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Response of PGRs on pod characters and yield attributes of cluster bean cv. Pusa Navbahar

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Abstract
An experiment was conducted, with a view to study the response of PGRs on pod characters and yield attributes of cluster bean cv. Pusa Navbahar at the Vegetable Research Scheme, Regional Horticultural Research Station of the Navsari Agricultural University, Navsari, Gujarat, India during Summer 2016 and 2017. The experiment was conducted in randomized block design with three replications, which included 13 treatments. Among pod characters, T_4 (GA_3 20 mg l^{-1}) was found best in statistical analysis for number of cluster plant^{-1}, number of pods cluster^{-1}, number of pods plant^{-1}, pod length, pod width, pod weight and number of seeds pod^{-1} as well as yield attributes namely, pod yield and harvest index on pooled basis. Based on green pod yield, maximum return was obtained from the foliar application of GA_3 20 mg l^{-1} with higher B:CR value of 2.1 followed by T_1 (B:CR value of 1.9).

Keywords: Cluster bean, PGRs, pod characters and yield attributes

Introduction
Cluster bean [*Cyamopsis tetragonoloba* (L.) Taub.] is grown for its young tender green immature pods, which are used as a nutritive vegetable. It can be grown on almost all types of soil in *Kharif* and Summer seasons. In spite of commercial importance of cluster bean crop in our daily diet and wide spread cultivation; availability of good quality cluster bean is not satisfactory. Several attempts have been made to increase the yield potential of pulses, but, very little attention has been given to the physiological processes, which limit the crop productivity. Application of growth promoting hormones *i.e.,* Plant Growth Regulators (PGRs) is a recent technique in this direction. Plant growth regulators are known to influence growth and development at very low concentrations but inhibit plant growth and development at high concentration (Ibrahim *et al.,* 2007) [4]. Such substances are therefore potentially useful in horticulture, because suitable concentrations applied at appropriate times will increase the yield either by altering dry matter distribution in the plant or by regulating growth. When growth regulators are used in appropriate concentrations, these substances influence the plant architecture in a typical fashion and improve the yield potential. Therefore, an attempt has been made to study the response of PGRs on pod characters and yield attributes of cluster bean cv. Pusa Navbahar.

Materials and Methods
The field experiment was carried out at the Vegetable Research Scheme, Regional Horticultural Research Station of the Navsari Agricultural University, Navsari, Gujarat, India during Summer 2016 and 2017 on cv. Pusa Navbahar to investigate the response of PGRs on pod characters and yield attributes of cluster bean cv. Pusa Navbahar. The experiment was conducted in randomized block design (RBD), which included 13 treatments namely, T_1 : NAA 20 mg l^{-1}, T_2 : NAA 40 mg l^{-1}, T_3 : NAA 60 mg l^{-1}, T_4 : GA_3 20 mg l^{-1}, T_5 : GA_3 40 mg l^{-1}, T_6 : GA_3 60 mg l^{-1}, T_7 : Thiourea 250 mg l^{-1}, T_8 : Thiourea 500 mg l^{-1}, T_9 : Thiourea 750 mg l^{-1}, T_{10} : NAA 20 mg l^{-1} + GA_3 20 mg l^{-1}, T_{11} : NAA 20 mg l^{-1} + Thiourea 250 mg l^{-1}, T_{12} : GA_3 20 mg l^{-1} + Thiourea 250 mg l^{-1} and T_{13} : Control. The experiment included three replications. At the time of 50 % flowering, foliar sprays were made at early hours of morning to avoid dehydration effect at mid-day.
For recording different field observations, five plants of cluster bean from each net plot area were selected randomly in the beginning and tagged with the labels.

The number of cluster per plant was counted at the time of each picking and average was worked out. The number of pods were counted per cluster at each picking and then averaged to obtained number of pods per cluster. The number of pods per plant were counted at each picking and then averaged to obtained number of pods per plant. From the ten randomly selected pods, the length of pod was measured in centimetre from the stalk to the apex by thread and mean pod length was determined by summing up the length of all ten pods and divided by ten. Pods used for measuring length were also used for the estimation of pod width. The width at the middle of the pod was recorded with the help of vernier caliper and its average was worked out in centimetre. Ten fresh and marketable pods from each treatment were selected randomly for weighing and their average value was recorded as pod weight in gram. The number of seeds per pod was recorded at tender stage from ten pods after each harvesting. Pod yield was derived by summing up the pod weight of all the pods harvested from the net plot during all the pickings and then summed to obtain the pod yield. The values of pod yield were converted in kg ha^{-1}. Harvest index was calculated by using formula. The benefit: cost ratio was also calculated for each treatment under the study. The collected data were subjected to statistical analysis as per Panse and Sukhatme (1967) [6].

