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Combining ability and gene action for pod yield and its agronomic traits in groundnut (*Arachis hypogaea* L.)

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ABSTRACT

Combining ability was studied with 12 parents in line x tester analysis for 12 quantitative characters in order to identify suitable parents/crosses, which could be utilized in *Arachis hypogaea* L. for further improvement programme. The analysis of variance revealed that both GCA and SCA variances were significant for all the characters indicated the importance of both additive and non-additive genetic components in controlling the expression of these traits. Average degree of dominance reflected the predominance of over dominance in these characters expression. Combining ability analysis suggested the preponderance of non-additive as well as additive type of gene action for all these traits. Among the parents, AG-1was the most good general combiners for pod yield and oil content. The cross combinations, AG-1 x ICGV-97079 and AG-2006-6 x ICGV-95070 were identified as potential ones based on their SCA and heterotic effects, which had involved either G x G orG x A general combiners and confirms the validity of average degree of dominance values.

Key words: Additive, combining ability, heterosis, non-additive, pod yield

Groundnut is first ranking oilseed crop of India and it is native of South America. It is a legume that ranks 6[th] among the oilseed crops and 13[th]among the food crops of the world (Groundnut, ICRISAT) and is the world's most important source of edible oil. Among oil seed crops grown in India, groundnut occupies pre-dominant position(Zalate and Padmani, 2009) in area and production. It has now not remained only as an important edible oilseed, but also gained prominence as an important cash crop and foreign exchange earner for India in general and for Gujarat in particular. Therefore, the groundnut is rightly called as "King of oilseeds" in India (Maurya *et al.* 2014). Shalled groundnuts are basically used as seed, consumed as raw edible groundnuts or after transformation into "prepared" groundnuts (roasted, salted, flavored, etc.) or into groundnut butter/paste. It has oil content around 45-50% (Maurya *et al.,* 2014) and extensively used for important source of vegetable oil. At present for the success of groundnut breeding programme, the basic need is selecting proper parents for hybridization. The study of heterosis shows the percentage as increase or decrease of the F_1 over the economic parents or better parents but it fails to identify the possible causes for the superiority of hybrid. The knowledge of combining ability provides a useful clue for selection of desirable parents for the development of better hybrids/genotypes, which are superior in yield, quality and resistance to diseases and pests over the presently cultivated. Thus, information regarding heterosis and combining ability are the basic requirements for a thorough understanding of genetic architecture of pod yield and its components. Keeping these views in mind, the present study was undertaken to obtain the information pertaining to the extent of heterosis and combining ability for 12 characters utilizing a line x tester mating design.

MATERIALS AND METHODS

The experimental material consists of 9 lines *viz.,*GG-6, AG-1, AG-2240, AG-2245, AG-2006-6, AG-2006-14, AG-2006-15, TAG-24, TG-26 and 3 testers *viz.,*ICGV-95070, ICGV-97079 and Dh-86 of *Arachis hypogaea* L. These parents were crossed in line x

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tester fashion during *kharif and* summer 2010-2011. The resulting 27 hybrids along with their parents and three standard check varieties namely GG-7, GJG-9 and TG-37 A were sown during *kharif* 2011in randomized block design with 3 replications at Regional Research Station, Anand Agricultural University, Anand. The parents and their F_1's were sown in single row of 5.0 m keeping a distance of 30 cm between rows and 10 cm between plants. All recommended agronomic practices were adopted. The observations were recorded on 5 randomly selected plants from each lines for 12 characters *viz.*,plant height at maturity (cm), number of mature pods per plant, dry pod yield per plant (g), kernel yield per plant (g), 100 pod weight (g), 100 kernel weight (g), sound mature kernels (%), shelling percentage (%), harvest index (%) and oil content (%)while days to 50 per cent flowering and days to maturity was recorded on plot basis. The mean data were subjected to line x tester analysis and combining ability effects and variances were estimated while, the magnitude of heterosis over better parent, GCA and SCA effects was estimated as:

a) Heterosis over better parent:

$$\text{Heterobeltiosis (\%)} = \frac{\overline{F_1} - \overline{BP}}{\overline{BP}} \times 100$$

b) GCA Effects: $\hat{g}_i = \frac{Y_{i}..}{rl} - \frac{Y...}{rlt}$ for lines

$$\hat{g}_j = \frac{Y._{j}.}{rt} - \frac{Y...}{rlt} \text{ for testers}$$

c) SCA Effects : $\hat{s}_{ij} = \frac{Y_{ij}.}{r} - \frac{Y_{i}..}{rl} - \frac{Y._{j}.}{rt} + \frac{Y...}{rlt}$

