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Effect of Zinc and Sulphur on Growth, Yield and Economics of Clusterbean [*Cyamopsis tetragonoloba* (L.) Taub.]

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A B S T R A C T

A field experiment was conducted during *Kharif* 2015 at cotton research station, Sirsa, CCS HAU, Hisar (India). The experiment was conducted in RBD with three replications. The experiment consist of 16 treatments in which N and P were applied as per recommended dose (N= 20 kg/ha, P_2O_5= 40 kg/ha) along with different doses of Zn (10, 20 and 30 kg/ha) and S (20, 30 and 40 kg/ha) and their combinations. Growth parameters *viz.* plant population, plant height and dry matter accumulation were recorded maximum in T_{16} (N @ 20 kg + P_2O_5 @ 40 kg+ $ZnSO_4$ @ 30 kg + S @ 40 kg/ha). Yield attributes *viz*. no. of pods/plant, no. of grains/pod, Yield *viz*. grain and straw yield were also recorded highest in T_{16}, while maximum harvest index was observed in T_8 (N @ 20 kg + P_2O_5 @ 40 kg+ $ZnSO_4$ @10 kg + S @ 20 kg/ha) and highest 1000 grains weight (test weight) was observed in T_{13} (N @ 20 kg + P_2O_5 @ 40 kg+ $ZnSO_4$ @ 20 kg + S @ 40 kg/ha) as compared to other nutrient treatments. In clusterbean, cost of cultivation and gross returns were recorded highest in T_{16}, while T_{10} recorded highest net returns and B: C than other nutrient treatments. All the parameters were recorded lowest in control treatments. It may be concluded that T_{16} resulted in better growth parameters, yield attributes, yield and economics except harvest index higher in T_8, and net returns higher in T_{10}. Increased in growth and yield parameter was observed, further study can be explored to optimize the nutrient requirement for yield maximization, profitability and sustainability.

Introduction

Clusterbean (*Cyamopsis tetragonoloba L. Taub.)* popularly known as guar, is a drought hardy and deep rooted legume crop grown for feed, fodder, green manure and vegetable purpose. Guar plant produces a cluster of flowers and pods, therefore, it is also known as cluster bean. It belongs to the family *Leguminaceae* and subfamily *Papilinaceae* and is known to improve soil fertility. Being a legume crop, it has the capacity to fix atmospheric nitrogen by its effective root nodules (Kumhar *et al.*, 2012). It is generally 50-100 cm tall and bears 4 to 10 branches (branch type). However, non-branch type varieties have main stem only, which is heavily clustered with pods.

India leads among the major guar producing countries of the world, contributing around 75 to 80% to the world's total production (7.5 to 10 lakhs tonnes) (Annonymous, 2012). It is an important cash crop of south-west (SW) Haryana as it is second largest producer of clusterbean having area 2.15 lakh hactare, with production of 2.9 lakh tones and productivity of 1348 kg/ha which is maximum in the country (Annonymous, 2013). According to Aykroyd (1963) the composition of clusterbean is 8.10 g moisture, 10.8 g carbohydrate, 23% protein, 1.4 g fat, 1.4 g minerals, 0.09 mg thiamine, 0.03 mg riboflavin, 47 I.U. vitamin C, 316 I.U, vitamin A (per 100 g of edible portion).

The potential yield of most of the varieties ranges from 18-20 q/ha but the average yield productivity of the country is less than potential average. This may be ascribed to many reasons but inadequate and imbalanced fertilization is the major factor. Sulphur plays an important role in synthesis of S containing amino acid and thus not only increases the crop yield but also improves the crop quality. Clusterbean is highly responsive crop to micronutrients. The micronutrient in general and zinc in particular. Zinc is required for plant growth, as an activator of several enzymes and is directly involved in the biosynthesis of growth regulators such as auxin which promotes production of more plant cells and biomass that will be stored in the plant organs especially in seeds and their deficiencies may be one of the important reasons of poor yields in light textured soils (Singh and Raj, 2001). The work undertaken on these aspects in clusterbean is very meagre. Therefore, keeping this in view a study was conducted on effect of zinc and sulphur on growth and yields of clusterbean.

