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Kiran Yadav
Ph.D., Scholar, Department of Soil Science and Agricultural Chemistry, College of Agriculture, JAU, Junagadh, Gujarat, India

SR Naga
Retd. Professor, Department of Soil Science and Agricultural Chemistry, S.K.N. Agriculture University, Jobner, Rajasthan, India

Corresponding Author:
Kiran Yadav
Ph.D., Scholar, Department of Soil Science and Agricultural Chemistry, College of Agriculture, JAU, Junagadh, Gujarat, India

Response of phosphorus and sulphur on yield attributes, yield and quality of clusterbean [*Cyamopsis tetragonoloba* (L.) Taub]

Kiran Yadav and SR Naga

Abstract
A field experiment was conducted during Kharif 2017 at Agronomy farm, S.K.N. College of Agriculture, Jobner, Jaipur (India). The experiment was conducted in RBD with three replications. The experiment consist of 16 treatment combinations in which P and S were applied in four different levels each of phosphorus (0, 20, 40 and 60 kg P_2O_5 ha^{-1}) and sulphur (0, 20, 40 and 60 kg S ha^{-1}). The variety of test crop (clusterbean) was RGC-1038. Based on the research investigation it was found that the application of phosphorus @ 40 kg ha^{-1} recorded maximum increase in number of pods per plant, number of seeds per pod, seed yield, straw yield, gum content and protein content as compared to other treatments such as control and P_{20}. The treatment P_{40} and P_{60} were remained statistically at par. The increasing levels of sulphur upto 40 kg ha^{-1} significantly increased the number of pods per plant, number of seeds per pod, seed yield, straw yield, gum content and protein content in seeds of clusterbean as compared to control and S_{20}.

Keywords: Clusterbean, phosphorus, sulphur, gum, protein and yield

1. Introduction

Clusterbean [*Cyamopsis tetragonoloba* (L.) Taub] popularly known as “Guar” is an important legume crop mainly grown under rainfed condition in arid and semi-regions of Rajasthan during kharif season. The word “guar” represent its derivation from Sanskrit word “Gauaahar” which means cow fodder or otherwise fodder of the livestock.

In India, clusterbean is grown for its green fodder and for the pods that are used for food and feed. Since it is a legume, it has soil enriching properties. There is no other legume crop so hardy and drought tolerant as cluster bean, which is especially suited for soil and climate of Rajasthan. In India, cluster bean is mostly grown in Rajasthan, Haryana, Punjab, Uttar-Pradesh and Madhya-Pradesh. Rajasthan occupies first position in India both in area and production. It accounts for almost 82.1% area and 70% production in India. In Rajasthan the guar area is 29.39 lakh hectare with the production of 14.25 lakh tonnes (Anonymous 2016-17) [2]. The use of guar gum has increased tremendously, as it is the natural absorbent. Guar gum is a endosperm that contains, gum, a substance which forms a gel in water. The India’s contribution is around 75-80% in world’s total production. 70% of India’s production comes from Rajasthan. According to APEDA sources, during the year 2016-17, there has been a total export of 4,23,283 tonnes of guar gum from the country. Guar gum is used in dairy products like ice cream and as a stabilizer in cheese and cold meat processing, as it is partially hydrolyzed, gum completely soluble in water and soft food. The beneficial effects of phosphorus on nodulation, growth and yield of legume crops have been well established because apart from important role in root development, phosphorus is necessary for growth of rhizobium bacterial, responsible for nitrogen fixation in nodules. Phosphorus application to legumes not only benefits the current crop but also favourably affects the suceeding non-legume crop. It also improve the crop quality and its resistance to diseases. It is a part of ADP, ATP, nucleic acid nucleoproteins, purine, pyrimidine, nucleotides, flavin nucleotides and many co-enzymes *viz*; NADP, pyridoxyl phosphate and thiamine phosphate. Fixation of atmospheric N in leguminous crops is an energy-intensive process which needs phosphorus supply to meet its ATP requirement.

Sulphur plays an important role in many plant physiological processes like synthesis of sulphur containing amino acids (cystine, cysteine and methionine), synthesis of certain vitamins (biotine and thiamine), and coenzyme-A, metabolism of carbohydrates, proteins and fats. Sulphur application increases drought and cold tolerance in plant due to the process of disulphide linkage. It also helps in control of diseases and pests.

Material and Methods

The field experiment was conducted at Agronomy farm, S.K.N College of Agriculture Jobner, Jaipur (Rajasthan). The Agronomy farm is situated at 750 28' East longitude and 260 08' North latitude and 427m above mean sea level. This region falls under Agro-climatic zone-IIIA (Semi-Arid Eastern Plains) of Rajasthan. The experimental soil was loamy sand in texture with high infiltration rate and saturated hydraulic conductivity. The experiment consisted 16 treatment combinations comprising of four levels each of phosphorus (0, 20, 40 and 60kg P_2O_5 ha^{-1}) and sulphur (0, 20, 40 and 60kg S ha^{-1}) was laid out in randomized block design and replicated thrice. The variety of Clusterbean used as a test crop was RGC-1038.

