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Response of Cluster Bean [*Cyamopsis tetragonoloba* (L.) Taub.] to Phosphorus and Sulphur in Torripsamments of Rajasthan, India

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A B S T R A C T

The present investigation was carried out during kharif season 2014 to assess the effect of different levels of phosphorus and sulphur on growth, yield attributes and yield. The experiment comprising 16 treatment combinations replicated three times, with four levels of phosphorus (Control, 20, 40 and 60 kg P_2O_5 ha^{-1}) and four levels of sulphur (0, 15, 30 and 45 kg S ha^{-1}), respectively. Application of phosphorus upto 40 kg ha^{-1} significantly increased total and effective root nodules per plant, total leaf chlorophyll content, number of pods per plant, number of seeds per pod, test weight, seed yield, straw yield, protein content, gum content and gum yield. Whereas, the total and effective root nodules per plant, total leaf chlorophyll content, number of pods per plant, number of seeds per pod, test weight, seed yield, straw yield, protein content, gum content and gum yield significantly increased by application of 45 kg S ha^{-1}over control, 15 and 30 kg S ha^{-1}.

Introduction

Cluster bean is mainly grown under rainfed conditions in arid and semi-arid regions of tropical India due to the hardy nature and suitability to poor soil and moisture stress conditions. Guar seeds are mainly used for extraction of endospermic gum having good binding properties and have high demand in food industry as an ingredient in products like sauces and ice creams etc. Further in textile and juice industry, guar gum is used for sizing and as a thickener and stabiliser.

In varnish industry, it is used as a protective colloid. Guar gum has also greater utility in pollution control and acts as absorbent in waste water treatment in textile industry as a flocculating and exchanging agent. Besides having high caloric and nutritive value, pods of cluster bean are also used as medicine for diabetic patients. The roasted guar is used as feed for pigs and poultry. Phoaphorus plays an important role in metabolic activity phosphates like, ADP, ATP, nucleic acid, nucleoprotein, purines, pyrimidines, nucleotides, many enzymes and coenzymes *viz*. NADP, NADH, pyridoxl phosphate and thiamine phosphate. The most essential constituents of plant like esters, phospholipids and phosphatides are synthesized by phosphorus when it combines with different organic acids, transformation of energy in carbohydrate metabolism, oxidation and reduction process and also in respiration of plant. Sulphur plays an important role in synthesis of chlorophyll and constituent of amino acids *viz*. cysteine, cystine and methionine, vitamins (biotins and thiamine), coenzymes and volatile.

Sulphur promotes nodulation in legumes and favors solubilization of organic nitrogen and decrease the quantity of insoluble nitrogen resulting in reduction of sulphur. Sulphur. Sulphur interacts with phosphorus as phosphate ion is more strongly bound than sulphate (Hedge and Murthy, 2005). Phosphorus fertilizer application results in increase of anion adsorption sites by phosphate, which releases sulphate ions into the soil solution (Tiwari and Gupta, 2006). Studies have indicated both synergistic and antagonistic relationship between sulphur and phosphorus.

Materials and Methods

A field experiment was conducted in sandy soil at Agronomy Farm, College of Agriculture, Bikaner during *kharif* season of 2014. Sixty treatment combinations comprising of four levels of phosphorus (0, 20, 40 and 60 kg P_2O_5 ha^{-1}) and four levels of sulphur (0, 15, 30 and 45 kg S ha^{-1}) were tested. The treatments were replicated three times in factorial RBD. In this way, 16 treatment combinations were allocated randomly to different plots by using random number from the table of Fisher (1950). The phosphorus was applied as per the treatments through DAP containing 46 per cent P_2O_5. Nitrogen containing in DAP was adjusted with urea. Sulphur was applied through elemental sulphur as per treatment. The whole quantity of sulphur was applied 25 days before sowing. The variety RGC 1066 of clusterbean was used as the test crop. The seeds were sown by pora method @ 20 kg ha^{-1} on 28th July, 2014. Fresh leaves of plant collected at 45 DAS to estimate chlorophyll 'a' and chlorophyll 'b' contents (Arnon, 1949). Protein content in seed was determined by multiplying per cent nitrogen in seed with a constant factor 6.25 (A.O.A.C., 1960), Gum content in seed was determined by Phenol-sulphuric acid method (Das, *et al.,* 1977).

