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Comparative Efficacy of Different Carriers for Sulfur Nutrition of Mung Crop (*Vigna radiata*) Grown on Alluvial Derived Soils

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ABSTRACT

A field experiment was carried out at an experimental research farm of Lovely Professional University (Punjab) during *kharif* season 2021, with definite objectives to examine the effect of various sources and levels of sulfur on growth, yield, quality attributes and worked out the economics of green gram crop (*Vigna radiata* L. *wilczek*) grown on alluvial derived soils. The experiment was set up in a Factorial Randomized Block Design with three sulfur sources (Gypsum, Bentonite and SSP) and four levels (0, 10, 20 and 30 kg S/ha) each replicated thrice. The study found that, maximum growth attributes (Plant height, Branches per plant, Nodules per plant, Leaf area per cm^2 and Chlorophyl content) at 30, 60 DAS and harvest, were recorded with the application of gypsum carrier at 20 kg S/ha followed by 30 kg of sulfur per hectare. A similar trend was noticed with respect to yield (seeds per pod, pods per plant, grain, straw and biological yield) and harvest index of green gram. However, use of sulfur dose at 20 kg/ha gave statistically significant result over control in growth and yield of the crop. Furthermore, a higher amount of protein content in seeds of green gram was observed with gypsum application at 30 kg of sulfur/hectare. Hence, to increase the growth, yield, quality of green gram and maximize the farmers' income, it is needed to be fertilized with sulfur at the rate of 20 kg/ha through gypsum along with the RDF.

Keywords Green gram, Growth parameters, Sulfur, Gypsum, Yield attributes.

INTRODUCTION

The most important pulse crop in South-East Asia, particularly in the Indian subcontinent is green gram (*Vigna radiata* L. *wilczek*), also known as 'mung' or 'mung bean. It is known for its excellent source of protein (24.3%) along with carbohydrates (56%), fiber content (4.1%) and a small amount of riboflavin and thiamine, thus showing its high nutritive value. It is also high in phosphorus and iron (Patel *et al.* 2013). Besides, it provides significant levels of lysine (4600 mg/g N) and tryptophan (60 mg/g N) and may be ingested as whole grain or dal for table usage. Green gram is a short-season crop, but it is photo and thermo-insensitive, which requires little input and may be cultivated as a catch crop or an intercrop in a variety of cereals, pulses and plantation crops in both the *kharif*

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and summer seasons. Moreover, it also preserves soil fertility through biological nitrogen fixation and hence plays an important role in promoting sustainable agriculture (Kannaiyan 1999). The production and area of green gram, in Punjab during the *kharif* season in 2014-15 were 3.7 thousand hectares and 3.1 thousand tonnes, respectively, with an average yield of 838 kg/ha (Anonymous 2016).

Although mung crop requires all the major plant nutrients, the essentiality of sulfur nutrient plays a crucial role in the production and quality of the crop. The requirement for sulfur is high for crops of Cruciferae, Leguminosae and Gramineae families. It has been designated as the fourth major important plant nutrient, because of its widespread deficit in many crops (Singh 2001). Sulfur is present both in organic and inorganic forms. The inorganic form of sulfur is found in agricultural plants and a large portion of the absorbed sulfur is reduced in plant tissues, becoming a component of diverse organic molecules (protein, vitamins, enzymes). Because of its effect on protein metabolism, oil synthesis, and amino acid production, sulfur is regarded as a quality nutrient, thereby showing its effect on yield (Sutar *et al.* 2017). It is mainly found in 3 amino acids, Methionine (21% S), Cysteine (26% S) and Cystine (27% S), which act as building blocks of protein. These amino acids not only enhance the protein and oil content in legumes and oilseeds and but are also involved in a variety of metabolic and enzymatic processes such as chlorophyll formation, respiration, which also allows photosynthesis (Patel *et al.* 2013). Furthermore, it also increases the formation of root nodules in legumes, which results in more sulfur being accessible throughout the vegetative growth stage and plant development stage (Yadav 2004).

