HETEROSIS AND INBREEDING DEPRESSION FOR SEED YIELD AND ITS COMPONENTS IN COWPEA[*Vigna unguiculata* (L.) Walp.]

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ABSTRACT

Forty five crosses generated in a diallel fashion excluding reciprocals using ten genotypes were evaluated to study the extent of heterosis and inbreeding depression for seed yield and yield attributing characters in cowpea. Standard heterosis, in general, were high in desired direction for days to 50 per cent flowering, days to maturity; moderate for seed yield per plant and plant height; and low for number of pods per plant, number of pods per cluster, harvest index and branches per plant, while the magnitude of heterobeltiotic effects were high in desired direction for plant height, seed yield per plant, number of seeds per pod and number of pods per plant; moderate for branches per plant, number of pods per cluster, days to maturity, number of clusters per plant, protein content, 100 seed weight, harvest index and days to 50% flowering; and low for pod length only. The variable number of crosses exhibited significant inbreeding depression for different characters. The maximum number of crosses showed inbreeding depression for 100 seed weight and pod length; moderate for number of clusters per plant, number of seeds per pod, branches per plant, seed yield per plant, days to 50 per cent flowering and number of pods per plant; and low for protein content and number of pods per cluster, harvest index, plant height and days to maturity. Negative estimates of heterotic effects observed in some traits may be attributed to inter-allelic interactions. No clear-cut relationship between heterosis and inbreeding depression was observed for seed yield and related traits. Superior segregants from the cross GC 2 x GC 5 may be selected for further improvement in the seed yield and its contributing traits.

KEY WORDS: Groundnut, Heterosis, Inbreeding depression, Seed yield

INTRODUCTION

Cowpea [*Vigna unguiculata* (L.) Walp.] is an important grain legume, which is tolerant to drought and other soil stresses. Cowpea is primarily used in the form of dry seeds, fodders, green pods, green manure and cover crops. Many constraints are identified for low productivity of dry seeds in cowpea. This crop exhibits rich genetic diversity for various traits and has a great scope for its improvement. In cowpea, seed yield is complex quantitative character and influenced by its contributing traits, *i.e.* number of pods per plant, pod length, seeds per pod and 100 seed weight. The selection of parents on the basis of *per se* performance does not necessarily lead to desirable results. Exploitation of hybrid vigour in crop plants for quantum jump in yield and other quantitative characters is one of the approaches in crop improvement to cope up with the ever-increasing demand for food grains. In cowpea, heterosis cannot be exploited for higher production through commercial hybrids due to cleistogamous nature of flower and poor seed recovery during hybridization. Hence, the heterosis assumes importance in breeding as heterotic crosses have the potentiality to throw out superior segregants in subsequent generations. The estimates of heterosis and inbreeding depression provide information about the nature of gene action involved in the expression of yield and related traits. The information is also essential to formulate efficient breeding programmes for the improvement of the crop. Though there are a number of reports on heterosis, information is limited in case of inbreeding depression especially for the traits like seed yield and yield components. Therefore, the present investigation was carried out to estimate the magnitude of the heterosis and inbreeding depression in 45 crosses of cowpea in F_1 and F_2 generations, respectively.

MATERIALS AND METHODS

Ten diverse lines of cowpea *viz.*, GC 1, GC 2, GC 4, GC 5, RC 101, KM 5, IT 389561, Pusa Phalguni, Pant Lobia 1 and Pant Lobia 2 were crossed in all possible combinations (excluding reciprocals). The 45 F_1's and 45 F_2's and 10 parents were grown in randomized block design with three replications at Instructional Farm, Junagadh Agricultural University, Junagadh (Gujarat) during summer 2014.

