Legume Research, 39 (5) 2016 : 762-767
Print ISSN:0250-5371 / Online ISSN:0976-0571

AGRICULTURAL RESEARCH COMMUNICATION CENTRE
www.arccjournals.com/www.legumeresearch.in

Role of zinc on productivity, quality traits and economic performance of cluster bean (*Cyamopsis tetragonoloba* L.) under semi-arid condition of Rajasthan, India

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Received: 12-02-2015 Accepted: 10-08-2015 DOI:10.18805/lr.v0iOF.6850

ABSTRACT

The experiment was conducted during *kharif* 2011 and 2012 at Avikanagar on different genotypes of cluster bean to assess the response of Zn on productivity and profitability under tropical environment of Rajasthan. The results reveal that maximum seed (2.55 t ha^{-1}) and stover yield (7.32 t ha^{-1}), protein content (27.2 %) and protein yield and (168.10 kg ha^{-1}), gum content (27%) and gum yield (180 kg ha^{-1}) were recorded with application of Zn @20 kg ha^{-1}. Further, quality traits *viz.* ADF, NDF, cellulose and lignin were also highest in grains. Maximum net return of ₹ 33,037 ha^{-1} with benefit: cost ratio (2.39) was received with the use of Zn @ 20 kg ha^{-1}. Highest seed yield (2.21 t ha^{-1}), protein content (25.6%), protein yield (166.20 kg ha^{-1}), gum content (25.4%) and gum yield (172.37 kg ha^{-1}) were obtained from genotype 'RGC 936' with the highest net returns of Rs 28,188 ha^{-1}. Application of Zn@20 kg ha^{-1} to cluster bean genotype 'RGC 936' gives highest yield and economic returns under tropical condition of Rajasthan.

Key words: Cluster bean, Economics, Genotype, Gum, Protein, Stover, Yield.

INTRODUCTION

Cluster bean commonly known as guar (*Cyamopsis tetragonoloba* L.) is a major arid legume traditionally cultivated as a system sustaining crop under poorly endowed situations with the least management and aftercare in arid regions. Besides, it is a subsistence source of vegetable, food, fodder and green manure under harsh environments, where other crops fall short even to negotiate and produce biomass. It is needless to emphasize its role in improving soil fertility through biological nitrogen fixation and addition of foliage to the soil. Rajasthan possess maximum area of 1.8 million ha (70% of total) under cluster bean cultivation with a production of 0.739 million tonnes annually. In Rajasthan, the average productivity is very low (0.25 t ha^{-1}) as compared to other states *viz.* Gujarat, Haryana and Punjab (0.37, 0.70 and 1.20 t ha^{-1}, respectively) being cultivated as arid legume (Henry, 2003). Moreover, its grains containing about 28% protein and 35 to 40% endosperm, which in turn contain 80% galactomanan gum.

Besides, guar has diversified industrial utilities in an array of value added products. Guar gum and its derivatives are widely used in various industries like food, textiles, mining, cosmetics, pharmaceutical, nutrition, health care, oil well drilling and paper industry as thickeners, stabilizers, binders, gelling agents, explosives and corrosive materials. In Rajasthan, two-third of its total production being used as animal feed and one-third is used for gum production and owing to this it has acquired important status among the industrial crops of arid regions of Rajasthan. The guar gum industry is a major industry in guar growing areas of Rajasthan of which Jodhpur is known as hub of guar industry. For this, Haryana and Gujarat providing employment as well as earning sizeable foreign exchange, Rs 13,390 million annually which has more potential to grow in volume due to untapped utilities (Singh *et al*., 2004). Looking to the importance of cluster bean, different fodder and seed producing genotypes have developed by NARS¼National Agricultural Research Systems) which is highly responsive to micronutrients. The continuous use of straight fertilizers which contain low amount of micronutrients,specially zinc resulted in deficient of this nutrient and the response of other major nutrients applied in the soil lead to low production potential from promising genotypes of clusterbean under semi-arid climatic conditions. Zinc is as essential element as it is required for structural and catalytic components of protein and enzymes in normal growth and development of plants (Prasad, 2006). The improved genotypes of cluster bean are more Zn responsive up to 15-20 kg ha^{-1} because this nutrient acts as catalytic components of protein and enzymes for normal growth and development as observed by Manivasagaperumal *et al*., (2011).

