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Research Article

Heterosis and combining ability analysis in tetraploid cotton (*G. hirsutum* L. and *G. barbadense* L.)

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Abstract

The present investigation was carried out with a view to study the heterosis, combining ability and gene action for seed cotton yield, yield attributing traits, ginning outturn and important fibre quality parameters in tetraploid cotton (*G. hirsutum* L. and *G. barbadense* L.). A set of 31 genotypes consisting of 21 (HxB) hybrids, seven lines of *G. hirsutum*, three testers of *G. barbadense* and one check hybrid DCH 32 was grown at Rasi Seeds Research and Development Farm, Attur. The hybrids were developed adopting Line x Tester mating design. Analysis of variance showed significant differences among the parents and hybrids for all the characters indicating presence of genetic variability. Combining ability analysis indicated that both additive and non additive gene effects were important in the inheritance of all the traits. The ratio of variance due to GCA to that of SCA was less than one for all the character under study indicating importance of dominance gene effects in the inheritance of these characters. The parents CG 64 (*hirsutum*), CG 67 (*hirsutum*) and CG 45 SB (*barbadense*) were good general combiner for the seed cotton yield per plant and number of bolls per plant. CG 45 SB was also a good combiner for the 2.5 per cent span length. The cross CG 64 x CG 45 SB recorded the highest *per se* performance and standard heterosis for seed cotton yield. Two crosses *viz.*, CG64 x CG45SB and CG67 x CG45SB registered significant *per se* performance, positive *sca* effects along with significant positive standard heterosis for seed cotton yield and majority of yield components and fibre quality traits.

Key words
Cotton, L x T analysis, heterosis, combining ability, gene action

Introduction

Cotton, the king of fibre, is one of the most momentous and important cash crops of the country. It is the most important commercial crop contributing nearly 65 per cent of the total raw material needs of the textile industry in our country. Cotton is cultivated in an area of 115.53 lakh hectares with the production of 375 lakh bales (Anonymous, 2014). Among the four cultivated species of cotton, the varieties and hybrids belonging to *G. hirsutum, G. barbadense, hirsutum X hirsutum* and *hirsutum X barbadense* hybrids were widely cultivated in India. In India, around 7 – 9 lakh bales of extra large staple (ELS) cotton is needed for the textile mills but the production is only around 5.0 lakh bales. The inter-specific hybrids *(G. hirsutum* x *G. barbadense),* which are one of the source for ELS cotton production, is to be exploited to meet the demand. Several workers reported higher heterosis in case of inter-specific hybrids. Exploitation of heterosis (*G. hirsutum* x *G. barbadense*) on commercial scale and systemic varietal improvement through hybridization are the main tools to increase ELS cotton production. Study of combining ability is important for selecting parents for hybridization. Sprague and Tatum (1942), proposed the concepts of general combining ability (*gca*) and specific combining ability (*sca*). According to them, GCA variance is due to additive variance and SCA variance is due to non-additive variance, both act as an important diagnostic tool in selection of suitable parents and cross combination. Among the various design used for combining ability analysis, Line x Tester analysis (Kempthorne, 1957) has been extensively used to assess the combining ability of parents and crosses for different quantitative characters as well as to study the extent of heterosis for yield, yield contributing characters and fibre quality traits in cotton.

Materials and Methods

The present investigation was carried out at Research and Development Farm of Rasi Seeds, Attur during winter, 2009. The experimental materials consisted of 21 hybrids (*hirsutum X barbadense*) obtained by crossing seven lines (*hirsutum*) *viz.*, CG62, CG64, CG67, CG91, CG92, CG150 and CG163 and three testers (*barbadense*) *viz.*, CG45SB, CG45E and CG305. The hybrids and parents were evaluated in randomized block design with two replications. Each treatment was raised in four rows of 6.8 m length spaced at 1.2 m apart with plant to plant distance of 75 cm. All the recommended agronomical practices and plant protection measures were followed as and when required to raise a good crop of cotton. Observations were recorded for number of bolls per pant, boll weight (g), seed cotton yield per plant (g), number of seeds per boll, ginning outturn (per cent), Lint Index (g), Seed Index (g), 2.5 Span Length(mm), Uniformity Ratio (per cent), Fibre Strength (g/tex), Micronaire and Elongation Percentage. Data were recorded on five random competitive plants from each entry from all replications and mean of five plants was taken for further analysis. Combining ability analysis were estimated as per Kempthorne (1957). Standard heterosis was estimated as per the procedure suggested by Shull (1948) and Liang *et al*. (1971).

