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YIELD AND BIOCHEMICAL QUALITY IN RELATION TO SPACING AND NUTRITION INTERACTIONS IN SEED GUAR VARIETIES

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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. Crude protein (%) Crude gum (%) and Nitrogen content (%) influenced byplanted at a spacing of 30 cm × 10 cm with higher fertilizer dose of 45N: 60P: 60K: 30S kg per ha in the variety HG 365. Seed yield per plot also exhibited significant superiority in this treatment combination.

Key words: Guar, Crude protein (%), Crude gum (%), Nitrogen content (%).

Introduction

Cluster bean is botanically called as *Cyamopsistetragonoloba* (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. This spherical shaped endosperm contains significant amounts of galactomannan gum, which accounts for 28% to 33% of the whole seed. Galactomannan is also referred as guar gum. The refined splits of guar are derived from this part of the seed. The remaining two parts, hull and germ, are high in protein and fibrer.

Material 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

Seed yield per plot (kg)

Significant differences were observed in the seed yield per plot (table 1) 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 × 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).

Crude gum (%)

Table 1: 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 × 10 cm) (33.3 plants per m²)	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 × 20 cm) (16.7 plants per m²)	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 × 10 cm) (25 plants per m²)	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*	*S Em±*	*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 × B	-	***NS***	-	***NS***
B × C	***0.16***	***0.47***	***0.14***	***0.42***
A × C	-	***NS***	-	***NS***
A × B × C	***0.20***	***0.57***	***0.18***	***0.51***

CD: CD at 5% level of significance

Significant differences were observed in the crude gum (table 3) due to variety, planting geometry, nutritional combinations and some of their interactions. Among the varieties HG 365 recorded the highest crude gum both in *kharif* (32.76 %) and *rabi* seasons (32.40 %). Planting geometry of 30 cm × 20 cm (S_2) recorded significantly the highest crude gum (*kharif* 33.72 %; *rabi* 33.35 %) followed by 40 cm × 10 cm (S_3) (*kharif* 31.43 %; *rabi* 31.08 %) (Fig. 7 and Plate 14). The lowest crude gum was recorded by the planting geometry at 30 cm × 10 cm (S_1) (*kharif* 30.45 %; *rabi* 30.11 %). Application of 45N: 60P: 60K: 30S kg per ha (F_3) recorded the highest crude gum (*kharif* 33.36 %; *rabi* 32.99 %) which was on par with 30N: 40P: 40K: 20S kg per ha (F_2) (*kharif* 31.59 %; *rabi* 32.14 %). The lowest crude gum (*kharif* 28.90 %; *rabi* 29.41 %) was recorded by the application of 15N: 20P: 20K: 10S kg per ha (F_1).

The content of crude gum in the seed governs the value of the guar produce since the gum is the product of export value. Among the varieties HG 365 exhibited the highest gum content and among the planting geometry levels, the lowest population density at 30 cm × 20 cm exhibited the highest gum content being the one having the bold sized seeds from significantly hefty pods and clusters. The individual plant being capable of drawing more nutrients and sufficient light over an extended period of duration spent in building up vegetative frame work as well as prolonged reproductive period, exhibited better quality parameters and therefore was also able to produce seeds with a higher content of galactomannan. The nutrient application at the highest level of 45N: 60P: 60K: 30S was on par with 30N: 40P: 40K: 20S thus making the effect of additional amount of nutrients non-significant in increasing gum content of individual seeds.