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In India this crop provides low cost source of livelihood for poor arid farmers (Kumar and Rodge, 2012). Hence the study was undertaken to assess the Zn response among different genotypes of cluster bean on growth and yield under semi-arid condition of Rajasthan.

MATERIALS AND METHODS

Field experiments was conducted during two consecutive *kharif* seasons of 2011 to 2012 at Central Sheep and Wool Research Institute, Avikanagar(75^0-28'E longitude, 26^0-26'N latitude and 320 m altitude), Rajasthan in semi-arid regions with a mean minimum and maximum temperature of 4^0C and 46^0C, respectively. The soil of the experimental plot was sandy loam in texture, low in organic carbon (0.30%), available N (136.01 kg ha^{-1}) and medium in phosphorus (16.33kg ha^{-1}) and potassium (252.37 kg ha^{-1}) having almost neutral pH (6.8). The treatments comprised of four genotypes of clusterbean *viz.*'BG 2' 'BG 3' 'RGC 936' and 'RGC 1017,' considered as main plots and four levels of zinc (control, 5, 10 and 20 kg ha^{-1}), as sub plots and replicated thrice in split plot design. Zn was applied in form of zinc sulphate. The seed rate of clusterbean was kept 20 kg ha^{-1} with a spacing of 30 cm. The crop was sown on 2^{nd} July in 2011 and 9^{th} July in 2012. The seed was treated with fungicide (*Bavistin* @ 2 g kg^{-1} seed) to prevent from fungal attacks. Methyl parathion (2% dust @ 25 kg ha^{-1}) was also incorporated in the soil before sowing for insect-pest control. One hand weeding was done after 30 DAS (days after sowing) in order to control the weeds. Timely growth and yield observations were recorded. Observations on yield were analyzed statistically and the treatment means were compared by Tukey's honest significant difference test. Clusterbean grains were grinded and digested as per the standard procedure recommended by Henry (2003) for determination of protein content. The grains was also analyzed for ascertaining the acid detergent fibre (ADF), neutral detergent fibre (NDF), cellulose and lignin by following method given by Van Soest and Robertson (1988).

RESULTS AND DISCUSSION

Growth indices: All growth parameters of clusterbean were influenced significantly with varied levels of Zn application (Table1). However, application of Zn @ 20 kg ha^{-1} resulted maximum increase in plant height, dry matter accumulation $plant^{-1}$, branches $plant^{-1}$, leaf area index (LAI) at 60 and 90 days after sowing (DAS) and nodules $plant^{-1}$ at 45 days after sowing (DAS) followed by application of Zn 10 kg ha^{-1}. There was no significant difference between control and Zn @ 5 kg ha^{-1} level for branches $plant^{-1}$, leaf area index (LAI), crop growth rate (CGR) and nodules $plant^{-1}$. Similarly, the difference between application of Zn @ 5 and 10 kg ha^{-1} levels was found at par for branches $plant^{-1}$, leaf area index (LAI) at 90 days after sowing (DAS), crop growth rate (CGR) and nodules $plant^{-1}$ at 45 days after sowing (DAS). By and large application of Zn @10 and 20 kg ha^{-1} levels being at par in respect of leaf area index at 60 and 90 days after sowing, crop growth rate and nodules $plant^{-1}$. The increase in growth parameters of cluster bean probably due to enhanced applied and already existed soil Zn (1.57ppm) to plant. The improvement in plant growth by Zn nutrient may be assigned to improved nodulation resulting in enhanced N fixation, which in turn might have improved leaf area index and photosynthesis. These results were in conformity with the findings of Meena *et al.* (2010).

The significant different among the genotypes was observed for different growth parameters *viz.* Plant height, dry matter accumulation, branches $plant^{-1}$, leaf area index (LAI), crop growth rate (CGR) and number of nodules $plant^{1}$ at 45 DAS. However, the highest values for these parameters were observed in 'BG 3' followed by 'BG 2', 'RGC 936' and 'RGC 1017'. This might be due to the fact that 'BG 3'

Table 1: Effect of zinc levels and promising genotypes of cluster bean on growth attributes (pooled data of 2 years).