Results and Discussion

Analysis of variance showed highly significant differences due to genotypes for all the traits indicating the presence of sufficient variability in the experimental materials (Table 1). Parents and hybrids showed significant differences for all the characters studied. Significance of variance in parents *vs* hybrids interaction provides the adequacy for comparing the heterotic expression for all the characters except lint index. The ratio of variance due to GCA to that of SCA was lesser than one for all the characters which shows the predominance of dominant gene action for all the characters under study indicating the exploitation of heterosis by hybrid development is the most suitable method of breeding. These findings are in agreement with those obtained by Simon *et al.* (2013).

Information on the *per se* performance and nature of general combining ability effects (*gca*) of characters is necessary for selection of suitable parents for developing hybrids. The *gca* effects of the parents along with their mean performance for various characters are given in Table 2 and 3. Based on the *per se* performance, the *hirsutum* line CG163 (217.6g), was superior for the seed cotton yield per plant followed by CG91 (217.15 g) and CG150 (207.9 g). The *barbadense* genotype CG45E was superior for 2.5 span length (41.10mm) and CG45 SB was superior for fibre strength (36.9 g/tex). The parents *viz.*, CG 45SB (37.87 g), CG 64 (31.94 g) and CG 67 (29.19 g) were good combiners for the seed cotton yield per plant. These parents also recorded significant *gca* effects of 25.48, 24.90 and 19.57 for number of bolls per plant, respectively. The genotype CG150 recorded the highest significant *gca* effect (0.24) for boll weight, number of seeds per boll (1.45), ginning outturn (2.96) and lint index (1.26). For the character 2.5 per cent span length, the genotypes CG 45SB and CG 62 recorded the highest significant *gca* effects (1.03). The genotype CG 67 registered the highest significant *gca* effect (2.63) followed by CG 62 (2.30) and CG 45SB (1.41) for fibre strength. This result was similar with the findings of Amir *et al. (*2012).

The *sca* effects of the hybrids along with their mean performance for various characters are given in Table 4. The specific combining ability (*sca*) effect alone may not be the appropriate choice for exploitation of heterosis because the hybrid with low mean value may also possess high *sca* effect. Hence, the cross combinations were to be identified based on two criteria *viz., per se* performance and the gene action involved in the crosses for further exploitation. In the present investigation, based on the *per se* performance, the cross combination CG64 x CG 45 SB was found to be the best based on superior for seed cotton yield (353.4 g), number of bolls per plant (166.5), boll weight (4.4 g) and number of seeds per boll (25.5). This cross combination also recorded the highest significant *sca* effects for boll weight (0.45), number of seeds per boll (3.31) and elongation percentage (0.66). The hybrid combination CG150 x CG45E was superior for ginning outturn which recorded 33.55 per cent of mean performance of ginning outturn. For lint index, CG 150 x CG 45 E was superior based on *per se* performance (6.9 g) and *sca* effect (0.41). Regarding the fibre quality traits, the cross combination CG 62 x CG 45SB recorded 39.8 mm for 2.5per cent span length followed by CG 64 x CG 45SB (39.45mm). For the fibre strength, the hybrid CG 64xCG 45SB was superior for mean performance (35.7 g/tex) and significant *sca* effect (1.72). Similar results were earlier reported by Vineela *et al*. (2012) and Amir *et al*. (2012).