Results and Discussion

Effect of phosphorus

Growth parameters

Phosphorus application upto 40 kg P_2O_5 ha^{-1} significantly increased the total and effective root nodules per plant and total chlorophyll content in leaves at 45 DAS (Table 1). It plays an important role in conservation and transfer of energy in metabolic reactions of living cells including biological energy transformations. The increase in photosynthetic activity in plant led to overall development in terms of growth. Thus, phosphorus fertilization enhanced the photosynthesis and other metabolic processes in the plant which ultimately enhanced growth in terms of number of branches per plant and total leaf chlorophyll content.

These results are in close conformity with those of Ayub *et al.,* (2013).This might be attributed to the optimum supply of available phosphorus to the plants resulting in better development of root nodules because rhizobium is an aerobic bacteria and leghaemoglobin provide oxygen to bacteriods.

Laghaemoglobin content of nodules probably increased due to application of phosphorus and it consistently made the nodules effective (Banasri *et al.*, 1989).

Yield attributes and yield

Yield attributes *viz.*, pods per plant, seeds per pod and test, seed yield and straw yield was also significantly increased with the application of phosphorus upto 40 kg kg P_2O_5 ha^{-1} (Table 1).

This might be attributed to the role of phosphorus in root development and proliferation, nodules formation and N_2 fixation by supplying assimilates to the roots. It is the main constituent of energy rich phosphate molecules *viz.* ATP and ADP which acts as "energy currency" within plants. Synchronized with the demand of crop for formation of more reproductive structure and thus might have favored the yield attributes *viz.* number of pod per plant, number of seed per pod and test weight. These results are in agreement to the findings of Meena and Sharma (2001), and Shivran (2004).

Effect on quality

The protein content increased significantly with increasing levels of phosphorus upto 40 kg P_2O_5 ha^{-1} (Table 2). Better root development and increased *Rhizobium* multiplication resulted in better utilization of soil and atmospheric nitrogen with the increasing levels of phosphorus and thereby nitrogen content of seed increased.

The reason behind the improvement of protein content might be that it is a function of nitrogen content, phosphorus being an energy source also plays an important role in protein synthesis. Similarly, fertilization with phosphorus enhanced the protein content in seed, which may be due to more protein synthesis in the presence of phosphorus and the formation of some stable phosphoprotein compounds. Gum content increased due to the fact that carbohydrates synthesis of phospholipids and nucleic acids. Since, gum yield is function of seed yield as well as gum content, the significant increase in content of the nutrients coupled with increased seed yield increased the gum yield substantially These results are in close conformity with the findings of Solanki and Sahu (2007) and Tiwari *et al.*, (2014).

Effect of sulphur

Growth parameters

Application of sulphur upto 45 kg ha^{-1} significantly increased the total leaf chlorophyll content, total and effective root nodules per plant at 45 DAS (Table 1).

It is well established fact that sulphur plays pivotal role in several physicological and biochemical processes which are of vital importance for growth and development of plants. Sulphur is main constituent of sulphur containing amino acids (cysteine, cystine and methionine), thus, it influence synthesis of protein, chlorophyll and vitamins etc. (Imsande, 1998). Rennenberg and Lomoureux (1990) reported that sulphur is one of the most important constituent of glutathion (glutamyl – cysteinyl – glycine) which though not a primary product of cellular metabolism, plays important role in detoxification of compounds, which are not favorable for growth. Sulphur being a constituent of succinyl Co enzymes-A which involved in chlorophyll formation and creates a balanced nutritional environment in the plant system in keeping the micronutrients physiologically active, has been very instrumental in increased chlorophyll synthesis in plant tissues. These findings are in close conformity with those of Choudhary *et al.*, (2006) and Kumar and Kumar (2013).