Treatment	Plant height (cm) at harvest	Branches $plant^{-1}$	Dry matter $plant^{-1}$(g)	LAI		CGR ($g^{-1}m^2day^{-1}$)	Nodules $Plant^{-1}$ at 45 DAS
				60 DAS	90 DAS		
Zinc levels (kg ha^{-1})							
0	93.39^d	5.08^c	60.70^d	4.27^b	3.56^b	17.56^b	5.23^c
5	99.16^c	5.70^b	65.14^c	5.08^b	4.66^a	18.53^b	5.53^{bc}
10	105.30^b	6.29^b	70.63^b	6.53^a	5.11^a	21.16^{ab}	5.76^{ab}
20	114.41^a	7.87^a	81.73^a	6.62^a	5.21^a	24.31^a	6.77^a
Genotypes							
'BG2'	105.68^b	6.49^a	72.77^a	5.99^{ab}	4.74^a	21.07^a	6.05^{ab}
'BG3'	117.78^a	7.17^a	74.23^a	6.21^a	5.11^{ab}	23.06^{ab}	6.70^a
'RGC936'	94.50^c	6.35^a	68.11^{bc}	5.47^a	4.66^a	20.04^a	5.70^a
'RGC1017'	94.29^c	5.03^b	64.30^c	4.82^b	4.02^b	18.94^b	4.84^b

Where, alphabet 'a' denotes treatment is significantly superior over remaining, 'b' denotes treatment is significantly superior over 'c' and 'd', alphabet 'c' denotes treatment is significantly superior over 'd'. Alphabet'd' denotes the treatment is lowest among all. Alphabet 'ab' and 'bc' denotes treatments are at par with each other.

and 'BG 2' being fodder varieties had faster vegetative growth. The results were in conformity with the findings of Kumar Virendra (2009).

Yield attributes: Pooled analysis of 2 years data showed that yield attributes of cluster bean *viz.* pods plant^{-1}, seeds pod^{-1}, 1000-seed weight and seed yield plant^{-1} improved remarkably due to application of Zn (Table2). The significant and maximum number of pods plant^{-1} and highest pod length were observed with Zn application @ 20kg ha^{-1}. While, these parameters were found at par with the application of 10 and 20 kg Zn ha^{-1}. The seeds pod^{-1} was increased significantly among the different treatments *viz.*control, 5, 10 and 20kgZn ha^{-1}, respectively. Addition of Zn into soil was also improved the 1000-seed weight as reported by Rathore *et al.*, (2007). But difference among the Zn levels themselves did not show significant effect except over the control treatment. Seed yield plant^{-1} increased significantly at various levels but the significant difference was exhibited up to 10 kg ha^{-1}.

Cluster bean genotype 'RGC936' and 'RGC 1017' showed better performance in respect of yield attributing characters such as number of pods plant^{-1}, pod length, seeds pod^{-1}, 1000- seed weight and seed yield plant^{-1}. However, both these two genotypes did not differ significant with each other for seeds pod^{-1} and 1000-seeds weight. On the other hand 'BG2'and 'BG3' genotypes were statistically at par for pod length and seed yield plant^{-1}. This in turn might have resulted in greater photosynthesis and hence better translocation of photosynthates besides large sink and strong reproductive phase, as reflected in maximum pods plant^{-1}, pod length, seeds pod^{-1}, 1000-seed weight and seed yield plant^{-1}. Whereas, the lowest seed yield attributes parameters were recorded in case of 'BG2' genotype.

Seed and stover yield: Application of Zn significantly improved the seed and stover yield of cluster bean on pooled data basis. However, application of Zn @ 20 kg ha^{-1} resulting significant increase in seed and stover yields by 91.72 and 48.78% higher as compared to control treatment (Table 2). The seed and stover yields were increased mainly due to progressive increase in growth and yield attributes with use of each successive dose of Zn nutrient probably due to influence on auxin synthesis, nodules formation and nitrogen fixation. Similar findings were also obtained by Islam *et al.*, (1989).