Yield attributes and yield

Number of pods per plant

Average number of pods per plant was recorded at harvest on the basis of five randomly selected plants from each net plot.

Number of seeds per pod

Ten pods were randomly selected from each plot from previously selected plants and number of seeds per pod was counted and average value was calculated.

Test weight

1000 seeds were counted from seed sample taken from seed yield of each plot separately and weighed on electrical balance. The weight was recorded as test weight of respective treatment.

Seed yield

The produce of each net plot was threshed out separately, cleaned and weighted separately and the seed yield was recorded and it was converted into kilogram per hectare (kg ha^{-1}).

Straw yield

Straw yield was obtained by subtracting the seed yield of each net plot from respective total dry matter and converted into kilogram per hectare (kg ha^{-1}).

Quality parameters

Protein content (%): The protein content in seed was worked out by multiplying nitrogen content in the seed (percent) with the constant factor 6.25 (A.O.A.C., 1960) [1].

Gum content (%)

The seed samples were analysed for gum content by phenol sulphuric acid method (Das *et al*. 1977) [4].

Results and discussion

Yield attributes and yield

Number of pods per plant

The effect of treatments (P, S) on number of pods per plant and seeds per pod is depicted in the table-1.

Effect of phosphorus

A perusal of data presented in table-1 revealed that increasing levels of phosphorus upto 40 kg P_2O_5 ha^{-1} significantly increased the number of pods per plant. Application of 40 kg P_2O_5 ha^{-1} brought significant increase in number of pods per plant over control and 20 kg P_2O_5 by 15.62 and 7.26 percent, respectively. However, the application of 40 kg P_2O_5 ha^{-1} and 60 kg P_2O_5 ha^{-1} remained statistically at par with each other.

Effect of sulphur

Data further revealed that increasing level of sulphur upto 40 kg S ha^{-1} significantly increased the number of pods per plant at harvest but being statistically at par with 60 kg S ha^{-1}. Application of 40 kg S ha^{-1} increased the number of pods per plant by 18.87 and 7.19 percent over control and 20 kg S ha^{-1}, respectively.

Seeds per pod

Effect of phosphorus

It is evident from the data given in table-1 showed that increasing level of phosphorus upto 40 kg P_2O_5 ha^{-1} significantly enhanced the seeds per pod of clusterbean. Application of 40 kg P_2O_5 ha^{-1} representing an increase of seeds per pod by 26.87 and 16.08 percent over control and 20 kg P_2O_5 ha^{-1}, respectively. However, treatment P_{40} and P_{60} were differed non significantly.

Effect of sulphur

Data further indicated that application of sulphur level upto 40 kg S ha^{-1} significantly influenced the seeds per pod of clusterbean. Application of 40 kg S ha^{-1} brought significant increase in number of seeds per pod over control and 20 kg S ha^{-1} by 24.08 and 12.58 percent, respectively. The treatment S_{40} was found statistically at par with the treatment S_{60}.

Table 1: Effect of phosphorus and sulphur on number of pods per plant and seeds per pod

Treatments	Number of pods per plant	Number of seeds per pod
Phosphorus (P_2O_5)		
P_0	27.58	7.85
P_{20}	29.73	8.58
P_{40}	31.89	9.96
P_{60}	32.44	10.50
S.Em+	0.66	0.20
CD (P=0.05%)	1.91	0.59
Sulphur		
S_0	27.07	7.93
S_{20}	30.02	8.74
S_{40}	32.18	9.84
S_{60}	32.37	10.38
S.Em+	0.66	0.20
CD (P=0.05%)	1.91	0.59

Seed yield
The effect of P and S applied at various levels on seed and straw yield is presented in table-2.

Effect of phosphorus
The data presented in table-2 showed that application of phosphorus had significant favourable effect on seed yield of clusterbean. Increasing levels of phosphorus upto 40 kg P_2O_5 ha^{-1} significantly increased the seed yield of clusterbean (1118 kg ha^{-1}) which was significantly superior to control and 20 kg P_2O_5 ha^{-1} but remained at par with 60 kg P_2O_5 ha^{-1}. Application of 40 kg P_2O_5 ha^{-1} represented an increase of seed yield over control and 20 kg P_2O_5 ha^{-1} by 34.69 and 10.80 percent, respectively.