Where,

$\hat{g}_i$ = Estimate of general combining ability effect of i^{th} lines parent (i = 1, 2 ...,l number of lines)

$\hat{g}_j$ = Estimate of general combining ability effect of j^{th} testers parent (j = 1, 2 ...,t number of testers)

$\hat{s}_{ij}$ = Estimate of specific combining ability effect of ij^{th} cross combination

Y... = Total of all hybrids in all replications

$Y_i..$ = Total of i^{th} lines over all testers and replications

$Y._j.$ = Total of j^{th} testers over all lines and replications

$Y_{ij.}$ = Total of ij^{th} cross combination over all replications

RESULTS AND DISCUSSION

The analysis of variance for combining ability revealed that the variance due to lines revealed significant differences among all the characters while variance due to testers showed significant differences for all the characters except days to 50% flowering, days to maturity and sound mature kernels. The variance due to interaction effect of lines and testers were significant for all the characters reflected the importance of non-additive gene action in the inheritance of these traits. The estimates of variance due to both general combining ability and specific combining ability variance were found to be significant for all characters indicated the involvement of additive and non-additive gene effects for genetic control of these characters (Ahuja and Dhayal, 2007). However, the ratio (GCA/SCA) indicated preponderance of additive gene action for plant height at maturity, 100 pod weight, 100 kernel weight, shelling percentage and oil content whereas, non-additive gene action for days to 50% flowering, days to maturity, number of mature pods per plant, pod yield per plant, kernel yield per plant, sound mature kernels and harvest index, respectively.

Estimates of general and specific combining ability

The estimates of GCA effects (Table 1) were ranged from 5.04 to - 4.07 per cent for days to 50 per cent flowering; 2.00 to -3.00per cent for days to maturity;14.92 to -16.80cm for plant height at maturity;- 6.59 to 5.09 for number of mature pods per plant; - 6.63 to 1.26 g for pod yield per plant;- 4.46 to 1.22 g for kernel yield per plant ;-16.10 to 22.19 g for 100 pod weight;- 4.87 to 7.34 g for 100 kernel weight;- 1.37 to 1.52 % for sound mature kernels;-10.97 to 5.13 % for shelling percentage;-1.61 to 1.74% for harvest index and -4.42 to 2.89 % for oil content. For pod yield per plant, 10 parents had positive GCA effects. Among these, 06 parents (Five line i.e. AG-1, AG-2245, AG-2006-6, AG-2006-15 and TG-26 and only tester i.e. ICGV-95070) had significant GCA effects in desirable direction indicated good general combiners. Six parents were found good general combiners for kernel yield per plant. The parents ICGC-95070, and AG - 2006-15 were found best combiner for pod and kernel yield per plant, whereas genotypes TAG-24 was best general combiners for oil content. However, for the characters*viz.,* days to 50% flowering (06), days to maturity (01), plant height at maturity (05), number of mature pods per plant (05), kernel yield per plant (06), 100 pod weight (03), 100 kernel weight (04),