Name and source of genotypes used in genetic studies

Sr. No.	Name of Genotypes	State of Release	Characteristics	Pedigree	Photographs
1.	GC 1	Gujarat	Highly resistant to both the species of Root Knot Nematodes.	Developed by selection from Barsati mutant obtained fron division of Myeology, IARI, New Delhi	
2.	GC 2	Gujarat	Tolerant to drought	A selection from local germplasm and tested as Chharodi -I	
3.	GC 4	Gujarat	High yield & White Bold Seeded	V 16 x Black eye 7-31 bulk in F_5 generation	
4.	GC 5	Gujarat	High yield	GC 2 x GC 8963	

5.	RC 101	Rajasthan	Low to moderate level of resistance to Yellow Vein Mosaic	IT 82 D x FS 68	
6.	KM 5	Tamilnadu	High level of resista nce to major Fungal, Bacterial & Viral diseases	A derivative of the cr oss between - JC 5 X DO FASLI.	
7.	IT 38956 1	Karnataka	Tolerant to water stress and hence suitable for dry lands	Introduction From II TA, Nigeria	
8.	PusaPhalgu ni	Delhi	High yield, Early maturity	Pureline Selection from the Canadian cultivar 'Dolique du Tonkin'	
9.	Pant Lobia 1	Uttrakhand	High level of resista nce to major Fungal, Bacterial & Viral diseases	IT-93 K-506-9-12 x IT-03-K-2046-4	
10.	Pant Lobia 2	Uttrakhand	Low to moderate level of resistance to Aphids, Thrips, Bruchid & o ther field pests.	KBC 2 x BundelLobia 1	

Each parent and F_1 planted in one row plot of 2.0 m long and three rows each of F_2 progenies with inter and intra row distance of 0.45 m x 0.15 m. Observations were recorded on five randomly selected plants from each parent and F_1 and twenty plants in F_2 from each replication for eleven traits *viz.*, plant height (cm), branches per plant, number of pods per plant, number of clusters per plant, number of pods per cluster, pod length (cm), number of seeds per pod, 100 seed weight (g), seed yield per plant (g), protein content (%) and harvest index (%), while days to 50 per cent flowering and days to maturity were recorded in 50 per cent and 80 per cent on the plot basis, respectively. Mean value were used for statistical analysis. Heterosis over better parent (BP) as per Fonseca and Patterson (1968) was calculated, while standard heterosis (SH) using GC 4 variety as standard check was calculated as per Meredith and Bridge (1972). Inbreeding depression (ID) from F_1 to F_2 was calculated by the formula, ID (%) = $[(F_1 – F_2) / F_1]$ x 100, where F_2 denotes the mean of F_2 population for a trait. The analysis was done using the WINDOSTAT 7.5 statistical package.

RESULT AND DISCUSSION

The analysis of variance (Table 1) revealed significant difference among the parents except for harvest index in both F_1 and F_2 generations indicating substantial amount of genetic variability among the parents for the characters studied. Mean squares due to parents *vs.* F_1 were also found significant for all yield and its components traits, except for days to maturity and protein content. This indicated substantial amount of heterosis in cross combinations and F_1 *vs*. F_2 revealed that the F_1's differed significantly from their F_2 for all the characters, except for number of pods per cluster and pod length suggesting presence of considerable amount of inbreeding depression in F_2 generation. This indicated that considerable amount of genetic variability were present in the material studied and also showed that the material was suitable for the study of manifestation of heterosis and genetic parameters involved in the inheritance of different traits.

The results presented in Table 2 indicated that some of crosses exhibiting standard heterosis in desirable direction for seed yield per plant (7) and its components like days to 50 % flowering (26), days to maturity (26), plant height (5), number of pods per plant (4), number of pods per cluster (4), harvest index (3) and branches per plant (1). In the present study, seed yield per plant was found to be the most heterotic trait as out of 45 crosses studied, twenty one and seven crosses depicted significant and positive heterosis over their better parent and standard parental values, respectively. The results are in correspondence with those reported earlier by Patil *et al.* (2005), Patel *et al.* (2009) and Chaudhari *et al.* (2013).

