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RESPONSE OF DIFFERENT SULPHUR SOURCES AND LEVELS ON NUTRIENT CONTENT, ITS UPTAKE, NUTRIENT USE EFFICIENCY AND THE AVAILABILITY OF SULPHUR IN POST-HARVEST SOILS OF GREEN GRAM

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ABSTRACT

A field experiment was carried out in the *Kharif* season of 2021, at soil science research farm of Lovely professional university (Punjab), to assess the effects of various sulphur sources and levels on the nutrient content, uptake, Nutrient use efficiency and the sulphur availability in post-harvest soil of green gram (*Vigna radiata* L.Wilczek) crop. The experiment was laid out in a factorial randomized block design, comprising of three sulphur sources (Gypsum, Single Super Phosphate and Bentonite sulphur), four levels (0, 10, 20 and 30 kg/ha) and replicated thrice. The results of the study revealed that the higher sulphur content and its uptake in leaf, shoot, grain, and straw yield were obtained with gypsum application at 20 kg S/ha. Moreover, statistically significant increase in Sulphur use efficiency and Agronomic use efficiency of green gram were recorded with the application of gypsum @ 20 kg S/ha respectively over control. However, the sulphur availability in soil after harvest, was maximum with the sulphur application of 30 kg/ha through bentonite sulphur. Therefore, gypsum application at the dosage of 20 kg/ha along with the Recommended dose of NPK, gave productive results with respect to green gram crop.

KEY WORDS: Sulphur content, Uptake, Nutrient use efficiency, Available sulphur, Green gram.

INTRODUCTION

The most significant crop in South-East Asia, particularly in the Indian subcontinent, is green gram (*Vigna radiata* L. Wilczek), sometimes referred to as "mung" or "mungbean". Being a leguminous crop, pulses are essential to the diet since they include 23.1% more protein than cereals, 0.5 to 4.33 percent fat, and 23.4 to 66.3 percent carbs (Sinha, 1977). The crop is particularly renowned as a best source of protein. Unlike other pulses, it is extremely digested and has no flatulent effects. The key element for increasing crop yields is nutrient balance. Nutrient mining from the soil has led to decreased crop output and eventually, impaired soil health due to excessive and unbalanced nutrient use. The production of crops and the health of the soil are directly impacted by the replenishment of these nutrients using organic methods alone or in combination with inorganic methods. To maintain soil status and crop yield, fertilizers are administered to the soil, while taking into consideration all the aspects connected to soil fertility and productivity. The green gram crop responds quite well to fertilizer treatment. The amount of fertilizer needed will vary depending on the initial soil fertility level and moisture availability.

Sulphur is typically referred to as the fourth major nutrient. Plants take up sulphur as the sulphate ion. Its concentration in the plants ranges from 0.1 to 0.4%. Also, it has a synergistic impact on agricultural yield. Higher response to pulse crops was noticed with the sulphur application along with recommended dose of fertilizers (i.e N, P and K)

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than cereals. It can be administered to the soil using suitable sulphur carriers, with the choice depending on the crop type, its availability, the cost and the requirement for additional nutrients. But, the deficiency of sulphur in soil, is increasing due to ongoing use of S-free fertilizers, rising cropping intensity with high yielding cultivars, and being more evident in coarse textured soils with low organic matter (Sipai *et al.*, 2016). Especially in Punjab, due to dominance of 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 sulphur and accounts for their low yields. Taking these facts into consideration, the present investigation was carried out to analyse the sulphur in plant samples and Available sulphur in soil before and after sowing of green gram crop.