Materials and Methods

A field experiment was conducted during *kharif* 2015 at Cotton Research Station, Sirsa, CCS HAU, Hisar (India) situated at 29°25′ N latitude, 74°40′ E longitude and at an altitude of 202 m above mean sea level. The soil of the experimental field was loamy sand, slightly alkaline in reaction, low in organic carbon (0.35 %) and nitrogen, medium in phosphorus, low in zinc and sulphur. The values of available N (kg/ha), P (kg/ha), Zn (mg/ha) and S (kg/ha) were 137, 13.4, 1.2, 9.82 and 133, 10.8, 1.01, 8.9 before sowing and 137, 13.4, 1.3, 11.6 and 133, 10.8, 1.07, 10.5 after harvest at 0-15 and 15-30 cm soil depth respectively.

During the crop growing period, the mean weekly temperature values ranged between 30 to 43 ºC and 13 to 27 ºC for maximum and minimum temperatures. The rainfall received was 205.07 mm during the crop growing period. The experiment was conducted in RBD with three replications. The experiment consist of 16 treatments in which N and P were applied as per recommended dose (RNP: N= 20 kg/ha, P_2O_5= 40 kg/ha) along with different doses of Zn (10, 20 and 30 kg/ha) and S (20, 30 and 40 kg/ha) and their combinations. The sowing of clusterbean variety HG-2-20 was done on 14th July, 2015 using seed rate of 15 kg/ha. Other agricultural practices were as per package of practices, CCS HAU, Hisar. The cropping history of the experimental field for the five years period prior to the present investigation is as under:

Results and Discussion

Effect of Zn and S on growth

Plant population differed with different nutrient treatments (Zn and S) and maximum plant population was recorded with the application of T_{16} (RNP + $ZnSO_4$ @30 kg + S @40 kg/ha), but it was at par with $T_{15,}$ T_{14} and T_{12} and the lowest value was obtained in T_1 (Table 2). Increase in plant population with increase in Zn and S doses was due to the reason that Zn and S application created a balanced nutritional environment in the rhizosphere which enhanced metabolic activities and photosynthetic rate, resulting in improvement in plant stand and helps in maintaining plant population.

Plant height is an index of plant growth and it increased with advancement of crop growth. The higher doses of Zn and S increased the plant height over control. The maximum plant height (74.90 cm) was obtained from application of T_{16} (RNP + $ZnSO_4$ @30 kg + S @40 kg/ha) as compared to the other nutrient treatments, while at par with T_{13} (RNP + $ZnSO_4$ @20 kg + S @40 kg/ha) (74.86 cm) and T_{15} (RNP + $ZnSO_4$ @30 kg + S @30 kg/ha) (74.86 cm). It was because the availability of Zn and S have stimulated the metabolic and enzymatic activity thereby increasing the plant height. Sulphur is constituent of glutathion, a compound supposed to play a part in plant respiration, hence increase plant height (Jordon and Reisenaur, 1957) and Zn play key role in stabilizing RNA and DNA structure and involves in biosynthesis of growth promoting hormones such as IAA and gibberellins (Mousavi, 2011). These results were in agreement with the findings of Kasturikrishna and Ahlawat (2000), Baviskar *et al.,* (2012), Ramawtar *et al.,* (2013). Addition of Zinc increases the plant height (Singh *et al.,* 2014).

