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Chetana Vasava
Department of Vegetable Science
ASPEE College of Horticulture and Forestry Navsari
Agricultural University Navsari, Gujarat, India

Patel NK
Department of Vegetable Science
ASPEE College of Horticulture and Forestry Navsari
Agricultural University Navsari, Gujarat, India

Himani Patel
Department of Vegetable Science
ASPEE College of Horticulture and Forestry Navsari
Agricultural University Navsari, Gujarat, India

Archana Mahida
Department of Fruit Science
ASPEE College of Horticulture and Forestry Navsari
Agricultural University Navsari, Gujarat, India

Tandel BM
Department of Fruit Science
ASPEE College of Horticulture and Forestry Navsari
Agricultural University Navsari, Gujarat, India

Corresponding Author:
Chetana Vasava
Department of Vegetable Science
ASPEE College of Horticulture and Forestry Navsari
Agricultural University Navsari, Gujarat, India

Effect of spacing and foliar spray of micronutrients on growth and yield of cluster bean (*Cyamopsis tetragonoloba* (L.) Taub.)

Chetana Vasava, Patel NK, Himani Patel, Archana Mahida and Tandel BM

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Abstract
An experiment was conducted, with a view to study the effect of spacing and foliar spray of micronutrient on growth and yield characters on cluster bean. Among levels of spacing, S_3 (45 cm × 30 cm) was found best in fresh weight, dry weight, number of clusters plant^{-1}, number of pods cluster^{-1}, number of pods plant^{-1}, total yield plant^{-1}, pod yield ha^{-1}. However, S_1 (45 cm × 20 cm) level of spacing gave maximum plant height and stem diameter. Foliar spray of 0.5% $FeSO_4$ + 0.5% $ZnSO_4$ showed maximum stem diameter at 90 DAS, fresh weight of plant (148.64 g), number of clusters plant^{-1}, number of pods cluster^{-1}, number of pods plant^{-1}, total pod yield plant^{-1}, respectively. The treatment combination S_3F_3 {(45 cm × 30 cm) + (0.5% $FeSO_4$ + 0.5% $ZnSO_4$)} showed significantly maximum number of pods plant^{-1}, pod yield plant^{-1} and hectare^{-1}.

Keywords: Cluster bean, Growth Parameters, Yield Attributes, Spacing, $ZnSO_4$ and $FeSO_4$.

Introduction
Cluster bean [*Cyamopsis tetragonoloba* (L.) Taub.] is a diploid and popularly known as '*Guar*' in India. It is one of the hardiest among all legume vegetables. The fleshy, long attractive, green, smooth tender pods with tender seeds rich in vitamin A and iron are consumed as vegetable. Vegetable legume crops require not only adequate macronutrients but also micronutrients for growth. Micronutrients are essential for the normal plant growth, deficiencies of which adversely affect the growth, metabolism and reproductive phase in plants. Zinc plays a vital role in the synthesis of chlorophyll, protein as well as nucleic acid. Zinc is the constituent of tryptophan which is a precursor of Auxin hormone. (Hafeez *et al*. 2013) [4]. Iron (Fe) play dominant role in oxidoredox reactions of photosynthesis and respiration. The deficiency of Fe in plants causes significant changes in plant metabolism and induce chlorosis, especially in young leaves and leads to very low reutilization. (Solanki *et al*. 2017) [15]. The plant to plant and row to row distance ensure proper utilization of different natural inputs. However, plants grown under optimum spacing had desirable population density per unit area which provides suitable conditions for crop growth and better plant canopy area due to maximum light interception, photosynthetic activity, assimilation and accumulation of more photosynthesis into plant system and hence they produce more seed yield with best quality traits (Mazumdar *et al*. 2007) [5].

Materials and Methods
The field experiment was carried out at Vegetable Research Scheme, Regional Horticultural Research Station, Navsari Agricultural University, Navsari, Gujarat, India during Summer season of 2017-18 on cv. Pusa Navbahar to investigate the effect of spacing and foliar spray of micronutrients on growth and yield of cluster bean. The experiment was conducted in Randomized Block Design with Factorial concept (FRBD) which included two factor namely, Factor one is Spacing (S) *viz*., S_1 – 45 cm × 20 cm; S_2 – 45 cm × 25 cm; S_3 – 45 cm × 30 cm and second factor is Foliar spray of micronutrients (F) F_0–Control (No spray); F_1– $FeSO_4$ - 0.5% ; F_2 – $ZnSO_4$ -0.5%; F_3 – $FeSO_4$ 0.5% + $ZnSO_4$ 0.5% and 12 treatment combination *viz*., 1.S_1F_0-(45 cm × 20 cm + control); 2.S_1F_1 - (45 cm × 20 cm + $FeSO_4$0.5%);3.S_1F_2- (45 cm ×