Table 2 : Crude protein (%) 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 × 10 cm) (33.3 plants per m^2)	F_1 (15N:20P:20K:10S)	21.44	19.30	***20.37***	20.37	18.33	***19.35***
	F_2 (30N:40P:40K:20S)	23.06	20.75	***21.91***	21.91	19.72	***20.81***
	F_3 (45N:60P:60K:30S)	23.60	21.24	***22.42***	22.42	20.17	***21.29***
	Mean	***22.70***	***20.43***	***21.56***	***21.56***	***19.41***	***20.48***
S_2 (30 cm × 20 cm) (16.7 plants per m^2)	F_1 (15N:20P:20K:10S)	25.10	22.59	***23.84***	23.84	21.46	***22.65***
	F_2 (30N:40P:40K:20S)	26.31	23.67	***24.99***	24.99	22.49	***23.74***
	F_3 (45N:60P:60K:30S)	26.64	23.97	***25.31***	25.31	22.77	***24.04***
	Mean	***26.01***	***23.41***	***24.71***	***24.71***	***22.24***	***23.48***
S_3 (40 cm × 10 cm) (25 plants per m^2)	F_1 (15N:20P:20K:10S)	22.54	20.29	***21.41***	21.41	19.27	***20.34***
	F_2 (30N:40P:40K:20S)	24.86	22.38	***23.62***	23.62	21.26	***22.44***
	F_3 (45N:60P:60K:30S)	25.55	22.99	***24.27***	24.27	21.84	***23.05***
	Mean	***24.32***	***21.88***	***23.10***	***23.10***	***20.79***	***21.95***
For Comparing varieties (A) and Nutritional combinations (C)							
F_1 (15N:20P:20K:10S)		23.03	20.72	***21.87***	21.87	19.69	***20.78***
F_2 (30N:40P:40K:20S)		24.74	22.27	***23.51***	23.51	21.15	***22.33***
F_3 (45N:60P:60K:30S)		25.26	22.73	***24.00***	24.00	21.60	***22.80***
Mean		***24.34***	***21.91***	***23.13***	***23.13***	***20.81***	***21.97***

Factor	*S Em±*	*CD*	*S Em±*	*CD*
Variety (A)	***0.34***	***1.00***	***0.33***	***0.95***
Ptg. Geom. (B)	***0.31***	***0.91***	***0.30***	***0.87***
Nutril. Combn.(C)	***0.22***	***0.64***	***0.21***	***0.61***
A × B	-	***NS***	-	***NS***
B × C	***0.51***	***1.48***	***0.48***	***1.40***
A × C	***0.54***	***1.56***	***0.51***	***1.48***
A × B × C	***0.84***	***2.43***	-	***NS***

CD: CD at 5% level of significance.

In one of the similar studies, Lakshmi Kalyani (2006) stated that among different cultivars, crude gum content varied significantly and the cultivar RGM 112 produced significantly more gum content and yield hectare^{-1} as compared to HG 563, RGC 1003 and GAUG 9703 in cluster bean. She attributed the same to the genotypic differences. The interaction effect between planting geometry + nutritional level was significant in both *kharif and rabi seasons* and in case of both protein as well as gum contents. Both these constinents were superior with the widest spacing + the highest nutritional dose (30 cm × 20 cm + 45N: 60P: 60K: 30S kg per ha) during *kharif* and *rabi seasons*.

The pod yield, seed yield and quality parameters including gum content were found to be maximum during *kharif* when compared to those during *rabi*. This indicated that the seed cluster bean crop benefitted much from the warm humid conditions rather than cool dry conditions as prevailed in the respective seasons which might be perhaps in the light of low annual rainfall of the location.

Nitrogen content (%)

Significant differences were observed in the nitrogen content in leaf (table 4 and 5) due to variety, planting geometry, nutritional combinations and some of their interactions. Among the varieties HG 365 recorded the highest nitrogen content in leaf both in *kharif* (1.60) and *rabi* seasons (1.42). Planting geometry of 30 cm × 20 cm (S_2) recorded significantly the highest nitrogen content in leaf (*kharif* 1.69; *rabi* 1.50) followed by 40 cm × 10 cm (S_3) (*kharif* 1.42; *rabi* 1.26). The lowest nitrogen content in leaf was recorded by the planting geometry at 30 cm × 10 cm (S_1) (*kharif* 1.33; *rabi* 1.19). Application