Table 1 General combining ability effects

Particulars	Days to 50 % flowering	Days to maturity	Plant height at maturity	Number of mature pods per plant	Pod yield per plant	Kernel yield per plant	100 pod weight	100 kernel weight	Sound mature kernels	Shelling %	Harvest index	Oil content
Lines												
GG-6	4.04**	2.00**	-16.80**	-6.59**	-6.63**	-4.46**	-16.10**	-4.87**	-0.59	-7.19**	-1.61**	-4.42**
AG-1	-0.85*	-1.22	7.98**	2.42**	1.19**	1.20**	-3.82*	-3.78**	0.63	4.16**	1.74**	0.72*
AG-2240	1.26**	1.11	8.55**	3.00**	0.58	0.79**	-9.07**	-0.18	1.52**	3.89**	-0.16	1.37**
AG-2245	-4.07**	-1.11	13.96**	0.18	0.67*	1.04**	0.93	-4.28**	0.30	5.13**	1.06*	1.02**
AG-2006-6	5.04**	1.67*	-8.88**	-2.67**	1.21**	-0.84**	20.85**	7.34**	-0.81	-10.97**	1.05*	1.45**
AG-2006-14	2.15**	0.33	0.34	-2.67**	0.47	0.52*	22.19**	5.68**	0.85*	2.17**	-1.55**	-1.19**
AG-2006-15	-2.19**	0.89	14.92**	0.87*	1.09**	1.22**	-0.84	-0.50	-1.37**	4.49**	0.42	0.18
TAG-24	-2.74**	-3.00**	-3.56**	0.36	0.31	0.32	-0.21	2.61**	-1.04*	1.34	-0.08	2.89**
TG-26	-2.63**	-0.67	-16.54**	5.09**	1.11**	0.21	-13.94**	-2.03**	0.52	-3.03**	-0.88	-2.00**
S.E. (Lines)	0.39	0.71	0.98	0.43	0.33	0.23	1.69	0.61	0.42	0.79	0.52	0.31
Testers												
ICGV-95070	0.33	-0.48	2.71**	0.82**	1.26**	0.87**	5.07**	-0.70*	-0.22	1.31**	-0.36	0.60**
ICGV-97079	0.07	0.78*	1.46**	0.34	0.14	0.14	-1.29	1.24**	-0.04	0.23	-0.63*	-0.03
Dh-86	-0.41*	-0.30	-4.16**	-1.15**	-1.40**	-1.00**	-3.78**	-0.55	0.26	-1.54**	-0.99**	-0.54**
S. E. (Testers)	0.20	0.35	0.49	0.21	0.16	0.11	0.85	0.30	0.21	0.39	0.26	0.15
Range: Min.	-4.07	-3.00	-16.80	-6.59	-6.63	-4.46	-16.10	-4.87	-1.37	-10.97	-1.61	-4.42
Max.	5.04	2.00	14.92	5.09	1.26	1.22	22.19	7.34	1.52	5.13	1.74	2.89
Positive	06	06	07	08	10	09	04	04	06	08	04	07
Positive Significant	04	06	06	05	06	06	03	04	02	06	03	06
Negative	06	06	05	04	02	03	08	08	06	04	08	05
Negative Significant	06	01	05	04	02	03	05	05	02	04	04	04

* and ** indicates significant at 0.05 and 0.01 level of probability, respectively

Table 2 Significant GCA effects of parents with desirable direction

Sr. No.	Character	Parent	Significant and desired GCA effects
1	Days to 50% flowering	AG-1	-0.85*
		AG-2245	-4.07**
		AG-2006-15	-2.19**
		TAG-24	-2.74**
		TG-26	-2.63**
		Dh-86	-0.41*
2	Days to maturity	TAG-24	-3.00**
3	Plant height at maturity	GG-6	-16.80**
		AG-2006-6	-8.88**
		TAG-24	-3.56**
		TG-26	-16.54**
		Dh-86	-4.16**
4	Number of mature pods per plant	AG-1	2.42**
		AG-2240	3.00**
		AG-2006-15	0.87*
		TG-26	5.09**
		ICGV-95070	0.82**
5	Kernel yield per plant	AG-1	1.20**
		AG-2240	0.79**
		AG-2245	1.40**
		AG-2006-14	0.52*
		AG-2006-15	1.22**
		ICGV-95070	0.87**
6	100 pod weight	AG-2006-6	20.85**
		AG-2006-14	22.19**
		ICGV-95070	5.07**
7	100 kernel weight	AG-2006-6	7.34**
		AG-2006-14	5.68**
		TAG-24	2.61**
		ICGV-97079	1.24**
8	Sound mature kernels	AG-2240	1.52**
		AG-2006-14	0.85*
9	Shelling %	AG-1	4.16**
		AG-2240	3.89**
		AG-2245	5.13**
		AG-2006-14	2.17**
		AG-2006-15	4.49**
		ICGV-95070	1.31**
10	Harvest index	AG-1	1.74**
		AG-2245	1.06*
		AG-2006-6	1.05*
11	Oil content	AG-1	0.72*
		AG-2240	1.37**
		AG-2245	1.02**
		AG-2006-6	1.45**
		TAG-24	2.89**
		ICGV-95070	0.60**