20 cm + $ZnSO_4$ 0.5%);4.S_1F_3 – [45 cm × 20 cm +($FeSO_4$ 0.5% + $ZnSO_4$ 0.5%)]; 5.S_2F_0 – [45 cm × 25 cm+ control]; 6.S_2F_1 – [45 cm × 25 cm+ $FeSO_4$ - 0.5%]; 7.S_2F_2 – [45 cm × 25 cm+ $ZnSO_4$ - 0.5%]; 8.S_2F_3- [45 cm × 25 cm+ ($FeSO_4$ 0.5% + $ZnSO_4$ 0.5%)]; 9.S_3F_0- [45 cm × 30 cm + control]; 10.S_3F_1 – [45 cm × 30 cm + $FeSO_4$ - 0.5%]; 11.S_3F_2 – [45 cm × 30 cm + $ZnSO_4$ - 0.5%]; 12.S_3F_3- [45 cm × 30 cm + ($FeSO_4$ 0.5% + $ZnSO_4$ 0.5%)]. The experiment included three replications. First foliar spray of micro nutrients was at 30 DAS and second at 45 DAS in early hours of morning.

The plant height was measured in centimeter with help of measuring tape from the ground level to top of the main shoot. The stem diameter was measured by Vernier caliperfrom the base of the primary leaf to base of hypocotyl and mean stem diameter was expressed in centimetre. For fresh weight plants fromeach treatment were uprooted carefully at the time of final harvesting and then fresh weight in gram per plant was recorded. For measurement of dry weight the plant was oven dried and then weight was measured with the help of weighing scale and noted. The number of clusters was counted on five plants and their average was expressed as number of clusters per plant. The number of pods borne on the individual cluster was counted from five tagged plants and the average was worked out and expressed as number of pods per cluster. The number of pods borne on individual plant was counted from plants and average was worked out, expressed as number of pods per plant. The pod yield at each picking was recorded and totalled worked out as pod yield per plant. The Pod yield per plot was multiplied with hectare conversion factor which expressed as pod yield ha^{-1} accordingly. The collected data were subjected to statistical analysis as per Panse and Sukhatme (1985) [8].

Results and Discussion

The statistical comparison shows the significant influence of level spacing at 90 DAS, S_1 exhibited maximum plant height of 106.57 cm which was at par with S_2. This occurs because of less plant canopy area in which plant can grow more freely in vertical growth due to stiffer competition for space, light, nutrients, moisture etc. thus, consequently attained more plant height at narrow spacing. These results were in accordance with the findings of earlier workers *viz.*, Chakravorty *et al.* (2009) [2], Dev (2010) [3] in French bean, Nandini *et al.* (2017) [7] and Priyadarshini *et al.* (2017) [9] in cluster bean.

In stem diameter, at 90 DAS S_1 recorded the highest diameter of 1.60 cm which was at par with S_2 and S_3.This might be due to narrow spacing plants which intercepted more sunlight for photosynthesis as well as more nutrients for proper growth and development. These were in accordance with the findings of earlier workers *viz.*, Dev (2010) [3] in French bean, Satodiya *et al.* (2015) [11] and Priyadarshini *et al.* (2017) [9] in cluster bean. Significantly maximum stem diameter of 1.78 cm was produced in F_3 (0.5% $FeSO_4$ + 0.5% $ZnSO_4$) level of foliar spray of micronutrients. It might be due to iron with zinc sulphate foliar spray of micronutrients which helped to increase accumulation of carbohydrates in stem region leading to increased thickness. Analogous results regarding foliar spray of micronutrients were also reported by Selvaraj and Lakshmi prasana (2012) in cluster bean, Tak *et al.* (2014) [17] in green gram and Sale *et al.* (2018) [10] in cluster bean.

In respect to the fresh weight of plants S_3 (45 cm × 30 cm) level of spacing recorded significantly maximum fresh weight (151.23 g) at harvest. This might be due to plants grown with wider spacing got better opportunity of available maximum space, light and nutrients leading to maximum fresh weight per plant. The maximum weight of plant (148.64 g) was recorded with the application of micronutrients, F_3 (0.5% $FeSO_4$ + 0.5% $ZnSO_4$) which was at par with F_2. Because zinc and iron sulphate foliar spray of micronutrients also helped to increase accumulation of carbohydrates in stem region leading to increased thickness. Analogous results regarding foliar spray of micronutrients were also reported by Selvaraj and Lakshmi prasana (2012) in cluster bean, Tak *et al.* (2014) [17] in green gram and Sale *et al.* (2018) [10] in cluster bean.

