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Agronomic and Genetic Analysis of Performance of Guar Varieties under Rainfed Conditions in a Semi-Arid Climate on Alfisols

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A B S T R A C T

Guar is known for its drought hardiness and preferred for extraction of galactomannan gum. Its adaptability is proved in Mediterranean and sub-tropical environments. Information on its adaptability in semi-arid environments is limited. Hence, we evaluated six released varieties of guar (HG-365, HG-563, RGC-936, RGC-1002, RGC-1035 and RGC-1066) under rainfed conditions during *kharif* 2013 and 2014 with a view to identify agronomically and genetically superior ones. Among the varieties tested, RGC-936 produced significantly higher no. of branches and clusters thus seed yield (0.92 t ha^{-1}). The seed yield was 87.8%, 44.0%, 35.7%, 26.5 and 24.5% higher than that of RGC-1066, RGC-1002, HG-563 and HG-365, respectively. Besides, higher gross and net returns (Rs. 46,508 and 31,758 ha^{-1}) and B: C ratio ((3.15) were also accrued due to RGC-936 variety. Genetic analysis showed that plants with short height, more no. of branches, clusters and pod plant^{-1} are the important traits to be given priority to develop high yielding cultivars, as they influenced economic yield positively and significantly.

Introduction

Guar [*Cyamopsis tetragonoloba* L. (Taub)] is commonly known as clusterbean. It is best adapted to tropical and subtropical regions. Due to high drought and salinity tolerance (Francois *et al.*, 1990; Ashraf *et al.*, 2005), guar could be a valuable alternative crop for the exploitation of the semiarid environments (Losavio *et al.*, 1995), where high temperature, poor erratic rainfall and elevated water and salt content do not allow the cultivation of many crops. Being a legume, it has good capability to fix atmospheric nitrogen (Elsheikh and Ibrahim, 1999). It is the potential vegetable cum industrial crop grown for its tender pods for vegetable and for endosperm gum i.e. galactomannan (22-33%) (Gresta *et al.*, 2013) and for guar meal (Singh *et al.*, 2014). This endosperm gum is used in textile, paper, pharmaceutical, neutraceutical, cosmaseutical and petroleum industries. It is grown primarily for gum purpose. India ranks first among the guar producing countries and contributes around 80% share of the worlds' total production. Though the crop is popular in Mediterranean and sub-tropical regions of the world, its spread is less in semi-arid environments. Hence, efforts are on to introduce guar crop in semi-arid tropical (SAT) climate under rainfed conditions especially for galactomannan purpose (Ramanjaneyulu *et al.*, 2016). Though, this crop is photosensitive and highly sensitive to winter temperatures, the climatic conditions in semi tropical climate are favourable to the crop, thus, it can be grown throughout the year. While introducing a crop and testing its suitability, identification of high yielding variety is utmost important. In view of this fact, we felt it was important evaluate few released guar varieties agronomically and genetically and identify suitable ones for rainfed conditions under semi-arid climate on Alfisols.

Materials and Methods

Experimental details and agronomic management

A field experiment was conducted at Regional Agricultural Research Station, Professor Jayashankar Telangana State Agricultural University, Palem, Southern Telangana Zone, Telangana state, India during *kharif* season of 2013 and 2014 under rainfed conditions. The soil of experimental site was Alfisol with a pH of 6.84, EC of 0.14 dSm^{-1}, low in available nitrogen and high in available phosphorus and potassium. Six varieties *viz*., HG-365, HG-563, RGC-936, RGC-1002, RGC-1035 and RGC-1066 were tested in a randomised block design with four replications. The characteristic features of varieties under test are furnished in Table 1. Seeds were dibbled at 45cmx15cm spacing on 7-8-2013 and 13-7-2014 during 2013 and 2014, respectively. A net plot size of 4.5mx6.0m ($27.0m^2$) was maintained. A fertilizer dose of 20 kg N, 40 kg P_2O_5 and 30 kg K_2O ha^{-1} through urea, single super phosphate and muriate of potash was applied as basal. Besides, seed inoculation was done with *Rhizobium* biofertilizer as it is a non-traditional crop in the region. The crop was kept weed free by spraying a pre-emergence herbicide pendimethalin @ 0.75 kg a.i ha^{-1} followed by two hand weedings at 30 and 45 days after sowing. Harvesting was done by uprooting the plants from net plot of each treatment followed by drying in the sun for a week and then pods were threshed to get seed. Seed from each net plot treatment was weighed and converted into tonnes per hectare (t ha^{-1}).