A crop will suffer from a sulfur deficiency if the amount of sulfur available in the soil, falls less than the critical limit (< 10 ppm). Sulfur-deficient soils are unable to supply enough sulfur to meet the crop demand, eventuating in sulfur deficit and suboptimal yield of the crop. In Punjab, due to the dominance of the rice-wheat cropping system, the cultivation of pulse crops including green gram has largely been restricted to marginal, less productive soils which are expected to be deficient in sulfur and account for their low yields. Also, increased use of sulfur-free fertilizer and inadequate use of organic manure has aggraded its deficiency in the soils of Punjab. Intensive cultivation of high-yielding varieties has further exhausted the soils of its S reserves affecting the yield of the crops grown on these soils having low and marginal content of sulfur. As sulfur nutrient is linked to the development of high-quality crops, both nutritionally and commercially, hence it is inevitable to study the effects of different sources and levels of sulfur on the yield and quality aspects of green gram. Since, the soils of the Punjab region are deficient in sulfur, the green gram crop responds well to the sulfur as its requirement is high. So, this research tries to give some possible results by comparing different sources of sulfur at different levels in green gram crop.

MATERIALS AND METHODS

The field trial was conducted in the soil science experimental area at the farm of Lovely Professional University, Phagwara, Punjab, India during the *kharif* season 2021. The geographical location of the experimental site was located at 31º14' 43.8" N and 75º41' 44.1" E longitude, at an elevation of roughly 232 m feet above sea level. The experimental region is part of the Agro-Ecological Sub Region of Northern Plain, Hot sub humid (Dry) Eco-Region of Punjab and Rohilkand plains, which comes under the agro-climatic zone (VI) Trans-Gangetic plains. The minimum and maximum temperatures vary greatly during both the summer and winter seasons. Temperatures range from 4°C to 37°C on average, which is ideal for crop production. The hottest month in this region is May and the coldest is January, where temperatures drop to 4°C. This area receives 500–750 mm of rainfall annually, most of which falls during the monsoon season (July to September). Cool weather with minimal rainfall is seen during winter. The experimental trial was conducted in Factorial Randomized Block Design, comprising of three different sources (Gypsum, Bentonite and SSP) and levels of sulfur (0, 10, 20 and 30 kg/ha) each replicated thrice.

The status of soil was weed free before starting the trial, with good drainage facilities. Before sowing the crop, the soil samples from the experimental site were collected randomly, at 0–15 cm depth, using a soil auger. All the collected soil samples were mixed

Table 1. Effect of different sulfur sources and levels on growth of green gram at different crop growth stages.

Treat-ments	Plant height (cm)			Number of branches per plant			Nodule per plant		Leaf area (cm^2/plant)			Chlorophyll content (μ mol/m^2)		
	30 DAS	60 DAS	Har-vest	30 DAS	60 DAS	Har-vest	30 DAS	60 DAS	30 DAS	60 DAS	Har-vest	30 DAS	60 DAS	Har-vest
Levels of sulfur (kg/ha)														
0	9.43	64.5	74.9	3.22	7.83	9.22	28.1	87.8	35.73	79.48	80.87	38.1	59.3	46.9
10	10.07	66.1	75.8	3.81	8.14	9.86	29	89.2	36.56	82.06	81.67	39.5	60.9	47.8
20	13.62	69.6	77.5	5.65	10.33	12.11	33.5	93	39.74	84.78	84.66	41.9	62.1	49.6
30	14.44	70.7	78.8	6.26	11.22	12.76	34.7	94.5	40.78	85.28	85.22	42.6	62.5	50.9
CD	0.959	2.4	1.49	0.692	0.726	0.943	1.2	1.7	1.57	1.65	1.42	1.34	1.4	1.41
SE	0.325	0.818	0.507	0.234	0.246	0.319	0.409	0.565	0.532	0.55	0.482	0.454	0.474	0.479
Sources of sulfur														
Gypsum	11.89	68.2	77.6	4.89	9.59	11.3	31.4	91.7	39.2	83.4	83.6	40.8	61.6	49.5
Bentonite	11.85	67.2	75.6	4.68	9.16	10.7	31.2	90.1	37.1	82.3	82.6	40.3	60.4	48.3
SSP	11.94	67.7	77.0	4.64	9.39	10.9	31.3	91.5	38.3	83	83.1	40.5	61.5	48.6
CD	NS	NS	1.2	NS	NS	0.4	NS	0.42	1.3	NS	NS	NS	NS	NS
SE	0.281	0.708	0.439	0.203	0.213	0.277	0.354	0.49	0.461	0.484	0.417	0.393	0.411	0.415
Interaction (Sources × levels)														
CD	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
SE	0.563	1.416	0.879	0.406	0.426	0.553	0.709	0.979	0.922	0.969	0.835	0.787	0.822	0.830