MATERIALS AND METHODS

The field experiment was carried out in a research farm College of Agriculture, Lovely Professional University, Punjab, during the Kharif season of 2021. The soil texture in the experimental plot was Sandy clay loam with low organic carbon content (0.379 %). The chemical composition of the soil prior to sowing of green gram crop includes available N (225 Kg/ha), available P (12.5 kg/ha) available K (190 kg/ha) and available sulphur (5 mg/kg) with slightly alkaline pH (7.89). The experimental site was laid out in Factorial Randomized block design (RBD) comprising of three sulphur carriers (Gypsum, SSP and Bentonite sulphur), four levels of sulphur (0,10,20 and 30 kg/ha) and replicated thrice. At the time of sowing, 12.5 kg/ha N and 43.52 kg/ha P_2O_5 (as per the RDF) was applied as a basal dose using Urea and DAP respectively. Along with these, sulphur was applied by broadcasting method, using different sulphur carriers, i.e gypsum, SSP and bentonite sulphur at different doses to each respective plots of green gram. In order to estimate the nutrient taken up by the plant, the sulphur % in leaf and shoot samples were analysed before flowering of the crop. The grain and straw of green gram was digested with diacid mixture (3:1 HNO_3 and $HCLO_4$) to estimate the sulphur content and its uptake by Turbidometric method (Chesnin and Yien, 1951). Similarly, the amount of available sulphur in post-harvest soils was determined by using 0.15% $CaCl_2$ solution (Chesnin and Yien, 1951), after harvest of green gram crop. The data was statistically evaluated using the methodology given by Gomez and Gomez (2010). The analysis of variance was used to examine the extent to which treatments had a significant effect on the green gram using a statistical tool 'OPSTAT' (created by O.P. Sheoran).

RESULTS AND DISCUSSION

Sulphur concentration in leaf and shoot sample (%)

Sulphur application exerted considerable effect on S content in leaf and shoot sample, before flowering of green gram crop. Data in Table 1 depicted that an enhancement in mean S content occurred with increasing rate of sulphur application from 0 to 30 kg/ha regardless of sources. It increased the sulphur concentration from 0.355 percent to 0.460 in leaves and 0.044 percent to 0.473 in shoot of the plant, when sulphur level was raised from 0 to30 kg/ha. However, a significant increase was found at 20 kg S/ha over other sulphur levels. It was claimed that sulphur, when administered in various amounts, had a substantial influence on raising its concentration in plant samples, thereby improving crop nutrition. Similar trends were noticed from the work done by Khurana and Bansal (2007) in raya crop, Biswas *et al*., (2006) in soyabean, Kumar *et al*. (2018) in mustard and Makol *et al.*, (2020) in cropping system of rice-chickpea.

When different sources of sulphur application irrespective of sulphur levels were considered for leaf and shoot S content, statistical analysis indicated that performance of all the sources proved equally efficient and all were at par with each other (Table 1). Compared to bentonite and single super phosphate, application of gypsum showed slight increase, though non-significant in leaf and shoot S content. The maximum concentration of sulphur was recorded through gypsum application with 0.428 % in plant leaf and 0.359 % in shoot of green gram followed by SSP. Although different sources of sulphur did not exhibit significant effect on S content in plant sample, but the reason for such response may be attributed to the fact that sulphur supplied either by material containing sulphate sulphur or elemental sulphur becomes equally effective only after a period of time. Elemental sulphur present in bentonite source is converted to sulphate sulphur by thiobasillus bacteria and become available to the plant in later stages of crop growth. Due to this, SSP and bentonite sulphur

Table 1. Effect of different sulphur sources and levels on the availability of sulphur content in leaf, shoot, grain and straw of green gram

Treatments	S content in leaf(%) - (Before flowering)	S content in shoot(%) - (before flowering)	S content in grain (%)	S content in straw(%)
Levels kg S/ha				
0	0.355	0.044	0.189	0.073
10	0.417	0.373	0.228	0.082
20	0.450	0.444	0.259	0.086
30	0.460	0.473	0.285	0.091
CD	0.022	0.045	0.012	0.005
SE	0.007	0.015	0.004	0.002
Sources				
Gypsum	0.428	0.359	0.244	0.085
Bentonite	0.407	0.311	0.237	0.082
SSP	0.424	0.331	0.241	0.083
CD	NS	NS	NS	NS
SE	0.006	0.013	0.003	0.001
Interaction (Source ×Level)				
CD	NS	NS	NS	NS
SE	0.0.13	0.027	0.007	0.003

didn't show much effect on green gram crop. The results were in agreement with Caires *et al*., (2002) in wheat crop.