Chemical analysis

Initial soil available N, P, and K were estimated using alkaline permanganate method (Subbiah and Asija, 1956), Olsens' method (Olsen *et al.*, 1954) and ammonium acetate method (Jackson, 1973), respectively. N, P and K content in the straw and seed samples were determined by micro-kjeldhal method (Piper, 1966), vanadomolybdo phosphoric yellow color method and flame photometer method (Jackson, 1973), respectively. Nutrient uptake by seed or straw was calculated as a function of nutrient content (%) and grain or straw yield. The protein content in the seed was calculated by multiplying nitrogen concentration with a factor 6.25 (AOAC, 1960).

Climate data

Minimum temperature (20 to 22^oC) was found to be low during 27th to 43rd standard meteorological weeks (SMW) and it was high (22 to 24^oC) during 34-36 (SMW) persisted. While during 2014, corresponding week wise minimum temperatures were slightly high (20 to 24^oC). RH (II) was also found to be high during cropping period during 2013 as compared to that of 2014. An amount of 374.89 mm rainfall was received during 27 to 38 SMW in 32 rainy days during 2013 against 363.4 mm in 31 days in 2014. On the otherhand, very high rainfall of 383.4 mm was received in 12 rainy days with high rainfall events of 152.8 mm during 41st SMW and 200.8 mm during 43rd SMW during 2013 against only 58 mm rainfall in 6 days during 2014. Besides, low evaporation rates were observed throughout cropping season during 2013 vis-a-vis 2014.

Statistical analysis

The data on all growth and yield traits, yield, quality and nutrient uptake were analyzed by using F-test as per the procedure given by Gomez and Gomez (1984). The estimates of PCV and GCV were classified as low (< 10%), medium (10-20%), and high (> 20%) and heritability estimates (broad-sense) for yield components were done following Singh and Chaudhary (1985). Genetic advance was estimated and categorised as > 20% = high; 10-20% = moderate; less than 10% = low as per the method given by Johnson *et al.*, (1955). The genotypic and phenotypic correlation coefficients were calculated using the method of Al-Jibouri *et al.*, (1958). The cause and effect relationships were estimated as per the procedure given by Dewey and Lu (1959).

Results and Discussion

Agronomic evaluation of guar varieties

Agronomic evaluation revealed that significant variation existed among varieties for different morphological and yield traits studied (Table 2). RGC-1066, a non-branching variety with significantly less no. of pods (39.8) and clusters plant^{-1} (8.8) grew significantly taller (142.5 cm) than all other varieties. On the contrary, RGC-936 variety has produced significantly more no. of branches (6.6), pods (51.2) and clusters plant^{-1} (18.9), however, it was at par with that of RGC-1035, HG-563, RGC-1002 and HG-365 for branches and pods; RGC-1035 and HG-365 for clusters plant^{-1}. While, 1000 seed weight of all six varieties was statistically similar.

Regardless of year of experimentation, RGC-936 has produced significantly higher seed yield (0.70 and 1.141 t ha^{-1}). Pooled data showed that RGC-936 (0.920 t ha^{-1}) being at with HG-365 (0.739 t ha^{-1}) has significantly out yielded rest of the four varieties *viz.*, HG-563 (0.727 t ha^{-1}), RGC-1002 (0.678 t ha^{-1}) and RGC-1066 (0.490 t ha^{-1}). Further, RGC-936 (3.095 t ha^{-1}) produced significantly more biological yield than other varieties barring RGC-1002 (2.921 t ha^{-1}), RGC-1035 (2.850 t ha^{-1}) and HG-365 (2.807 t ha^{-1}). The variety HG-563 (30.2) stood first in recording significantly higher harvest index and is followed by RGC-936 (29.3). The outstanding performance of guar variety RGC-936 could be attributed to highest number of branches, pods and clusters plant^{-1} than other varieties (Table 3). It means the variety has very good adaptation capacity to the semi-arid environment.