to make a composite sample. This composite soil sample was analyzed for physico-chemical properties prior to sowing. The soil texture of the experimental site was sandy clay loam with a textured composition (68% sand, 17% silt and 15% clay) (Gavlak *et al.* 2005). The chemical composition of the soil includes pH (7.8), EC (0.42 ds/m), organic carbon (0.379%), available nitrogen (225 kg/ha), phosphorus (12.5 kg/ha), potassium (190 kg/ha) and sulfur (5.0 mg/kg). The variety of green gram SML-668 is suitable, to be grown in the Punjab region. Plants of this variety are dwarf and take 60 to 70 days to mature. The crop was fertilized with 12.5 kg/ha N, 43.52 kg/ha P_2O_5 and sulfur as per the treatments allotted to each plot, before sowing. The data for growth attributes i.e plant height, branches and nodule count, leaf area and chlorophyll content were measured at different growth stages and harvest. Randomly five plants from each plot were selected and data on the above parameters was recorded. Similarly, data for yield attributes were also recorded after the harvest of the crop.

Statistical analysis

The data of this experiment includes twelve treatments, replicated thrice. It was conducted in a Factorial Randomized Block Design and statistically analyzed using the standard procedure as described by Gomez and Gomez (2010). To analyze the significance of variance (ANOVA), tables were prepared with the data for crop growth, yield and quality attributes using a statistical tool 'OPSTAT' (created by OP Sheoran).

RESULTS AND DISCUSSION

Growth attributes

Data on growth parameters of a green gram at different stages of the crop showed a progressively increasing trend when the application of sulfur increased from 0 to 30 kg/ha irrespective of the sources as mentioned below (Table 1). But the significant increase in growth attributes i.e plant height, branches and nodule count, leaf area and chlorophyll content of green gram were recorded with the application of 20 kg S/ha. Although an increase in the above parameters was noticed when sulfur was applied at the rate of 30 kg/ha over the application rate of 20 kg/ha. But this increase was not statistically significant indicating that the application

Table 2. Effect of different sulfur sources and levels on yield and quality of green gram crop.

Treatments	Seeds/ pod	Pods/ plant	Grain yield (q/ha)	Straw yield (q/ha)	Biolo- gical yield (q/ha)	Harvest index (%)	Protein content (%)
Levels of sulfur (kg/ha)							
0	6.06	23.7	8.16	17.43	25.59	31.83	16.94
10	6.47	24.3	8.43	17.73	26.16	32.18	19.21
20	8.03	26.1	9.71	19.28	29.00	33.46	20.82
30	8.43	26.9	9.94	19.49	29.43	33.62	22.43
CD	0.48	1.3	0.332	0.326	0.473	0.919	1.549
SE	0.16	0.43	0.112	0.11	0.16	0.311	0.525
Sources of sulfur							
Gypsum	7.70	25.8	9.19	18.53	27.72	33.0	20.3
Bentonite	7.38	24.7	8.95	18.41	27.37	32.63	19.3
SSP	7.48	25.2	9.04	18.50	27.55	32.73	19.5
CD	NS	NS	NS	NS	NS	NS	NS
SE	0.14	0.43	0.097	0.095	0.139	0.269	0.455
Interaction (Sources × levels)							
CD	NS	NS	NS	NS	NS	NS	NS
SE	0.312	0.765	0.195	0.191	0.277	0.539	0.909

of 20 kg S/ha was sufficient. Because, sulfur is likely responsible for the improved growth and development, because of the multiple roles that sulfur plays in the metabolism of proteins and carbohydrates in plants by activating many enzymes involved in the dark reaction of photosynthesis, which increased the growth of the plant. The crop getting a higher dose of sulfur may have benefited from more active root growth and chlorophyll content, which increased photosynthesis, thereby enhancing the growth attributes of the crop (Ravi *et al.* 2010). These results were similar to work from Arun Raj *et al*. (2018) and Patel *et al.* (2010) in green gram and Jaiswal *et al.* (2019) in black gram.