The highest seed yield was recorded in 'RGC936' (2.21 t ha^{-1}) thereafter in 'RGC 1017' (1.94 t ha^{-1}) and both these genotypes were found significantly superior over 'BG 3' (1.85 t ha^{-1}) and 'BG 2' (1.61 t ha^{-1}) for seed production. The increase in growth along with better expression of yield attributes might have led to enhance in seed yield of clusterbean. This might be due to that 'BG 2'and 'BG 3' has developed for fodder type. Whereas, the trend in case of stover yield was observed negative and the highest stover yield was obtained with 'BG 3' genotype (6.85 t ha^{-1}) and it gave 7.87, 13.23 and 18.71% higher over remaining genotypes, which was closely followedby 'BG 2' (6.35 t ha^{-1}). The lowest stover yield was shown in 'RGC 1017' (5.77 t ha^{-1}). It might be obvious due to this genotypes have the ability to produce more yield attributes than growth attributes led to less biomass production.

Protein content and protein yield: Application of Zn had significant influence on protein content and protein yield of seed of clusterbean (Table 3). The progressive increment in protein content was recorded with increasing Zn levels up to 20 kg ha^{-1}. The pooled data presented shows that application of Zn at various levels *viz.* 5, 10 and 20 kg ha^{-1} registered 12.3, 26.5 and 36.6% higher protein content and 22.3, 44.7 and 57.8 kg ha^{-1} higher protein yield when compared with control treatment. The highest level of Zn @ 20 kg ha^{-1} did not show much higher improvement in protein content and protein yield over 10 kg Zn ha^{-1}. However, both the levels had significant effect on protein yield as compared to control and protein yield was increased to the tune of 11.9, 32.2 and 52.4% higher in comparison to no use of Zn. An increase in protein yield with application of Zn has also

Table 2: Effect of zinc levels and promising genotypes on yield attributes, seed yield and stover yield of clusterbean (pooled data of 2 years)

Treatment	Pods plant^{-1}	Pod length (cm)	Seeds pod^{1}	1000-seed weight (g)	Seed yield (t ha^{-1})	Stover yield (t ha^{-1})
Zinc levels (kg ha^{-1})						
0	53.19^{d}	4.57^{c}	3.85^{d}	39.32^{c}	1.33^{c}	4.92^{c}
5	57.02^{c}	5.04^{b}	4.27^{c}	41.03^{bc}	1.63^{bc}	5.89^{bc}
10	58.47^{b}	5.36^{ab}	4.61^{b}	42.92^{ab}	2.06^{ab}	6.82^{ab}
20	61.03^{a}	5.71^{a}	5.12^{a}	45.61^{a}	2.55^{a}	7.32^{a}
Genotypes						
'BG 2'	53.35^{c}	4.78^{b}	3.85^{c}	33.51^{c}	1.61^{a}	6.35^{a}
'BG 3'	57.15^{b}	4.83^{b}	4.34^{b}	42.40^{b}	1.84^{a}	6.85^{ab}
'RGC 936'	61.07^{a}	6.02^{a}	4.95^{a}	46.82^{a}	2.21^{a}	6.05^{a}
'RGC1017'	58.09^{b}	5.01^{b}	4.70^{ab}	44.81^{ab}	1.94^{a}	5.77^{b}

been reported by Manivasagaperumal*et al*., ¼2011). Protein content in seed and its yield were influenced significantly due to genotypes variation was also reported by Kumar Virendra (2009). However, genotype 'RGC 936' was found more superior in terms of protein content and protein yield than other genotypes. This might be attributed to the genetic potential of this genotype. However, 'RGC 936' and 'RGC 1017' genotypes were being at par for protein content and protein yield. On the other hand, significant variation in 'RGC 936'and 'BG 2' genotypes was observed for quality parameters. By and large genotypes i.e. 'RGC 936' and 'RGC 1017' were found significantly superior over 'BG2' in terms of higher protein content and protein yield, which gave 24.2 and 19.4%higher protein content and 31.1 and 27.6% higher protein yield than 'BG 2' genotype. The lower protein content was estimated in seed of 'BG 2'genotype (20.6%). The magnitude of protein content and protein yield in 'BG 2' genotype was reduced by 14.4 and 12.7% as compared to 'BG 3' genotype.

