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EFFECT OF PLANTING GEOMETRY AND NUTRITION ON GROWTH AND FLOWERING OF SEED GUAR CULTIVARS

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Abstract

The effect of planting geometry and nutrition on growth and flowering of seed guar cultivars *viz*., HG 365 and HG 563 was analysed under Mahanandi conditions. The growth parameters like plant height and leaf area were recorded significantly the highest values in the variety HG 365 planted at the spacing of 30 cm × 10 cm and applied with the fertilizer dose of 45N: 60P: 60K: 30S kg per ha. The earliest flowering was recorded by the spacing of 30 cm × 10 cm and the lowest fertilizer dose of 15N: 20P: 20K: 10S kg per ha. However, the highest seed yield per plot was recorded by the variety HG 365 planted at the spacing of 30 cm × 10 cm and applied with the fertilizer dose of 45N: 60P: 60K: 30S kg per ha.

Key words : Seed guar, planting geometry, nutrition and flowering.

Introduction

Cluster bean is botanically called as *Cyamopsis tetragonoloba* (L.) Taub. It belongs to the family Leguminaceae. The crop is popularly known as guar referring to its seed. India is considered as native place for guar or cluster bean. It has been used as vegetable in our country from hundreds of years. The crop is renowned as drought hardy, being deep rooted and having a low water requirement. It requires a low annual rainfall of about 400 mm to 500 mm. Guar tolerates high temperature and dry conditions, thus gaining popularity in arid and semi arid climates (Undersander *et al*., 2006).

Materials and Methods

The experiment was conducted in factorial randomized design with three factors *viz*., varieties (2), planting geometry levels (3) and nutritional levels (3) replicated thrice. The plot was laid out at Horticultural Research Station, Mahanandi, Kurnool district of Andhra Pradesh during both *kharif* and *rabi* seasons of the years 2014-15 and 2015-16. The data obtained from both the years was pooled and presented in the tables.

Results and Discussion

Plant height

The data on plant height (tables 1a, 1b) revealed that there were significant differences due to variety, planting geometry, nutritional combinations and their interactions. Among the varieties HG 365 recorded the highest plant height both in *kharif* (77.91 cm) and *rabi* seasons (69.34 cm) at 90 DAS. Planting geometry of 30 cm x 10 cm (S_1) recorded significantly the highest plant height (*kharif* 79.91 cm; *rabi* 71.12 cm) followed by 40 cm x 10 cm (S_3) (*kharif* 71.11 cm; *rabi* 63.29 cm). The lowest plant height was recorded by the planting geometry at 30 cm × 20 cm (S_2) (*kharif* 65.20 cm; *rabi* 58.03 cm). Application of 45N: 60P: 60K: 30S kg per ha (F_3) recorded the highest plant height (*kharif* 74.06 cm; *rabi* 65.92 cm) which was on par with 30N: 40P: 40K: 20S kg per ha (F_2) (*kharif* 72.85 cm; *rabi* 64.84 cm). The lowest plant height (*kharif* 69.29 cm; *rabi* 61.67 cm) was recorded by the application of 15N: 20P: 20K: 10S kg per ha (F_1).

The height of plant was found to show significant variations among the different levels of planting geometry. The S_1 (30 cm × 10 cm) accommodated 33.33 plants per m^2 area as against 16.7 plants in m^2 area in S_2 (30 cm × 20 cm) and 25 plants per m^2 area in S_3 (40 cm × 10 cm). There was highest average plant height with the highest density as compared to the lowest density of plants positioned at wider planting geometry. This might be perhaps to the reason that, the plants grew tall and lengthy in search of sunlight when the population was crowded, whereas, the plants under lower density would have not competed for light and grew normally.

Table 1 a : Plant height (cm) as influenced by variety, planting geometry and nutritional combination during *kharif* (pooled data of 2014-15 & 2015-16).

Planting Geometry (B)	Nutritional Combination (C)	Variety (A)								
		30 DAS			60 DAS			90 DAS		
		HG 365	HG 563	*Mean*	HG 365	HG 563	*Mean*	HG 365	HG 563	*Mean*
S_1 (30 cm x 10 cm) (33.3 plants per m^2)	F_1 (15N:20P:20K:10S)	31.20	26.52	***28.86***	68.02	57.81	***62.91***	84.34	71.69	***78.01***
	F_2 (30N:40P:40K:20S)	32.18	27.35	***29.76***	70.14	59.62	***64.88***	86.98	73.93	***80.45***
	F_3 (45N:60P:60K:30S)	32.50	27.62	***30.06***	70.84	60.22	***65.53***	87.85	74.67	***81.26***
	Mean	***31.96***	***27.16***	***29.56***	***69.67***	***59.22***	***64.44***	***86.39***	***73.43***	***79.91***
S_2 (30 cm x 20 cm) (16.7 plants per m^2)	F_1 (15N:20P:20K:10S)	25.03	21.27	***23.15***	54.56	46.38	***50.47***	67.66	57.51	***62.58***
	F_2 (30N:40P:40K:20S)	26.33	22.38	***24.35***	57.39	48.78	***53.08***	71.16	60.49	***65.82***
	F_3 (45N:60P:60K:30S)	26.87	22.84	***24.86***	58.58	49.79	***54.19***	72.64	61.74	***67.19***
	Mean	***26.07***	***22.16***	***24.12***	***56.84***	***48.32***	***52.58***	***70.49***	***59.91***	***65.20***
S_3 (40 cm x 10 cm) (25 plants per m^2)	F_1 (15N:20P:20K:10S)	26.91	22.87	***24.89***	58.66	49.86	***54.26***	72.74	61.83	***67.29***
	F_2 (30N:40P:40K:20S)	28.91	24.57	***26.74***	63.02	53.57	***58.29***	78.15	66.42	***72.29***
	F_3 (45N:60P:60K:30S)	29.49	25.07	***27.28***	64.30	54.65	***59.47***	79.73	67.77	***73.75***
	Mean	***28.44***	***24.17***	***26.30***	***61.99***	***52.69***	***57.34***	***76.87***	***65.34***	***71.11***
For Comparing varieties (A) and Nutritional combinations (C)										
F_1 (15N:20P:20K:10S)		27.71	23.56	***25.63***	60.41	51.35	***55.88***	74.91	63.68	***69.29***
F_2 (30N:40P:40K:20S)		29.14	24.77	***26.95***	63.52	53.99	***58.75***	78.76	66.95	***72.85***
F_3 (45N:60P:60K:30S)		29.62	25.18	***27.40***	64.57	54.89	***59.73***	80.07	68.06	***74.06***
Mean		***28.82***	***24.50***	***26.66***	***62.83***	***53.41***	***58.12***	***77.91***	***66.23***	***72.07***