Table 3 : Crude gum (%) 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 × 10 cm) (33.3 plants per m²)	F_1 (15N:20P:20K:10S)	29.22	27.61	***28.41***	28.90	27.31	***28.10***
	F_2 (30N:40P:40K:20S)	32.02	30.27	***31.14***	31.67	29.93	***30.80***
	F_3 (45N:60P:60K:30S)	32.67	30.89	***31.78***	32.31	30.55	***31.43***
	Mean	***31.30***	***29.59***	***30.45***	***30.96***	***29.26***	***30.11***
S_2 (30 cm × 20 cm) (16.7 plants per m²)	F_1 (15N:20P:20K:10S)	32.77	30.98	***31.88***	32.41	30.64	***31.52***
	F_2 (30N:40P:40K:20S)	35.29	33.38	***34.34***	34.91	33.01	***33.96***
	F_3 (45N:60P:60K:30S)	35.91	33.96	***34.94***	35.51	33.59	***34.55***
	Mean	***34.66***	***32.77***	***33.72***	***34.28***	***32.41***	***33.35***
S_3 (40 cm × 10 cm) (25 plants per m²)	F_1 (15N:20P:20K:10S)	29.74	28.10	***28.92***	29.41	27.79	***28.60***
	F_2 (30N:40P:40K:20S)	32.91	31.11	***32.01***	32.54	30.77	***31.66***
	F_3 (45N:60P:60K:30S)	34.29	32.43	***33.36***	33.91	32.07	***32.99***
	Mean	***32.31***	***30.55***	***31.43***	***31.96***	***30.21***	***31.08***
For Comparing varieties (A) and Nutritional combinations (C)							
F_1 (15N:20P:20K:10S)		30.58	28.90	***29.74***	30.24	28.58	***29.41***
F_2 (30N:40P:40K:20S)		33.41	31.59	***32.50***	33.04	31.24	***32.14***
F_3 (45N:60P:60K:30S)		34.29	32.43	***33.36***	33.91	32.07	***32.99***
Mean		***32.76***	***30.97***	***31.86***	***32.40***	***30.63***	***31.51***

Factor	*S Em±*	*CD*	*S Em±*	*CD*
Variety (A)	***0.36***	***1.06***	***0.35***	***1.00***
Ptg. Geom. (B)	***0.23***	***0.64***	***0.21***	***0.62***
Nutril. Combn.(C)	***0.37***	***1.07***	***0.35***	***1.01***
A × B	-	***NS***	-	***NS***
B × C	***0.66***	***1.91***	***0.63***	***1.82***
A × C	***0.70***	***2.02***	***0.66***	***1.92***
A × B × C	***1.01***	***2.92***	-	***NS***

CD: CD at 5% level of significance.

of 45N: 60P: 60K: 30S kg per ha (F_3) recorded the highest nitrogen content in leaf (*kharif* 1.60; *rabi 1.43)* which was on par with 30N: 40P: 40K: 20S kg per ha (F_2) (*kharif* 1.55; *rabi* 1.38). The lowest nitrogen content in leaf (*kharif* 1.29; *rabi* 1.15) was recorded by the application of 15N: 20P: 20K: 10S kg per ha (F_1).

Nitrogen content in pod (table 4 and 5) exhibited significant differences due to variety, planting geometry, nutritional combinations and their interactions. Among the varieties HG 365 recorded the highest nitrogen content in stem both in *kharif* (1.84) and *rabi* seasons (1.64). Planting geometry of 40 cm × 10 cm (S_3) recorded significantly highest nitrogen content in stem (*kharif* 2.21; *rabi* 1.96) on followed by 30 cm × 20 cm (S_2) (*kharif* 1.62; *rabi* 1.44). The lowest nitrogen content in stem was recorded by the planting geometry at 30 cm × 10 cm (S_1) (*kharif* 1.28; *rabi* 1.14). Application of 45N: 60P: 60K: 30S kg per ha (F_3) recorded the highest nitrogen content in stem (*kharif* 1.85; *rabi* 1.64) which was on par with 30N: 40P: 40K: 20S kg per ha (F_2) (*kharif* 1.79; *rabi* 1.59). The lowest nitrogen content in stem (*kharif* 1.47; *rabi* 1.31) was recorded by the application of 15N: 20P: 20K: 10S kg per ha (F_1)

The data on nitrogen content in pod (table 36a, 36b) revealed that there were significant differences due to variety, planting geometry, nutritional combinations and some of their interactions. Among the varieties HG 365 recorded the highest nitrogen content in flower and pod both in *kharif* (2.61) and *rabi* seasons (2.32). Planting geometry of 30 cm × 20 cm (S_2) recorded significantly highest nitrogen content in pod (*kharif* 2.76; *rabi* 2.45) on followed by 40 cm × 10 cm (S_3) (*kharif* 2.32; *rabi* 2.06). The lowest nitrogen content in pod was recorded by the planting geometry at 30 cm × 10 cm (S_1) (*kharif*

