Heterosis Studies in Groundnut (*Arachis hypogaea* L.) for Pod Yield and its Components Traits

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Twenty seven crosses generated in a line x tester fashion using 9 and 3 genotypes as a female and male parents were evaluated to study the extent of heterosis for dry pod yield and yield attributing characters in groundnut. Most of crosses showed significant heterosis over better parent (BP) and standard heterosis (SH) with undesirable direction may be attributed to non-allelic interaction with the large number of decreasing alleles for all the characters under studied. The cross combinations, AG-2245 x ICGV-95070 and AG-1 x ICGV-97079 exhibited significant and positive heterobeltiosis (35.74 %) and standard heterosis (24.81 %) with mean performance of 17.64 gm. and 19.87 gm. for dry pod yield per plant. This two crosses also showed its heterotic effect for kernel yield per plant and number of mature pods per plant, respectively. Superior segregants with this crosses may be selected for further improvement in the pod yield and its contributing traits.

Keywords: Dry pod yield, groundnut, heterosis.

India is one of the largest producers of oilseeds in the world and occupies an important position in the Indian agricultural economy. It is estimated that nine oilseeds namely groundnut, rapeseed-mustard, soybean, sunflower, safflower, sesame, Niger, castor and linseed, accounted for an area of 23.44 million hectares with the production of 25.14 million tones Groundnut called as the 'King' of oilseeds is a premier first ranking oilseed crop and enjoying pre-dominant position in India, contributing about 27% of the total area and 33% of the total production of the oilseed crops. Cultivated groundnut is commonly known as monkey nut, peanut and popularly called as mungphooli. While being a valuable source of all the nutrients, it is a low-priced commodity. It is a rich source of edible oil (around 40-55%) which have high amount of vitamin A, B and E, high quality protein (around 22%), fat (around 18%) and carbohydrates (around 11%); Thus groundnut is also known as the "King" of oilseeds or "Wonder nut" or "Poor man's cashew nut". Groundnut is valued both for edible oil and confectionary purpose. About 12% of total groundnut production in country is used for seed purpose, 6% for domestic use, 81% for oil and only 1% for export. Thus, groundnut proves to be an important crop of Indian agriculture. 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 and oil production. The basic requirement in any crop improvement programme is to increase yield potential of the crop. The character pod yield has

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complex nature and so in order to study it properly, different factors affecting the yield must be considered and evaluated with regards to their contribution to yield. In groundnut, 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 provide information about the nature of gene action involved in the expression of yield and its contributing traits. The information is also essential to formulate efficient breeding programmes for the improvement of the crop. Therefore, the present investigation was carried out to estimate the magnitude of the heterosis in 27 crosses of groundnut in F_1 generation, respectively.

MATERIALS AND METHODS

The experimental material for the present study comprised nine female lines *viz.,* GG 6, AG-1, AG-2240, AG-2245, AG-2006-6, AG-2006-14, AG-2006-15, TAG-24 and TG-26 and three male as a testers *viz.,* ICGV-95070, ICGV-97079 and Dh-86. Three standard checks *viz.,* GG-7, GJG-9 and TG-37 A were used for comparison in present study. These genotypes were crossed in Line x Tester mating fashion to develop 27 F_1S **(Figure 1)** at Regional Research Station, Anand Agricultural University, Anand, which were evaluated along with 12 parents and 3 checks in randomized block design with three replications during *kharif* 2011 season at the same location. Each entry consisted of single row of 5 m length for each of parents and F_1S, Inter- and intra-row spacing adopted was 30 and 10 cm, respectively. All the recommended agronomical package of practices and plant protection measures for the region were followed to raise crop successfully. The observations were recorded on five randomly selected competitive plants in parents, F_1S and checks for 11 characters. Heterosis over mid parent value (MP) as per Turner, 1953, Heterosis over better parent (BP) as per Fonseca and Patterson, 1968 and Standard heterosis (SH) using standard check as per Meredith and Bridge, 1972 were calculated.