A summarized account of the best parent *per se*, best general combiner, best F_1 *per se*, most heterotic crosses and best specific combination for various characters studied in the present investigation are presented in Table 5. The best performing cross CG 64 x CG 45SB recorded the highest *per se* and standard heterosis for seed cotton yield per plant, number of bolls per plant, number of seeds per boll, uniformity ratio followed by the CG 67 x CG 45 SB for seed cotton yield, number of bolls per plant and fibre quality traits. All the parents involved in these crosses are having good general combining ability for seed cotton yield per pant and number of bolls per plant. The heterosis in this cross might have resulted from interaction of dominant gene contributed by both good combining parents. Pathak and Kumar (1975) reported close relationship between *gca* effects of parents and *sca* effect of their resultant crosses. In case of fibre quality properties, the cross CG 64 x CG 45 SB recorded 39.45 mm of 2.5 per cent span length, and 33.15 g/tex of fibre strength and standard heterosis of 8.45 and 21.21 per cent, respectively with the positive significant *sca* effects. The respective parents are also having significant positive *gca* effects for the 2.5 per cent span length and fibre strength. The next overall best hybrid CG 67 x CG 45 SB recorded high *per se* performance and standard heterosis for 2.5 per cent span length, fibre strength but negative *sca* effect for 2.5 per cent span length. Both the parents involved in this cross were having good general combining ability. Marked negative *sca* effect for 2.5 per cent span length in the cross CG 67 x CG 45 SB could be attributed to the lack of co-adaptation between favorable alleles of the parents involved. Gururaj Rao *et al.* (1977) reported that this was probably due to mutual cancellation of components of heterosis. The results are in agreement with the research findings of Patel *et al*. (2012) and Sekhar *et al*. (2012).

In the present investigation, the parent CG 64, CG 67 and CG 45 SB were found to be promising due to their high yield potential as well as significant and positive general combining ability effects for yield and its attributes and for 2.5 per cent span length and fibre strength. Therefore, these three parents could be effectively used for hybrid breeding programme as well as introgression breeding. The cross combinations having high mean yield, high heterosis and desirable *sca* effects is of immense importance for hybrid cotton breeding programme. For seed cotton yield and major yield attributes as well as important fibre quality parameters the hybrids *viz.*, CG 64 x CG 45SB and CG 67 x CG 45 SB showed positive and significant *per se*, standard heterosis and *sca* effects. Consequently, these two hybrids appeared promising for commercial release after thorough testing. The results are in conformity with the reports of Maisuria *et al*. (2007) and Sekhar *et al*. (2012).

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Table 1. Analysis of variance for combining ability for twelve characters in cotton

Source of variation	DF	Number of bolls per plant	Boll Weight (g)	Seed cotton yield per plant (g)	Number of seeds per boll	Ginning outturn (%)	Lint Index (g)	Seed Index (g)	2.5 Span Length (mm)	Uniformity Ratio (per cent)	Fibre Strength (g/tex)	Micronaire	Elongation
Cross	20	1542.18**	0.12**	3037.92**	6.50**	7.23**	1.01**	1.29**	3.53**	3.04**	17.27**	0.22**	0.62**
Line	6	2222.21**	0.14**	3701.64**	4.10**	17.83**	2.52**	1.91**	4.96**	3.73**	39.92**	0.27**	1.02**
Tester	2	7249.45**	0.18**	16411.07**	6.45**	0.77**	1.27**	2.24**	13.94**	10.47**	33.85**	0.52**	0.81**
L X T	12	250.95**	0.11**	477.20**	7.70**	3.01**	0.21**	0.83**	1.08**	1.46**	3.18**	0.15**	0.39**
Cross VS parents	1	21672.26**	5.17**	146733.33**	44.83**	116.65**	0.00	28.73**	97.00**	4.12**	72.40**	4.73**	0.08**
Error	30	13.74	0.01	5.69	0.78	0.05	0.01	0.02**	0.03	0.03	0.02	0.01	0.02
Var of GCA		50.44	0.00	100.03	0.05	0.16	0.03	0.02	0.10	0.06	0.55	0.00	0.01
Var of SCA		124.46	0.05	237.13	3.49	1.50	0.10	0.41	0.53	0.72	1.58	0.07	0.19
GCA/SCA		0.41	0.01	0.42	0.01	0.11	0.31	0.04	0.18	0.09	0.35	0.04	0.05

* Significant at 5 % probability level, ** Significant at 1 % probability level.