Table 4 : Nitrogen content (%)in different plant parts at 90 DAS 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)								
		Leaf			Stem			Pod		
		HG 365	HG 563	*Mean*	HG 365	HG 563	*Mean*	HG 365	HG 563	*Mean*
S_1 (30 cm × 10 cm) (33.3 plants per m^2)	F_1 (15N:20P:20K:10S)	1.22	1.04	***1.13***	1.17	0.99	***1.08***	1.99	1.69	***1.84***
	F_2 (30N:40P:40K:20S)	1.52	1.29	***1.41***	1.46	1.24	***1.35***	2.48	2.11	***2.30***
	F_3 (45N:60P:60K:30S)	1.58	1.34	***1.46***	1.52	1.29	***1.40***	2.58	2.19	***2.38***
	Mean	***1.44***	***1.22***	***1.33***	***1.38***	***1.17***	***1.28***	***2.35***	***2.00***	***2.17***
S_2 (30 cm × 20 cm) (16.7 plants per m^2)	F_1 (15N:20P:20K:10S)	1.67	1.42	***1.54***	1.60	1.36	***1.48***	2.72	2.31	***2.52***
	F_2 (30N:40P:40K:20S)	1.87	1.59	***1.73***	1.80	1.53	***1.66***	3.06	2.60	***2.83***
	F_3 (45N:60P:60K:30S)	1.94	1.65	***1.79***	1.86	1.58	***1.72***	3.17	2.69	***2.93***
	Mean	***1.83***	***1.55***	***1.69***	***1.75***	***1.49***	***1.62***	***2.98***	***2.53***	***2.76***
S_3 (40 cm × 10 cm) (25 plants per m^2)	F_1 (15N:20P:20K:10S)	1.29	1.09	***1.19***	2.00	1.70	***1.85***	2.10	1.79	***1.94***
	F_2 (30N:40P:40K:20S)	1.64	1.39	***1.52***	2.55	2.16	***2.36***	2.67	2.27	***2.47***
	F_3 (45N:60P:60K:30S)	1.68	1.43	***1.55***	2.61	2.22	***2.41***	2.74	2.33	***2.53***
	Mean	***1.53***	***1.30***	***1.42***	***2.38***	***2.03***	***2.21***	***2.50***	***2.13***	***2.32***
For Comparing varieties (A) and Nutritional combinations (C)										
F_1 (15N:20P:20K:10S)		1.39	1.18	***1.29***	1.59	1.35	***1.47***	2.27	1.93	***2.10***
F_2 (30N:40P:40K:20S)		1.68	1.43	***1.55***	1.93	1.64	***1.79***	2.74	2.33	***2.53***
F_3 (45N:60P:60K:30S)		1.73	1.47	***1.60***	2.00	1.70	***1.85***	2.83	2.40	***2.62***
Mean		***1.60***	***1.36***	***1.48***	***1.84***	***1.56***	***1.70***	***2.61***	***2.22***	***2.42***

Factor	*S Em±*	*CD*	*S Em±*	*CD*	*S Em±*	*CD*
Variety (A)	***0.03***	***0.10***	-	***NS***	-	***NS***
Ptg. Geom. (B)	***0.04***	***0.11***	-	***NS***	-	***NS***
Nutril. Combn.(C)	***0.03***	***0.10***	***0.04***	***0.12***	***0.06***	***0.16***
A × B	-	***NS***	-	***NS***	-	***NS***
B × C	***0.07***	***0.20***	***0.13***	***0.37***	***0.11***	***0.32***
A × C	-	***NS***	***0.08***	***0.22***	***0.11***	***0.30***
A × B × C	-	***NS***	-	***NS***	-	***NS***