Factor	*S Em±*	*CD*	*SEm±*	*CD*	*SEm±*	*CD*
Variety (A)	***0.61***	***1.77***	***1.33***	***3.86***	***1.65***	***4.79***
Ptg. Geom. (B)	***0.55***	***1.59***	***1.19***	***3.46***	***1.48***	***4.29***
Nutril. Combn.(C)	***0.23***	***0.66***	***0.67***	***1.94***	***0.62***	***1.80***
A x B	-	***NS***	-	***NS***	-	***NS***
B x C	***0.74***	***2.14***	***1.77***	***5.13***	***2.00***	***5.78***
A x C	-	***NS***	-	***NS***	-	***NS***
A x B x C	-	***NS***	-	***NS***	***3.57***	***10.33***

CD: CD at 5% level of significance, DAS : Days after sowing.

Table 1 b : Plant height (cm) as influenced by variety, planting geometry and nutritional combination during *rabi* (pooled data of 2014-15 & 2015-16).

Planting Geometry(B)	Nutritional Combination (C)	Variety (A)								
		30 DAS			60 DAS			90 DAS		
		HG 365	HG 563	*Mean*	HG 365	HG 563	*Mean*	HG 365	HG 563	*Mean*
S_1 (30 cm x 10 cm) (33.3 plants per m^2)	F_1 (15N:20P:20K:10S)	27.77	23.60	***25.69***	60.53	51.45	***55.99***	75.06	63.80	***69.43***
	F_2 (30N:40P:40K:20S)	28.64	24.34	***26.49***	62.43	53.06	***57.74***	77.41	65.80	***71.60***
	F_3 (45N:60P:60K:30S)	28.92	24.58	***26.75***	63.05	53.59	***58.32***	78.18	66.45	***72.32***
	Mean	***28.44***	***24.18***	***26.31***	***62.00***	***52.70***	***57.35***	***76.88***	***65.35***	***71.12***
S_2 (30 cm x 20 cm) (16.7 plants per m^2)	F_1 (15N:20P:20K:10S)	22.28	18.93	***20.60***	48.56	41.28	***44.92***	60.21	51.18	***55.70***
	F_2 (30N:40P:40K:20S)	23.43	19.91	***21.67***	51.08	43.41	***47.25***	63.33	53.83	***58.58***
	F_3(45N:60P:60K:30S)	23.92	20.33	***22.12***	52.14	44.31	***48.22***	64.65	54.95	***59.80***
	Mean	***23.21***	***19.73***	***21.47***	***50.59***	***43.00***	***46.80***	***62.73***	***53.32***	***58.03***
S_3 (40 cm x 10 cm) (25 plants per m^2)	F_1 (15N:20P:20K:10S)	23.95	20.36	***22.15***	52.21	44.38	***48.29***	64.74	55.03	***59.89***
	F_2 (30N:40P:40K:20S)	25.73	21.87	***23.80***	56.09	47.68	***51.88***	69.55	59.12	***64.33***
	F_3 (45N:60P:60K:30S)	26.25	22.31	***24.28***	57.22	48.64	***52.93***	70.96	60.31	***65.64***
	Mean	***25.31***	***21.51***	***23.41***	***55.17***	***46.90***	***51.04***	***68.42***	***58.15***	***63.29***
For comparing varieties (A) and Nutritional combinations (C)										
F_1 (15N:20P:20K:10S)		24.66	20.96	***22.81***	53.77	45.70	***49.74***	66.67	56.67	***61.67***
F_2 (30N:40P:40K:20S)		25.93	22.04	***23.99***	56.53	48.05	***52.29***	70.10	59.58	***64.84***
F_3 (45N:60P:60K:30S)		26.36	22.41	***24.39***	57.47	48.85	***53.16***	71.26	60.57	***65.92***
Mean		***25.65***	***21.80***	***23.73***	***55.92***	***47.53***	***51.73***	***69.34***	***58.94***	***64.14***

Factor	30 DAS *SEm±*	30 DAS *CD*	60 DAS *SEm±*	60 DAS *CD*	90 DAS *SEm±*	90 DAS *CD*
Variety (A)	***0.54***	***1.58***	***1.19***	***3.44***	***1.47***	***4.26***
Ptg. Geom. (B)	***0.49***	***1.41***	***1.06***	***3.08***	***1.32***	***3.82***
Nutril. Combn.(C)	***0.20***	***0.59***	***0.60***	***1.73***	***0.55***	***1.60***
A x B	-	***NS***	-	***NS***	-	***NS***
B x C	***0.66***	***1.90***	***1.58***	***4.57***	***1.78***	***5.14***
A x C	-	***NS***	-	***NS***	***1.92***	***5.57***
A x B x C	-	***NS***	-	***NS***	-	***NS***

CD: CD at 5% level of significance, DAS: Days after sowing.

As the fertilizer dose increased the vertical growth was also found increased but, such an increase was not statistically significant beyond F_2 level (30N:40P:40K:20S) indicating a much balanced nutrition at F_2 level (30N:40P:40K:20S). However, maximum plant height was noticed at F_3 level (45N:60P:60K:30S). Since, there was no significant increase in plant height at F_3 level over F_2 level (30N:40P:40K:20S), the extra fertilizers given might not be utilised effienciently and might be proven uneconomical.

Among the interactions, the effects of planting geometry *versus* nutrient combination were found significant at all growth stages during both the seasons. The combination of variety HG 365, planting geometry at 30 cm x 10 cm coupled with F_3 level (45N:60P:60K:30S) exhibited superior performance, which was on par with the same variety and planting geometry together with the application of F_2 level (30N:40P:40K:20S). Similar increase in plant height at higher population density was also observed by Naik (2007).

Significant variations in plant height were noticed by Akhtar *et al.* (2012) among the varieties of french bean and attributed the same to their genetic variability. Different spacing treatments were found significant regarding their influence on plant height and number of branches per plant. They noted that row spacing of 45 and 60 cm appeared equally effective for increasing both plant height and number of branches per plant. There was a gradual increase in plant height with the increase of row spacing up to 60 cm but decreased at further wider planting geometry levels (Akhtar *et al*., 2012).

