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Interaction Effect of Phosphorus and Sulphur on Yield and Quality of Clusterbean in Typic Haplustept

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Abstract: A pot experiment was carried out to study the phosphrous-sulphur interaction at Department of Agricultural Chemistry and Soil Science, Rajasthan College of Agriculture, Udaipur on a sandy loam soil (Typic Haplustept) medium in P and deficient in S with clusterbean. The treatment consisted of three levels of P (0, 20 and 40 kg P_2O_5 ha^{-1}) and three levels of S (0, 10 and 20 kg ha^{-1}) applied from gypsum and triple superphosphate, respectively. Number and weight of nodules, grain and straw yield, content of P and S were increased with increase in level of P and S individually as well as in various combinations. Applied P and S increased grain nitrogen and protein contents. Available P in soil was increased with increasing levels of phosphorus. Similarly available S in soil was increased with increasing levels of sulphur. The synergistic effect of phosphorus and sulphur was reported on number and weight of nodules $plant^{-1}$, N, P, S and protein content of clusterbean.

Key words: Phosphorus · Sulphur · Interaction · Nodules · Nutrient content · Clusterbean

INTRODUCTION

Clusterbean (*Cyamopsis tetrogonoloba*) is a deep rooted drought hardy crop, source of green fodder, green manuring and lavish Fe and Zn rich green vegetables. Rajasthan the largest area under cultivation of this crop (82.1%) followed by Haryana (8.5%), Gujarat (8.3%) and Punjab (1.0%) with average productivity of 272 kg ha^{-1} in Rajasthan, 881 kg ha^{-1} in Hayana, 522 kg ha^{-1} in Gujarat and 748 kg ha^{-1} in Punjab, respectively [1].

Sulphur interacts with phosphorus as phosphate ion is more strongly bound than sulphate [2]. Phosphorus fertilizer application results in increased of anion adsorption sites by phosphate, which releases sulphate ions into the soil solution [3]. Thus, it may be subjected to leaching if not taken up by plant roots. Studies have indicated both synergistic and antagonistic relationship between sulphur and phosphorus but their relationship depends on their rate of application and crop species [4, 5]. Synergistic effect of applied P and S was observed by Kumawat *et al.* [6] for *taramira*, Kumar and Singh [7] for soybean, Islam *et al.* [8] for rice, Pandey *et al.* [9] for linseed, Chandra Deo and Khaldelwal [10] for chickpea. Antagonistic relationship between P and S was observed in *moong* and wheat by Islam *et al*. [8] and in lentil and chickpea by Hedge and Murthy [2]. The interaction of these nutrient elements may affect the critical levels of available P and S below which response to their application could be observed. Information on effect of combined application of P and S on yield, quality and content of each nutrient in clusterbean is rather limited. Therefore, the present investigation was undertaken to study interactive effects of P and S application on yield and quality of clusterbean.

MATERIALS AND METHODS

A pot experiment was conducted during *Kharif* 2009 at Department of Agricultural Chemistry and Soil Science, Rajasthan College of Agriculture, Udaipur. The experimental soil had pH 8.2, EC 0.48 dSm^{-1} and OC 6.9 g kg^{-1}. Available nitrogen, phosphorus and potassium content in soil were, 427 kg, 23 kg and 345 kg ha^{-1} respectively. Soil was deficient in available sulphur (9.2 mg kg^{-1}) and medium in available phosphorus. Nine treatments consisting of three levels of P (0, 20 and 40 kg P_2O_5 ha^{-1}) and three levels of S (0, 10 and 20 kg S ha^{-1}) were laid in a CRD with four replications. Phosphorus and