The highest magnitude of standard heterosis was observed for days to 50 % flowering and days to maturity followed by seed yield per plant, plant height, number of pods per plant, number of pods per cluster, harvest index and branches per plant. High magnitude of heterosis indicates over dominance and predominance of non-additive gene action in the expression of these characters. The results are in correspondence with those reported earlier by Zaveri *et al*. (1983), Kajale and Ravindrababu (2012) and Patel *et al.* (2013).

Swaminathan *et al*. 1972 suggested heterosis of 20-25 per cent over better parent could compensate the cost of hybrid seed in size. The cross, RC 101 x GC 1 recorded the highest standard heterosis (8.50 %) with seed yield per plant (31.24 g) followed by KM 5 x GC 1 (7.39 %) with seed yield per plant (31.15 g) and GC 2 x GC 5 (5.21 %) with seed yield per plant (34.15 g). In such a case, expression of heterotic response over standard parents indicated the real superiority of these three cross combinations and their exploitation to get better transgressive segregants in future segregating generations (Table 3). High heterosis for seed yield has been reported by several workers Patel *et al.* (2009) and Chaudhari *et al*. (2013. Gopikrishnan *et al.* 2003 advocated to utilization of hybrids having 20 per cent heterosis over better parent for improving cowpea.

The cross combination GC 2 x GC 5 exhibited highest significant and positive heterobeltiosis and high standard heterosis along with low magnitude of inbreeding depression followed by GC 4 x Pant Lobia 2, RC 101 x GC 1, KM 5 x GC 1, IT 38956 1 x KM 5 and IT 38956 1 x GC 5 indicated that these crosses may be exploited for development of high yielding stable lines. The cross Pusa Phalguni x GC 2 exhibited high significant and positive heterobeltiosis and standard heterosis along with high magnitude of inbreeding depression followed by GC 2 x Pant Lobia 1, GC 4 x Pant Lobia 1, Pusa Phalguni x Pant Lobia 1, Pusa Phalguni x Pant Lobia 2, RC 101 x Pant Lobia 2, RC 101 x Pant Lobia 1 and GC 1 x GC 4 suggested that these crosses could be suitable to get better transgressive segregants in segregating generations.

The cross combination, GC 2 x GC 5 recorded significant and positive heterobeltiosis for seed yield per plant, which indicated that in different crosses, pathways for releasing heterotic effects varied. Thus, the results revealed that plant height, number of pods per plant, number of pods per cluster, number of seeds per pod and harvest index were the main contributors towards increased seed yield. Similar findings have also been reported by several workers *viz*., Chaudhari *et al*. (2013) and Patel *et al*. (2013).

With regards to days to 50 per cent flowering, twenty six crosses exhibited significant standard heterosis and five crosses showed significant heterobeltiosis in the desired (negative) direction, So that thereby indicating the partial dominance of earliness over lateness. This result is in agreement with Pal *et al.* (2007) and Patel *et al.* (2013).

With respect to days to maturity, twenty six crosses exhibited significant standard heterosis and nine crosses showed significant heterobeltiosis in the desired (negative) direction, indicating over dominance for this trait. Significant and negative standard heterosis for this trait was also reported by Prajapati (2000) and Patel *et al.* (2013).

With respect to plant height, 21 and five crosses showed significant and positive heterobeltiosis and standard heterosis, respectively. In general, most of the hybrids were shorter than standard parent which was indicative partial dominance. The heterosis in the positive direction for plant height was reported by Nwosu and Awa (2013) and Sharma *et al.* (2010).

With respect to branches per plant, 12 crosses showed significant and positive heterobeltiosis and only one cross expressed significant and positive standard heterosis. The heterosis in the positive direction for branches per plant was also reported by Sharma *et al.* (2010) and Kajale and Ravindrababu (2012).

With respect to number of pod per plant, four and fifteen crosses exhibited standard heterosis and heterobeltiosis in the desired direction, respectively. This is in confirmation with the results of Kajale and Ravindrababu (2012) and Patel *et al.* (2013).