Different varieties differed in their ability in mining nutrients from the soil. Among all varieties under test, RGC-936 variety has removed significantly higher quantity of N (152.8 kg ha^{-1}) and P (14.3 kg ha^{-1}) barring RGC-1002 and RGC-1035 in case of N and RGC-1002, RGC-1035 and HG-365 for P. Potassium uptake by different varieties followed similar trend as that of N.. Though more protein content (31.2%) was observed with RGC-1002, significantly higher protein yield (0.284 t ha^{-1}) was recorded with RGC-936 having 30.8% protein content (Table 3). Economic analysis showed that, higher gross

(Rs. 46508 ha^{-1}) and net (Rs. 31758 ha^{-1}) returns besides highest B: C ratio (3.15) were accrued with RGC-936 variety (Table 3). Earlier, Meena (2014) reported significantly higher NPK uptake, net returns and B: C ratio in RGC-1025 variety among the varieties under test. Review of published work internationally revealed that, of the four varieties *viz.,* Esser, Kinman, Lewis and Santa Cruz tested in a Mediterranean environment in South Italy, Lewis and Santa Cruz were found to be most productive ones (Gresta *et al.,* 2013) due to tallness, more dry matter production and 1000 seed weight besides longer duration. Among three varieties viz., 2/1, Mills and Brooks varieties studies in Bahawalpur, Pakistan, the variety "2/1" with more no. of branches and pods and 1000 seed weight, has significantly outyielded the other two varieties (Mahmood *et al.,* 1988). Literature in India over the years inferred that guar variety RGC-986 produced significantly more number of yield attributing characters thus higher grain yield than RGC 1003, RGC-1017 and RGC- 936 varieties (Choudhary *et al.,* 2006). The variety RGC-197 produced significantly higher seed yield than RGC-936 and RGC-986 (Sharma and Nehara, 2004).

Choudhary *et al.,* (2004) found that out of 28 genotypes, the highest average seed yield was recorded with RGC-1012. A variety RGM-112 gave significantly higher mean seed yield as against the check RGC 936 and HGS 365 in the co-ordinated experiments (Bhansali and Bhandri, 2004). Thus, most of the literature shows that it is the inherent ability of a variety to produce better morphological and yield attributes thus seed yield.

Genetic analysis of guar varieties

The extent of variability for any character is very important for the improvement of a crop through breeding. The variability of the characters is measured by mean, range, Genotypic Coefficient of Variation (GCV), Phenotypic Coefficient of Variation (PCV), Heritability (h^2b), Genetic Advance (GA) and GA as percentage of mean. In the present study, the variability in the characters were assessed using all these statistics and are presented in Table 4. Good amount of variation was observed for all the traits except for harvest index. All the traits expressed high phenotypic and genotypic variances except for branches $plant^{-1}$, 1000 seed weight and harvest index. PCV and GCV were lower for 1000 seed weight. PCV was higher than GCV for all the traits studied indicating the presence of environmental influence on the expression of these traits. Majumder *et al.,* (2008) reported similar result in case of spring wheat. Heritability was high for plant height and branches $plant^{-1}$. The result is in agreement with Sultan *et al.,* (2012) who reported similar results in guar. Low heritability value was observed for 1000 seed weight indicating that this character had more of environmental influence. Similar such observations were earlier made in guar by Morris (2010) and Manivannan *et al.,* (2015).

Table.1 Characteristic features of guar varieties used in the experiment

S. No.	Variety	Characteristic features
1	HG-365	Late (110-120 days) maturing and branching variety
2	HG-563	Late (110-120 days) maturing and branching variety
3	RGC-936	Early (85-100 days) maturing and branching variety with pinkish seed
4	RGC-1002	Early (85-100 days) maturing and branching variety
5	RGC-1035	Early (85-100 days) maturing and branching variety
6	RGC-1066	Early (85-100 days) maturing and single stem/unbranched variety

Table.2 Variation in growth, yield traits, yield and nutrient uptake among different varieties of guar (Pooled data of 2013 and 2014)