An increase in plant height due to higher dose of sulphur was recorded by Kumawat and Khangarot (2002) which was attributed to the increased photosynthetic activity as it helps in chlorophyll formation. Sulphur was proved as an essential constituent of amino acids like cystine, cystidine and methionine and was responsible for the synthesis of biotine and thiamine, metabolism of carbohydrates, protein and fats.

Leaf area

Leaf area per plant varied significantly (tables 2a, 2b,) by the effect of variety, planting geometry, nutritional combinations as well as their interactions at all growth stages and during both the seasons. Among the varieties HG 365 recorded the highest leaf area both in *kharif* (533.96 cm^2) and *rabi* seasons (475.23cm^2) at 90 DAS. Planting geometry of 30 cm × 10 cm (S_1) recorded significantly the highest leaf area (*kharif* 509.82 cm^2; *rabi* 453.74 cm^2) followed by 40 cm × 10 cm (S_3) (*kharif* 495.30 cm^2; *rabi* 440.82 cm^2). The lowest leaf area was recorded by the planting geometry at 30 cm x 20 cm (S_2) (*kharif* 476.63 cm^2: *rabi* 424.20 cm^2). Application of 45N: 60P: 60K: 30S kg per ha (F_3) recorded the highest leaf area (*kharif* 536.88 cm^2; *rabi* 477.82 cm^2) which was on par with 30N: 40P: 40K: 20S kg per ha (F_2) (*kharif* 504.89 cm^2; *rabi* 449.35 cm^2). The lowest leaf area (*kharif* 439.97 cm; *rabi* 391.58 cm^2) was recorded by the application of 15N: 20P: 20K: 10S kg per ha (F_1).

The leaf area per plant was dependent up on the number of leaves per plant during both the seasons. The variety HG 365 under the highest density (33.33 plants / m^2) spaced at 30 cm × 10 cm and applied with nutrients at 45N:60P:60K:30S (F_3) showed the highest leaf area as compared to other treatment combinations. It is perhaps due to the reason that, higher the number of leaves with proportionately larger individual leaf area higher was the leaf area per plant. However the widely spaced plants (30 cm × 20 cm, S_2) wherein 16.7 plants were accommodated per m^2 area recorded the lower leaf area, because their multiple branches had smaller leaf numbers. Since there was no significant improvement in the number of leaves beyond F_2 level (30N:40P:40K:20S), the leaf area also did not increase significantly by increasing nutritional dose over and above F_2 level.

The treatment combinations with higher leaf area could have maintained maximum photosynthetic rate provided they had a good quantity of chlorophyll content. Ayub *et al*. (2012), Lone *et al*. (2010) also noted similar improvement in leaf area with increased nutrient dose and increased planting density.

Among the similar studies on cluster bean, Ayub *et al*. (2012) stated that among all recorded parameters, the leaf area per plant showed a steady increase with each increase in PK rates. The higher leaf area with PK application was felt to be the result of higher leaf expansion rates rather than leaf numbers.

Days to first flowering

The variations observed in days to first flowering (table 3) due to variety, planting geometry, nutritional combinations and their interactions were found to be significant. Among the varieties, HG 563 recorded the earliest days to first flowering both in *kharif* (23.32) and *rabi* seasons (20.75). Planting geometry of 30 cm x 10 cm (S_1) recorded the least number of days to first flowering (*kharif* 23.20; *rabi* 20.65) followed by 40 cm × 10 cm (S_3) (*kharif* 24.40; *rabi* 21.71). The highest number of days to first flowering was recorded by the planting geometry at 30 cm × 20 cm (S_2) (*kharif* 25.82; *rabi* 22.98). Application of 15N: 20P: 20K: 10S kg per

Table 2 a : Leaf area per plant (cm²) as influenced by variety, planting geometry and nutritional combination during *kharif* (pooled data of 2014-15 & 2015-16).

Planting Geometry(B)	Nutritional Combination (C)	Variety (A) 30 DAS HG 365	30 DAS HG 563	30 DAS *Mean*	60 DAS HG 365	60 DAS HG 563	60 DAS *Mean*	90 DAS HG 365	90 DAS HG 563	90 DAS *Mean*
S_1 (30 cm x 10 cm) (33.3 plants per m²)	F_1 (15N:20P:20K:10S)	235.87	200.49	218.18	514.20	437.07	475.64	488.49	415.22	451.85
	F_2 (30N:40P:40K:20S)	270.00	229.50	249.75	588.59	500.30	544.45	559.16	475.29	517.23
	F_3 (45N:60P:60K:30S)	292.52	248.64	270.58	637.69	542.04	589.87	605.81	514.94	560.37
	Mean	266.13	226.21	246.17	580.16	493.14	536.65	551.15	468.48	509.82
S_2 (30 cm x 20 cm) (16.7 plants per m²)	F_1 (15N:20P:20K:10S)	222.11	188.80	205.45	484.21	411.58	447.89	460.00	391.00	425.50
	F_2 (30N:40P:40K:20S)	256.62	218.13	237.37	559.43	475.52	517.47	531.46	451.74	491.60
	F_3 (45N:60P:60K:30S)	267.68	227.53	247.60	583.53	496.00	539.77	554.36	471.20	512.78
	Mean	248.80	211.48	230.14	542.39	461.03	501.71	515.27	437.98	476.63
S_3 (40 cm x 10 cm) (25 plants per m²)	F_1 (15N:20P:20K:10S)	231.03	196.37	213.70	503.64	428.09	465.86	478.46	406.69	442.57
	F_2 (30N:40P:40K:20S)	264.06	224.45	244.25	575.65	489.30	532.48	546.87	464.84	505.85
	F_3 (45N:60P:60K:30S)	280.58	238.49	259.53	611.66	519.91	565.78	581.07	493.91	537.49
	Mean	258.55	219.77	239.16	563.65	479.10	521.37	535.46	455.15	495.30
For Comparing varieties (A) and Nutritional combinations (C)										
F_1 (15N:20P:20K:10S)		229.67	195.22	212.45	500.68	425.58	463.13	475.65	404.30	439.97
F_2 (30N:40P:40K:20S)		263.56	224.02	243.79	574.56	488.37	531.47	545.83	463.96	504.89
F_3 (45N:60P:60K:30S)		280.26	238.22	259.24	610.96	519.32	565.14	580.41	493.35	536.88
Mean		257.83	219.15	238.49	562.07	477.76	519.91	533.96	453.87	493.92