The highest estimates of heterobeltiosis of 53.17 per cent and standard heterosis of 11.33 per cent for number of pods per plant were recorded by the cross Pusa Phalguni x GC 2 which was followed by the cross GC 4 x Pant Lobia 2, IT 38956 1 x KM 5 and IT 38956 1 x GC 4 with a heterobeltiosis of 46.44, 14.16 and 11.83 per cent and standard heterosis of 11.13, 14.01 and 11.68 per cent, respectively. These four crosses hold promise for further evaluation and selection in subsequent generations for increase the number of pods per plant. This is in confirmation with the results of Chaudhari *et al*. (2013) and Patel *et al*. (2013).

With respect to number of clusters per plant, only 8 cross combinations expressed significant positive heterobeltiosis. This result is in accordance with Mehta (2000) and Patel (2000).

With regard to number of pods per cluster, four crosses exhibited significant standard heterosis in the desired direction, while ten crosses showed significant heterobeltiosis for the same. This result is in accordance with Yadav *et al.* (2010) reported positive heterosis for number of pods per cluster.

For pod length, only one cross showed significant heterobeltiosis in the positive direction and thirty six cross revealed significant heterobeltiosis in negative direction. The heterosis in the positive direction for pod length was also reported by Patil, *et al.* (2005) and Kajale and Ravindrababu (2012). The heterosis in the negative direction for pod length was also reported by Sawale *et al.* (2003) in mungbean.

With respect to number of seeds per pod, 19 cross combinations expressed significant positive heterobeltiosis. This is in confirmation with the results of Kajale and Ravindrababu (2012) and Patel *et al.* (2013). None of the cross showed significant positive standard heterosis for this trait.

For 100 seed weight, only 6 cross combination expressed significant positive heterobeltiosis. This finding is in confirmation with the findings Patel *et al.* (2013). However, the heterosis in negative direction was also reported by of Sawant *et al.* (1994) for this trait.

With respect to protein content, seven crosses exhibited heterobeltiosis in the desired direction. Savithramma *et al.* (2001) and Patel *et al.* (2009) recorded positive heterosis for protein content.

With respect to harvest index, three and six crosses exhibited standard heterosis and heterobeltiosis in the desired direction, respectively. The negative and significant heterobeltiosis and standard heterosis was exhibited by 10 and 33 crosses, respectively. The cross RC 101 x Pant Lobia 1 exhibited the maximum value and of significant positive heterobeltiosis (26.62 %) and standard heterosis (21.18 %) followed by GC 2 x GC 5 exhibited the significant positive heterobeltiosis (15.43%) and standard heterosis (6.91 %). These two crosses hold promise for further evaluation and selection in subsequent generations. Similar findings were also reported by Patel *et al.* (2013) for harvest index.

In general, it might be inferred that magnitude of standard heterosis effects were high in desired direction for days to maturity and moderate for days to 50 % flowering, seed yield per plant and plant height, and low for number of pods per plant, number of pods per cluster, harvest index and branches per plant, while the magnitude of heterobeltiotic effects were high in desired direction for plant height, seed yield per plant, number of seeds per pod and number of pods per plant; moderate for branches per plant, number of pods per cluster, days to maturity, number of clusters per plant, protein content, 100 seed weight, harvest index and days to 50% flowering; and low for pod length only.

The presence of appreciable amount of heterotic effects in most of the crosses for different traits studied in this investigation may be attributed to non-allelic interaction, which can either increase or decrease the expression of heterosis. A few modifier genes with negative effects might also be involved.

In general, it might be inferred that magnitude of inbreeding depression was high for 100-seed weight and pod length; moderate for number of clusters per plant, number of seeds per pod, branches per plant, seed yield per plant, days to 50 per cent flowering and number of pods per plant; and low for protein content, number of pods per cluster, harvest index, plant height and days to maturity.