Varieties	Plant height (cm)	No. of branches plant^{-1}	No. of pods plant^{-1}	No. of clusters plant^{-1}	1000 seed weight (g)	Seed yield (t ha^{-1})			Protein content (%)	Protein yield (t ha^{-1})	N uptake (kg ha^{-1})	P uptake (kg ha^{-1})	K uptake (kg ha^{-1})
						2013	2014	Pooled					
HG 365	62.0	6.3	49.5	15.6	32.2	0.548	0.931	0.739	28.4	0.210	127.3	12.5	64.4
HG 563	59.2	5.3	44.0	14.2	31.6	0.608	0.847	0.727	29.6	0.214	115.5	10.6	58.5
RGC 936	67.1	6.6	51.2	18.9	32.3	0.700	1.141	0.920	30.9	0.284	152.8	14.3	73.3
RGC 1002	59.1	6.1	47.0	13.4	32.2	0.545	0.812	0.678	31.2	0.212	146.2	14.2	65.8
RGC 1035	68.4	5.0	49.8	17.7	31.6	0.423	0.853	0.638	30.8	0.196	140.5	13.6	63.8
RGC 1066	142.5	0.0	39.8	8.8	32.1	0.339	0.641	0.490	26.6	0.130	108.8	10.6	59.9
SEm±	3.30	0.4	3.3	1.32	0.4	0.080	0.091	0.057	0.5	0.016	4.8	0.8	3.5
LSD (0.05)	10.0	1.3	10.0	4.0	1.3	0.241	0.275	0.137	1.4	0.047	14.6	2.5	NS
CV (%)	8.7	18.1	14.1	17.9	2.7	30	21	17	3.1	15.0	7.3	13.1	10.9

LSD: Least Significant Difference SEm±: Standard Error of Mean CV: Co-efficient of Variation

Table.3 Variation in biological yield, harvest index and economics of guar varieties

Varieties	Biomass yield (t ha^{-1})			Biological yield (t ha^{-1})			Pooled data of two years 2013 and 2014			
	2013	2014	Pooled	2013	2014	Pooled	HI (%)	Gross returns (Rs ha^{-1})	Net returns (Rs ha^{-1})	B:C ratio
HG 365	1.761	2.375	2.068	2.308	3.306	2.807	25.5	37358	22608	2.53
HG 563	1.330	2.103	1.716	1.938	2.949	2.443	30.2	36751	22001	2.49
RGC 936	1.927	2.422	2.175	2.627	3.563	3.095	29.3	46508	31758	3.15
RGC 1002	2.132	2.353	2.242	2.676	3.165	2.921	23.1	34274	19524	2.32
RGC 1035	2.065	2.360	2.213	2.488	3.213	2.850	22.2	32252	17502	2.19
RGC 1066	1.381	2.769	2.075	1.720	3.410	2.565	19.1	24770	10021	1.68
SEm±	0.148	0.148	0.082	0.176	0.195	0.106	0.016			
LSD (0.05)	0.445	0.446	0.247	0.532	0.587	0.319	0.049			
CV (%)	17	12	78	15	12	8	13.1			

Market rate of guar seed: Rs. 50552 t^{-1} B: C ratio: Benefit: Cost ratio

Table.4 Estimates of variance (genotypic, phenotypic, means, GCV, PCV, h^2 and genetic advance of important quantitative traits of guar genotypes (Pooled data of 2013 and 2014)

Character	Plant height (cm)	No. of branches $plant^{-1}$	No. of pods $plant^{-1}$	No. of clusters $plant^{-1}$	1000 seed weight (g)	Seed yield (kg ha^{-1})	Biomass yield (kg ha^{-1})	Biological yield (kg ha^{-1})	Harvest index
Var Environmental	48.41	1.07	32.78	13.67	0.01	10616.50	81185.18	164816.48	0.00
ECV	9.04	21.16	12.22	25.06	2.60	14.74	13.69	14.60	19.87
Var Genotypical	1041.30	5.95	14.26	11.13	0.00	18521.31	26942.35	36268.92	0.00
GCV	41.94	49.96	8.06	22.61	0.48	19.47	7.89	6.85	15.89
Var Phenotypical	1089.70	7.02	47.04	24.80	0.01	29137.81	108127.53	201085.41	0.00
PCV	42.90	54.25	14.64	33.75	2.65	24.42	15.80	16.13	25.44
h^2 (Broad Sense)	0.96	0.85	0.30	0.45	0.03	0.64	0.25	0.18	0.39
Genetic Advancement 5%	64.98	4.63	4.28	4.60	0.01	223.52	168.79	166.61	0.05
Genetic Advancement 1%	83.28	5.93	5.49	5.90	0.01	286.45	216.31	213.52	0.07
Gen. Adv as % of Mean 5%	84.45	94.76	9.14	31.19	0.18	31.98	8.11	5.99	20.43
Gen. Adv as % of Mean 1%	108.23	121.44	11.72	39.98	0.23	40.98	10.39	7.68	26.19
General Mean	76.94	4.88	46.85	14.75	3.20	698.94	2081.31	2780.25	0.25
Range lowest	59.0688	0,0000	39.7813	8.8000	3.1550	490.2500	1716.1250	2443.3880	0.1900
Range highest	142.5125	6.6313	51.1550	18.8875	3.2313	920.5000	2242.3750	3095.0480	0.3025