Table 3 General combining effects of parents in groundnut

Characters	Parents	Per se performance	GCA effects
Days to 50% flowering	AG-2006-14	26.00	2.15**
	TAG-24	26.00	-2.74**
Days to maturity	TAG-24	117.00	-3.00**
	GG-6	117.33	2.00**
Plant height at maturity	TG-26	26.67	-16.54**
	Dh-86	28.00	-4.16**
Number of mature pods per plant	TG-26	25.47	5.09**
	Dh-86	18.63	-1.15**
Pod yield per plant	TG-26	18.20	1.11**
	AG-2006-15	16.92	1.09**
Kernel yield per plant	AG-2006-15	10.49	1.22**
	AG-2006-14	10.19	0.52*
100 pod weight	ICGV-97079	137.74	-1.29
	AG-2006-6	99.52	20.85**
100 kernel weight	ICGV-97079	53.96	1.24**
	AG-2006-6	49.80	7.34**
Sound mature kernels	ICGV-95070	93.33	-0.22
	TAG-24	92.33	-1.04*
Shelling percentage	AG-1	65.23	4.16**
	AG-2240	64.67	3.89**
Harvest index	AG-2245	38.16	1.06*
	AG-2006-14	36.48	-1.55**
Oil content	ICGV-95070	52.70	0.60**
	Dh-86	52.63	-0.54**

sound mature kernels (02), Shelling percentage (06), harvest index (03) and oil content (06) parents manifested GCA effects significant with desirable direction (Table 2.), respectively. The superior parents results into superior hybrids. Hence, these parents may therefore be used in crop breeding programme to improve different traits.

The results revealed that the most of the parents had high degree of correspondence between *per se* performance and their GCA effects for most of the characters, which showed additivity of genes (Table 3). Therefore, in selection of parents for varietal development programme due weightage should be given to *per se* performance along with their GCA effects. This findings are in confirmation with the findings of Nadaf *et al.* 1988, Dwivedi *et al.* 1989, Bansal *et al.* 1991, Upadhyay *et al.* 1992, Anderson *et al.* 1993, Ali *et al.* 1995 and Dobaria *et al.* 2004.

In general, the F_1's which had higher estimates of HB (Heterobeltiosis) for pod yield per plant also had positive heterotic effects with number of mature pods per plant, kernel yield per plant and harvest index while had negative heterotic effects with days to maturity (Table 4). The estimates of specific combining ability effect (Table 4) by and large provide information on role of intra and interallelic interactions in the expression of heterosis and inheritance of a character. Best cross combinations revealed the high SCA effect of F_1's in general corresponded to their high heterotic response, but this may also be accompanied by poor and/or average GCA effect of the parents. This may be due to the presence of genetic diversity in the form of dispersed genes for these characters. It revealed that good x good type of combinations not necessarily results into high SCA effects. This is probably due to internal cancellation of gene effects in these parents.

