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Studies on combining ability and gene action for seed cotton yield and its component traits in interspecific hybrids of cotton

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Abstract
The experiment was carried out to obtain information on combining ability effects of parents and identifying best hybrids for improving seed cotton yield. The $\sigma^2_{gca}/\sigma^2_{sca}$ ratio indicated dominant role of non-additive gene action for all the studied characters except days to 50% flowering, ginning outturn, fiber fineness, uniformity index, seed index and lint index. Based on general combining ability effects, five parents *viz.*, AHC-1, ABC-1, GSB-45, DB-1502 and RHcb-1014 were found good general combiners for seed cotton yield and its component traits suggesting the exploitation of heterosis breeding for development of hybrids. The sca effects revealed that none of the hybrids was consistently and significantly superior for all the traits. Out of all, only nine hybrids depicted significantly positive sca effects for seed cotton yield per plant. Based on sca effects, three superior cross combinations for seed cotton yield per plant were AHC-26 × ARBB-27, AHC-50 × GSB-44 and AHC-1 × GSB-43-1 and these crosses further evaluated for development of new hybrids.

Keywords: Combining ability, gene action, cotton, line × tester mating design

Introduction
Cotton is also known as White Gold as well as King of fiber crops and mainly often cross-pollinated crop which belongs to the family Malvaceae and genus *Gossypium*. Genus *Gossypium* includes approximately 50 species, out of which 43 are diploid and seven are tetraploid in nature but only four species are cultivated which are *G. hirsutum* L., *G. barbadense* L., *G. arboreum* L. and *G. herbaceum* L. Among the four cultivated species, *G. arboreum* L. and *G. herbaceum* L. are diploid (2n = 2x = 26) in nature and known as old world cotton while, *G. hirsutum* L. and *G. barbadense* L. are tetraploid (2n = 4x = 52) in nature and known as new world cotton. The species which are referred to as its progenitors are *G. africanum* L. and *G. raimondii* L. African linted diploid species (*G. africanum* L.) reached America through Pacific Ocean and after crossing with American lintless wild diploid species (*G. raimondii* L.) gave birth to tetraploid cotton. The chromosome doubling took place in nature resulting in the development of fertile amphidiploids (*G. hirsutum* L.).
India ranks first in terms of area (13.47 million hectares), while second in terms of production (12.88 million tonnes) among cotton growing countries after China, whereas, productivity is around 955.7 kg/ha in India (Anon., 2020) [1].
Nowadays in cotton breeding programmes more emphasis given on simultaneous improvement of seed cotton yield and fiber quality traits to meet the demand of textile industries. The key characteristic of the species like, *G. hirsutum* L. having high yielding potential and *G. barbadense* L. has excellent fiber quality makes it possible to producing hybrids with higher yield and superior fiber quality through interspecific hybridization. The first step in any breeding programme is to identify parents having good general combining ability. The parent which produce good progenies upon crossing has immense value in breeding programme. In crop improvement programme, much of the success depends on isolation of useful gene combinations. This necessitates the study of combining ability effects for selection of superior parents and their hybrids.
For estimation of combining ability and gene action many mating designs are available but line × tester design given by Kempthorne (1957) [8] is widely used. Line × tester is most efficient and simplest design to evaluate large number of inbreds for their combining ability.

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This design provides information about the potentiality of parents (GCA), their hybrids (SCA) along with gene action involved in the inheritance of various traits which found useful in identification of desired segregants from segregating generations. Therefore, current investigation was undertaken with the objective to find out general and specific combining ability effects of parents and hybrids for seed cotton yield per plant and its component traits along with gene action involved in inheritance of various traits.