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Table 2. Mean Performance of Lines and testers for twelve characters in cotton

PARENTS	Number of bolls per plant	Boll Weight (g)	Seed cotton yield per plant (g)	Number of seeds per boll	Ginning outturn (per cent)	Lint Index (g)	Seed Index (g)	2.5 Span Length (mm)	Uniformity Ratio (per cent)	Fibre Strength (g/tex)	Micronaire	Elongation Percentage
LINES												
CG64	65.50	4.55	157.00	26.00*	35.00**	5.65	10.20	30.80	46.25**	24.25	4.35**	5.85**
CG91	102.00**	4.65	217.15**	26.50*	38.20**	7.00**	11.65**	29.15	46.15**	22.05	4.65**	5.55*
CG150	90.50**	5.30**	207.90**	27.50**	42.40**	8.20**	12.00**	29.30	47.35**	24.05	4.85**	6.85**
CG62	66.00	5.35**	170.40	28.50**	32.25	5.15	10.75	36.05**	44.85	27.00	4.05**	5.35
CG67	72.50	5.00**	175.50**	26.50*	33.40*	5.35	10.65	36.30**	44.80	26.15	4.10**	5.05
CG92	66.00	5.45**	166.90	27.00*	35.65**	5.15	9.75	35.15*	45.05	26.10	3.45	4.65
CG163	76.00	5.65**	217.60**	30.00**	33.00*	5.15	9.95	33.55	42.65	25.75	3.40	5.55
TESTERS												
CG45SB	59.50	3.60	109.95	18.00	25.55	4.45	12.85**	40.50**	44.55	36.90**	2.80	4.55
CG45E	51.50	3.45	138.50	17.50	24.65	4.45	13.55**	41.10**	44.55	34.85**	3.15	4.40
CG305	46.50	3.75	104.65	19.50	28.60	5.15	12.35**	37.70	43.55	32.45**	3.25	5.30
Mean of Parents	69.60	4.67	166.55	24.70	32.87	5.57	11.37	34.96	44.98	27.96	3.81	5.31
CD 5%	7.56	0.19	4.86	1.79	0.43	0.21	0.28	0.35	0.32	0.29	0.18	0.26
CD 1%	10.19	0.26	6.56	2.42	0.59	0.28	0.38	0.47	0.43	0.39	0.24	0.35

* Significant at 5 % probability level, ** Significant at 1 % probability level.

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Table 3. Estimates of general combining ability (*gca*) effects of Lines and testers for twelve characters in cotton

PARENTS	Number of bolls per plant	Boll Weight (g)	Seed cotton yield per plant (g)	Number of seeds per boll	Ginning outturn (per cent)	Lint Index (g)	Seed Index (g)	2.5 Span Length (mm)	Uniformity Ratio (%)	Fibre Strength (g/tex)	Micronaire	Elongation Percentage
LINES												
CG64	24.90 **	-0.22 **	31.94 **	-1.38 **	-0.02	-0.18 **	0.12 **	0.16 *	1.08 **	1.05 **	0.05	0.06
CG91	-3.10 **	0.08	0.38	-0.21	1.15 **	0.42 **	0.62 **	-1.30 **	-0.34 **	-3.48 **	0.14 **	0.31 **
CG150	-23.60 **	0.24 **	-28.02 **	1.45 **	2.96 **	1.26 **	0.37 **	-1.15 **	-1.31 **	-3.45 **	0.24 **	0.60 **
CG62	12.90 **	0.06	7.16 **	0.12	-1.92 **	-0.23 **	0.32 **	1.03 **	-0.36 **	2.30 **	-0.23 **	-0.35 **
CG67	19.57 **	-0.07	29.19 **	0.12	-2.00 **	-0.56 **	-0.14 **	0.88 **	0.33 **	2.63 **	-0.31 **	-0.65 **
CG92	-18.10 **	-0.11 *	-29.44 **	-0.05	0.01	-0.59 **	-1.09 **	0.18 *	-0.11 **	1.50 **	-0.06 ns	0.10 *
CG163	-12.60 **	0.03	-11.21 **	-0.05	-0.19 **	-0.13 **	-0.21 **	0.20 *	0.71 **	-0.55 **	0.19 **	-0.07
TESTERS												
CG45SB	25.48 **	0.11 **	37.87 **	0.69 **	0.08 *	0.11 **	0.41 **	1.03 **	0.81 **	1.41 **	-0.11 **	-0.06 *
CG45E	-7.17 **	0.00	-9.10 **	-0.02	-0.26 **	-0.34 **	-0.39 **	-0.06	0.10 **	0.25 **	-0.11 **	-0.21 **
CG305	-18.31 **	-0.11 **	-28.77 **	-0.67 **	0.19 **	0.23 **	-0.02	-0.96 **	-0.91 **	-1.67 **	0.22 **	0.26 **