The accumulation of dry matter in clusterbean is a good index to express the photosynthetic efficiency of the plants. The dry matter accumulation per plant was influenced due to different nutrient treatments (Zn and S) and significantly higher dry matter accumulation 26.52 g/plant was obtained by applying T_{16} (RNP + $ZnSO_4$ @30 kg + S @40 kg/ha) which was significantly superior to rest of treatments, but at par with T_{13} (RNP + $ZnSO_4$ @20 kg + S @40 kg/ha) (26.35 g/plant) and T_{10} (RNP + $ZnSO_4$ @10 kg + S @40 kg/ha) (26.23 g/plant) because Zn and S application created a balanced nutritional environment which enhanced metabolic activities and photosynthetic rate, resulting in improvement in plant height and ultimately accumulation of dry matter. Similar types of results were reported by Meena *et al.,* (2006), Ramawtar *et al.,* (2013).

Effect of Zn and S on yield attributes and yields

Successive increase in sulphur and zinc fertilization up to 40 and 30 kg/ha respectively, significantly improved the yield attributes *viz.,* no. of pods/plant, no. of grains/pod, test weight; and grain and straw yield of clusterbean (Table 2). The number of pods/plant was significantly influenced due to Zn and S levels and the highest number of pods per plant (43.73) was recorded with T_{16} (RNP + $ZnSO_4$@30kg + S 40kg/ha) as compared to rest of the treatments, but it was at par with T_{13} (RNP + $ZnSO_4$ @ 20 kg + S @ 40 kg/ha). The number of grains per pod increased with successive increase in doses of Zn and S

Table.1 Cropping history of the experimental field

Year	*Kharif*	*Rabi*
2010-2011	Clusterbean	Wheat
2011-2012	Cotton	Wheat
2012-2013	Cotton	Wheat
2013-2014	Cotton	Wheat
2014-2015	Clusterbean	Wheat
2015-2016	Clusterbean (Experimental crop)	-

Table.2 Effect of different nutrient treatments on growth, yield attributes and yields of clusterbean

Treatments	**Plant Population (per plot)**	**Plant height (cm)**	**Dry matter accumulation (g/plant)**	**No. of pods/ plant**	**No. of grain/ pod**	**1000 grains weight (g)**	**Grain yield (kg/ha)**	**Straw yield (kg/ha)**	**Harvest index (%)**
T_1 (RNP)	402	67.81	21.00	32.22	6.33	29.25	801	2498	24.28
T_2 (RNP + $ZnSO_4$ @10 kg/ha)	406	68.83	21.63	33.35	6.67	29.35	841	2586	24.55
T_3 (RNP + $ZnSO_4$ @20 kg/ha)	410	69.85	22.20	34.00	7.33	29.35	857	2641	24.51
T_4 (RNP + $ZnSO_4$ @30 kg/ha)	418	70.05	22.68	34.22	8.33	29.45	873	2656	24.74
T_5 (RNP + S* @20 kg/ha)	418	71.54	23.84	37.28	7.00	30.15	958	2753	25.82
T_6 (RNP + S* @30 kg/ha)	415	74.46	23.82	37.65	8.00	28.55	988	2893	25.45
T_7 (RNP + S* @40 kg/ha)	416	74.59	24.51	41.73	9.00	30.20	998	2960	25.20
T_8 (RNP + $ZnSO_4$ @10 kg + S @20kg/ha)	419	71.75	24.59	39.31	7.67	30.10	978	2798	25.89
T_9 (RNP + $ZnSO_4$ @10 kg + S @30 kg/ha)	422	74.66	25.73	40.60	8.00	30.15	1017	3035	25.10
T_{10} (RNP + $ZnSO_4$ @10 kg + S @40 kg/ha)	420	74.80	26.23	43.02	9.00	30.15	1034	3075	25.15
T_{11} (RNP + $ZnSO_4$ @20 kg + S @20 kg/ha)	418	71.88	24.80	39.80	7.67	30.00	980	2821	25.78
T_{12} (RNP + $ZnSO_4$ @20 kg + S @30 kg/ha)	423	74.73	25.94	40.99	8.67	30.10	1036	3115	24.95
T_{13} (RNP + $ZnSO_4$ @20 kg + S @40 kg/ha)	424	74.86	26.35	43.40	9.00	30.30	1059	3142	25.21
T_{14} (RNP + $ZnSO_4$ @30 kg + S @20 kg/ha)	425	72.02	24.99	40.12	8.00	30.25	984	2873	25.51
T_{15} (RNP + $ZnSO_4$ @30 kg + S @30 kg/ha)	425	74.86	26.10	41.31	9.00	30.25	1060	3120	25.35
T_{16} (RNP + $ZnSO_4$ @30 kg + S @40 kg/ha)	426	74.90	26.52	43.73	9.00	30.25	1062	3145	25.23
SEm±	1	0.02	0.13	0.18	0.10	0.07	1.97	2.34	0.002
CD at 5%	4	0.05	0.37	0.52	0.57	0.21	5.72	6.78	0.005