The significant, positive and high inbreeding depression for seed yield per plant (g) was recorded in only one cross, GC 1 x GC 4 (Table 4). This cross also exhibited highly significant and positive inbreeding depression for number of pods per cluster, harvest index, number of seeds per pod, pod length, 100-seed weight and protein content.

This indicated that the pathways for releasing inbreeding depression varied from one cross to the other. Therefore, the present findings revealed that in cowpea number of pods per cluster, harvest index, number of seeds per pod, pod length, 100-seed weight and protein content were the main contributing traits for high inbreeding depression as far as seed yield per plant is concerned. These findings of inbreeding depression are in agreement for various characters with the findings of Yadav *et al*. (2010) and Patel *et al.* (2013).

Crosses showing high heterobeltiosis and inbreeding depression for seed yield per plant are RC 101 x Pant Lobia

1, RC 101 x Pant Lobia 2, Pusa Phalguni x GC 2, Pusa Phalguni x Pant Lobia 1, Pusa Phalguni x Pant Lobia 2, GC 1 x GC 2, GC 1 x GC 4, GC 2 x Pant Lobia 1 and GC 4 x Pant Lobia 1. The result suggested that predominance of non-additive gene action in these crosses and hence, these crosses have a potential to throw desirable segregants in the subsequent generations following pedigree method of breeding for genetic improvement of seed yield in cowpea.

CONCLUSION

The results revealed that both additive and non-additive gene effects are main genetical components which control pod yield and its contributing traits. Therefore, the breeding methods will have to be modified in respect to capitalize the genetic variance due to fixable and non-fixable gene interactions. The efforts can be made to develop multiple crosses among desirable F_1s, following some sort of inter mating, which will considerably increase the frequency of potential and desirable trangressive segregants in the segregating generations. These segregating generations are to be subjected to intensive objective oriented selection for crop improvement.

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Table 1: Analysis of variance for the experimental design for different characters in cowpea

Source	d. f.	Mean Squares						
		Days to 50% Flowering	Days to Maturity	Plant Height (cm)	Branches per Plant	Number of Pods per Plant	No. of Clusters per Plant	No. of Pods per Cluster
Replications	2	16.04*	0.05	0.59	0.57*	1.42	0.52	0.10
Genotypes	99	54.35**	30.44**	158.55**	1.84**	32.28**	3.79**	0.69**
Parents	9	68.67**	13.21**	75.56**	1.32**	14.88**	2.50**	0.19*
F_1	44	52.17**	34.64**	177.22**	1.83**	34.76**	4.11**	0.79**
F_2	44	36.45**	23.49**	118.96**	1.10**	33.07**	2.48**	0.52**
Parents *vs.* crosses	1	21.55**	0.74	84.20**	6.73**	79.86**	1.31*	1.03**
F_1 *vs.* F_2	1	449.94**	93.15**	52.26**	3.84**	28.71**	8.67**	0.02
Error	198	2.54	2.94	1.35	0.09	1.30	0.33	0.09

Table 1. Contd…..

Source	d. f.	Mean Squares					
		Pod Length (cm)	No. of Seeds per Pod	100 Seed Weight (g)	Seed Yield per Plant (g)	Protein Content (%)	Harvest Index (%)
Replications	2	10.21*	4.05*	1.07	2.19	0.03	1.35
Genotypes	99	14.62**	8.84**	16.60**	28.67**	2.73**	24.47**
Parents	9	17.51**	5.46**	6.17**	14.61**	2.02**	9.39
F_1	44	11.95**	8.92**	18.74**	29.76**	2.91**	22.61**
F_2	44	6.48**	7.04**	7.45**	31.90**	4.64**	27.14**
Parents *vs.* crosses	1	106.09**	35.62**	16.23**	107.23**	1.13	155.05**
F_1 *vs.* F_2	1	19.13	25.97**	1.64**	9.47**	10.48*	16.67**
Error	198	0.50	0.41	0.81	1.20	0.39	9.14