Table.1 Effect of phosphorus and sulphur on growth yield attributes and yield of clusterbean

Treatments	Total leaf chlorophyll content (mg g^{-1})	Total root nodules per plant	Effective root nodules per plant	Number of pods per plant	Number of seeds per pod	Test weight (g)	Yield (kg ha^{-1})	
							Seed	Straw
Phosphorus (kg P_2O_5 ha^{-1})								
0	2.11	30.26	24.26	32.35	6.08	23.97	1112.42	2985.36
20	2.24	32.74	26.24	35.32	6.58	25.61	1181.08	3192.21
40	2.33	34.65	27.65	38.06	6.99	26.82	1238.75	3362.13
60	2.37	35.48	28.15	38.66	7.17	27.32	1252.33	3402.05
S.Em. ±	0.02	0.54	0.44	0.49	0.12	0.38	18.72	50.60
C.D. (P=0.05)	0.07	1.56	1.27	1.42	0.36	1.09	54.06	146.16
Sulphur (kg S ha^{-1})								
0	2.11	29.67	23.96	32.86	5.98	23.56	1092.17	2932.04
15	2.22	32.38	25.87	35.31	6.51	25.32	1169.92	3155.07
30	2.32	34.68	27.57	37.34	6.97	26.83	1233.33	3345.38
45	2.40	36.41	28.90	38.89	7.35	28.01	1289.17	3509.26
SEm±	0.02	0.54	0.44	0.49	0.12	0.38	18.72	50.60
C.D. (P=0.05)	0.07	1.56	1.27	1.42	0.36	1.09	54.06	146.16

Table.2 Effect of phosphorus and sulphur on quality attributes of clusterbean

Treatments	Protein content in seed (%)	Gum content in Seed (%)	Gum yield (kg ha^{-1})
Phosphorus (kg P_2O_5 ha^{-1})			
0	19.70	25.94	289.64
20	21.32	27.46	325.33
40	22.54	28.42	352.94
60	23.05	28.83	362.09
S.Em. ±	0.33	0.28	6.52
C.D. (P=0.05)	0.94	0.80	18.84
Sulphur (kg S ha^{-1})			
0	19.34	25.84	282.72
15	21.15	27.16	318.82
30	22.52	28.37	350.46
45	23.59	29.29	378.00
SEm±	0.33	0.28	6.52
C.D. (P=0.05)	0.94	0.80	18.84

Yield attributes and yield

Successive increase in sulphur fertilization up to 45 kg ha^{-1} tended to increase number of pods per plant, number of seeds per pod and test weight of clusterbean. Consequently, the crop fertilized with 45 kg S ha^{-1} produced significantly higher seed and straw yields (Table 1). The favourable effects thus led to increased translocation of photosynthates towards seeds resulting in formation of bold seeds. Cumulative effect of improvement of growth parameters through efficient metabolic activity and increased rate of photosynthesis led to maximum expression of yield. With increasing supply of sulphur the process of tissue differentiation from somatic to reproductive, meristematic activity and development of floral primordial might have increased, resulting in more flowers and pods. In clusterbean sink lies in pods and seed. When supply of sulphur is optimum, greater translocation of photosynthate occur from leaves to the sink site *i.e.* pods and seeds, resulting in robust pods and better seeds. The sum total effect will be higher seed yield (Singh and Verma, 1989). Increase in straw yield can be ascribed due to overall improvement in plant organs associated with faster and uniform vegetative growth of the crop under the effect of sulphur over control. Results of present study corroborate with the findings of Karche *et al.*, (2012) and Ramawtar *et al.*, (2013).

Effect on quality

Significant increase in protein, gum content and gum yield of clusterbean were also noted with the application of sulphur upto 45 kg ha^{-1} (Table 2). It might be due to increased availability of sulphur to plants which formed increased nitrogen absorption from soil. Because protein is a function of nitrogen content, as nitrogen content of seed increased with the application of sulphur the protein content also increased. Sulphur synthesized some sulphur containing amino acids like cystine, cysteine and methionine, resulting in synthesis of more protein (Bapat *et al.,* 1984 and Pareek, 1995). The gum content in seed increased due to increasing nutrient uptake with the addition of sulphur. Gum is formed in the seed of clusterbean with the fat metabolism and formation of sulpholipids and protein content in seed increased the endosperm of seed which indirectly enhanced the gum content in seed (Kaushik *et al.*, 1996). The results of present investigation corroborate with the findings of Tiwari *et al.*, (2014).

It may be concluded that application of 40 kg P_2O_5 ha^{-1} and 45 kg S ha^{-1} gave highest seed and straw yield of clusterbean. Application of 40 kg P_2O_5 ha^{-1} and 45 kg S ha^{-1} also gave significant higher growth, yield attribute, protein content, gum content and gum yield in seed, respectively.

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