RESULTS AND DISCUSSION

The estimates of mean sum of squares (Table 1) due to genotypes, parents and hybrids were highly significant for all the characters studied indicating the presence of significant variation among the genotypes as well as crosses studied. The mean squares for parents vs. F_1S were also found significant for yield and its components traits *viz.,* Days to 50% flowering, Dry pod yield per plant, Kernel yield per plant, 100 pod weight, 100 kernel weight and Sound mature kernels which indicated the presence of substantial amount of heterosis in cross combinations. The mean squares due to checks vs. hybrids were also significant for all the traits except days to maturity, Sound mature kernels, Shelling out turn, Harvest index and oil content which indicated the presence of considerable amount of standard heterosis in hybrids. The three checks differed significantly for all the characters except days to maturity, Dry pod yield per plant, Kernel yield per plant, Sound mature kernels and harvest index. This revealed the existence of considerable genetic variability among the checks. The considerable genetic variation for various traits including pod yield have also been reported by many workers (Golakia *et al.* 2005; John *et al.* 2006; Kadam *et al.* 2007; Khote *et al.* 2009; Korat *et al.* 2009).

The mean performance and various heterotic effects as well as promising crosses identified for the characters studied are presented in Table 2. The range of mean performance was wide for all the characters under studied except for days to 50% flowering, days to maturity, harvest index and oil content. Flowering is a complex trait and sensitive to photoperiod and temperature. However, under long day conditions, as those prevail in summer season, only negligible variation has been observed for flower initiation among various genotypes. All the crosses exhibited wider range as compared to their parents for majority of the traits. However, the various heterotic effects were high for dry pod yield per plant, kernel yield per plant, number of mature pods per plant, 100 pod weight, 100 kernel weight, harvest index, shelling out turn and days to 50% flowering.

Few of the crosses exhibited significant and desirable heterosis over mid parent (MP) for number of mature pods per plant (08) and sound mature

Table 1. Analysis of variance (mean sum of squares) for the experimental design for 11 characters in groundnut

Source of variation	d.f.	Days to 50% flowering	Days to maturity	Number of mature pods per plant	Dry pod yield per plant (gm)	Kernel yield per plant (gm)	100 pod weight (gm)	100 kernel weight (gm)	Sound mature kernels (%)	Shelling out turn (%)	Harvest index (%)	Oil content (%)
Replication	2	6.06	8.88	5.01	1.93	0.13	5.88	8.09	1.56	30.97*	0.74	7.16**
Genotypes	41	49.53**	17.14**	53.62**	31.48**	13.13**	853.88**	106.88**	7.89**	89.31**	19.28**	14.79**
Parents (P)	11	18.67**	21.97**	40.58**	21.41**	6.53**	1353.35**	181.91**	12.79**	52.26**	14.68**	11.85**
Females (F)	8	2.81	17.70*	43.73**	25.80**	7.43**	548.40**	164.02**	13.59**	70.74**	9.28**	11.75**
Males (M)	2	61.78**	49.78**	39.51**	14.19**	6.18**	4657.86**	262.74**	1.44**	4.21	40.66**	12.02**
F vs. M	1	59.26**	0.45	17.52**	0.71	0.06	1183.91**	163.38**	29.05**	0.49	5.87	12.23**
Hybrids (H)	26	52.98**	15.79**	64.71**	38.99**	17.41**	612.88**	75.47**	5.98*	108.77**	23.49**	17.16**
P vs. H	1	218.80**	23.63	4.96	16.52**	6.93**	2005.66**	143.20**	16.50*	22.86	0.58	16.72
Checks vs. Hybrids	1	236.84**	1.60	12.52**	21.59**	7.07**	1461.25**	184.82**	5.88	0.38	5.31	1.28
Between checks	2	30.11**	11.11	27.21**	4.53	0.92	614.95**	69.68**	0.33	117.96**	6.40	4.95*
Error	82	2.71	7.25	2.67	1.60	0.85	44.26	6.29	3.15	8.23	3.29	1.35

* , ** Significant at 0.05 % and 0.01 % level of probability, respectively.

Table 2. Range of *per se* performance, mid parent heterosis (MP), heterobeltiosis (BP) and standard heterosis (SH) along with most heterotic crosses for 11 characters in groundnut