Factor	SEm±	CD	SEm±	CD	SEm±	CD
Variety (A)	**5.47**	**15.84**	**11.92**	**34.54**	**11.33**	**32.81**
Planting Geom. (B)	**1.61**	**4.65**	**3.50**	**10.15**	**3.33**	**9.64**
Nutril. Combn.(C)	**5.96**	**17.27**	**13.35**	**38.66**	**12.34**	**35.76**
A x B	**-**	**NS**	**14.65**	**42.45**	**13.92**	**40.33**
B x C	**7.19**	**20.83**	**16.01**	**46.37**	**14.89**	**43.13**
A x C	**10.86**	**31.46**	**24.01**	**69.54**	**22.49**	**65.14**
A x B x C	**-**	**NS**	**27.33**	**79.18**	**25.65**	**74.30**

CD at 5% level of significance, DAS: Days after sowing.

Table 2 b : Leaf area per plant (cm^2) as influenced by variety, planting geometry and nutritional combination during *rabi* (pooled data of 2014-15 & 2015-16).

Planting Geometry(B)	Nutritional Combination (C)	Variety (A)								
		30 DAS			60 DAS			90 DAS		
		HG 365	HG 563	*Mean*	HG 365	HG 563	*Mean*	HG 365	HG 563	*Mean*
S_1 (30 cm x 10 cm) (33.3 plants per m^2)	F_1 (15N:20P:20K:10S)	209.93	178.44	***194.18***	457.64	388.99	***423.32***	434.76	369.54	***402.15***
	F_2 (30N:40P:40K:20S)	240.30	204.25	***222.28***	523.85	445.27	***484.56***	497.66	423.01	***460.33***
	F_3 (45N:60P:60K:30S)	260.34	221.29	***240.82***	567.55	482.41	***524.98***	539.17	458.29	***498.73***
	Mean	***236.86***	***201.33***	***219.09***	***516.34***	***438.89***	***477.62***	***490.53***	***416.95***	***453.74***
S_2 (30 cm x 20 cm) (16.7 plants per m^2)	F_1 (15N:20P:20K:10S)	197.68	168.03	***182.85***	430.94	366.30	***398.62***	409.40	347.99	***378.69***
	F_2 (30N:40P:40K:20S)	228.39	194.13	***211.26***	497.89	423.21	***460.55***	473.00	402.05	***437.52***
	F_3 (45N:60P:60K:30S)	238.23	202.50	***220.36***	519.35	441.44	***480.39***	493.38	419.37	***456.38***
	Mean	***221.43***	***188.22***	***204.83***	***482.73***	***410.32***	***446.52***	***458.59***	***389.80***	***424.20***
S_3 (40 cm x 10 cm) (25 plants per m^2)	F_1 (15N:20P:20K:10S)	205.61	174.77	***190.19***	448.24	381.00	***414.62***	425.83	361.95	***393.89***
	F_2 (30N:40P:40K:20S)	235.01	199.76	***217.39***	512.33	435.48	***473.90***	486.71	413.70	***450.21***
	F_3 (45N:60P:60K:30S)	249.71	212.26	***230.98***	544.37	462.72	***503.55***	517.15	439.58	***478.37***
	Mean	***230.11***	***195.60***	***212.85***	***501.65***	***426.40***	***464.02***	***476.56***	***405.08***	***440.82***
For Comparing varieties (A) and Nutritional combinations (C)										
F_1 (15N:20P:20K:10S)		204.41	173.75	***189.08***	445.61	378.77	***412.19***	423.33	359.83	***391.58***
F_2 (30N:40P:40K:20S)		234.57	199.38	***216.97***	511.36	434.65	***473.00***	485.79	412.92	***449.35***
F_3 (45N:60P:60K:30S)		249.43	212.01	***230.72***	543.76	462.19	***502.97***	516.57	439.08	***477.82***
Mean		***229.47***	***195.05***	***212.26***	***500.24***	***425.20***	***462.72***	***475.23***	***403.94***	***439.59***

Factor	30 DAS *SEm±*	30 DAS *CD*	60 DAS *SEm±*	60 DAS *CD*	90 DAS *SEm±*	90 DAS *CD*
Variety (A)	***4.87***	***14.10***	***10.61***	***30.74***	***10.08***	***29.20***
Ptg. Geom. (B)	***1.43***	***4.14***	***3.12***	***9.03***	***2.96***	***8.58***
Nutril. Combn. (C)	***5.30***	***15.37***	***11.88***	***34.41***	***10.99***	***31.83***
A x B	-	***NS***	***13.04***	***37.78***	***12.39***	***35.89***
B x C	***6.40***	***18.54***	***14.25***	***41.27***	***13.25***	***38.39***
A x C	***9.66***	***28.00***	***21.36***	***61.89***	***20.01***	***57.98***
A x B x C	***11.02***	***31.93***	***24.33***	***70.47***	***22.83***	***66.13***

CD: CD at 5% level of significance, DAS: Days after sowing.

Table 3 : Days to first flowering as influenced by variety, planting geometry and nutritional combination during *kharif* & *rabi* (pooled data of 2014-15 & 2015-16).