* Significant at 5 % probability level, ** Significant at 1 % probability level.

Table 4. ***Per se*** **performance and estimates of specific combining ability (*sca*) effects of hybrids for twelve characters in cotton**

Crosses	Number of bolls per plant		Boll weight (g)		Seed cotton yield per plant (g)		Numbr of seed per boll		Ginning outturn (per cent)		Lint intex (g)	
	MEAN	*sca*	MEAN	*sca*	MEAN	*sca*	MEAN	*sca*	MEAN	*sca*	MEAN	*sca*
CG64 X CG45SB	166.50**	6.52 **	4.40**	0.45 **	353.40**	12.96 **	25.50**	3.31 **	31.20**	1.20 **	5.45	-0.06
CG64 X CG45E	141.00**	13.67 **	3.45	-0.38 **	308.55**	15.09 **	19.50	-1.98 **	28.35	-1.30 **	4.95	-0.11
CG64 X CG305	96.00	-20.19 **	3.65	-0.07	245.75	-28.05 **	19.50	-1.33 *	30.20*	0.10	5.80*	0.17 *
CG91 X CG45SB	123.50**	-8.48 **	4.15	-0.10	298.45**	-10.42 **	21.50	-1.86 **	29.95	-1.21 **	5.80*	-0.31 **
CG91 X CG45E	102.50	3.17 **	4.20	0.07	271.40	9.50 **	24.00	1.36 *	32.15**	1.33 **	5.75	0.09
CG91 X CG305	93.50	5.31 **	4.05	0.03	243.15	0.92	22.50	0.50	31.15**	-0.12	6.45**	0.22 **
CG150 X CG45SB	118.50**	7.02 **	4.35**	-0.06	284.25**	3.78 **	24.50	-0.52	32.20**	-0.78 **	6.75**	-0.19 *
CG150 X CG45E	71.50	-7.33 **	4.35**	0.05	225.65	-7.85 **	23.00	-1.31 *	32.95**	0.31 **	6.90**	0.41 **
CG150 X CG305	68.00	0.31	4.20	0.01	217.90	4.07 **	25.50**	1.83 **	33.55**	0.46 **	6.85**	-0.21 **
CG62 X CG45SB	154.00**	6.02 **	3.95	-0.28 **	323.50**	7.85 **	23.00	-0.69	28.65	0.55 **	5.35	-0.11
CG62 X CG45E	108.00	-7.33 **	4.35**	0.23 **	251.90	-16.78 **	23.50	0.52	26.65	-1.10 **	4.75	-0.26 **
CG62 X CG305	105.50	1.31	4.05	0.05	257.95	8.93 **	22.50	0.17	28.75	0.55 **	5.95**	0.37 **
CG67 X CG45SB	161.50**	6.86 **	4.25*	0.15 *	342.00**	4.31 **	24.50	0.81	28.20	0.19 *	5.30	0.17 *
CG67 X CG45E	120.50**	-1.50	4.05	0.07	284.50**	-6.21 **	25.00*	2.02 **	27.75	0.08	4.65	-0.03
CG67 X CG305	105.50	-5.36 **	3.65	-0.22 **	272.95	1.90	19.50	-2.83 **	27.85	-0.27 **	5.10	-0.15 *
CG92 X CG45SB	112.50*	-4.48 **	3.95	-0.11	275.45*	-3.60 **	22.50	-1.02	28.55	-1.48 **	5.25	0.16 *
CG92 X CG45E	86.50	2.17 *	4.05	0.10	244.05	11.97 **	23.50	0.69	30.15	0.46 **	4.35	-0.29 **
CG92 X CG305	75.50	2.31 *	3.85	0.01	204.05	-8.37 **	22.50	0.33	31.15**	1.01 **	5.35	0.14
CG163 X CG45SB	109.00	-13.48 **	4.15	-0.05	282.40**	-14.89 **	23.50	-0.02	31.35**	1.52 **	5.90**	0.34 **
CG163 X CG45E	87.00	-2.83 *	3.95	-0.13	244.60	-5.71 **	21.50	-1.31 *	29.70	0.21 *	5.30	0.19 *
CG163 X CG305	95.00	16.31 **	4.15	0.18 *	251.25	20.60 **	23.50	1.33 *	28.20	-1.74 **	5.15	-0.53 **
Mean of hybrids	109.60		4.06		270.62		22.88		29.94		5.58	
CD 5 %	2.97		0.19		3.58		1.77		0.22		0.20	
CD 1 %	4.05		0.26		4.88		2.42		0.30		0.28	