Results and Discussion

The statistical comparison shows the significant influence of different treatments on number of cluster $plant^{-1}$ during cropping period as well as in pooled analysis also. With regard to the pooled mean, the values varied from 32.20 to 45.27. Here, the treatment T_4 recorded higher number of cluster $plant^{-1}$ (45.27) and was at par with T_1, T_{11} and T_7. This occurs because of exogenous application of plant growth regulators (GA_3 and NAA) which stimulated the enzymatic activities for hormones that increased size of leaf area, leaf area index as well as increased net assimilation rate that contributed for better formation of biological yield and ultimately increased number of pods as well as clusters $plant^{-1}$. The treatment NAA also increases retention of flowers and thereby pods per clusters which indirectly enhance the pod setting. The results are in accordance with the findings of Satodiya *et al.* (2011) [11] and Patel, Priyanka *et al.* (2015) [9] in cluster bean as well as Patel *et al.* (2011) [7] in cowpea.

Pooled mean data revealed that number of pods $cluster^{-1}$ values varied from 3.55 to 4.63. Maximum number of pods $cluster^{-1}$ (4.63) was observed with the application of GA_3 20 mg l^{-1} (T_4) and it was significantly superior treatment. The minimum number of pods $cluster^{-1}$ (3.55) was recorded with the treatment T_{10} (NAA 20 mg l^{-1} + GA_3 20 mg l^{-1}) which was on par with T_9 (Thiourea 750 mg l^{-1}). It is amply clear from the study that exogenous application of plant growth regulators stimulate the effects of enzymatic activities of natural occurring hormones that accelerated and modified the growth and development of plants and hence increase number of pods $cluster^{-1}$. The results are in line with the findings of Satodiya *et al.* (2011) [11] in cluster bean and Patel *et al.* (2011) [7] in cowpea.

Looking to the pooled mean, the maximum number of pods $plant^{-1}$ (197.57) was recorded in treatment of T_4 (GA_3 20 mg l^{-1}) and was found to be at par with the treatments of T_1 and T_{11}. The minimum number of pods $plant^{-1}$ (121.73) was recorded in the treatment of T_{10} and was at par with the treatment T_9 (Thiourea 750 mg l^{-1}). This was happened due to balanced C/N ratio by application of hormones, which might have increased the synthesis of carbohydrates which ultimately promoted greater growth and yield component like number of pods per plant. This type of result is also reported by Patel *et al.* (2006) [8] and Satodiya *et al.* (2011) [11] in cluster bean; Patel *et al.* (2011) [7] and Nabi *et al.* (2014) [5] in cowpea; Rathod *et al.* (2015) [10] in french bean; Singh *et al.* (2015) [12] in pea; Ibrahim *et al.* (2007) [4], Zewail *et al.* (2011) [13] and Amin *et al.* (2014) [1] in faba bean.

The pooled data of pod length revealed that the values varied from 8.01 to 10.91 cm. Treatment T_4 (GA_3 20 mg l^{-1}) recorded the maximum pod length (10.91 cm) over rest of the treatments; whereas, the minimum pod length (8.01 cm) was recorded with the treatment T_{10} and was at par with T_9. GA_3 treatment enhanced cell elongation and cell division and checking of the vegetative growth phase and diversification of photosynthetic materials towards the source *i.e.*, pods which ultimately increased the pod length. Similar result was also noted by Satodiya *et al.* (2011) [11] and Patel, Priyanka *et al.* (2015) [9] in cluster bean; Patel *et al.* (2011) [7], Nabi *et al.* (2014) [5] and Golakiya *et al.* (2017^b) [3] in cowpea; Rathod *et al.* (2015) [10] in french bean; Singh *et al.* (2015) [12] in pea; Ibrahim *et al.* (2007) [4] in faba bean. (Table 1)

The perusal of the pooled data further revealed that the pod width obtained under different treatments varied from 0.68 to 0.86 cm. Maximum pod width (0.86 cm) was obtained from the plants applied with GA_3 20 mg l^{-1} (T_4) and was statistically at par with the similar trend as in second year result. The minimum pod width of 0.68 cm was recorded in the treatment T_{10}, which was at par with T_9. This occurred due to positive correlation with bio-chemical and physiological processes of plant growth regulators that increased size of photosynthetic area, which contributed for biological yield as well as pods, which ultimately increase pod width also. Similar result was also recorded by Patel, Priyanka *et al.* (2015) [9] in cluster bean.