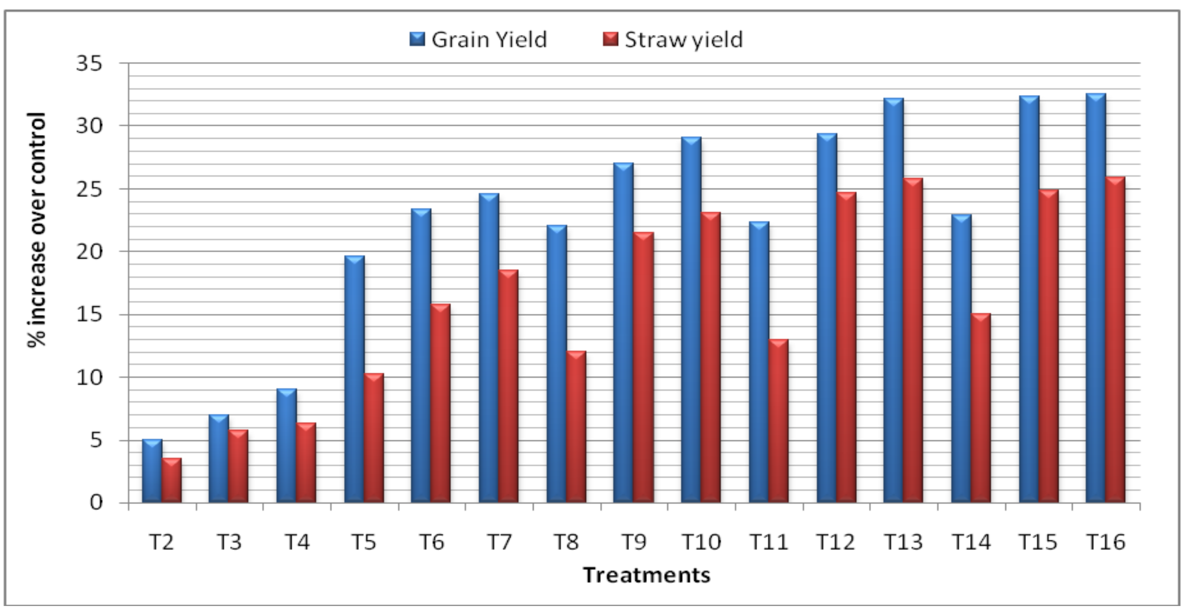
Note: In all treatments, N and P_2O_5 doses are as per recommendation (RNP: N= 20 kg/ha, P_2O_5= 40 kg/ha), *= source of S was gypsum (19 % S) and one plot = 27 m^2.