Effect of sulphur
Data given in same table further showed that application of 40 kg S ha^{-1} resulted in significantly higher seed yield of clusterbean (1135 kg ha^{-1}) over control and 20 kg S ha^{-1}, which was found at par with 60 kg S ha^{-1}. Application of 40 kg S ha^{-1} (S_{40}) significantly increased the seed yield of clusterbean by 47.21 and 9.55 percent over S_0 and S_{20}, respectively.

Straw yield
Effect of phosphorus
It is evident from the data (Table-2) that progressive and significant improvement in straw yield of clusterbean (2651 kg ha^{-1}) was recorded with increasing levels of phosphorus upto 40 kg ha^{-1}. Application of 40 kg P_2O_5 ha^{-1} significantly increased the straw yield over control and 20 kg P_2O_5 ha^{-1} by 20.17 and 7.54 percent, respectively. The application of 40 kg P_2O_5 ha^{-1} and 60 kg P_2O_5 ha^{-1} were differed non significantly.

Effect of sulphur
Data further showed that the effect of application of sulphur on straw yield of clusterbean (2747 kg ha^{-1}) was found significant with increasing levels of sulphur upto 40 kg ha^{-1}, which was increased the straw yield by 40.36 and 7.30 percent over control and 20 kg S ha^{-1}, respectively. The levels of sulphur @ 40 kg S ha^{-1} and 60 kg S ha^{-1} were found statistically at par.

Test weight

Table 2: Effect of phosphorus and sulphur on seed, straw yield and test weight of clusterbean

Treatments	Seed yield (kg/ha)	Straw yield (kg/ha)	Test weight (g)
Phosphorus (P_2O_5)			
P_0	830	2206	24.30
P_{20}	1009	2465	26.68
P_{40}	1118	2651	28.46
P_{60}	1146	2721	29.12
S.Em+	24	63	0.56
CD (P = 0.05%)	70	182	1.61
Sulphur			
S_0	771	1957	24.29
S_{20}	1036	2560	26.01
S_{40}	1135	2747	28.82
S_{60}	1161	2780	29.44
S.Em+	24	63	0.56
CD (P = 0.05%)	70	182	1.61

Effect of phosphorus
Data given in table-2 revealed that increasing levels of phosphorus significantly increased the test weight. Application of 40 kg P_2O_5 ha^{-1} resulted in significantly maximum test weight over control and 20 kg P_2O_5 $ha^{-1}$by 17.11 and 6.67 percent, respectively. The level 40 kg P_2O_5 ha^{-1} was remained statistically at par with the level 60 kg P_2O_5 ha^{-1}.

Effect of sulphur
Data presented in same table further indicated that application of sulphur levels upto 40 kg S ha^{-1} significantly increased the test weight, which was found at par with 60 kg S ha^{-1}. Application of sulphur @ 40 kg ha^{-1} significantly increased the test weight by 18.64 and 10.80 percent over control and 20 kg S ha^{-1}, respectively.
Increasing levels of phosphorus significantly increased the seed yield which could attributed to the role of phosphorus in legume growth by promoting extensive root development, nodulation, proper growth and seed yield, which is known to extract water and nutrient from deeper depth. This might be attributed to the role of phosphorus in root development and proliferation, nodules formation and N2 fixation by supplying assimilates to the roots. These results are in agreement with the findings of Meena *et al.*, (2002) [9], Kumawat and Khangarot (2012) [8], Karche *et al.*, (2012) [6], Singh and Chauhan (2015) [16], Rani *et al.*, (2016) [13] and Raiger *et al.*, (2017) [11].
Fertilizing the crop with sulphur significantly increased yield attributes and yield of clusterbean crop (Table-1 & 2) over no sulphur application. This might be also due to cumulative effect of improvement of growth parameters through efficient metabolic activity and increased rate of photosynthesis which might led to maximum expression of yield. Results of present study corroborate with the findings of Saxena *et al.*, (2003) [14], Nagar and Meena (2004) [10], Gandhi and Shankhela (2005) [5], Karche *et al.*, (2012) [6], Ramawtar *et al.*, (2013) [12] and Raiger *et al.*, (2017) [11].

Quality Parameters
The influence of treatments on the protein content and gum content in seed and gum yield is depicted in table-3.

Protein content
Effect of phosphorus
It is evident from the data given in table-3 showed that phosphorus application had significant improvement in protein content of seed. Protein content of seed increased significantly with increase in phosphorus levels upto 40 kg P_2O_5 ha^{-1} but remained statistically at par with application of

60 kg P_2O_5 ha^{-1}. Application of 40 kg P_2O_5 ha^{-1}recorded significantly increased the protein content in seed by 18.80 and 8.15 percent over control and 20 kg P_2O_5 ha^{-1}, respectively.