Planting Geometry (B)	Nutritional Combination (C)	Variety (A)					
		Kharif			*Rabi*		
		HG 365	HG 563	*Mean*	HG 365	HG 563	*Mean*
S_1 (30 cm x 10 cm) (33.3 plants per m^2)	F_1 (15N:20P:20K:10S)	22.91	20.85	***21.88***	20.39	18.56	***19.47***
	F_2 (30N:40P:40K:20S)	24.18	22.00	***23.09***	21.52	19.58	***20.55***
	F_3 (45N:60P:60K:30S)	25.79	23.47	***24.63***	22.95	20.89	***21.92***
	Mean	***24.29***	***22.11***	***23.20***	***21.62***	***19.68***	***20.65***
S_2 (30 cm x 20 cm) (16.7 plants per m^2)	F_1 (15N:20P:20K:10S)	25.84	23.51	***24.67***	23.00	20.93	***21.96***
	F_2 (30N:40P:40K:20S)	27.11	24.67	***25.89***	24.12	21.95	***23.04***
	F_3 (45N:60P:60K:30S)	28.18	25.64	***26.91***	25.08	22.82	***23.95***
	Mean	***27.04***	***24.61***	***25.82***	***24.07***	***21.90***	***22.98***
S_3 (40 cm x 10 cm) (25 plants per m^2)	F_1 (15N:20P:20K:10S)	24.47	22.27	***23.37***	21.78	19.82	***20.80***
	F_2 (30N:40P:40K:20S)	25.74	23.42	***24.58***	22.91	20.85	***21.88***
	F_3 (45N:60P:60K:30S)	26.42	24.04	***25.23***	23.52	21.40	***22.46***
	Mean	***25.55***	***23.25***	***24.40***	***22.74***	***20.69***	***21.71***
For Comparing varieties (A) and Nutritional combinations (C)							
F_1 (15N:20P:20K:10S)		24.41	22.21	***23.31***	21.72	19.77	***20.75***
F_2 (30N:40P:40K:20S)		25.68	23.36	***24.52***	22.85	20.79	***21.82***
F_3 (45N:60P:60K:30S)		26.80	24.38	***25.59***	23.85	21.70	***22.78***
Mean		***25.63***	***23.32***	***24.47***	***22.81***	***20.75***	***21.78***

Factor	*SEm±*	*CD*	*SEm±*	*CD*
Variety (A)	***0.33***	***0.94***	***0.29***	***0.840***
Ptg. Geom. (B)	***0.26***	***0.76***	***0.23***	***0.680***
Nutril. Combn.(C)	***0.23***	***0.66***	***0.20***	***0.590***
A x B	-	***NS***	-	***NS***
B x C	***0.47***	***1.35***	***0.42***	***1.200***
A x C	-	***NS***	***0.47***	***1.360***
A x B x C	-	***NS***	-	***NS***

CD: CD at 5% level of significance, DAS: Days after sowing.

ha (F_1) recorded the earliest first flowering (*kharif* 23.31; *rabi* 20.75) followed by 30N: 40P: 40K: 20S kg per ha (F_2) (*kharif* 24.52; *rabi* 21.82). The more number of days to first flowering (*kharif* 25.59; *rabi* 22.78) was recorded by the application of 45N: 60P: 60K: 30S kg per ha (F_3).

Days to 50% flowering

The variations observed in days to 50% flowering (table 4) due to variety, planting geometry, nutritional combinations and some of their interactions were found to be significant. Among the varieties HG 563 recorded the earliest days to 50% flowering both in *kharif* (25.98) and *rabi* seasons (23.12). Planting geometry of 30 cm x 10 cm (S_1) recorded earliest days to 50% flowering (*kharif* 25.99; *rabi* 23.13) followed by 40 cm x 10 cm (S_3) (*kharif* 27.19; *rabi* 24.20). The more number of days to 50% flowering was recorded by the planting geometry at 30 cm × 20 cm (S_2) (*kharif* 28.62; *rabi* 25.47). Application of 15N: 20P: 20K: 10S kg per ha (F_1) recorded the earliest days to 50% flowering (*kharif* 26.10; *rabi* 23.23) followed by 30N: 40P: 40K: 20S kg per ha (F_2) (*kharif* 27.31; *rabi* 24.31). The more number of days to 50% flowering (*kharif* 28.38; *rabi* 25.26) was recorded by the application of 45N: 60P: 60K: 30S kg per ha (F_3).

Among the two way interactions, significant

Table 4 : Days to 50% flowering as influenced by variety, planting geometry and nutritional combination during *kharif* & *rabi* (pooled data of 2014-15 & 2015-16).

Planting Geometry (B)	Nutritional Combination (C)	Variety (A)					
		Kharif			*Rabi*		
		HG 365	HG 563	*Mean*	HG 365	HG 563	*Mean*
S_1 (30 cm x 10 cm) (33.3 plants per m^2)	F_1 (15N:20P:20K:10S)	25.84	23.51	***24.67***	23.00	20.93	***21.96***
	F_2 (30N:40P:40K:20S)	27.11	24.67	***25.89***	24.12	21.95	***23.04***
	F_3 (45N:60P:60K:30S)	28.71	26.13	***27.42***	25.56	23.26	***24.41***
	Mean	***27.22***	***24.77***	***25.99***	***24.22***	***22.04***	***23.13***
S_2 (30 cm x 20 cm) (16.7 plants per m^2)	F_1 (15N:20P:20K:10S)	28.76	26.17	***27.47***	25.60	23.29	***24.45***
	F_2 (30N:40P:40K:20S)	30.03	27.33	***28.68***	26.73	24.32	***25.52***
	F_3 (45N:60P:60K:30S)	31.10	28.30	***29.70***	27.68	25.19	***26.44***
	Mean	***29.97***	***27.27***	***28.62***	***26.67***	***24.27***	***25.47***
S_3 (40 cm x 10 cm) (25 plants per m^2)	F_1 (15N:20P:20K:10S)	27.40	24.93	***26.16***	24.38	22.19	***23.29***
	F_2 (30N:40P:40K:20S)	28.67	26.09	***27.38***	25.51	23.22	***24.36***
	F_3 (45N:60P:60K:30S)	29.35	26.71	***28.03***	26.12	23.77	***24.94***
	Mean	***28.47***	***25.91***	***27.19***	***25.34***	***23.06***	***24.20***
For comparing varieties (A) and Nutritional combinations (C)							
F_1 (15N:20P:20K:10S)		27.33	24.87	***26.10***	24.33	22.14	***23.23***
F_2 (30N:40P:40K:20S)		28.60	26.03	***27.31***	25.45	23.16	***24.31***
F_3 (45N:60P:60K:30S)		29.72	27.05	***28.38***	26.45	24.07	***25.26***
Mean		***28.55***	***25.98***	***27.27***	***25.41***	***23.12***	***24.27***

Factor	*SEm±*	*CD*	*SEm±*	*CD*
Variety (A)	***0.36***	***1.05***	***0.32***	***0.94***
Ptg. Geom. (B)	***0.26***	***0.76***	***0.23***	***0.68***
Nutril. Combn.(C)	***0.23***	***0.66***	***0.20***	***0.59***
A x B	*-*	*NS*	*-*	*NS*
B x C	***0.47***	***1.35***	***0.42***	***1.20***
A x C	***0.56***	***1.63***	*-*	*NS*
A x B x C	*-*	*NS*	***0.72***	***2.09***

CD: CD at 5% level of significance.

differences were observed for the interaction between planting geometry *vs* nutiitional level during both *kharif* and *rabi* seasons. During *kharif* the earliest occurrence af 50% flowering stage in 24.67 days was observed in the plants spaced at 30 cm × 10 cm and applied with 15N: 20P: 20K:10S kg per ha, whereas the highest delay to reach 50% flowering stage (29.70 days) was noticed in the planting pattern of 30 cm × 20 cm and supplied with 45N:60P:60K:30S kg per ha. Similar trend was also noticed in *rabi* season.