S concentration in grain and straw yield (%)

Regardless of the source of the sulphur, the sulphur concentration in grain and straw yield considerably increased with rising sulphur levels (Table 1). As the soil found to be deficient in available sulphur, this suggests that the crop responded well to sulphur application. Due to graded levels of sulphur, the amounts of sulphur content in seed and straw were 0.18 to 0.28 and 0.07 to 0.09 percent at 0 to 30 kg S/ha, respectively. The concentration of sulphur in green gram crop steadily increased with the increase in S rate. It might be due to mobilization of sulphur in the form of sulphate, from different plant parts to the yield of the crop. These results find support from the work done by Bharvi *et al*., (2020); Dharwe *et al*., (2019); Italiya *et al*., (2019) in green gram and Khurana *et al.*, (2002) in lentil as a test crop.

When different sources of sulphur application were compared, regardless of sulphur levels for S content in grain and straw yield, the statistical data revealed that the performance of all the sources was similarly efficient and comparable (Table 1). Although different sulphur sources had no noticeable effect on S concentration in seed and straw yield, but gypsum fertilizer showed a slight increase in the amount of sulphur content in grain and straw of green gram. It could be because, at later phases of crop development, all different sources of sulphur, whether sulphate sulphur or elemental sulphur, become equally effective over time. Comparatively, the plot treated with gypsum application showed maximum sulphur %in grain and straw yield followed by SSP. Above results are similar with the findings of Patel *et al*. (2010) in green gram, Singh and Singh (2007) in linseed and Karwasara *et al*., (2017) in wheat crop.

S uptake in grain and straw (kg/ha)

Significant variations in the sulphur sources and levels for seed and straw sulphur uptake over control were observed (Table 2). Regardless of the sources, the total sulphur intake increased along with the rise in sulphur levels. The sulphur dose with 30 kg/ha had showed higher sulphur uptake in grain (2.84 kg/ha) and straw yield (1.79 kg/ha) over control, which was at par with 20 kg S/ha, respectively. However, the total sulphur uptake of green gram crop also gave similar results.The seed yield of green gram has more sulphur uptake over straw yield. This could be as a result of sulphur being mobilized from plant parts to seed. The amount of S absorbed by pulse crops varies from 5 to 13 kg S, depending on the type of crop, the soil's fertility level, and the agronomic management practices used. A large portion of the S absorbed by pulses is transferred to seed (Tandon, 1991). The findings indicate that S uptake by greengram is significantly influenced by S levels as compared to sources. The results were supported by the findings of Bairwa *et al.* (2014); Bera and Ghosh (2015); (Singh, 2017) in green gram and Singh *et al*. (2017) in mustard.

Response of different sulphur carriers to sulphur uptake in green gram, proved to be equally effective (Table 2). Compared to bentonite and single super phosphate, application of gypsum produced more mean sulphur uptake, though non-significant. It is noted that mean sulphur uptake by grain and straw with application of gypsum source was (2.28 kg/ha and 1.59 kg/ha) followed closely in sequence by SSP and bentonite sulphur, signifying the superiority of both gypsum and single superphosphate compared to bentonite. Similar trend was noticed with respect to total sulphur uptake of the green gram crop. Hence, the superiority of gypsum response to the S uptake might be due to readily available form of sulphate sulphur to the crop, thereby increasing the yield and uptake of sulphur after harvest. Similar findings were reported by Jyothi and Rao (2018), Usha Rani *et al*. (2009) in sunflower and Karwasara *et al*. (2017) in wheat.

Sulphur Use Efficiency (SUE) and Agronomic Use Efficiency (AUE) (%)

Data pertaining to SUE and AUE of green gram crop studied during the investigation is presented in Table 2. It significantly varied with the application of different levels of sulphur. Highest sulphur and agronomic use efficiency were recorded at 20 kg S/ha (4.71 and 7.96 percent) and lowest at 10 kg S/ha (3.83 and 4.25 percent) respectively over control. Higher sulphur availability as well as a significant increase in protein composition due to increased synthesis of sulphur-containing amino acids might have resulted in increased yield and sulphur uptake, thereby enhancing the SUE and AUE of the crop. The results were in agreement with conclusions of Bharathi and Poongothai (2008) in maize and subsequent green gram, Rakesh and Banik (2016) in mustard crop.