Different sources of sulfur did not exhibit much effect on growth parameters at 30 DAS. However, at 60 days after sowing and harvest, application of sulfur sources i.e gypsum and single superphosphate regardless of sulfur levels considerably increased the plant height, branches and nodule count per plant, leaf area and chlorophyll content when compared to bentonite as showed below (Table 1). The performance of both the sources was at par for its effect on the growth attributes of green gram. Application of sulfur through gypsum would have enhanced plant metabolism and meristematic activity, which would have led to greater apical growth of the plant (Intodia and Tomar 2013). Also, the sulfate ions of sulfur are easily and readily available to the plants, thereby increasing the growth and nodulation activity in the root zone of the crop. The minimum response of sulfur carriers to growth parameters of the crop was obtained with the application of bentonite owing to its oxidation to sulfate ion by thiobacillus bacteria before it becomes available to the plant. Consequently, it was less available to the crop because of its delayed availability. Hence the response of bentonite is less over SSP and gypsum. Similar findings were reported by Singh *et al*. (2017) in green gram crop, Jawahar *et al.* (2013) in rice-fallow black gram and Yadav *et al*. (2018) in black gram.

The interaction effect of different sources and levels of sulfur on growth attributes of green gram was found to be non-significant over one another.

Yield attributes and yield

Sulfur application exerted significant influence on the yield attribute of green gram (Table 2). On examining the data, it depicted an enhancement in mean seeds/pod, pods/plant of green gram crop with increasing rate of sulfur application from 0 to 30 kg/ha regardless of sources. Response of sulfur to the crop increased with the increase in the rate of sulfur. But the maximum increase was noticed with the application of 20 kg S/ha. Although there was an increase in yield attributes when sulfur was applied at the rate of 30 kg/ha over the application rate of 20 kg/ha, this magnitude could not increase the amount of seed/pod and pods/plant to its maximum extent, suggesting that application of 20 kg S/ha was sufficient for green gram. It is due to the fact that the application of sulfur in a sufficient and appropriate amount aids in floral primordial initiation for its reproductive component, which regulates the number of seeds per pod and pods per plant, which may account for the rise in yield contributing characteristics (Dey and Basu 2004, Singh and Yadav 2007). Compared to different sulfur carriers, it was found that the performance of all the sources proved equally efficient and all were at par with each other. It suggested that different sources of sulfur did not exhibit a significant effect on seeds/pod and pods/plant. It appears that sulfur supplied either by a material containing sulfate sulfur or elemental sulfur becomes equally effective later. Elemental sulfur present in bentonite source is converted to sulfate sulfur by thiobacillus bacteria and becomes available to the crop in later stages of growth and hence did not show much effect on this crop as its duration is less. The results were in agreement with the conclusions of Das (2017) in green gram and Parmar *et al*. (2018) in sesame crop.

Response of different levels of sulfur showed a considerable effect on the yield of green gram (Table 2). Due to different S levels, a considerable change in grain, straw, biological yield and harvest index was observed. When compared to the other S levels, the application of 30 kg S/ha resulted in higher grain (9.9 q/ha), straw (19.4 q/ha) and biological yield (29.4 q/ha) of the crop. But the sulfur level at 20 kg/ha proved to be effective in increasing the yield, whereas 30 kg of S/ha did not exhibit statistically significant results in the green gram crop. Maximum harvest index (33.6 %) was reported with the application of 30 kg S/ha, and it considerably differed from the control but was statistically on par with 20 kg S/ha. It might be due to the result of the applied sulfur's stimulatory effect on protein synthesis, which may have significantly improved photosynthesis and enhanced the most of yield-contributing attributes, leading to a significantly higher yield of the crop (Tulasi *et al.* 2014). These results were similar with work from of Bera and Ghosh (2015) in green gram, Khurana and Bansal (2007) in mung-raya crop.

Different carriers of sulfur showed a substantial improvement in yield components and harvest index of green gram as shown in the Table 2. Among different sulfur sources, application of gypsum showed a substantial increase in grain yield (9.19 q/ha), straw yield (18.53 q/ha), biological yield (27.72 q/ha) and harvest index (33 %) compared to SSP and bentonite, however, it was at par with SSP. The higher increase in the yield components through gypsum carrier might be due to the release of the higher solubility of sulphate ions, quickly released into the soil solution. This in turn results in superior yields from the crop. But the bentonite source showed less effect on the yield of the crop due to high concentration and slow release of sulfur into the soil solution. Results of Jeevitha *et al.* (2019) in green gram and Kumar *et al.* (2011) in sun flower are in complete agreement with the above results.