* Significant at 5 % probability level, ** Significant at 1 % probability level.

Contd.,

Table 4. Contd.,

CROSS	Seed Index (g)		2.5 Span Length (mm)		Unifomity Ratio (%)		Fibre Strength (g/tex)		Micronaire		Elongation Percentage	
	MEAN	***Sca***	**MEAN**	***sca***	**MEAN**	***sca***	**MEAN**	***sca***	**MEAN**	***sca***	**MEAN**	***sca***
CG64 X CG45SB	12.75	-0.61 **	39.45**	0.62 **	47.15**	0.84 **	33.15**	0.42 **	3.00	-0.16 *	6.05**	0.66 **
CG64 X CG45E	12.55	-0.01	37.40	-0.34 *	45.20**	-0.40 **	31.05**	-0.52 **	3.45*	0.30 **	5.15	-0.09
CG64 X CG305	13.55**	0.62 **	36.55	-0.29 *	44.15	-0.44 **	29.75	0.10	3.35	-0.14 *	5.15	-0.56 **
CG91 X CG45SB	13.75**	-0.11	36.40	-0.96 **	44.45	-0.45 **	27.65	-0.55 **	3.65**	0.41 **	5.30	-0.34 **
CG91 X CG45E	12.35	-0.71 **	37.30	1.03 **	44.35	0.17 *	26.35	-0.69 **	3.15	-0.09	5.75**	0.26 **
CG91 X CG305	14.25**	0.82 **	35.30	-0.07	43.45	0.28 **	26.35	1.23 **	3.25	-0.32 **	6.05**	0.09
CG150 X CG45SB	13.65**	0.04	38.45**	0.94 **	43.15	-0.78 **	27.35	-0.88 **	3.45*	0.11	5.75**	-0.18 *
CG150 X CG45E	13.50**	0.69 **	35.75	-0.67 **	42.60	-0.61 **	26.25	-0.82 **	3.05	-0.29 **	6.15**	0.37 **
CG150 X CG305	12.45	-0.73 **	35.25	-0.27 *	43.60	1.39 **	26.85	1.70 **	3.85**	0.18 *	6.05**	-0.20 **
CG62 X CG45SB	13.25**	-0.31 **	39.80**	0.10	45.25**	0.37 **	35.70**	1.72 **	2.80	-0.08	5.25	0.27 **
CG62 X CG45E	13.05*	0.29 **	38.95**	0.35 *	44.75**	0.59 **	33.35**	0.53 **	2.75	-0.12	4.45	-0.38 **
CG62 X CG305	13.15**	0.02	37.25	-0.45 **	42.20	-0.96 **	28.65	-2.25 **	3.40*	0.20 **	5.40	0.10
CG67 X CG45SB	13.15**	0.06	39.30**	-0.25	45.75**	0.19 **	34.55**	0.24 *	2.95	0.16 *	4.25	-0.43 **
CG67 X CG45E	12.05	-0.24 **	38.90**	0.45 **	44.25	-0.60 **	34.00**	0.85 **	2.60	-0.19 *	4.75	0.22 **
CG67 X CG305	12.85	0.19 *	37.35	-0.20	44.25	0.41 **	30.15	-1.08 **	3.15	0.03	5.20	0.20 **
CG92 X CG45SB	13.15**	1.01 **	38.95**	0.10	44.25	-0.88 **	32.20**	-0.98 **	2.65	-0.39 **	5.25	-0.18 *
CG92 X CG45E	11.10	-0.24 **	37.45	-0.30 *	45.25**	0.84 **	32.85**	0.83 **	3.25	0.21 **	4.85	-0.43 **
CG92 X CG305	10.95	-0.76 **	37.05	0.20	43.45	0.04	30.25	0.15	3.55**	0.18 *	6.35**	0.60 **
CG163 X CG45SB	12.95	-0.08	38.30**	-0.56 **	46.65**	0.70 **	31.15**	0.02	3.25	-0.04	5.45	0.19 **
CG163 X CG45E	12.45	0.22 **	37.25	-0.52 **	45.25**	0.02	29.80	-0.17	3.45*	0.16 *	5.15	0.04
CG163 X CG305	12.45	-0.15	37.95	1.08 **	43.50	-0.72 **	28.20	0.15	3.50**	-0.12	5.35	-0.23 **
Mean of hybrids	12.83		37.64		44.42		30.27		3.21		5.39	
CD 5 %	0.21		0.37		0.18		0.28		0.19		0.18	
CD 1 %	0.29		0.50		0.24		0.38		0.26		0.25	