Different sources of sulphur exerted their significant effect on sulphur use efficiency as shown in the Table 2. Gypsum source recorded higher sulphur use efficiency (3.77 percent) and Agronomic use efficiency (5.44 percent) whereas SSP and Bentonite were at par with each other. The increase in the SUE and AUE of green gram might be due to the presence of readily available form of sulphur supplied to the plant through gypsum carrier resulting in higher yield and uptake of sulphur. The above results are similar with the findings of Gill and Sharma (2017) in soyabean.

Available sulphur in post-harvest soil (mg/kg)

The available sulphur content in soil after harvest of green gram increased with increase in sulphur levels

Table 2. Effect of sulphur sources and levels on Sulphur uptake in grain and straw, SUE, AUE and available sulphur content in post-harvest soil of green gram.

Treatment	Grain S uptake (kg/ha)	Straw S uptake (kg/ha)	Total S uptake (kg/ha)	Sulphur use efficiency (%)	Agronomic use efficiency (%)	Available (0.15% $CaCl_2$ extractable) sulphur (mg/kg)
Levels kg S/ha						
0	1.55	1.27	2.82	0	0	5.8
10	1.93	1.45	3.38	3.83	4.25	8.3
20	2.52	1.66	4.18	4.71	7.96	11.7
30	2.84	1.79	4.63	4.37	6.01	13.0
CD	0.145	0.10	0.188	1.029	1.99	0.520
SE	0.049	0.03	0.064	0.349	0.676	0.176
Sources						
Gypsum	2.28	1.59	3.87	3.77	5.44	9.50
Bentonite	2.14	1.51	3.65	3.13	4.28	9.92
SSP	2.21	1.54	3.75	2.78	3.95	9.65
CD	NS	NS	0.156	NS	NS	NS
SE	0.042	0.03	0.053	0.302	0.586	0.152
Interaction (Source ×Level)						
CD	NS	NS	NS	NS	NS	NS
SE	0.082	0.06	0.106	0.604	1.172	0.305

compared to initial sulphur status of the soil (Table 2). However, the available sulphur in soil was substantially higher with 30 kg S/ha and much lower with 10 kg S/ha. Compared to the other sulphur levels, 20 kg/ha of sulphur gave statistically significant results although 30 kg of sulphur showed slight increase in available sulphur status in post-harvest soil. Similar results were reported by Singh *et al.,* (2017), Bharathi and Poongothai, (2008) in green gram and Gajghane *et al.,* (2015) in mustard.

On comparison of different sources of sulphur application irrespective of sulphur levels for available sulphur in post-harvest soil, the results revealed that the performance of all the sources showed slight difference and were at par with each other (Table 2). Compared to gypsum and SSP, application of bentonite produced more sulphur available in soil after harvest, though non-significant. Since the uptake of sulphur by the plant in case of bentonite is low, so it is likely that the sulphur available in soil after harvest would be higher. These outcomes were consistent with the conclusions reached by Kumar *et al.* (2017) in mustard crop.

The interaction effect of different sulphur sources and levels on Sulphur content and its uptake in leaf, shoot sample, grain and straw yield, SUE, AUE and the available sulphur status in soil after harvest of green gram were found to be non-significant.

CONCLUSION

According to the findings of the current study, a considerable response to sulphur fertilization was found on green gram crop. In comparison to other sulphur sources and levels, the application of S through gypsum at 20 kg/ha proved to be the optimum dose of sulphur for the higher amount of sulphur content, its uptake and nutrient use efficiencies of the crop. It might be due to the fact that, the sulphur when supplied through gypsum became easily soluble and readily available to plants. But the maximum available sulphur in post-harvest soil was recorded with bentonite sulphur at 30 kg S/ha in green gram. Also, the interaction effect of different sulphur sources and levels was found to be non-significant for all the above-mentioned parameters in green gram crop. Hence, Gypsum application at the rate of 20 kg/ha proved to be advantageous to farmers with their significant results on green gram.

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Competing Interests

The authors have affirmed that no competing interests exist.

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