Table.3 Effect of different nutrient treatments on economic of clusterbean

Treatments	Cost of cultivation (Rs/ha)	Gross returns (Rs/ha)	Net returns (Rs/ha)	B:C
T_1 (RNP)	20054	39006	18952	1.94
T_2 (RNP + $ZnSO_4$ @10 kg/ha)	20494	40900	20406	2.00
T_3 (RNP + $ZnSO_4$ @20 kg/ha)	20934	41688	20754	1.99
T_4 (RNP + $ZnSO_4$ @30 kg/ha)	21374	42416	21042	1.98
T_5 (RNP + S* @20 kg/ha)	20654	46299	25645	2.24
T_6 (RNP + S* @30 kg/ha)	20954	47823	26869	2.28
T_7 (RNP + S* @40 kg/ha)	21254	48336	27082	2.27
T_8 (RNP + $ZnSO_4$ @10 kg + S @20kg/ha)	21049	47213	26164	2.24
T_9 (RNP + $ZnSO_4$ @10 kg + S @30 kg/ha)	21349	50883	29534	2.38
T_{10} (RNP + $ZnSO_4$ @10 kg + S @40 kg/ha)	21649	51225	29576	2.37
T_{11} (RNP + $ZnSO_4$ @20 kg + S @20 kg/ha)	21444	47352	25908	2.21
T_{12} (RNP + $ZnSO_4$ @20 kg + S @30 kg/ha)	21744	51215	29471	2.36
T_{13} (RNP + $ZnSO_4$ @20 kg + S @40 kg/ha)	22044	51325	29281	2.33
T_{14} (RNP + $ZnSO_4$ @30 kg + S @20 kg/ha)	21839	47607	25768	2.18
T_{15} (RNP + $ZnSO_4$ @30 kg + S @30 kg/ha)	22139	51315	29176	2.32
T_{16} (RNP + $ZnSO_4$ @30 kg + S @40 kg/ha)	22439	51436	28997	2.29

Note: In all treatments, N and P_2O_5 doses are as per recommendation (RNP: N= 20 kg/ha, P_2O_5= 40 kg/ha), *= source of S was gypsum (19 % S).

Fig.1 Per cent increase in grain and straw yield with the application of Zn and S



The highest numbers of grains per pod (9.00) was recorded with T_{16} (RNP + $ZnSO_4$ @ 30 kg + S @ 40 kg/ha), T_{15} (RNP + $ZnSO_4$ @ 30 kg + S @ 30 kg/ha, T_{13} (RNP + $ZnSO_4$ @ 20 kg + S @ 40 kg/ha, T_{10} (RNP + $ZnSO_4$ @10 kg + S @ 40 kg/ha and T_7 (RNP + S @ 40 kg/ha which were significantly higher over control (6.33). Numerically highest test weight (30.30 g) was obtained with application of T_{13} (RNP + $ZnSO_4$ @20 kg + S

@40 kg/ha) which was at par with T_5, T_7, T_8, T_9, T_{10}, T_{12}, T_{14}, T_{15} and T_{16} while the lowest test weight was recorded with control (29.25 g).

The improvement in growth might be due to the fact that application of S improves overall nutritional environment in rhizosphere by improving not only the availability of S, but it also reduced the pH, which is the principle reason for availability and mobility of nutrients specially of P, Fe, Mn and Zn (Hilal and Abdelfattah, 1987). The improvement in nutritional environment ultimately resulted in better plant metabolism and photosynthetic activity improved yield components. The grain yield being the function of cumulative effect of yield attributes, increased significantly due to addition of S.

Application of higher doses of Zn and S increased grain yield. Significantly higher grain yield (1062 kg/ha) was recorded with application of T_{16} (RNP + $ZnSO_4$ @30 kg + S @40 kg/ha) than other nutrient treatment, while it was at par with T_{15} (RNP + $ZnSO_4$ @30 kg + S @30 kg/ha (1060 kg/ha) and T_{13} (RNP + $ZnSO_4$ @20 kg + S @40 kg/ha (1059 kg/ha). Clear disparity in grain yield was noticed between zinc and sulphur treatments. Among all the zinc treatments tried, $ZnSO_4$ @30 kg resulted in higher grain yield (873 kg/ha) irrespective of zinc management practices, S (40 kg/ha) resulted in higher grain yield (998 kg/ha). All nutrient treatments provided significantly higher straw yield compared to the treatment of control. Straw yield among the different treatments was significantly higher in T_{16} (RNP + $ZnSO_4$ @30kg + S @40 kg/ha) (3145 kg/ha) as compared to other nutrient treatments, which was at par with T_{13} (RNP + $ZnSO_4$ @20 kg + S @40 kg/ha).