****, ** Significant at 5 % and 1 % levels, respectively***

Table 2: Magnitude of heterobeltiosis and standard heterosis in cowpea

Sr. No.	Character	Range of Heterosis (%)				Number of Crosses with Significant Heterosis			
		Heterobeltiosis		Standard Heterosis		Heterobeltiosis		Standard Heterosis	
		From	To	From	To	+ve	-ve	+ve	-ve
1	Days to 50 % Flowering	-18.30	46.34	-27.54	36.36	14	5	9	26
2	Days to Maturity	-7.04	19.51	-12.00	8.89	16	9	2	26
3	Plant Height (cm)	-14.25	77.78	-64.79	29.41	21	5	5	39
4	Branches per Plant	-23.81	36.00	-32.65	8.16	12	11	1	26
5	Number of Pods/ Plant	-24.22	53.17	-36.37	14.01	15	13	4	26
6	Number of Clusters/Plant	-34.39	43.17	-42.15	8.68	8	17	0	35
7	No. of pods per Cluster	-38.90	51.24	-16.40	39.85	10	10	4	17
8	Pod length (cm)	-14.46	-0.15	-23.65	8.65	1	36	0	41
9	N0. of Seeds per Pod	-38.21	38.96	-39.95	5.21	19	9	0	26
10	100 Seed Weight (g)	-53.02	25.04	-57.40	3.93	6	21	0	28
11	Seed Yield per Plant (g)	-17.41	26.17	-19.58	8.50	21	11	7	23
12	Protein Content (%)	-15.73	9.46	-21.60	5.68	7	14	0	32
13	Harvest Index (%)	-11.31	26.62	-17.86	21.18	6	10	3	33

Table 3: Comparative study of three heterobeltiotic crosses for seed yield per plant (g) with their heterobeltiotic effects for yield components

Crosses	Percent Heterosis over Better Parent (Hetrobeltiosis)							
	Seed Yield per Plant (g)	Days to 50% Flowering	Days to Maturity	Plant Height (cm)	Branches per Plant	No. of Pods per plant	No. of Clusters per Plant	No. of Pods per Cluster
GC 2 x GC 5	26.17**	1.55	-6.10**	11.20**	-3.33	44.31**	-2.99	48.82**
GC4xPantLobia 2	22.01**	-5.93*	-2.80**	1.34	21.33**	46.44**	43.17**	-10.21
RC 101 x GC 1	17.94**	-2.27	4.90*	-14.13**	6.67	13.91**	10.66	-10.33

Table 3: Contd

Crosses	Number of seeds per pod	Pod length	100 seed weight (g)	Protein content (%)	Harvest index (%)
GC 2 x GC 5	34.14**	-14.91**	-2.32	0.86	15.43**
GC 4 x Pant Lobia 2	38.96**	-16.49**	-11.33*	4.45	-2.02
RC 101 x GC 1	21.78**	2.96	21.78**	-1.50	-7.75

****, ** Significant at 5 % and 1 % levels, respectively***

Table 4: Comparative study of the cross, GC 1 x GC 4 involving high inbreeding depression for seed yield per plant with their inbreeding depression for yield components

Sr. No.	Character	Magnitude of inbreeding depression
1	Days to 50 % Flowering	3.82
2	Days to Maturity	5.50*
3	Plant Height (cm)	-1.08
4	Branches per Plant	-6.21**
5	Number of Pods per Plant	1.74
6	Number of Clusters per Plant	-31.20**
7	Number of pods per Cluster	24.92**
8	Pod length (cm)	7.75**
9	Number of Seeds per Pod	9.39**
10	100 Seed Weight (g)	3.98**
11	Seed Yield per Plant (g)	20.36**
12	Protein Content (%)	1.87**
13	Harvest Index (%)	14.87**

, ** Significant at 5 % and 1 % levels, respectively

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