 29.5 kg ha^{-1} after the harvest of mustard crop during 2012 (Table 7).

Table-7: Effect of graded levels and sources of Sulphur on available Sulphur (kg ha^{-1}) in soil after harvest of green gram

S Level (kg ha^{-1})	Sources of S			Mean
	Gypsum	**MagSulph**	**Single superphosphate**	
0	8.6	8.6	8.6	8.6
20	18.0	11.8	16.5	15.4
40	12.6	14.6	15.6	14.3
60	22.8	23.8	25.4	27.3
80	29.5	24.6	26.2	24.8
Mean	18.3	16.7	19.3	18.1
Control	8.6			
Initial	**3.25**			
	Source	Level	Source x Level	
SEm (±)	**0.2**	**0.3**	**0.6**	
C.D (P=0.05)	**0.7**	**0.9**	**1.6**	
C.V. %	**5.3**			
FRBD(0.05)	S	S	S	

It is interesting to note that the increase in available sulphur content in soils, after harvest of green gram crop increased with increasing levels of sulphur application from 0 to 80 kg S ha^{-1}. A significant increase in available sulphur in soil was observed with all the 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 sulphur status. Balangoudar *et al.* [30] also reported that the available sulphur content in soils increased with increase in sulphur levels from 0 to 40 kg S ha^{-1} after the harvests of moong.

Changes of pH in soils after green gram harvest

The data on changes in soil pH as a result of application of graded levels and sources of sulphur after the harvest of green gram crop is presented in Table 4.1.8.

Table-8: Effect of different graded levels and sources of Sulphur on pH in soil after harvest of Green gram

Level of S (kg ha^{-1})	pH in soil after harvesting of green gram			
	Sources of S			Mean
LEVEL	Gypsum	Mag-Sulph	Single supper phosphate	
20	4.69	4.72	4.78	4.73
40	4.61	4.66	4.76	4.68
60	4.73	4.58	4.62	4.64
80	4.5	4.51	4.6	4.54
Mean	4.66	4.65	4.71	4.67
Control	4.77			
Initial	**4.99**			

The results (Table 8) clearly show 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 not only neutralises the soil acidity but favours sulphur availability. In general, the rate of sulphur oxidation in acid soils increases with increasing soil pH. Calcium carbonate additions to soils can increase the rate of sulphur oxidation [31, 32]. The effect of liming on the mineralisation of organic soil sulphur has also been reported by Nelson [33].

CONCLSION

Field experiment conducted on green gram (V*igna radiata* L.)during 2012 in a typical red and lateritic soil revealed that sources (Gypsum, Magnesium sulphate and Single superphosphate) and levels of sulphur (0, 20, 40, 60 and 80 kg S ha^{-1}) have significant influence on seed yield, straw yield and total biological yield, sulphur content in seed and straw, total sulphur uptake and protein content. Although the yield is increased with the increasing levels of sulphur but optimum economic yield was obtained due to application of sulphur @ 60 kg ha^{-1} irrespective of sources of S. The sources of S were *at par* with regards to the increase of yield and quality parameters of seed. Among the sources of sulphur, Magnesium sulphate has a slight edge over Single superphosphate and Gypsum with respect to yield and quality parameters of seed of green gram in Red and Lateritic soils of West Bengal.

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