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sulphur were applied through diammonium phosphate and gypsum, respectively. Ten seeds of clusterbean were sown in each pot and five plants were maintained after germination. One pot from each treatment was harvested at the time of flowering and root nodules from each pot were counted. At maturity remaining three pots were harvest, seed and straw yields were recorded. Plant samples were colleted for chemical analysis of phosphorus, sulphur and nitrogen in seed and straw samples. In ground seed samples, N was estimated by micro Kjeldahal method as described by Piper [11]. For P and S plant samples were digested in HNO_3:$HClO_4$ (4:1) diacid mixture and P in the extract was determined by vanadomolybdate yellow colour method [12]. Sulphur content in the plant was determined according to method given by Tabatabai and Bremner [13]. Soil samples from every pot were collected for chemical analysis after harvesting the crop. For available P, soil samples were extracted with 0.5M $NaHCO_3$ (pH=8.5) [14] and P content in the extract was determined as described by Jackson [12]. Available S was determined by extracting soil samples with 0.15% $CaCl_2$ [15] and S in the extract was estimated by turbidimetric method [16]. Crude protein was computed by multiplying the nitrogen content with 6.25.The data were statistically analyzed as per the procedure outlined by Gomez and Gomez [17].

RESULTS AND DISCUSSION

Number of Nodules Plant^{-1}: Data presented in Table 1 showed that the application of 40 kg P_2O_5 ha^{-1} increased the number of nodules plant^{-1} by 10.2 and 31.9% over 20 kg P_2O_5 and control. Application of S @ 20 kg ha^{-1} also increased number of nodules plant^{-1} significantly over control and 10 kg ha^{-1}. The increase in number of nodules was 16.6% over control and 9.6% over 10 kg S ha^{-1}. Similar results were also reported by Kachhava *et al.* [18] and Chandra Deo and Khaldelwal [10] in chickpea, Srinivasan *et al.* [19] in black gram and Munshi *et al.* [20] in groundnut. The interaction effect of P and S also significantly influenced number of nodules plant^{-1}. The maximum number of nodules plant^{-1} was reported at the highest level of phosphorus (40 kg P_2O_5 ha^{-1}) along with sulphur (20 kg S ha^{-1}).The increase in number of nodules plant^{-1} might be due to better root development with increasing levels of these nutrients. Phosphorus, being the constituent of nucleic acid and different forms of proteins, might have stimulated cell division resulting in increased growth of plants. Choudhary and Das [21] reported beneficial effect of S by lowering soil pH and improving physical condition of the soil

Table 1: Interaction effect of P and S on number of nodules, weight of nodules and grain, straw yield of clusterbean

	Added S (Kg ha^{-1})			
Added P (P_2O_5 kg ha^{-1})	0	10	20	Mean
Number of nodules plant^{-1}				
0	18.0	18.5	20.0	18.8
20	21.0	22.8	23.8	22.5
40	22.5	24.0	27.8	24.8
Mean	20.5	21.8	23.9	
CD(p=0.05)	P=0.98	S=0.40	P x S=1.15	
Dry weight of nodules (mg plant^{-1})				
0	21.77	22.53	26.63	23.64
20	23.34	25.88	28.84	26.02
40	26.63	29.26	33.39	29.76
Mean	23.91	25.89	29.62	
CD(p=0.05)	P=1.31	S=0.94	P x S=2.10	
Grain Yield (g pot^{-1})				
0	6.96	7.39	7.45	7.27
20	7.85	8.02	8.51	8.13
40	8.43	8.97	9.69	9.03
Mean	7.72	8.13	8.55	
CD(p=0.05)	P=0.10	S=0.05	P x S=0.40	
Straw Yield (g pot^{-1})				
0	11.12	11.77	11.95	11.61
20	12.02	12.92	13.10	12.68
40	12.69	13.79	14.53	13.67
Mean	11.94	12.83	13.19	
CD(p=0.05)	P=0.11	S=0.09	P x S=0.15	

Dry weight of Nodules Plant^{-1}: There was a significant increase in dry weight of nodules with increasing level of both phosphorus and sulphur (Table 1). Applications of 40 kg P_2O_5 ha^{-1} increase the weight of nodules plant^{-1} by 25.9 and 14.4 % over control and 20 kg P_2O_5 ha^{-1}. Application of S @ 20 kg ha^{-1} also increased weight of nodules plant^{-1} significantly over its lower doses; the increase in nodule weight was 14.3 and 23.8% over 10 kg S ha^{-1} and control. Weight of nodules plant^{-1}also influenced significantly by the interaction effect of P and S. The maximum weight of nodules plant^{-1} was observed at the highest level of phosphorus along with highest level of sulphur. The increase in weight of nodules plant^{-1} might be due to better nodulation and more number of nodules plant^{-1}. Konde *et al*. [22] reported that P availability in soil had favourable effect on the nodule formation. Results are in conformity with the findings of Srinivasan *et al.* [19] in black gram and Munshi *et al*. [20] in groundnut.