* Significant at 5 % probability level, ** Significant at 1 % probability level.

Table 5. Relationship between *per se*, *sca* effects and Standard heterosis for twelve characters in cotton

Sl.No	Character	Hybrids	*per* se	Hybrids	*sca* effects	Hybrids	Standard Heterosis (%)	Hybrids selected as whole
1.	Number of bolls per plant	CG64 X CG45SB	166.50	CG163 X CG305	16.31	CG64 X CG45SB	129.66	CG64(24.90)X CG45SB (25.48)
		CG67 X CG45SB	161.50	CG64 X CG45E	13.67	CG67 X CG45SB	122.76	CG67 (19.57) X CG45SB (25.48)
		CG62 X CG45SB	154.00	CG150 X CG45SB	7.02	CG62 X CG45SB	112.41	
2.	Boll Weight (g)	CG64 X CG45SB	4.40	CG64 X CG45SB	0.45	CG64 X CG45SB	3.53	CG64 (-0.22) X CG45SB (0.11)
		CG150 X CG45SB	4.35	CG62 X CG45E	0.23	CG150 X CG45SB	2.35	CG150(0.24) X CG45SB (0.11)
		CG150 X CG45E	4.35	CG163 X CG305	0.18	CG150 X CG45E	2.35	
3.	Seed cotton yield per plant (g)	CG64 X CG45SB	353.40	CG163 X CG305	20.60	CG64 X CG45SB	49.81	CG64 (31.94) X CG45SB (37.87)
		CG67 X CG45SB	342.00	CG64 X CG45E	15.09	CG67 X CG45SB	44.98	CG67(29.19) X CG45SB (37.87)
		CG62 X CG45SB	323.50	CG64 X CG45SB	12.96	CG62 X CG45SB	37.13	
4.	Number of seeds per boll	CG64 X CG45SB	25.50	CG64 X CG45SB	3.31	CG64 X CG45SB	2.00	CG64 (-1.38) X CG45SB (0.69)
		CG150 X CG305	25.50	CG67 X CG45E	2.02	CG150 X CG305	2.00	CG150 (1.45)X CG305(-0.67)
		CG67 X CG45E	25.00	CG150 X CG305	1.83			
5.	Ginning outturn (per cent)	CG150 X CG305	33.55	CG163 X CG45SB	1.52	CG150 X CG305	7.02	CG150 (2.96) X CG305 (0.19)
		CG150 X CG45E	32.95	CG91 X CG45E	1.33	CG150 X CG45E	5.10	CG150 (2.96) X CG45E (-0.26)
		CG150 X CG45SB	32.20	CG64 X CG45SB	1.20	CG150 X CG45SB	2.71	
		CG64 X CG45SB	31.20					
6.	Lint Index (g)	CG150 X CG45E	6.90	CG150 X CG45E	0.41	CG150 X CG45E	22.12	CG150 (1.26) X CG45E (-0.34)
		CG150 X CG305	6.85	CG62 X CG305	0.37	CG150 X CG305	21.24	CG150 (1.26) X CG305(0.23)