Table.5 Phenotypic and genotypic coefficient of correlation among different traits of guar genotypes (Pooled data of 2013 and 2014)

Character	Plant height (cm)	No. of branches plant^{-1}	No. of pods plant^{-1}	No. of clusters plant^{-1}	1000seed weight (g)	Biomass yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index	Seed yield (t ha^{-1})
Plant height (cm)	**1.000 (1.000)**	-0.876*** (-0.973)	-0.421** (-0.849)	-0.479*** (-0.811)	0.110 (0.416)	0.056 (0.039)	-0.173 (-0.486)	-0.476*** (-0.738)	-0.574*** (0.725)
No. of branches plant^{-1}		**1.000 (1.000)**	0.549*** (0.964)	0.604*** (0.872)	0.130 (0.003)	0.084 (0.109)	0.347* (0.698)	0.435** (0.761)	0.672*** (0.862)
No. of pods plant^{-1}			**1.000 (1.000)**	0.615*** (1.067)	0.240 (0.101)	0.148 (0.609)	0.316* (1.119)	0.101 (0.548)	0.381** (0.887)
No. of clusters plant^{-1}				**1.000 (1.000)**	0.267 (-0.535)	0.325* (0.182)	0,477*** (0.772)	0.202 (0.716)	0.479*** (0.890)
1000 Seed weight (g)					**1.000 (1.000)**	0.359* (0.961)	0.228 (1.359)	-0.208 (-0.111)	0.006 (0.646)
Biomass yield (t ha^{-1})						**1.000 (1.000)**	0.832*** (0.795)	-0.500*** (-0.536)	-0.010 (0.003)
Biological yield (t ha^{-1})							**1.000 (1.000)**	-0.046 (0.146)	0.461*** (0.680)
Harvest index								**1.000 (1.000)**	0.803*** (0.861)
Seed yield (t ha^{-1})									**1.000 (1.000)**

* Significant at 5% level; **Significant at 1% level; ***Significant at 0.5% level

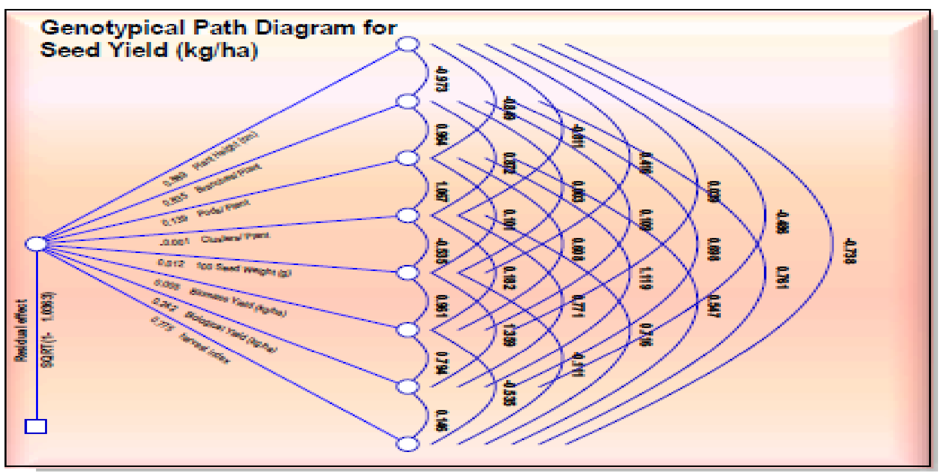
Table.6 Phenotypic path matrix of seed yield of guar genotypes (Pooled data of 2013 and 2014)