Table 2: Interaction effect of P and S on nitrogen and protein content in clusterbean

Added P (P_2O_5 kg ha^{-1})	Added S (Kg ha^{-1}) 0	10	20	Mean
Nitrogen (%)				
0	3.62	4.18	4.24	4.01
20	4.46	4.74	5.32	4.84
40	4.87	5.22	5.55	5.21
Mean	4.32	4.71	5.04	
CD(p=0.05)	P=0.11	S=0.05	P x S=0.20	
Protein (%)				
0	22.63	26.13	26.50	25.09
20	27.87	29.63	33.25	30.25
40	30.44	32.19	34.69	32.44
Mean	26.98	29.32	31.48	
CD(p=0.05)	P=0.15	S=0.08	P x S=1.15	

Grain and Straw Yield: With increasing level of both phosphorus and sulphur grain and straw yield of clusterbean were increased significantly (Table 2). The percent increase in grain yield due to phosphorus and sulphur varied from 11.8 to 24.2% and 5.3 to 10.8%, respectively, whereas the straw yield was increased from 9.2 to 17.7% and 7.5 to 10.5%. The magnitude of response was more in case of phosphorus as compared to sulphur. Synergistic effect of phosphorus and sulphur interaction on grain and straw yield was highest at 40 kg P_2O_5 and 20 kg S ha^{-1}. The magnitude of increase in grain and straw yield was 22.8 and 18.6% due to combined application of phosphorus and sulphur 40 kg P_2O_5 and 20 kg S ha^{-1} over control, respectively. The synergistic effect of P and S may be due to utilization of high quantities of nutrients through their well developed root system and nodules which might have resulted in better growth and yield at medium. These results confirm the earlier findings of Nagar *et al*. [23] in soybean, Sinha *et al*. [5] in winter maize, Choudhary and Das [21] in black gram, Shankaralingappa *et al.* [24] in cowpea, Randhawa and Arora [25] in wheat, Teotia *et al.* [26] in moong bean, Kumawat *et al.* [6] in *taramira* and Islam *et al.* [8] in rice. Kumar and Singh [7] with soybean reported a suitable balance between P and S for producing increased yield. Aulakh *et al.* [27] and Singh *et al.* [28] have shown that nature of P and S interaction depends on their rates of application.

Nitrogen and Protein Content: Nitrogen content (Table 2) was significantly increased with the increase in level of P and S. Dwivedi and Bapat [29] reported that nitrogen content in soybean increased significantly by P and S application up to 50 kg $ha^{-1}$of each nutrient. The interaction of P and S was significant and maximum nitrogen content was recorded at 40 kg P_2O_5 and 20 kg S ha^{-1}.Protein content in clusterbean grain was increased significantly with application of P and S individually as well as in combination (Table 2). The maximum increase in protein content (34.69 %) was obtained with 40 kg P_2O_5 and 20 kg S ha^{-1} together. Protein was increased by 53.29% over control. The response to applied P with respect to protein content in clusterbean is attributed to more nitrogen fixation. Similar results were also reported by Shankaralingappa *et al.* [30] in cowpea and Kumawat *et al.* [6] in *taramira*. Increasing doses of sulphur application resulted in a significant increase in protein content of clusterbean. The positive response to added sulphur is assigned to low status of available S of soil or due to stimulating effect of applied sulphur in the synthesis of chloroplast protein resulting in greater photosynthetic efficiency which in turn translated in term of increased yield. Dwividi and Bapat [29] reported significant increase in the protein content of soybean with application of P and S up to 50 kg ha^{-1} over control. The findings are similar to Jogendra-Singh *et al.* [31] in summer *moong* and Srinivasan *et al.* (2000) in black gram.