Characters	Range					Better parents based on *per se* performance	Number of hybrids with significant heterosis						Best hybrid based on mean performance		
	Per se performance		Heterosis				Over MP		Over BP		Over SH		Heterosis effect over		
	Parents	Crosses	MP (%)	BP (%)	SH (%)		+ve	-ve	+ve	-ve	+ve	-ve	MP	BP	SH
Days to 50% flowering	26.00 to 35.33	25.33 to 39.67	-18.09 to 48.10	-6.10 to 50.00	13.43 to 77.61	AG-2006-14, TAG-24 (26.00)	11	04	15	00	27	00	AG-2245 x Dh-86 (25.67)	-	-
Days to maturity	117.00 to 125.33	116.67 to 126.00	-2.57 to 5.90	-1.10 to 7.10	-3.58 to 4.13	TAG-24 (117.00)	04	00	06	00	03	01	-	-	TAG-24 x Dh-86 (116.67)
Number of mature pods per plant	11.40 to 25.47	9.07 to 27.40	-44.49 to 106.38	-47.08 to 89.27	-51.95 to 45.20	TG-26 (25.47)	08	08	04	11	04	12	AG-1 x ICGV-97079 (25.87)	AG-1 x ICGV-97079 (25.87	AG-2240 x ICGV-95070 (27.40)
Dry pod yield per plant (gm)	9.49 to 18.20	5.16 to 19.87	-57.44 to 58.73	-60.29 to 35.74	-67.59 to 24.81	TG-26 (18.20)	06	13	04	14	01	20	AG-1 x ICGV-97079 (19.87)	AG-2245 x ICGV-95070 (17.64)	AG-1 x ICGV-97079 (19.87)
Kernel yield per plant (gm)	6.20 to 10.49	2.94 to 12.77	-61.48 to 62.13	-63.30 to 44.03	-67.00 to 43.37	AG-2006-15 (10.49)	06	11	03	14	03	10	AG-1 x ICGV-97079 (12.77)	AG-2245 x ICGV-95070 (11.54)	AG-1 x ICGV-97079 (12.77)
100 pod weight (gm)	61.13 to 137.74	55.74 to 108.33	-46.15 to 26.36	-58.94 to 23.55	-46.42 to 4.51	ICGV-97079 (137.74)	05	14	01	18	00	23	AG-2006-14 x ICGV-95070 (107.87)	AG-2006-14 x ICGV-95070(107.87)	-

Table 3. Comparative study of three best heterobeltiotic crosses for dry pod yield with other yield components in groundnut

Name of cross	Percent heterosis over better parent (heterobeltiosis)										
	Dry pod yield per plant (gm)	Days to 50% flowering	Days to maturity	Number of mature pods per plant	Kernel yield per plant (gm)	100 pod weight (gm)	100 kernel weight (gm)	Sound mature kernels (%)	Shelling out turn (%)	Harvest index (%)	Oil content (%)
AG-2245	35.74**	-5.00	2.56	30.12**	44.03**	-2.92	-11.47*	-1.79	5.70	-8.26*	0.63
xICGV-95070	(17.64)	(25.33)	(120.33)	(21.60)	(11.54)	(80.98)	(33.20)	(91.67)	(65.24)	(35.00)	(53.03)
AG-2006-6	35.38**	37.50**	4.55*	6.44	9.82	8.86	-10.06**	-4.64**	-19.79**	1.47	-2.20
xICGV-95070	(17.81)	(36.67)	(122.67)	(16.53)	(8.80)	(108.33)	(44.79)	(89.00)	(49.50)	(36.55)	(51.54)
AG-2240	28.89**	17.50**	3.12	76.39**	34.08*	-20.19**	-16.27**	0.71	-0.86	-3.77	-5.91**
xICGV-95070	(16.75)	(31.33)	(121.00)	(27.40)	(10.74)	(66.58)	(32.46)	(94.00)	(64.12)	(34.66)	(49.58)

* , ** Significant at 0.05 % and 0.01 % level of probability, respectively.
( ) Shows the value of *per se* performance.

Table 4. Comparative study of three best standard heterotic crosses for dry pod yield with other yield components in groundnut

Name of cross	Percent heterosis over standard check (standard heterosis)										
	Dry pod yield per plant (gm)	Days to 50% flowering	Days to maturity	Number of mature pods per plant	Kernel yield per plant (gm)	100 pod weight (gm)	100 kernel weight (gm)	Sound mature kernels (%)	Shelling out turn (%)	Harvest index (%)	Oil content (%)
AG-1	24.81**	40.30**	-0.55	37.08**	43.37**	-25.21**	-23.22**	-2.15	-4.17	5.02	-1.53
xICGV-97079	(19.87)	(31.33)	(120.33)	(25.87)	(12.77)	(77.53)	(35.87)	(91.00)	(64.32)	(38.74)	(49.98)
AG-2006-6	11.85	64.18**	1.38	-12.38	-1.27	4.51	-4.13	-4.30**	-26.24**	-0.93	1.55
xICGV-95070	(17.81)	(36.67)	(122.67)	(16.53)	(8.80)	(108.33)	(44.79)	(89.00)	(49.50)	(36.55)	(51.54)
AG-2245	10.78	13.43*	-0.55	14.47*	29.47**	-21.88**	-28.94**	-1.43	-2.80	-5.13	4.48*
xICGV-95070	(17.64)	(25.33)	(120.33)	(21.60)	(11.54)	(80.98)	(33.20)	(91.67)	(65.24)	(35.00)	(53.03)

* , ** Significant at 0.05 % and 0.01 % level of probability, respectively.
(   ) Shows the value of *per se* performance.