Effect of sulphur

Data presented in same table further indicated that the beneficial effect of sulphur application was observed resulting in significantly increase in protein content in seed upto the level 40 kg S ha^{-1}. The maximum protein content in seed was observed under 40 kg S ha^{-1} and registered 21.91 and 8.96 percent higher protein content in seed over control and 20 kg S ha^{-1}, respectively.

Gum content

Effect of phosphorus

Data indicated that increasing levels of phosphorus upto 40 kg P_2O_5 ha^{-1} significantly increased the gum content in seeds of clusterbean. However, the application of phosphorus @ 40 and 60 kg P_2O_5 ha^{-1} were remained statistically at par to each other. Application of 40 kg P_2O_5 ha^{-1} recorded significantly higher gum content in seed over control and 20 kg P_2O_5 ha^{-1} by 16.72 and 7.73 percent, respectively.

Effect of sulphur

Data further showed that the increasing levels of sulphur upto 40 kg S ha^{-1} significantly increased the gum content in clusterbean seeds. The application of 40 kg S ha^{-1} significantly enhanced the gum content over control and 20 kg S ha^{-1} by 17.41 and 8.13 percent in seed. The application of sulphur @ 40 and 60 kg S ha^{-1} were remained statistically at par to each other.

Gum yield

Effect of phosphorus

It is evident from the data that application of phosphorus had significant favourable effect on gum yield of clusterbean. Increasing levels of phosphorus upto the level 40 kg P_2O_5 ha^{-1} significantly increased the gum yield (369.80 kg ha^{-1}) which was significantly superior to control and 20 kg P_2O_5 ha^{-1} but remained statistically at par with 60 kg P_2O_5 ha^{-1}. Application of 40 kg P_2O_5 ha^{-1} represented an increase of gum yield over control and 20 kg P_2O_5 ha^{-1} by 57.22 and 19.37 percent, respectively.

Effect of sulphur

Application of 40 kg S ha^{-1}significantly higher the gum yield (372.51 kg ha^{-1}) over control and 20 kg S ha^{-1}, which was found significantly at par with 60 kg S ha^{-1}. The increase in level of sulphur of upto 40 kg S ha^{-1} significantly increased the gum yield by 72.84 and 18.46 percent over S_0 and S_{20}, respectively.

Table 3: Effect of phosphorus and sulphur on protein content, gum content and gum yield at harvest

Treatments	Protein content (%)	Gum content (%)	Gum yield (kg/ha)
Phosphorus (P_2O_5)			
P_0	20.31	28.04	235.20
P_{20}	22.31	30.38	309.78
P_{40}	24.13	32.73	369.80
P_{60}	24.38	32.90	381.03
S.Em+	0.31	0.80	8.67
CD (P=0.05%)	0.89	2.30	25.04
Sulphur			
S_0	19.94	27.74	215.52
S_{20}	22.31	30.12	314.44
S_{40}	24.31	32.57	372.51
S_{60}	24.56	33.62	393.33
S.Em+	0.31	0.80	8.67
CD (P=0.05%)	0.89	2.30	25.04

The protein content in seed increased significantly with increasing levels of phosphorus upto 40 kg P_2O_5 ha^{-1} (Table-3). This might be due to enhanced uptake and translocation of nitrates which provide nitrogen for amino acid synthesis. Moreover, phosphorus is involved in the synthesis of ATP that is required in N uptake and protein synthesis. Similar results were also observed by Shankaralingappa *et al*., (2000) [15] in cowpea, Yadav (2011) [19] and Yadav *et al*., (2014) [21] in clusterbean. Significant increase in gum content and gum yield of clusterbean were also noted with the application of phosphorus upto 40 kg P_2O_5 ha^{-1} (Table-3). 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), Tiwari *et al*., (2014) and Raiger *et al*., (2017) [17, 18, 11]. Significant increase in protein, gum content and gum yield of clusterbean were also noted with the application of sulphur upto 40 kg ha^{-1} (Table-3). 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. The results of present investigation corroborate with the findings of Baviskar *et al*., (2011) [3], Kumar *et al*., (2012) [7], Yadav *et al*., (2012) [20], Tiwari *et al*., (2014) [18].

Conclusion

Based on the experimental results, it was concluded that the significantly maximum number of pods per plant, number of seeds per pod, test weight, seed yield and straw yield were obtained under the treatment 40 kg P_2O_5 ha^{-1}. Application of 40 kg P_2O_5 ha^{-1} gave significantly maximum protein content and gum content in seed and gum yield of clusterbean but the treatment P_{40} and P_{60} remained statistically at par.

Application of sulphur @ 40 kg ha^{-1} significantly increased the number of pods per plant, number of seeds per pod, test weight, seed yield, straw yield, protein content, gum content and gum yield and proved significantly superior over lower levels of sulphur but it was remained statistically at par with 60 kg S ha^{-1}.

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