Material and Methods
For present investigation the crossing program was undertaken during *Kharif*-2020 and evaluation was carried out in *Kharif*-2021 at the Regional Research Station, Anand Agricultural University, Anand. The experimental material comprised of five lines (*G. hirsutum*), nine testers (*G. barbadense*), 45 hybrids and one standard check. These lines and testers were crossed in line × tester fashion to obtain 45 interspecific hybrids. The experiment was laid out in randomized complete block design with three replications. The lines were AHC-1 (L1), G. Cot-12 (L2), G. Cot-20 (L3), AHC-50 (L4) and AHC-26 (L5), and testers were ABC-1 (T1), ARBB-27 (T2). GSB-41 (T3), GSB-43-1 (T4), GSB-44 (T5), GSB-45 (T6), DB-1502 (T7), RHcb-1014 (T8) and DB-1602 (T9) and one standard check was G. Cot. Hy. 102. The seeds of 45 F₁s were produced by hand pollination and parent seeds were obtained by selfing of parents. The package of practices will be followed as per the recommendations for raising the good and healthy crop. Observations were recorded for 16 different characters *viz.*, days to 50% flowering, days to 50% boll bursting, plant height, monopodia per plant, sympodia per plant, bolls per plant, boll weight, ginning outturn, fiber fineness, fiber strength, fiber length, uniformity index, seed index, lint index, lint yield per plant and seed cotton yield per plant. The experimental plot wise mean values of five randomly selected plants were used in each statistical analysis for different characters. The estimation of heterosis over better parent and standard check is more realistic. Hence, in the present investigation, heterosis was estimated over better parent and standard check, referred to as heterobeltiosis and standard heterosis, respectively.

Results and Discussion
The analysis of variance for combining ability (Table 1) revealed that mean sum of square due to lines were significant for most of characters except bolls per plant, uniformity index, lint yield per plant and seed cotton yield per plant whereas, mean sum of square due to testers was found significant for all characters except sympodia per plant, boll weight and fiber length indicated paramount of genetic variation present in lines and testers. The analysis also depicted significant difference in line × tester interaction for all the characters under study except uniformity index showed that interaction variance contributed largely towards total genetic variance and both lines as well as testers interacted differently in crosses.

The both variance gca and sca were important for inheritance of various studied traits. The ratio of $\sigma^2_{gca}/\sigma^2_{sca}$ revealed greater magnitude of sca variance for all characters except days to 50% flowering, ginning outturn, fiber fineness, uniformity index, seed index and lint index indicated preponderance of non-additive gene action in expression of these characters and suggested the scope for exploitation of hybrids for said traits. Predominant role of non-additive gene action for seed cotton yield and its component traits was also reported by Sawarkar *et al.* (2015) [15], Monicashree *et al.*

(2017) [11], Khokhar *et al.* (2018) [9], Roy *et al.* (2018) [14], Gnanasekaran *et al.* (2019) [4], Premalatha *et al.* (2020) [13], Hamed and Said (2021) [6], Chakholoma *et al.* (2022) [2].

The proportional contribution of lines, testers and their interactions towards the total variance are shown in Fig 1. Relative contribution of lines towards the total variance was higher for the trait days to 50% flowering, boll weight, ginning outturn, fiber fineness, fiber strength, seed index and lint index whereas, the testers showed their highest contribution for the trait days to 50% boll bursting and monopodia per plant. For the remaining traits *viz.*, plant height, sympodia per plant, bolls per plant, fiber length, uniformity index, lint yield per plant and seed cotton yield per plant, the highest contribution was exhibited by line × tester interactions.

General combining ability
The line which can be used as a parent in crossing programme for development of commercial hybrids is determined based on their good general combining ability effects. Combining ability of the parents may be considered as reliable guide for prediction of yield potential of a crosses. Estimates of general combining ability effects for different characters are presented in Table 2. Among the parents, five parents *viz.*, AHC-1, DB-1502, ABC-1, RHcb-1014 and GSB-45 were found good general combiners for seed cotton yield and its component traits. That's why they were recognized as good source of favourable genes for increasing seed cotton yield through various yield contributing characters. These parents having significant gca effects would be useful in crosses and subjected them to selection in segregating generations to identify desirable segregants having a high seed cotton yield with superior quality traits.