Fibre content: The pooled data analysis presented in Table 3 indicated that application of Zn significantly affect the fibre content in seed of cluster bean. The fibre content *viz*.acid detergent fibre (ADF), neutral detergent fibre (NDF), cellulose and lignin were influenced significantly with an increase in Zn levels up to 20 kg ha^{-1}.The fibre content was increased progressively with increasing in Zn levels but difference among levels themselves was found statistically at par with each other. Further, application of Zn @ 20 kg ha^{-1} resulted in higher ADF, NDF, cellulose and lignin content than control, 5 and 10 kg ha^{-1}. The maximum fibre content was increased with supplied of 20 kgZn ha^{-1} and increase to the tune of 6.7, 5.7 and 2.8% higher in ADF, 4.1,2.1 and 1.5% in NDF and 10.2, 8.2 and 5.7% in cellulose than control,5 and 10 kg Zn ha^{-1}, respectively. Whereas, the difference between 10 and 20 kg Zn ha^{-1} for ADF, NDF, cellulose and lignin did not found significant with each other. Whereas, the difference between 20kg Zn ha^{-1} and control treatment was observed significantly superior owing to ADF, NDF, cellulose and lignin content. Moreover, the fibre content was recorded lowest under control treatment as compared to other higher levels. These results are in agreement with the findings of Singh *et al*., (1997).

Among the genotypes, 'RGC 936' had registered higher ADF (18.2%) and NDF (54.4%), cellulose (19.1%) and lignin content (0.5%) followed by 'RGC 1017' genotype. While the both these two genotypes were found significantly superior to the recorded values over the rest genotypes. Whereas, lower in content of ADF, NDF, cellulose and lignin were observed in 'BG 3'genotype. This might be ascribed due to younger and succulent plants than other genotypes.

Gum content and gum yield: Application of Zn @ 20 kg ha^{-1} caused significantly higher gum content (27.1%) and gum yield (180.1kg ha^{-1}) over its lower levels, representing significant increase of 5.0, 8.1 and 21.2% in gum content and 12.8, 20.1 and 31.1%in gum yield over control, respectively (Table3). There was no difference observed with Zn levels and genotypes and these results are in close conformity with the findings of Sammauria *et al*., (2009)and Kasturikrishna and Ahlawat (2000). The maximum gum content (25.1%) and gum yield (172.4 kg ha^{-1}) were recorded in 'RGC936'genotype followed by 'RGC 1017' 'BG 3' and 'BG 2,'respectively. This might be due to genetic variability among the genotypes. Similar results were also observed by Joshi *et al*., (2015) they reported that gum content varied from 26.12 to 31.46% in different genotypes of guar. The gum content in 'RGC 936' genotype increased to the tune of 1.9, 5.2 and 10% higher over 'RGC 1017', 'BG 3'and 'BG 2' genotypes, respectively.

Zinc use efficiency: The Zn use efficiency was decreased significantly with subsequent higher doses of Zn nutrient.

Table 3: Effect of zinc levels and genotypes on protein content, protein yield, fibre content and gum content and gum yield of cluster bean (pooled data of 2 years).