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

Table 5 : Nitrogen content (%) in different plant parts at 90 DAS 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)								
		Leaf			Stem			Pod		
		HG 365	HG 563	*Mean*	HG 365	HG 563	*Mean*	HG 365	HG 563	*Mean*
S_1 (30 cm × 10 cm) (33.3 plants per m^2)	F_1 (15N:20P:20K:10S)	1.08	0.92	***1.00***	1.04	0.89	***0.96***	1.77	1.50	***1.64***
	F_2 (30N:40P:40K:20S)	1.35	1.15	***1.25***	1.30	1.10	***1.20***	2.21	1.88	***2.04***
	F_3 (45N:60P:60K:30S)	1.41	1.19	***1.30***	1.35	1.15	***1.25***	2.29	1.95	***2.12***
	Mean	***1.28***	***1.09***	***1.19***	***1.23***	***1.05***	***1.14***	***2.09***	***1.78***	***1.93***
S_2 (30 cm × 20 cm) (16.7 plants per m^2)	F_1 (15N:20P:20K:10S)	1.48	1.26	***1.37***	1.42	1.21	***1.32***	2.42	2.06	***2.24***
	F_2 (30N:40P:40K:20S)	1.67	1.42	***1.54***	1.60	1.36	***1.48***	2.72	2.31	***2.52***
	F_3 (45N:60P:60K:30S)	1.73	1.47	***1.60***	1.66	1.41	***1.53***	2.82	2.40	***2.61***
	Mean	***1.63***	***1.38***	***1.50***	***1.56***	***1.33***	***1.44***	***2.65***	***2.26***	***2.45***
S_3 (40 cm × 10 cm) (25 plants per m^2)	F_1 (15N:20P:20K:10S)	1.15	0.97	***1.06***	1.78	1.51	***1.65***	1.87	1.59	***1.73***
	F_2 (30N:40P:40K:20S)	1.46	1.24	***1.35***	2.27	1.93	***2.10***	2.38	2.02	***2.20***
	F_3 (45N:60P:60K:30S)	1.49	1.27	***1.38***	2.32	1.97	***2.15***	2.44	2.07	***2.25***
	Mean	***1.37***	***1.16***	***1.26***	***2.12***	***1.80***	***1.96***	***2.23***	***1.89***	***2.06***
For Comparing varieties (A) and Nutritional combinations (C)										
F_1 (15N:20P:20K:10S)		1.24	1.05	***1.15***	1.42	1.20	***1.31***	2.02	1.72	***1.87***
F_2 (30N:40P:40K:20S)		1.49	1.27	***1.38***	1.72	1.46	***1.59***	2.44	2.07	***2.25***
F_3 (45N:60P:60K:30S)		1.54	1.31	***1.43***	1.78	1.51	***1.64***	2.52	2.14	***2.33***
Mean		***1.42***	***1.21***	***1.32***	***1.64***	***1.39***	***1.51***	***2.32***	***1.98***	***2.15***

Factor	Leaf *S Em±*	Leaf *CD*	Stem *S Em±*	Stem *CD*	Pod *S Em±*	Pod *CD*
Variety (A)	-	***NS***	-	***NS***	-	***NS***
Ptg. Geom. (B)	***0.03***	***0.10***	-	***NS***	-	***NS***
Nutril. Combn.(C)	***0.03***	***0.09***	***0.04***	***0.10***	***0.05***	***0.14***
A × B	-	***NS***	-	***NS***	_	***NS***
B × C	***0.06***	***0.17***	-	***NS***	-	***NS***
A × C	-	***NS***	-	***NS***	-	***NS***
A × B × C	-	***NS***	-	***NS***	-	***NS***

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

2.17; *rabi* 1.93). Application of 45N: 60P: 60K: 30S kg per ha (F_3) recorded the highest nitrogen content in pod (*kharif* 2.62; *rabi* 2.33) which was on par with 30N: 40P: 40K: 20S kg per ha (F_2) (*kharif* 2.53; *rabi* 2.25). The lowest nitrogen content in pod (*kharif* 2.10; *rabi* 1.87) was recorded by the application of 15N: 20P: 20K: 10S kg per ha (F_1).