The interaction effect on yield attributes and yield of a green gram for different sources and levels of sulfur was found to be non-significant.

Quality attributes

Regardless of the sulfur source, the protein content of green gram increased relative to the control with rising sulfur levels, given in the Table 2. The percentage of protein in green gram varied between 16% and 22%. It is important to observe that, irrespective of the different sources, protein content increased as S concentrations rose over 30 kg S/ha. It might be due to the significant impact of sulfur, which is essential for nodulation and the synthesis of amino acids, notably sulfur-containing amino acids like methionine, cysteine and cystine, which may be the cause of the increase in protein content. These amino acids eventually make up the structure of proteins.

Table 3. Effect of sulfur sources and levels on economics of green gram.

Treatments	Cost of cultiva-tion (Rs/ha)	Gross returns (Rs/ha)	Net returns (Rs/ha)	Benefit cost ratio
Levels of sulfur (kg/ha)				
0	21,015	55,120	35,105	2.62
10	21,692	61,010	39,318	2.81
20	21,965	68,970	47,005	3.13
30	22,153	70,580	48,427	3.18
Sources of sulfur				
Gypsum	25,685	64,330	38,645	2.50
Bentonite	25,935	62,650	36,715	2.41
SSP	25,961	63,280	37,319	2.43

The increase in amino acid status may be driven by nutrient absorption and mobilization of sulfur and increased enzyme activity during the production of amino acids containing sulfur (Singh *et al.* 2002). similar supporting results are seen from work of Singh (2017) in green gram and Kumar and Trivedi (2012) in mustard.

Different sources of sulfur did not exhibit any significant influence on the protein content of the crop, as seen in the Table 2. Compared to bentonite and single super phosfate, the application of gypsum showed a slight increase in the mean protein content of the green gram crop. It is noted that when sulfur was applied from different sources, protein content with the application of gypsum source was (20.3%) followed in sequence by single super phosfate (19.9 %) and bentonite (19.3%) signifying that gypsum maintained its superiority over other sources, whereas SSP and bentonite were at par with each other. Gypsum's superiority in green gram might be due to its high solubility, which resulted in an adequate supply of sulfur to the crop, thus enhancing the crop yield and quality. Similar findings were reported by Yadav *et al.* (2018) in black gram.

Economics

The application of sulfur at different levels showed a significant effect on the economics of green gram, as mentioned below (Table 3). highest net and gross returns were reported with the sulfur level at 30 kg/ha over control. Similarly, the benefit-cost ratio was also higher with sulfur application at 30 kg/ha. But the sulfur dose at 20 kg/ha was found to be statistically significant over 30 kg/ha in increasing the economics of the green gram. The yield trend caused by the different sulfur applications and the relative cost of inputs in proportion to output may be the cause for net returns and benefit-cost ratio. Among different sources of sulfur, gypsum was found to be effective in increasing the economics of green gram. The response of gypsum carrier showed a substantial rise in net returns, gross returns and benefit-cost ratio of the crop followed by SSP and the least was recorded with the bentonite. The economics of green gram through gypsum showed superiority over SSP and bentonite due to the lower cost of fertilizer and higher response to yield of the crop. These results are in agreement with Singh *et al.* (2017) in green gram and Jimo and Singh (2017) in linseed.

CONCLUSION

On the basis of the field experiment done in 2021, on green gram in alluvial derived soils of Punjab region, the results revealed that sources and levels of sulfur have a substantial impact on growth, yield attributes and yield of the crop. Although the growth and yield increases with higher sulfur levels, the application of sulfur at 20 kg/ha found to be statistically significant over control, regardless of the S sources. The sources of sulfur were almost at par with each other in terms of growth and yield, however gypsum slightly outperforms SSP and bentonite among the sources of sulfur. But the maximum protein content of green gram was obtained with sulfur level at 30 kg/ha through gypsum over control. Hence, it can be concluded that gypsum at 20 kg S/ha to green gram crop, found to be beneficial and economical to farmers in generating a greater yield with a high B : C ratio.

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