Other hand, dry weight S_3 (45 cm × 30 cm) produced maximum dry weight (18.42 g) which was at par with S_2. It produced more photosynthates and maximum dry weight per plant which ultimately reflected in to better development of growth attributes with these treatments. These results were in accordance with the findings of earlier workers *viz.*, Shrikanth (2008) in lablab bean, Satodiya *et al.* (2015) [11] and Afifi *et al.* (2016) [1] in cowpea, Nandini *et al.* (2017) [7] and Priyadarshini *et al.* (2017) [9] in cluster bean.

In the spacing level of S_3 (45 cm × 30 cm) recorded maximum number of clusters per plant (27.92), number of pods per cluster (6.96) and number of pods per plant(86.38) and it was at par with S_2.These must be due to wider spacing had relatively less inter-plant competition because of more space availability to individual plants for reproductive growth. The findings of earlier workers Siddaraju (2010) [14] and Nadini *et al.* (2017) in cluster bean. Foliar spray of micronutrients, F_3 (0.5% $FeSO_4$ + 0.5% $ZnSO_4$)} recorded significantly maximum number of clusters per plant (30.84), number of pods per cluster (6.58) and number of pods per plant (87.42). It might be due to reason that micronutrients provided a stimulus in the plant system, which in turn increased directly in various physiological processes and enzymatic activity for higher accumulation of food materials and Zinc was responsible for Auxin biosynthesis. The findings of earlier workers Mostafavi *et al.* (2012) [6] and Afifi *et al.* (2016) [1] in cow pea, Solanki *et al.* (2017) [15], Sale *et al.* (2018) [10] in cluster bean. The interaction effect S_3F_3 {(45 cm × 30 cm) + (0.5% $FeSO_4$ + 0.5% $ZnSO_4$)} exhibited higher number of clusters per plant (34.73), number of pods per cluster (7.20) and number of pods per plant(123). The noticed influence might be due to better supply of

Table 1: Effect of spacing and foliar spray of micronutrients on plant height and stem diameter of cluster bean.

Treatments	Plant height (cm)at 90 DAS					Stem diameter (cm) at 90 DAS				
	F_0	F_1	F_2	F_3	S Mean	F_0	F_1	F_2	F_3	S Mean
S_1	104.00	104.67	107.87	109.73	106.57	1.50	1.50	1.71	1.68	1.60
S_2	104.06	103.06	102.80	106.80	104.18	1.44	1.57	1.50	1.79	1.57
S_3	101.73	104.60	101.93	102.93	102.80	1.48	1.77	1.78	1.86	1.72
F Mean	103.27	104.11	104.20	106.49		1.47	1.61	1.66	1.78	
	S		F		S × F	S		F		S × F
S. Em. ±	0.97		1.13		1.96	0.02		0.04		0.06
C.D.at 5%	2.87		NS		NS	0.08		0.11		NS
C.V.%	3.24					7.21				

Table 2: Effect of spacing and foliar spray of micronutrients on fresh weight and dry weight of cluster bean plant

Treatments	Fresh weight at harvest (g)					Dry weight at harvest (g)				
	F_0	F_1	F_2	F_3	S Mean	F_0	F_1	F_2	F_3	S Mean
S_1	105.97	119.33	122.32	143.24	122.72	16.22	17.48	17.52	17.66	17.22
S_2	109.92	138.76	139.49	139.64	131.95	16.92	17.68	17.84	18.89	17.83
S_3	118.74	147.49	175.62	163.05	151.23	19.00	18.00	18.48	18.21	18.42
F Mean	111.54	135.19	145.81	148.64		17.38	17.72	17.95	18.25	
	S		F		S × F	S		F		S × F
S. Em. ±	3.42		3.95		6.84	0.24		0.28		0.49
C.D.at 5%	10.02		11.58		NS	0.71		NS		NS
C.V.%	8.75									

Table 3: Effect of spacing and foliar spray of micronutrients on number of cluster per plant and number of pods per cluster of cluster bean.

Treatments	Number of clusters per plant					Number of pods per cluster				
	F_0	F_1	F_2	F_3	S Mean	F_0	F_1	F_2	F_3	S Mean
S_1	14.73	23.40	24.60	27.73	22.62	5.50	4.60	5.20	6.33	5.41
S_2	23.60	24.40	27.00	30.07	26.27	4.50	5.53	5.33	6.20	5.39
S_3	23.07	25.33	28.53	34.73	27.92	5.10	7.07	8.47	7.20	6.96
F Mean	20.47	24.38	26.71	30.84		5.03	5.73	6.33	6.58	
	S		F		S × F	S		F		S × F
S. Em. ±	1.02		1.18		2.04	0.33		0.38		0.66
C.D.at 5%	2.99		3.46		NS	0.97		1.12		NS
C.V.%	13.81					19.34				

Table 4: Effect of spacing and foliar spray of micronutrients on number of pods per plant of cluster bean.