As regards to the data on flowering, the cultivar HG 365 exhibited delayed initiation of flowering as compared to the var. HG 563, which may be probably because of the early vigour for vegetative growth in the var. HG 365 due to its genetic character. Among the population densities the highest density at the planting geometry of 30 cm × 10 cm was the earliest to initiate flowering compared to the less denser populations. The highest density per unit area might have promoted the crop to initiate flowering early because of the competition to nutrients, space and light. There might be adequate temperature also inside the crops micro climate and thus the thickest population could have exhibited flowering at the earliest followed by next thicker density in cluster bean. Among the nutritional combinations it appears that the highest dose of 45N: 60P: 60K: 30S resulted in the

Table 5 : Seed yield per plant (g) as influenced by variety, planting geometry and nutritional combination during *kharif* & *rabi* (pooled data of 2014-15 & 2015-16).

Planting Geometry (B)	Nutritional Combination (C)	Variety (A)					
		Kharif			*Rabi*		
		HG 365	HG 563	*Mean*	HG 365	HG 563	*Mean*
S_1 (30 cm x 10 cm) (33.3 plants per m^2)	F_1 (15N:20P:20K:10S)	15.53	13.20	***14.36***	13.82	11.75	***12.78***
	F_2 (30N:40P:40K:20S)	17.77	15.11	***16.44***	15.82	13.45	***14.63***
	F_3 (45N:60P:60K:30S)	19.26	16.37	***17.81***	17.14	14.57	***15.85***
	Mean	***17.52***	***14.89***	***16.21***	***15.59***	***13.25***	***14.42***
S_2 (30 cm x 20 cm) (16.7 plants per m^2)	F_1 (15N:20P:20K:10S)	18.54	15.76	***17.15***	16.50	14.03	***15.27***
	F_2 (30N:40P:40K:20S)	21.42	18.21	***19.82***	19.07	16.21	***17.64***
	F_3 (45N:60P:60K:30S)	22.35	18.99	***20.67***	19.89	16.90	***18.40***
	Mean	***20.77***	***17.66***	***19.21***	***18.49***	***15.71***	***17.10***
S_3 (40 cm x 10 cm) (25 plants per m^2)	F_1 (15N:20P:20K:10S)	17.81	15.14	***16.47***	15.85	13.47	***14.66***
	F_2 (30N:40P:40K:20S)	20.35	17.30	***18.83***	18.11	15.40	***16.76***
	F_3 (45N:60P:60K:30S)	21.63	18.38	***20.00***	19.25	16.36	***17.80***
	Mean	***19.93***	***16.94***	***18.43***	***17.74***	***15.08***	***16.41***
For comparing varieties (A) and Nutritional combinations (C)							
F_1 (15N:20P:20K:10S)		17.29	14.70	***16.00***	15.39	13.08	***14.24***
F_2 (30N:40P:40K:20S)		19.85	16.87	***18.36***	17.67	15.02	***16.34***
F_3 (45N:60P:60K:30S)		21.08	17.91	***19.50***	18.76	15.94	***17.35***
Mean		***19.41***	***16.50***	***17.95***	***17.27***	***14.68***	***15.98***

Factor	*SEm±*	*CD*	*SEm±*	*CD*
Variety (A)	***0.41***	***1.19***	***0.37***	***1.06***
Ptg. Geom. (B)	***0.31***	***0.90***	***0.28***	***0.80***
Nutril. Combn.(C)	***0.45***	***1.29***	***0.40***	***1.15***
A x B	***0.69***	***1.99***	-	***NS***
B x C	***0.72***	***2.09***	***0.64***	***1.86***
A x C	-	***NS***	-	***NS***
A x B x C	-	***NS***	***0.99***	***2.87***

CD: CD at 5% level of significance.

latest flowering as compared to lesser nutritional doses. It is worthy to mention here that the application of 30N: 40P: 40K: S20 recorded on par values as per majority of the observations regarding flowering, pod drying and crop duration.

The stage of 50% flowering was also achieved at the earliest by those treatments and combinations having the earliest flower initiation which could be perhaps due to the reason that the one which was early to initiate flowering succeeded the journey over time to 50 per cent flowering also early in the proportion. Similarly, the duration between flowering and pod drying showed that the early flowering treatments had achieved pod drying stage at the earliest compared to late flowering treatment combinations. The variety HG 365 in combination with the lowest population density at 30 cm × 20 cm and the highest nutritional dose at 45N: 60P: 60K: 30S was found to show the greatest duration from flowering to pod drying duly suggesting that these treatments retained greenery in their pods for an expanded period of time so that they would probably reach a better size and filling of individual plants, though it might not be leading to superior values on per unit area basis in all cases.

An extension of this discussion aptly suits to the fact that the variety HG 365 coupled with the lowest population density at 30 cm x 20 cm and the highest nutritional dose at 45N: 60P: 60K: 30S exhibited the longest crop duration which might be clearly due to the enlarged duration of time spent in pod drying coupled with their delayed initiation of flowering and arriving 50% flowering as well as complete flowering stages. However, the application of medium dose of fertilisers at 30N: 40P: 40K: S20 was also on par with the highest dose mentioned above suggesting that the marginal increase in the fertiliser dose above this level could not expand the crop duration and pod maturity time significantly which may probably influence the corresponding abilities to yield significantly different quantities of pods.

The significant variations due to fertilizer levels were also observed for flowering parameters. Significantly lesser number of days to flowering and 50% flowering were seen in the lower fertilizer level compared to higher dose of fertilizers. This was attributed to be due to the fact that the plants fertilized with lower fertilizer dose suffered a sort of stress resulting in early initiation of floral bud (Gireesh and Malabasari, 2014) and thus transforming early into reproductive phase.