Table 4 Superior cross combination based on SCA effects in groundnut

Characters	Crosses	Per se performance	Heterosis over better parent	SCA effects	GCA effects
Days to 50% flowering	AG-2245 x ICGV-95070	25.33	-5.00	-1.89**	G x A
	TG-26 x ICGV-95070	25.33	-5.00	-3.33**	G x A
	AG-1 x ICGV-95070	26.00	-2.50	-4.44**	G x A
Days to maturity	TAG-24 x Dh-86	116.67	-0.28	-1.70	G x A
	TAG-24 x ICGV-95070	117.67	0.57	-0.52	G x A
	AG-1 x ICGV-95070	119.33	1.70	-0.63	A x A
Plant height at maturity	TG-26 x ICGV-97079	27.67	3.75	-3.66**	G x P
	GG-6 x Dh-86	28.53	1.90	3.10*	G x G
	TG-26 x Dh-86	29.27	9.75	3.56**	G x G
Number of mature pods per plant	AG-2240 x ICGV-95070	27.40	76.39**	6.74**	G x G
	AG-1 x ICGV-97079	25.87	89.27**	6.26**	G x A
	TG-26 x ICGV-95070	24.40	-4.19	1.65**	G x G
Pod yield per plant	AG-1 x ICGV-97079	19.87	27.81**	5.86**	G x A
	AG-2006-6 x ICGV-95070	17.81	35.38**	2.65**	G x G
	AG-2245 x ICGV-95070	17.64	35.74**	3.02**	G x G
Kernel yield per plant	AG-1 x ICGV-97079	12.77	33.71**	3.81**	G x A
	AG-2245 x ICGV-95070	11.54	44.03**	2.00**	G x G
	AG-2240 x ICGV-95070	10.74	34.08**	1.45**	G x G
100 pod weight	AG-2006-6 x ICGV-95070	108.33	8.86	7.21**	G x G
	AG-2006-14 x ICGV-95070	107.87	23.55**	5.41*	G x G
	AG-2006-14 x ICGV-97079	97.41	-29.28**	1.32	G x A
100 kernel weight	AG-2006-6 x ICGV-97079	47.99	-11.06**	2.34**	G x G
	AG-2006-6 x ICGV-95070	44.79	-10.06**	1.08	G x P
	AG-2006-14 x ICGV-97079	43.90	-18.64**	-0.09	G x G
Sound mature kernels	AG-2240 x ICGV-95070	94.00	0.71	0.89	G x A
	AG-2006-14 x ICGV-97079	94.00	1.81	1.37*	G x A
	AG-1 x Dh-86	93.67	1.81	0.96	A x A
Shelling percentage	AG-1 x ICGV-95070	66.41	1.80	1.23	G x G
	AG-2245 x ICGV-97079	66.37	8.13*	1.29	G x A
	AG-2245 x ICGV-95070	65.24	5.70	-0.92	G x G
Harvest index	AG-1 x Dh-86	38.99	8.12	1.79*	G x G
	AG-1 x ICGV-97079	38.74	10.30*	3.17**	G x P
	AG-2006-6 x ICGV-97079	38.51	11.71**	3.63**	G x P
Oil content	TAG-24 x ICGV-97079	53.06	1.10	0.51	G x A
	AG-2245 x ICGV-95070	53.03	0.63	1.73**	G x G
	TAG-24 x Dh-86	53.01	0.72	1.02*	G x P

Some of the crosses showed significant SCA effects, which had the combination of good x good and good x average GCA effects for pod yield per plant, number of mature pods per plant and kernel yield per plant may be explained because of the main role of the additive gene action. Good x good general combiners showed additive x additive gene action for many characters and its possibility of fixation, single plant selection could be practiced in further segregating generations to isolate superior pure lines from such combinations.The data indicate that none of the hybrids showed consistent SCA effects for all the traits under study. The cross AG-1 x ICGV-97079 and AG-2006-6 x ICGV-95070 recorded the more pod yield, kernel yield, number of mature pod, 100 pod weight and 100 kernel weight. This cross also showed significant heterobeltiosis, SCA effects and both the parents involved were mostly good general combiners.

On the basis of *per se* performance, heterotic response, combining ability estimates, nature of gene action for pod yield and its agronomic traits, AG-1 x ICGV-97079 was found superior and may be used as transgressive segregants in later generations to utilize both the types of gene actions and exploited commercially after critical evaluation for its superiority and stability across the locations and over years.

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