Crude protein (%)

Significant differences were observed in the crude protein (table 2) due to variety, planting geometry, nutritional combinations and their interactions. Among the varieties HG 365 recorded the highest crude protein both in *kharif* (24.34 %) and *rabi* seasons (23.13 %). Planting geometry of 30 cm × 20 cm (S_2) recorded significantly the highest crude protein (*kharif*: 24.71 %; *rabi*: 23.48 %) followed by 40 cm × 10 cm (S_3) (*kharif*: 23.10 %; *rabi*: 21.95 %). The lowest crude protein was recorded by the planting geometry at 30 cm × 10 cm (S_1) (*kharif* 21.56 %; *rabi* 20.48 %). Application of 45N: 60P: 60K: 30S kg per ha (F_3) recorded the highest crude protein (*kharif* 24.00 %; *rabi* 22.80 %) which was on par with 30N: 40P: 40K: 20S kg per ha (F_2) (*kharif* 23.51 %; *rabi* 22.33 %). The lowest crude protein (*kharif* 21.87 %; *rabi* 20.78 %) was recorded by the application of 15N: 20P: 20K: 10S kg per ha (F_1). The interaction effect of planting geometry plus nutrient level was found significant both during *kharif and rabi.* The highest crude protein was recorded by the planting pattern of 30 cm × 20 cm plus application of 45N: 60P: 60K: 30S kg per ha (*kharif* 25.31; *rabi* 24.04) and HG 365 + application of 45N: 60P: 60K: 30S kg per ha (*kharif* 26.01; *rabi* 24.71).

It is observed from the results on nitrate reducase activity and crude protein that both of them were associated together. Higher the nitrate reductase activity higher was the crude protein content and *vice versa.* Thus in the present study both these values were recorded at maximum level by the variety HG 365 in combination with planting geometry at 30 cm × 20 cm (the lowest population density) and the highest level nutritional combination at 45N: 60P: 60K: 30S. The enzyme nitrate reductase helps in the assimilation of nitrate nitrogen into the plants and therefore it might help in higher nitrogen content in various plant parts making it available for the biosynthesis of protein molecules. This might be the reason as to why a higher activity of nitrate reductase as observed in the variety HG 365 in combination with planting geometry at 30 cm × 20 cm (the lowest population density) and the highest level nutritional combination at 45N: 60P: 60K: 30S might have led to a higher content of crude protein. However, it was observed that both the activity of enzyme and content of protein did not increase significantly with increase in nutrient application from the level of 30N: 40P: 40K: 20S to the level of 45N: 60P: 60K: 30S thus making the effect of additional amount of nutrients null and void. However, the additional dose of nutrients were found beneficial provided there was an increase in the population density as evident from the comparison between these values recorded from the highest population density coupled with highest dose and lowest population densities supplied with highest dose.

The increase in protein content at high nutritional dose could be due to a high S content, since the nutrient sulphur is an important constituent of some amino acid molecules and therefore resulted in increases in protein content at higher doses (Baviskar *et al.*, 2012). Singh *et al.* (2006) was also of the same opinion.

According to Yadav (2011) the synergistic effect of P and S may be due to utilization of high quantities of nutrients through their well developed root system and nodules which might have resulted in better growth and yield. Increasing doses of sulphur application resulted in a significant increase in protein content of cluster bean. The positive response to added sulphur is assigned to low status of available S in the soil or due to stimulating effect of applied sulphur in the synthesis of chloroplast protein resulting in greater photosynthetic efficiency which in turn got translated in term of increased yield. In his studies, nitrogen content was significantly increased with the increase in level of P. and S. Dwivedi and Bapat (1998) reported that nitrogen content in soybean increased significantly by P and S application up to 50 kg ha^{-1} of each. The interaction of P and S was significant and maximum nitrogen content was recorded at the highest dose of P and S. Protein content in cluster bean grain was increased significantly with application of P and S individually as well as in combination. The maximum increase in protein content obtained with the highest P and S was attributed to more nitrogen fixation. Similar results were also reported by Shankaralingappa *et al.* (2000) in cowpea and Kumawat *et al.* (2004) in *taramira*. Increasing doses of sulphur application resulted in a significant increase in protein content of cluster bean. The positive response to added sulphur is assigned to low status of available S in soil or due to stimulating effect of applied sulphur in the synthesis of chloroplast protein resulting in greater photosynthetic efficiency which in turn translated in term of increased yield.

The maximum crude protein content was obtained when nitrogen was applied at higher dose. The higher crude protein at higher nitrogen levels was felt mainly due to structural role of nitrogen in building up amino acids. The progressive increase in crude protein contents with increasing nitrogen rates were also reported by Kumawat *et al*. (2000), Sheikh (2004), Morshed *et al*., (2008) and Ibrahim (2009).

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