Seed yield per plant (g)

Significant differences were observed in the seed yield per plant (table 5) due to variety, planting geometry, nutritional combinations and some of their interactions. Among the varieties HG 365 recorded the highest seed yield per plant both in *kharif* (19.41 g) and *rabi* seasons (17.27 g). Planting geometry of 30 cm × 20 cm (S_2) recorded significantly the highest seed yield per plant (*kharif* 19.21 g; *rabi* 17.10 g) which was on par with 40 cm x 10 cm (S_3) (*kharif* 18.43 g; *rabi* 16.41g). The lowest seed yield per plant was recorded by the planting geometry at 30 cm × 10 cm (S_1) (*kharif* 16.21 g; *rabi* 14.42g). Application of 45N: 60P: 60K: 30S kg per ha (F_3) recorded the highest seed yield per plant (*kharif* 19.50 g; *rabi* 17.35 g) which was on par with 30N: 40P: 40K: 20S kg per ha (F_2) (*kharif* 18.36 g; *rabi* 16.34 g). The lowest seed yield per plant (*kharif* 16.00 g; *rabi* 14.24 g) was recorded by the application of 15N: 20P: 20K: 10S kg per ha (F_1).

Seed yield per plot (kg)

Significant differences were observed in the seed yield per plot (table 6) due to variety, planting geometry, nutritional combinations and their interactions. Among the varieties HG 365 recorded the highest seed yield per plot both in *kharif* (2.39 kg) and *rabi* seasons (2.12 kg). Planting geometry of 30 cm × 10 cm (S_1) recorded significantly the highest seed yield per plot (*kharif*: 2.77 kg; *rabi*: 2.46 kg) followed by 40 cm × 10 cm (S_3) (*kharif*: 2.36 kg; *rabi*: 2.10 kg). The lowest seed yield per plot was recorded by the planting geometry at 30 cm x 20 cm (S_2) (*kharif* 1.64 kg; *rabi* 1.46 kg). Application of 45N: 60P: 60K: 30S kg per ha (F_3) recorded the highest seed yield per plot (*kharif* 2.45 kg; *rabi* 2.18 kg) which was on par with 30N: 40P: 40K: 20S kg per ha (F_2) (*kharif* 2.30 kg; *rabi* 2.05 kg). The lowest seed yield per plot (*kharif* 2.01 kg; *rabi* 1.79 kg) was recorded by the application of 15N: 20P: 20K: 10S kg per ha (F_1). The interaction effect between planting geometry and nutritional level was found significant during both *kharif* and *rabi* with respect to seed yield per plot. The highest seed yield per plot was recorded by the closest planting pattern of 30 cm × 10 cm and applied with 45N: 60P: 60K: 30S kg per ha (*kharif* 3.04; *rabi* 2.71), which was on par with the same planting geometry + application of 30N: 40P: 40K: 20S kg per ha (*kharif* 2.81; *rabi* 2.50) and followed by the planting geometry of 40 cm × 10 cm + application of 45N: 60P: 60K: 30S kg per ha (*kharif* 2.56; *rabi* 2.28).

Seed yield was significantly influenced by the variety, planting geometry and nutrient combinations and also by their interactions as well. The seed yield is the ultimate parameter contributing to the revenue of profits accrued from the cultivation of the guar crop because it is the economic product which yields gum upon processing. The effect of variety, planting geometry and nutritional combination was found to exert significant effect on many parameters contributing to seed yield per plant, per plot and per ha as evident from the previous discussions. As it is observed in case of growth, flowering and quality parameters, the seed yield was also found to be at maximum in case of the variety HG 365 compared to the other variety HG 563 which might be due to the varietal superiority. Owing to the great variations in population densities, the weight of seeds per individual plant was found to be maximum at the lowest population density at the spacing of 30 cm × 20 cm as compared to other planting geometry levels. This merit is also revealed from the stand point of corresponding superiority of lowest population density in having highest duration of reproductive phase, higher numbers of clusters, pods and and seeds per pod ultimately leading to the highest individual weight of seeds per plant at the widest spacing. Each plant is vested with a great amount of space, light and nutrients at wider spacing compared to closer level of planting geometry. The difference between 30 cm × 20 cm and 40 cm × 10 cm was not found significant in terms of seed yield per plant, however, there was significant difference between these two levels of planting geometry or population density with respect to per plot yield of seeds. This may be due to the fact that even

Table 6 : Seed yield per plot (kg) as influenced by variety, planting geometry and nutritional combination during *kharif* & *rabi* (pooled data of 2014-15 & 2015-16).

Planting Geometry (B)	Nutritional Combination (C)	Variety (A)					
		Kharif			*Rabi*		
		HG 365	HG 563	*Mean*	HG 365	HG 563	*Mean*
S_1 (30 cm x 10 cm) (33.3 plants per m^2)	F_1 (15N:20P:20K:10S)	2.59	2.31	***2.45***	2.31	2.05	***2.18***
	F_2 (30N:40P:40K:20S)	2.97	2.64	***2.81***	2.64	2.35	***2.50***
	F_3 (45N:60P:60K:30S)	3.22	2.86	***3.04***	2.86	2.55	***2.71***
	Mean	***2.93***	***2.60***	***2.77***	***2.60***	***2.32***	***2.46***
S_2 (30 cm x 20 cm) (16.7 plants per m^2)	F_1 (15N:20P:20K:10S)	1.55	1.38	***1.46***	1.38	1.23	***1.30***
	F_2 (30N:40P:40K:20S)	1.79	1.59	***1.69***	1.59	1.42	***1.50***
	F_3 (45N:60P:60K:30S)	1.87	1.66	***1.76***	1.66	1.48	***1.57***
	Mean	***1.73***	***1.54***	***1.64***	***1.54***	***1.37***	***1.46***
S_3 (40 cm x 10 cm) (25 plants per m^2)	F_1 (15N:20P:20K:10S)	2.23	1.99	***2.11***	1.99	1.77	***1.88***
	F_2 (30N:40P:40K:20S)	2.55	2.27	***2.41***	2.27	2.02	***2.14***
	F_3 (45N:60P:60K:30S)	2.71	2.41	***2.56***	2.41	2.15	***2.28***
	Mean	***2.50***	***2.22***	***2.36***	***2.22***	***1.98***	***2.10***
For comparing varieties (A) and Nutritional combinations (C)							
F_1 (15N:20P:20K:10S)		2.12	1.89	***2.01***	1.89	1.68	***1.79***
F_2 (30N:40P:40K:20S)		2.44	2.17	***2.30***	2.17	1.93	***2.05***
F_3 (45N:60P:60K:30S)		2.60	2.31	***2.45***	2.31	2.06	***2.18***
Mean		***2.39***	***2.12***	***2.25***	***2.12***	***1.89***	***2.01***