		CG150 X CG45SB	6.75	CG163 X CG45SB	0.34	CG150 X CG45SB	19.47	
		CG64 X CG45SB	5.45					
7.	Seed Index (g)	CG91 X CG305	14.25	CG92 X CG45SB	1.01	CG91 X CG305	13.10	CG91 (0.62) X CG305 (-0.02)
		CG91 X CG45SB	13.75	CG91 X CG305	0.82	CG91 X CG45SB	9.13	
		CG150 X CG45SB	13.65	CG150 X CG45E	0.69	CG150 X CG45SB	8.33	CG91(0.62) X CG45SB (0.41)
8.	2.5 Span Length (mm)	CG62 X CG45SB	39.80	CG163 X CG305	1.08	CG62 X CG45SB	8.45	CG 62 (1.03) X CG45SB (1.03)
		CG64 X CG45SB	39.45	CG91 X CG45E	1.03	CG64 X CG45SB	7.49	
		CG67 X CG45SB	39.30	CG150 X CG45SB	0.94	CG67 X CG45SB	7.08	CG 64(0.16) X CG45SB (1.03)
9.	Unifomity Ratio (per cent)	CG64 X CG45SB	47.15	CG150 X CG305	1.39	CG64 X CG45SB	9.65	CG64 (1.08) X CG45SB (0.81)
		CG163 X CG45SB	46.65	CG64 X CG45SB	0.84	CG163 X CG45SB	8.49	CG163 (0.71) X CG45SB (0.81)
		CG67 X CG45SB	45.75	CG92 X CG45E	0.84	CG67 X CG45SB	6.40	
10.	Fibre Strength (g/tex)	CG62 X CG45SB	35.70			CG62 X CG45SB	30.53	
		CG67 X CG45SB	34.55	CG62 X CG45SB	1.72	CG67 X CG45SB	26.33	CG62 (2.30) X CG45SB (1.41)
		CG67 X CG45E	34.00	CG150 X CG305	1.70	CG67 X CG45E	24.31	CG67(2.63)X CG45SB (1.41)
		CG64 X CG45E	33.35	CG91 X CG305	1.23	CG64 X CG45E	21.94	
		CG64 X CG45SB	33.15			CG64 X CG45SB	21.21	
11.	Micronaire	CG150 X CG305	3.85	CG91 X CG45SB	0.41	CG150 X CG305	18.46	CG150 (0.24)X CG305(0.22)
		CG91 X CG45SB	3.65	CG64 X CG45E	0.30	CG91 X CG45SB	12.31	CG91(0.14)X CG45SB (-0.11)
		CG92 X CG305	3.55	CG92 X CG45E	0.21	CG92 X CG305	9.23	
12.	Elongation Percentage	CG92 X CG305	6.35	CG64 X CG45SB	0.66	CG92 X CG305	12.39	CG92(0.10)X CG305(0.26)
		CG150 X CG45E	6.15	CG92 X CG305	0.60	CG150 X CG45E	8.85	CG150(0.60)X CG45E(-0.21)
		CG64 X CG45SB	6.05	CG150 X CG45E	0.37	CG64 X CG45SB	7.08	

*****Figures in parenthesis indicates *gca* effects