Character	Plant height (cm)	No. of branches plant^{-1}	No. of pods plant^{-1}	No. of clusters plant^{-1}	1000seed weight (g)	Seed yield (t ha^{-1})	Biomass yield (t ha^{-1})	Biological yield (t ha^{-1})	Correlation with seed yield
Plant height (cm)	**0.1057**	-0.0925	-0.0445	-0.0506	0.0117	0.0059	-0.0182	-0.0503	-0.574***
No. of branches plant^{-1}	-0.2278	**0.2601**	0.1427	0.1572	0.0339	0.0218	0.0904	0.1132	0.672***
No. of pods plant-1	-0.0396	0.0516	**0.0941**	0.0579	0.0226	0.0139	0.0297	0.0095	0.381**
No. of clusters plant^{-1}	0.0176	-0.0223	-0.0226	**-0.0368**	-0.0098	-0.0126	-0.0176	-0.0075	0.479***
1000 seed Weight (g)	0.0017	0.0020	0.0037	0.0042	**0.0156**	0.0056	0.0036	-0.0033	0.006
Biomass yield (t ha^{-1})	-0.0022	-0.0034	-0.0060	-0.0138	-0.0144	**-0.0403**	-0.0335	0.0201	-0.010
Biological yield (t ha^{-1})	-0.0762	0.1533	0.1394	0.2106	0.1004	0.3671	**0.4414**	-0.0204	0.461***
Harvest index	-0.3534	0.3227	0.0745	0.1501	-0.1544	-0.3711	-0.0343	**0.7417**	0.803***
Partial R²	-0.0607	0.1747	0.0359	-0.0176	0.0001	0.0004	0.2036	0.5956	

R^2= 1.0363 Residual effect = SQRT (1-1.0363)

Diagonal bold values indicate direct effects

Fig.1 Diagrammatic representation of direct effects and correlation coefficients of variable on dependent variables of guar genotypes (Pooled data of 2013 and 2014)



Heritability estimates along with genetic advance will be more useful in predicting the effect for selecting the best individual. The analysis of GA as percentage of mean was high for the characters such as plant height, seed yield, biomass yield and biological yield indicating selection based on these traits yield good results.

It is desirable for a plant breeder to know the extent of relationship between the yield and its various components which will facilitate the breeder in selecting plants of desirable characteristics. The phenotypic and genotypic correlation coefficients studied for all the traits are presented in Table 5. For majority of the traits, the genotypic correlation coefficients were higher than the phenotypic correlation coefficients. These results suggest that number of clusters plant^{-1}, pods plant^{-1} and branches plant^{-1} and harvest index had high phenotypic and genotypic correlation coefficients with yield. Pods plant^{-1} had high positive correlation with biological yield and clusters plant^{-1}. The correlation of pods and clusters plant^{-1} with branches plant^{-1} was highly significant and positive. 1000 seed weight had recorded significant and positive correlation with biological yield, but, it had very low heritability and genetic advance. On the otherhand, plant height had negative correlation with yield attributes and yield. Furthermore, harvest index is negatively correlated with plant height, 1000 seed weight and biomass yield. Singh *et al.,* (2004), Vir and Singh (2015), Saini *et al.,* (2010) and Manivannan *et al.,* (2015) have reported similar relationships among yield components and with yield itself in guar. This suggests that, in guar, genotypes with short height but with more number of branches plant^{-1} produce higher yield.

Path coefficients have been used in several crop species to provide information on interrelationships of complex characters and also to develop selection criteria. The relationship between yield and yield components may be positive or negative but it is the net result of direct effects of that particular trait and indirect effects through other traits. Hence, it is necessary to determine the path coefficients which position the observed correlation into direct and indirect effects and also reveals the cause and effect relationships between yield and their related traits.

The genotypic path matrix of seed yield indicated high positive direct effect of biological yield (0.7417) and biomass yield (0.4414) on seed yield (Table 6; Fig.1). However, branches plant^{-1}, clusters plant^{-1} and pods plant^{-1} had correlated indirectly to the seed yield.

Harvest index contributed maximum indirect effects to this trait. Crippa *et al.,* (2009) reported similar finding in lentil. In guar, it is observed that the improvement for the yield could be achieved by applying selection pressure through indirect selection of pods plant^{-1}, clusters plant^{-1} and branches plant^{-1}. Sheela *et al.,* (2014) reported that pods plant^{-1} was the primary selection factor in their studies aimed at increasing yield in guar.

Results of our two year study clearly indicated that the variety RGC-936 is found agronomically and genetically superior as it produced higher yield traits such as branches, pods and clusters plant^{-1} thus seed and biological yield. Furthermore, all the traits under study expressed high GCV indicating good selection response.

Though, high heritability coupled with genetic advance was observed for traits such as plant height, seed and biomass yield, there was a negative correlation between seed yield and plant height. Hence, plant breeders have to design breeding programmes based on no.

of pods, clusters and branches plant^{-1} which have positive association and direct contribution to yield in guar.

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