The perusal of the pooled data further revealed that the pod weight obtained under different treatments varied from 1.43 to 1.71 g. Maximum pod weight (1.71 g) was obtained from the T_4 and was statistically at par with the treatment of T_1, T_{11}, T_7, T_2 and T_{12}. The minimum pod weight of 1.43 g was noticed from the T_{10}, which was at par with the T_9. Reproductive parts showed an increasing trend throughout the growing period of the crop due to growth regulator treatments which increased the pod weight. Similar results were also found by Patel *et al.* (2011) [7] and Nabi *et al.* (2014) [5] in cowpea; Zewail *et al.* (2011) [13] in faba bean.

Looking to the pooled mean data at a glance, the values for number of seeds pod^{-1} were ranging from 6.59 to 8.50. The results showed that treatment T_4, holding GA_3 20 mg l^{-1}, recorded maximum number of seeds pod^{-1} (8.50) and was at par with the treatment T_1, T_{11}, T_7, T_2 and T_{12}. This happened under GA_3 treatment, might be due to enhancement of flowering, pod setting which increased seed in green pod also. This observation is also in close conformity with the report of Satodiya *et al.* (2011) [11] and Patel, Priyanka *et al.* (2015) [9] in cluster bean; Patel *et al.* (2011) [7] and Nabi *et al.* (2014) [5] in cowpea; Singh *et al.* (2015) [12] in pea; Ibrahim *et al.* (2007) [4] and Zewail *et al.* (2011) [13] in faba bean.

Looking at the pooled analysis results, the pod yield ranged from 7158.18 to 13309.80 kg ha^{-1}. The maximum pod yield (13309.80 kg ha^{-1}) was noticed under the treatment of T_4 receiving GA_3 20 mg l^{-1}, which was found to be statistically at par with the treatment T_1 only. However, the treatment T_{10} (NAA 20 mg l^{-1} + GA_3 20 mg l^{-1}) observed the minimum pod yield (7158.18 kg ha^{-1}), which was found to be at par with the

T_9. Since, pod yield is influenced by leaf area index, NAR and yield components and these all variables enhanced by exogenous plant growth regulators application. The pod yield in cluster bean depends on the accumulation of photo assimilates and redistribution of dry matter in plant, thereby bring about an improvement in yield potential. The present findings are in agreement with those reported by Patel, Priyanka *et al*. (2015) [9] in cluster bean; Patel *et al.* (2011) [7], Golakiya *et al.* (2017[a]) [2] and Golakiya *et al.* (2017[b]) [3] in cowpea; Rathod *et al.* (2015) [10] in french bean and Amin *et al.* (2014) [1] in faba bean.

The results of harvest index were found non-significant during both the years of study. But significant in pooled analysis. Furthermore, on the basis of pooled it can be noted that harvest index ranged from 30.82 to 41.67 %. Maximum harvest index was observed in T_4 (41.67 %) and it was at par with T_1 (39.77). Minimum harvest index was observed in T_{10} (30.82 %) and it was at par with T_9 (32.47). This might be due to exogenous application of plant growth regulators which stimulated and enhance the enzymatic activities and checking the vegetative growth phases and diversification of photosynthetic materials towards the source *i.e.* pods which ultimately increase harvest index. These finding are in agreement with the experimental results reported by various scientist *viz*., Satodiya *et al.* (2011) [11] and Patel, Priyanka *et al*. (2015) [9] in cluster bean; Nabi *et al.* (2014) [5] in cowpea; Ibrahim *et al.* (2007) [4] and Amin *et al.* (2014) [1] in faba bean. (Table 2)

The data analysis revealed that among the different treatments; T_4 (GA_3 20 mg l^{-1}) registered the highest net profit 1,80,263 Rs. ha^{-1} with B:CR of 2.1 as compared to rest of the treatment combinations, followed by T_1 (B:CR of 1.9). Whereas, treatment T_{10} (NAA 20 mg l^{-1} + GA_3 20 mg l^{-1}) recorded the lowest net realization 57,205 Rs. ha^{-1} with lowest B:CR value of 0.7. This might be due to higher green pod yield registered under T_4. The similar result was also reported by Patel *et al.* (2006) [8] in cluster bean; Golakiya *et al.* (2017[a]) [2] and Golakiya *et al.* (2017[b]) [3] in cowpea. (Table 3)