Treatment	Protein content (%)	Protein yield (kg ha^{-1})	ADF (%)	NDF (%)	Cellulose (%)	Lignin (%)	Gum content (%)	Gum yield (kg ha^{-1})
Zinc levels(kg ha^{-1})								
0	19.88^{b}	110.27^{c}	15.05^{b}	49.99^{b}	15.89^{c}	0.32^{c}	22.24^{a}	137.24^{b}
5	22.33^{ab}	123.37^{bc}	15.19^{b}	51.03^{ab}	16.19^{bc}	0.35^{a}	23.36^{a}	154.84^{ab}
10	25.12^{a}	145.79^{ab}	15.63^{a}	51.28^{ab}	16.57^{ab}	0.33^{bc}	24.01^{a}	164.45^{ab}
20	27.15^{a}	168.10^{a}	16.06^{a}	52.03^{a}	17.51^{a}	0.34^{ab}	26.95^{a}	179.96^{a}
Genotypes								
'BG2'	20.63^{b}	127.00^{b}	14.51^{b}	49.59^{b}	15.79^{c}	0.29^{c}	22.60^{a}	136.77^{a}
'BG3'	23.60^{a}	143.08^{ab}	13.71^{c}	47.46^{c}	15.04^{c}	0.24^{d}	23.65^{a}	161.15^{a}
'RGC936'	25.63^{ab}	166.47^{a}	18.24^{a}	54.38^{a}	18.95^{a}	0.48^{a}	24.87^{a}	172.37^{a}
'RGC1017'	24.63^{a}	161.99^{a}	15.33^{b}	52.79^{a}	16.39^{b}	0.32^{b}	24.43^{a}	166.20^{a}

Table 4: Effect of zinc levels and genotypes on zinc use efficiency, cost of cultivation, net return and benefit: cost ratio (pooled data of 2 years).

Treatment	Zn use efficiency (kg seed yield kg^{-1} Zn applied)	Cost of cultivation (₹ ha^{-1})	Net returns (₹ ha^{-1})	B:C ratio
Zinc levels (kg ha^{-1})				
0	—	12115^{c}	19679^{d}	1.82^{b}
5	374.25	12825^{b}	23442^{c}	1.83^{b}
10	205.12	13426^{b}	29688^{b}	2.21^{a}
20	96.00	13822^{a}	33037^{a}	2.39^{a}
Genotypes				
'BG2'	511.31	11281^{b}	19987^{c}	1.77^{c}
'BG3'	562.00	11542^{b}	23662^{b}	2.05^{b}
'RGC936'	717.68	12311^{ab}	28188^{a}	2.29^{a}
'RGC1017'	635.06	12527^{a}	25234^{b}	2.01^{b}

Highest Zn use-efficiency was recorded with the application of 5kg Zn ha^{-1} (374.3) followed by 10 and 20kg ha^{-1}, respectively (Table 4). This might be due to utilization of additional amount of Zn could not increase the desired yield. Among the genotypes, 'RGC 936' recorded higher Zn-use efficiency (717.7) followed by 'RGC 1017' (635.1) and the lowest Zn-use efficiency was recorded with 'BG 2' genotype (511.3).

Economic returns: Total cost of cultivation was highest (₹ 13,822 ha^{-1}) with the application of 20kg Zn ha^{-1}. The maximum net return (₹ 33,037 ha^{-1}) was realized from the use of Zn @ 20 kg ha^{-1}, which was significantly higher than other Zn levels (control, 5 and 10 kg ha^{-1}). The benefit: cost ratio was also highest with the same level (2.39). While the lowest net return (₹ 19, 679 ha^{-1}) was obtained from clusterbean when no Zn used. Similar results have also been observed by Singh and Mann (2007). The mean values of 2 years revealed that cost of cultivation was the highest of 'RGC 1017' genotype (₹ 12,527 ha^{-1}). But the highest net returns (₹ 28,188 ha^{-1}) as well as benefit:cost (2.29) was recorded with 'RGC 936'genotype than others genotypes. This might be due to higher productivity under this genotype. The lowest returns and benefit: cost ratio was realized with 'BG 2'genotype. This was mainly due to higher cost of cultivation (₹ 11, 281 ha^{-1}) and less seed production (₹ 1.61 t ha^{-1}).

CONCLUSION

The cluster bean is an important leguminous crop and it has tremendous impact on gum industry of Rajasthan. Cluster bean is highly responsive to the inputs (major and micronutrients) and the response of inputs depends on the rainfall and the availability of life saving irrigation particularly in the arid and semi-arid regions. So, this is the time to include the micro nutrients like Zn in the system along with recommended dose of major fertilizers to increase the quantity and quality of produce. Some genotypes are more responsive and some are less so, selection of genotypes also play a crucial role in achieving the higher productivity in the arid and semi-arid regions.

ACKNOWLEDGMENT

The authors are grateful to reviewer for valuable comments.

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