Factor	*S Em±*	*CD*	*SEm±*	*CD*
Variety (A)	***0.04***	***0.11***	***0.03***	***0.10***
Ptg. Geom. (B)	***0.11***	***0.33***	***0.10***	***0.29***
Nutril. Combn. (C)	***0.06***	***0.16***	***0.05***	***0.15***
A x B	-	***NS***	-	***NS***
B x C	***0.16***	***0.47***	***0.14***	***0.42***
A x C	-	***NS***	-	***NS***
A x B x C	***0.20***	***0.57***	***0.18***	***0.51***

CD: CD at 5% level of significance.

though an individual plant yielded more at wider spacing, due to less number of plants per unit area, the net yield per unit area might had worked out to be lower compared to the case, where there were more number of plants per unit area yielding lesser weight of pods per plant. The marginal increase on per plant yield by reducing population did not compensate the marginal increase with elevated population levels per unit area.

Application of nutrients at the highest dose made significant difference at all the population levels as compared to lowest fertiliser dose. However, the difference between the doses at 45N: 60P: 60K: 30S and 30N: 40P: 40K: 20S was not found significant. The additional dose of nutrients beyond the medium level resulted in a non-significant increase in the weight of seeds per plant as well as per plot. The highest population density supplied with the highest nutritional dose showed the weight of seeds per plant on par with moderate population density supplied with medium level of nutrients. With every increase in population density, supply of additional dose of nutrients was found to be beneficial up to the level of 30N: 40P: 40K: 20S. A higher population level at 30 cm x 10 cm was found to exhibit parity with lower population level at 40 cm × 20 cm when supplied with the highest nutritional dose of 45N: 60P: 60K: 30S while the later was receiving moderate nutritional level of 30N: 40P: 40K: 20S. This was also found to be true between the population levels maintained at 40 cm x 20 cm and 30 cm × 20 cm. It is leading to a point that a marginal increase in nutritional level was found beneficial with increased population but not so at the same level of population.

The trend in seed yield from individual plants in respect of planting geometry got inverted when it comes to seed yield per plot. As mentioned earlier, this is only due to more number of plants though yielded relatively lesser seeds per plant, could contribute to a higher gross value of seed yield per unit area or per plot. Further, an examination of interactions between planting geometry and nutritional level at per plot level revealed that enhanced nutrient dose boosted the yield significantly from the lowest level 15N:20P:20K:10S to medium level 30N:40P: 40K:20S; further increase being non-significant at a particular planting geometry level. On the contrary, the increase in the nutritional level was found significant when lower population density would be compared with a higher population density a higher population *i.e.* in other words, plants at higher population level at 30 cm x 10 cm supplied with the highest nutritional dose of 45N: 60P: 60K: 30S were found to be on par with lower population level at 40 cm × 20 cm supplied with 30N: 40P: 40K: 20S. However, widely spaced plants with the highest nutritional dose were significantly superior to closely spaced plants supplied with the same dose. The same fact can also be extorted from the observations on pod yield between the other population densities.

These discussions were also expressed by the earlier workers like Akhtar *et al.* (2012) who noticed significant differences among varieties for grain yield and reported the superiority of the variety S-4002 while BR-99 and BR-99- Super stood second and third, respectively. Siddaraju *et al.* (2010) revealed that the difference in seed yield was due to varietal potential and genotypic ability which was exhibited in terms of efficient photosynthetic activity, uptake of nutrients and better translocation of photosynthates from source to sink. They further recorded a higher seed yield per plot in closer spacings of 45 cm × 15 cm as compared to wider spacings 45 cm × 30 cm and 60 cm × 30 cm and attributed to the density of population as is the case with the present study.

Grain yield per ha was found to vary significantly with row spacing (Akhtar *et al.*, 2012). The grain yields were found to decrease as the row to row spacing increased from 30 cm to 60 cm. Similar finding was also reported earlier by Sharma *et al.* (1984).

Ayub *et al.* (2012) observed significantly higher seed yield with more nitrogen containing manures and fertilisers. The increase in seed yield was attributed to be due to a corresponding increase in higher number of pods per plant, number of seeds per pod, 100-seed weight, pod yield per plant and seed yield per plant. Increase in these parameters was attributed to improved growth parameters and yield components which ultimately resulted in higher yield. Sharma and Verma (2011) reported that increased levels of K along with N increased seed yield and net returns in rajmash over the recommended dose. The response of the crop to applied K in terms of increased seed yield was ascribed to be due to improved growth and yield contributing traits. The increased yield and net returns was attributed to the fact that N had significant influence on translocation of nutrients and dry matter accumulation during reproductive stage which in turn improved the yield attributes and ultimately seed yield (Sharma *et al*., 2003 and Singh *et al*., 2009).

Similarly, Yadav (2011) noticed that with increasing level of both phosphorus and sulphur, grain and straw yield of cluster bean increased significantly. The per cent increase in grain yield due to phosphorus and sulphur varied from 11.8% to 24.2% and 5.3 to 10.8%, respectively. The magnitude of response was more in case of phosphorus as compared to sulphur. Synergistic effect of phosphorus with sulphur was observed on grain yield which was the highest at higher levels of both the nutrient elements. The synergistic effect of P and S may be due to utilization of high quantities of nutrients which were absorbed through their well developed root system as reported by Yadav (2011).

The beneficial effect of P on cluster bean growth and eventual increase in all the yield attributes like pods per plant, seeds per pod, length of pod, test weight, seed and straw yield were attributed to greater nitrogen fixation and uptake of nutrients (Naagar and Meena, 2004).

The increased seed yield with higher fertiliser level was attributed to enhanced photosynthetic activity, greater accumulation and translocation of photysynthates from source to sink resulting in heavier and bolder seeds (Siddaraju *et al*., 2010). Agreement with these facts was also found in the works of Anilkumara (2004) in fenugreek and Srikant (2003) in cluster bean. Hugar and Kurdikeri (2000) noted that there was increase in seed size with increased levels of NPK and also due to varietal differences. The increase in seed size might be due to metabolic differences which could directly or indirectly increase the synthesis of carbohydrates and proteins and seed size in soyabean.

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