Table 1: Effect of different treatments on pod characters *viz.*, Number of cluster plant^{-1}, Number of pods cluster^{-1}, Number of pods plant^{-1} and Pod length (cm) of cluster bean cv. Pusa Navbahar

Treatments	Number of cluster plant^{-1}			Number of pods cluster^{-1}			Number of pods plant^{-1}			Pod length (cm)		
	2016	2017	Pooled	2016	2017	Pooled	2016	2017	Pooled	2016	2017	Pooled
T_1	44.53	43.80	44.17	4.20	4.37	4.28	165.00	202.27	183.63	10.36	10.35	10.35
T_2	41.33	40.93	41.13	3.66	4.26	3.96	154.53	187.47	171.00	10.26	10.26	10.26
T_3	38.73	35.73	37.23	3.51	3.84	3.67	135.13	145.93	140.53	9.00	9.02	9.01
T_4	46.00	44.53	45.27	4.60	4.65	4.63	180.47	214.67	197.57	10.91	10.92	10.91
T_5	40.00	39.07	39.53	3.58	4.15	3.87	148.13	169.20	158.67	9.84	9.86	9.85
T_6	39.33	36.27	37.80	3.55	4.06	3.81	144.00	156.60	150.30	9.29	9.28	9.28
T_7	42.33	42.80	42.57	3.72	4.27	4.00	157.07	191.07	174.07	10.27	10.27	10.27
T_8	38.80	36.13	37.47	3.55	3.92	3.74	142.60	149.47	146.03	9.20	9.19	9.20
T_9	37.93	34.27	36.10	3.49	3.72	3.61	135.07	125.40	130.23	8.73	8.72	8.73
T_{10}	32.93	31.47	32.20	3.48	3.62	3.55	123.40	120.07	121.73	8.00	8.02	8.01
T_{11}	42.40	43.53	42.97	3.88	4.32	4.10	163.40	200.07	181.73	10.31	10.30	10.30
T_{12}	40.87	39.07	39.97	3.65	4.20	3.93	148.27	172.00	160.13	9.89	9.88	9.88
T_{13}	39.73	38.93	39.33	3.57	4.12	3.85	145.33	168.87	157.10	9.44	9.45	9.45
Year Mean	40.38	38.96	39.67	3.73	4.12	3.92	149.42	169.47	159.44	9.65	9.65	9.65
S.Em. ±	2.07	2.15	1.37	0.16	0.17	0.11	9.52	13.38	8.12	0.45	0.46	0.29
C.D. at 5 %	6.04	6.28	3.88	0.45	0.49	0.31	27.78	39.04	22.98	1.32	1.34	0.82
C.V. %	8.88	9.57	9.22	7.23	7.09	7.16	11.03	13.67	12.61	8.13	8.24	8.18
YT : S.Em. ±			2.11			0.16			11.61			0.46
YT : C.D. at 5 %			NS			NS			NS			NS

Table 2: Effect of different treatments on pod characters and yield attributes *viz.*, Pod width (cm), Pod weight (g), Number of seeds pod^{-1}, Pod yield (kg ha^{-1}) and Harvest index (%) of cluster bean cv. Pusa Navbahar