Phosphorus and Sulphur Content: With increasing in level of S from 0 to 10 and 10 to 20 kg ha^{-1}, P and S content in grain and straw were increased significantly. Similarly P and S contents were increased significantly with increasing levels of phosphorus from 0 to 20 and 20 to 40 kg P_2O_5 ha^{-1}.The combined application of 40 kg P_2O_5 and 20 kg S ha^{-1} significantly increased P and S content in grain and straw (Table 3). Phosphorus content in clusterbean ranged from 0.23 to 0.37% in grain and 0.12 to0.26% in straw, while S content raged from 0.30 to 0.40% in grain and 0.10 to 0.13% in straw. Similar results were reported by Teotia *et al.* [26] and Islam *et al.* [8] in mungbean, Singh and Singh [32] in black gram and Chandra Deo and Khaldelwal [10] in chickpea.

Available Phosphorus and Sulphur: The results presented in Table 4 showed that the available P was increased consistently with increasing in level of phosphorus; P content in soil increased from 22.3 kg ha^{-1} in control to 32.9 kg P_2O_5 ha^{-1} with application of 40 kg P_2O_5 ha^{-1}. Similar results were also reported by Balaguravaish *et al.* [33] and Chandra Deo and Khaldelwal [10]. Application of S did not affect the available P significantly in the soil but it tends to increase with

Table 3: Interaction effect of P and S on P and S content in grain and straw of clusterbean

Added P (P_2O_5 kg ha^{-1})	Added S (Kg ha^{-1}) 0	10	20	Mean
P content in grain (%)				
0	0.23	0.27	0.30	0.27
20	0.32	0.33	0.34	0.33
40	0.35	0.36	0.37	0.36
Mean	0.30	0.32	0.34	
CD(p=0.05)	P=0.02	S=0.01	P x S=0.03	
S content in grain (%)				
0	0.296	0.348	0.375	0.340
20	0.309	0.366	0.385	0.353
40	0.354	0.378	0.395	0.376
Mean	0.320	0.364	0.385	
CD(p=0.05)	P=0.004	S=0.002	P x S=0.009	
P content in straw (%)				
0	0.124	0.132	0.143	0.133
20	0.189	0.203	0.212	0.201
40	0.231	0.244	0.263	0.246
Mean	0.181	0.193	0.206	
CD(p=0.05)	P=0.006	S=0.003	P x S=0.025	
S content in straw (%)				
0	0.102	0.109	0.119	0.110
20	0.111	0.121	0.122	0.118
40	0.116	0.125	0.128	0.123
Mean	0.110	0.118	0.123	
CD(p=0.05)	P=0.002	S=0.002	P x S=0.003	

Table 4: Interaction effect of P and S on the available phosphorus and sulphur in soil

Added P (P_2O_5 kg ha^{-1})	Added S (Kg ha^{-1}) 0	10	20	Mean
Phosphorus (Kg ha^{-1})				
0	22.36	22.32	22.14	22.27
20	25.72	25.75	26.08	25.85
40	32.64	32.85	33.18	32.89
Mean	26.91	26.97	27.13	
CD(p=0.05)	P=1.5	S=NS	P x S=NS	
Sulphur (Kg ha^{-1})				
0	9.12	10.87	13.64	11.21
20	8.86	11.05	14.09	11.33
40	8.83	11.35	14.15	11.44
Mean	8.94	11.09	13.96	
CD(p=0.05)	P= NS	S=1.2	P x S= NS	

increasing level of sulphur. Application of S significantly increased the available S content in the soil and increase was 56 and 24% with the application of 20 kg and 10 kg S ha^{-1} over control. Kothari and Jethra [34] and Chandra Deo and Khaldelwal [10] also reported that the available sulphur was increased with increasing levels of sulphur application. Phosphorus application had no effect on sulphur content of the soil. The findings are similar to Chandra Deo and Khaldelwal [10], reported that application of 60 kg P_2O_5 ha$^{-1,}$ had no effect on sulphur content of the soil.

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