		Testers			Selfing of Lines
		1	2	3	
Lines	1	1 x 1	1 x 2	1 x 3	1
	2	2 x 1	2 x 2	2 x 3	2
	3	3 x 1	3 x 2	3 x 3	3
	4	4 x 1	4 x 2	4 x 3	4
	5	5 x 1	5 x 2	5 x 3	5
	6	6 x 1	6 x 2	6 x 3	6
	7	7 x 1	7 x 2	7 x 3	7
	8	8 x 1	8 x 2	8 x 3	8
	9	9 x 1	9 x 2	9 x 3	9
Selfing of Testers		1	2	3	

Fig. 1. L x T crosses: 27 hybrids will be produced including 12 Patents

kernels (05), whereas in most of crosses, significant heterosis over better parent (BP) and standard heterosis (SH) was observed with undesirable direction for all the characters under studied. The negative heterosis observed in most of the crosses may be attributed to non-allelic interaction with the large number of decreasing alleles.

A perusal of the crosses revealed that none of the crosses under studied were superior for yield and its attributing characters and also for heterosis effects over mid parent value, better parent and standard check. However, the crosses, AG-1 x ICGV-97079 **(25.87)** for number of mature pods per plant; AG-2006-14 x ICGV-95070 **(107.87)** for 100 pod weight; AG-2245 x ICGV-97079 **(66.37)** for shelling out turn, AG-2006-6 x ICGV-97079 **(38.51)** for harvest index and AG-2240 x ICGV-97079 **(51.54)** for oil content showed significant and desired mid patent heterosis and heterobeltiosis along with maximum *per se* performance (Table 2). For dry pod yield per plant, the cross AG-1 x ICGV-97079 **(19.87)** and for kernel yield per plant, the cross AG-1 x ICGV-97079 **(12.77)** manifested significant and positive mid patent heterosis and standard heterosis with high mean *per se* performance.

None of the crosses showed significant heterosis in desirable direction *viz.*, mid parent heterosis for days to maturity and 100-kernel weight; heterobeltiosis for days to 50% flowering, days to maturity, 100-kernel weight and sound mature kernels; and standard heterosis for days to 50% flowering, 100 pod weight, 100 kernel weight, sound mature kernels, Shelling out turn and harvest index. The crosses, TAG-24 x Dh-86, AG-2240 x ICGV-95070 and AG-2245 x ICGV-95070 showed significant and positive standard heterosis for days to maturity, number of mature pods per plant and oil content, respectively. Significant heterosis in desirable direction for pod yield and its contributing traits has been reported by Makhne *et al.* 1994; Mathur *et al.* 2003; Yadav *et al.* 2006; Venkateswarlu *et al.* 2007; Busa *et al.* 2008; Chen *et al.* 2009; Sharma and Gupta 2010 and John *et al.* 2012.

If breeding programme will be made through attributing agro economical characters than improvement may be fitted and/or suitable for a complex trait like pod yield in groundnut. The comparison of three best crosses with high heterobeltiosis and standard heterosis for dry pod yield with other yield attributing traits (Table 3 and 4) revealed that manifestation of significant and positive heterobeltiosis by cross AG-2245 x ICGV-95070 and AG-2240 x ICGV-95070, whereas cross AG-1 x ICGV-97079 and again AG-2245 x ICGV-95070 with significant and positive standard heterosis for dry pod yield also showed its heterotic effect for kernel yield per plant and number of mature pods per plant, respectively.

The results revealed that both additive as well as 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. This segregating generations are to be subjected to intensive objective oriented selection for crop improvement.

CONCLUSION

The analysis of variance revealed significant differences among the hybrids for all the characters under study. Among all the crosses, AG-1 x ICGC-97079 cross exhibited maximum dry pod yield per plant and other yield contributing characters. Significant and positive standard heterosis with high mean *per se* performance was manifested by cross AG-1 x ICGV-97079 (1**9.87)** for dry pod yield per plant. This cross also showed its heterotic effect for kernel yield per plant and number of mature pods per plant, respectively.

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