Treatments	Pod width (cm)			Pod weight (g)			Number of seeds pod^{-1}			Pod yield (kg ha^{-1})			Harvest index (%)		
	2016	2017	Pooled	2016	2017	Pooled	2016	2017	Pooled	2016	2017	Pooled	2016	2017	Pooled
T_1	0.82	0.83	0.82	1.65	1.65	1.65	8.32	8.34	8.33	12770.06	11654.32	12212.19	40.82	38.73	39.77
T_2	0.78	0.77	0.78	1.63	1.64	1.63	8.15	8.12	8.14	10235.34	9420.53	9827.93	35.87	33.99	34.93
T_3	0.72	0.72	0.72	1.46	1.45	1.46	7.25	7.27	7.26	9444.45	7750.00	8597.22	37.08	32.65	34.87
T_4	0.86	0.87	0.86	1.72	1.71	1.71	8.50	8.51	8.50	13989.20	12630.40	13309.80	43.05	40.28	41.67
T_5	0.74	0.74	0.74	1.60	1.59	1.59	7.77	7.77	7.77	9899.69	8980.71	9440.20	35.23	32.96	34.10
T_6	0.73	0.73	0.73	1.50	1.50	1.50	7.58	7.60	7.59	9205.25	8552.47	8878.86	35.96	34.21	35.09
T_7	0.81	0.80	0.81	1.63	1.64	1.64	8.23	8.23	8.23	11307.87	10076.39	10692.13	38.02	35.32	36.67
T_8	0.73	0.73	0.73	1.46	1.47	1.46	7.41	7.43	7.42	9436.73	8251.54	8844.14	36.67	33.64	35.15
T_9	0.70	0.71	0.71	1.45	1.43	1.44	7.24	7.22	7.23	8381.17	6993.83	7687.50	34.41	30.52	32.47
T_{10}	0.68	0.67	0.68	1.43	1.43	1.43	6.60	6.58	6.59	7550.15	6766.20	7158.18	31.82	29.81	30.82
T_{11}	0.82	0.82	0.82	1.65	1.65	1.65	8.30	8.30	8.30	11051.70	10550.93	10801.31	37.35	36.36	36.86
T_{12}	0.74	0.75	0.75	1.60	1.60	1.60	8.02	8.00	8.01	10252.32	9208.33	9730.32	35.89	33.43	34.66
T_{13}	0.73	0.73	0.73	1.59	1.58	1.59	7.69	7.70	7.69	9587.19	8556.33	9071.76	35.88	33.28	34.58
Year Mean	0.76	0.76	0.76	1.57	1.56	1.57	7.78	7.77	7.77	10239.32	9184.00	9711.66	36.77	34.25	35.51
S.Em. ±	0.04	0.03	0.02	0.06	0.06	0.04	0.32	0.32	0.20	786.92	794.20	505.31	2.40	2.57	1.59
C.D. at 5 %	0.10	0.09	0.06	0.19	0.19	0.11	0.92	0.92	0.57	2296.96	2318.21	1429.24	NS	NS	4.48
C.V. %	8.06	7.13	7.61	7.07	7.09	7.08	7.02	7.05	7.04	13.31	14.98	14.10	11.28	13.02	12.13
YT : S.Em. ±			0.03			0.06			0.32			790.56			2.49
YT : C.D. at 5 %			NS			NS			NS			NS			NS

Table 3: Economics of different treatments (Rs. ha^{-1}) of cluster bean cv. Pusa Navbahar

Treatments	Pod yield (kg ha^{-1})	Treatment Cost	Operational cost	Total Cost	Gross Return	Net Return	B:CR
T_1 : NAA 20 mg l^{-1}	12212.19	26	85,345	85,371	2,44,244	1,58,873	1.9
T_2 : NAA 40 mg l^{-1}	9827.93	52	85,345	85,397	1,96,559	1,11,162	1.3
T_3 : NAA 60 mg l^{-1}	8597.22	78	85,345	85,423	1,71,944	86,521	1.0
T_4 : GA_3 20 mg l^{-1}	13309.80	588	85,345	85,933	2,66,196	1,80,263	2.1
T_5 : GA_3 40 mg l^{-1}	9440.20	1,175	85,345	86,520	1,88,804	1,02,284	1.2
T_6 : GA_3 60 mg l^{-1}	8878.86	1,763	85,345	87,108	1,77,577	90,469	1.0
T_7 : Thiourea 250 mg l^{-1}	10692.13	56	85,345	85,402	2,13,843	1,28,441	1.5
T_8 : Thiourea 500 mg l^{-1}	8844.14	113	85,345	85,458	1,76,883	91,425	1.1
T_9 : Thiourea 750 mg l^{-1}	7687.50	169	85,345	85,514	1,53,750	68,236	0.8
T_{10} : NAA 20 mg l^{-1} + GA_3 20 mg l^{-1}	7158.18	613	85,345	85,959	1,43,164	57,205	0.7
T_{11} : NAA 20 mg l^{-1}+Thiourea 250 mg l^{-1}	10801.31	82	85,345	85,427	2,16,026	1,30,599	1.5
T_{12} : GA_3 20 mg l^{-1} + Thiourea 250 mg l^{-1}	9730.32	644	85,345	85,989	1,94,606	1,08,617	1.3
T_{13} : Control	9071.76	0	85,167*	85,167	1,81,435	96,268	1.1

* Excluding treatment cost application.

Conclusion

By considering the statistical analysis, it is seen that treatment T_4 (GA_3 20 mg l^{-1}) at the time of 50 % flowering stage was found highly remunerative for growing of cluster bean cv. Pusa Navbahar for vegetable purpose which gave better performance for pod characters and yield attributes. It is evident from the economics based on green pod yield, maximum return was obtained from the foliar application of GA_3 20 mg l^{-1} with higher B:CR value of 2.1 followed by T_1 (B:CR value of 1.9).

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