Sulphur of chloroplast protein resulted in greater photosynthetic efficiency which in turn translated in terms of increase in yield (Karche *at el.*, 2012). Similar results were also reported by Singh and Mann (2007) and Baviskar *et al.*, (2010). Zinc play an important role in biosynthesis of indole acetic acid which is responsible for initiation of primodial for reproductive parts and partitioning of photosynthesis towards them which resulted in better yield (Srivastava *et al.*, 2006, Ram and Katiyar, 2013).

Application of $T_{16,}$ T_{15}, T_{13} and T_{12} treatments increased the grain yield by 32.58, 32.33, 32.21 and 29.34 percent and straw yield by 25.9, 24.9, 25.78 and 24.70 percent, respectively over control i.e., T_1 treatment (Fig. 1). Even in treatment T6 and T7 where sulphur is applied @ 30 and 40 kg/ha (along with recommended dose of N and P) respectively, gave 23.35 and 24.59 percent higher grain yield and 15.81 and 18.49 percent higher straw yield respectively over control.

Significantly higher harvest index of 25.89% was observed with application of T_8 (RNP + $ZnSO_4$ @10 kg + S @20 kg/ha as compared to control (24.28%). It may be attributed to the fact that gypsum as sulphur source possibly enhances sulphur availability faster to plants as compared to control. Similar results were found by Yadav (2004) and Kumawat *et al.*, (2006).

Effect of Zn and S on Economics

Highest total cost of cultivation was recorded in T_{16} (RNP + $ZnSO_4$ @30kg + S @40 kg/ha) (Rs 22439/ha) followed by T_{15} (RNP + $ZnSO_4$ @30 kg + S @30 kg/ha) (Rs 22139/ha).

Highest gross returns was observed in T_{16} (RNP + $ZnSO_4$ @30 kg + S @40 kg/ha) (Rs 51436/ha) followed by T_{13} (RNP + $ZnSO_4$ @20 kg + S @40 kg/ha) (Rs 51325/ha). Highest net returns was observed in T_{10} (RNP

+ $ZnSO_4$ @10kg + S @40 kg/ha) (Rs 29576/ha) followed by T_9 (RNP + $ZnSO_4$ @10 kg + S @30 kg/ha) (Rs 29534/ha). Highest benefit-cost ratio was observed in T_9 (RNP + $ZnSO_4$ @10 kg + S @30 kg/ha) (2.38) followed by T_{10} (RNP + $ZnSO_4$ @10kg + S @40 kg/ha) (2.37). Lowest gross returns, net returns and B: C were observed in control treatment (Table 3). Application of higher doses of Zn and S gave better results in terms of gross returns, net returns and in B: C. This was due to comparatively more increase in yield was obtained under S treatment (Baviskar *at el.*, 2010). These results are in accordance with the findings of Jat *et al.*, (2006) and Singh and Mann (2007).

Based on the results of experiment, it can be concluded that T_{16} (RNP + $ZnSO_4$ @30 kg + S @40 kg/ha) resulted in better growth parameters, yield attributes and yields, and economics except harvest index higher in T_8 (RNP + $ZnSO_4$ @10 kg + S @20 kg/ha), and net returns higher in T_{10} (RNP + $ZnSO_4$ @10kg + S @40 kg/ha). So clusterbean crop has shown immense potential to respond toward Zn and S fertilization. Application of Zn and S with recommended dose of N and P improved the growth parameters, yield attributes and yields, and economics.

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