Treatments	Number of pods per plant				
	F_0	F_1	F_2	F_3	S Mean
S_1	35.47	45.53	56.73	77.80	53.88
S_2	41.40	61.87	55.87	61.47	55.15
S_3	57.13	77.26	88.13	123	86.38
F Mean	44.67	61.56	66.91	87.42	
	S		F		S × F
S. Em. ±	1.11		1.28		2.22
C.D.at 5%	3.25		3.75		6.50
C.V.%	5.90				

Table 5: Effect of spacing and foliar spray of micronutrients on pod yield per plant and pod yield per hectare of cluster bean.

Treatments	Pod yield per plant					Pods yield per hectare				
	F_0	F_1	F_2	F_3	S Mean	F_0	F_1	F_2	F_3	S Mean
S_1	63.84	7.09	9.11	12.60	13.45	7.09	9.11	12.60	13.45	10.56
S_2	85.68	7.62	10.15	8.66	9.71	7.62	10.15	8.66	9.71	9.03
S_3	111.96	8.29	10.90	11.72	16.40	8.29	10.90	11.72	16.40	11.83
F Mean	87.16	7.67	10.05	10.99	13.19	7.67	10.05	10.99	13.19	
	S		S		F	S		F	S	
S. Em. ±	4.62		0.48		0.55	0.48		0.55	0.48	
C.D.at 5%	13.54		1.41		1.62	1.41		1.62	1.41	
C.V.%	13.46					15.85				

Nutrients along with conducive physical environment leading to better root activity and higher nutrient absorption, which resulted better yield attributes. This might be due to integrated use of zinc sulphate with iron sulphate fertilizers attributed to could have enhanced the plant nutrition which increases the assimilate production and balance of Auxin in plant also regulates the cluster drop in plants which ultimately increased the total number of pods per plant. The present findings on interaction effect are in agreement with those reported by Srivastava *et al*. (2017) [16] in green gram.

The data of pod yield per plant and hectare among various levels of spacing, S_3 (45 cm × 30 cm) noticed maximum pod yield per plant and hectare (16.40 g and 11.83 t). It occurs because spacing is responsible to less competition for space, moisture and nutrients which accelerated normal photosynthetic activity and more interception of photo-synthetically active radiation. The present findings on spacing treatment are in agreement with those reported by Siddaraju (2010) [14] and Nadini *et al.* (2017) in cluster bean. In case of foliar spray of micronutrients levels, F_3 (0.5% $FeSO_4$ + 0.5% $ZnSO_4$) recorded significantly maximum pod yield per plant and hectare of (10.99 g and 13.19 t). An application of Zn and Fe were sprayed in combination involved directly in various physiological processes and enzymatic activity for higher accumulation of food materials and Zinc is responsible for Auxin biosynthesis. The balance of Auxin in plant also regulates the flower drop or retention in plants, which ultimately increased the total pods yield per plant and per hectare. Similar results on foliar spray of micronutrients were obtained by Mostafavi *et al*. (2012) [6] and Afifi *et al.* (2015) in cow pea, Solanki *et al.* (2017) [15], Sale *et al*. (2018) [10] in cluster bean. The interaction effect S_3F_3 {(45 cm × 30 cm) + (0.5% $FeSO_4$ + 0.5% $ZnSO_4$)} recorded maximum pod yield of 11.72 g per plant and 16.40 t per hectare. These may be due to influence of spacing on developing pods which resulted in reduction in plant population per unit area under wider

spacing and was able to compensate total yield, which further resulted in higher yield, increased pod yield per plant and per hectare production in wider spacing. Other hand fact that the balance of Auxin in plant also regulates the cluster drop in plants, which ultimately increased the total number of pods per plant noticed in combined zinc sulphate and iron sulphate. The present findings on interaction effect are in agreement with those reported by Srivastava *et al*. (2017) [16] in green gram.

Conclusions

From this experiment and by considering the statistical analysis we can conclude that, in light of the results obtained in the present investigation, it inferred that growth and yield of cluster bean can be increased by interaction effect of spacing with foliar spray of micronutrients S_3F_3 {(45 cm × 30 cm) + (0.5% $FeSO_4$ + 0.5% $ZnSO_4$)} followed by S_1F_3.

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