Parents AHC-50, AHC-1, AHC-26, DB-1502, RHcb-1014 and GSB-44 were considered good general combiners for days to 50% flowering while, the parents AHC-1, DB-1502, RHcb-1014 and GSB-44 were found good general combiners for days to 50% boll bursting. For plant height, the parents AHC-26, AHC-1, ARBB-27 and GSB-41 were good combiners whereas, G. Cot-20, AHC-50, DB-1502, GSB-44, GSB-45 and ABC-1 were observed as good general combiners for monopodia per plant. In case of sympodia per plant, the parents AHC-1, AHC-26, GSB-45, ABC-1 and DB-1502 were good general combiners and parents G. Cot-20, AHC-1, DB-1502, ABC-1 and RHcb-1014 were good combiners for bolls per plant. For boll weight, AHC-26, AHC-1, GSB-45 and GSB-41 recognized as good combiners while, parents AHC-50, G. Cot-20, GSB-43-1 and DB-1502 were good combiners for ginning outturn. The parents good general combiners for fiber fineness were G. Cot-12, GSB-41, GSB-43-1 and DB-1602 whereas for fiber strength, AHC-1, G. Cot-12, G. Cot-20, GSB-43-1, ARBB-27 and ABC-1 were good combiners. AHC-26, GSB-43-1 and ARBB-27 recognized as good combiners for fiber length while, AHC-1, ARBB-27 and GSB-44 were good general combiners for uniformity index. For seed index, AHC-26 and GSB-45 whereas, parents AHC-26, GSB-45 and GSB-43-1 were found good general combiners for lint index. With respect to lint yield per plant and seed cotton yield per plant, the parents AHC-1, DB-1502, RHcb-1014, ABC-1 and GSB-45 recognized as a good general combiner (Table 2). These results are in accordance with the reports of Sawarkar *et al.* (2015) [15], Monicashree *et al.* (2017) [11], Khokhar *et al.* (2018) [9], Roy *et al.* (2018) [14], Gnanasekaran *et al.* (2019) [4], Hibbiny *et al.* (2020) [7], Premalatha *et al.* (2020) [13], Gnanasekaran and Thiyagu (2021) [3], Hamed and Said (2021)

[6] and Chakholoma et al. (2022) [2] as they observed different parents with good general combiners for seed cotton yield and its component traits.

In general, it was evident from Table 3 that, the parents which were good general combiner for seed cotton yield viz., AHC-1, DB-1502, RHcb-1014, ABC-1 and GSB-45 were also good combiners for other yield component traits like days to 50% flowering, plant height, sympodia per plant, bolls per plant, boll weight, fiber strength, seed index and lint yield per plant. So, use of these lines as parents would be more rewarding for increasing seed cotton yield. It was further noted that involvement of these parents had resulted into hybrids expressing economic heterosis for various traits in majority of the cases.

Specific combining ability
Estimation of sca effects (Table 4) revealed that none of the hybrids was consistently and significantly superior for all the component traits. Out of 45 hybrids, nine hybrids depicted significantly positive sca effects for seed cotton yield per plant and bolls per plant, eight for lint yield per plant, fiber strength and boll weight, seven for ginning outturn and sympodia per plant, six for fiber length, five for seed index and plant height, four for lint index, one for uniformity index while, significantly negative sca effects exhibited by 10 and 6 hybrids for days to 50% flowering, monopodia per plant and days to 50% boll bursting, fiber fineness, respectively. These results are in agreement with the findings of Sawarkar et al. (2015) [15], Monicashree et al. (2017) [11], Murthy et al. (2018) [12], Roy et al. (2018) [14], Gnanasekaran et al. (2019) [4], Manonmani et al. (2020) [10], Premalatha et al. (2020) [13], Gnanasekaran and Thiyagu (2021) [3] and Chakholoma et al. (2022) [2].

Three superior cross combinations based on significantly positive sca effects for seed cotton yield per plant were AHC-26 × ARBB-27 (61.98), AHC-50 × GSB-44 (47.88) and AHC-1 × GSB-43-1 (46.38). Among these best hybrids, the hybrid AHC-26 × ARBB-27 also had significant and desirable sca estimates for days to 50% flowering, days to 50% boll bursting, bolls per plant, ginning outturn, fiber fineness, lint index and lint yield per plant. While, hybrid AHC-50 × GSB-44 recorded significant and desirable sca estimates for the characters bolls per plant and lint yield per plant whereas, the hybrid AHC-1 × GSB-43-1 also depicted significant and desirable sca effects for days to 50% boll bursting, bolls per plant and lint yield per plant. This appeared appropriate as yield being a complex trait and depends on a number of component traits. If these crosses further evaluated then there is good scope for identifying desirable cross combination for seed cotton yield and its component traits with superior fiber quality. Significant and positive sca effects for seed cotton yield and its component traits had also been reported by Roy et al. (2018) [14], Gnanasekaran et al. (2019) [4], Premalatha et al. (2020) [13], Hamed and Said (2021) [6] and Chakholoma et al. (2022) [2].

The highest significant sca effects in desired direction for various characters was exhibited by different hybrids viz., AHC-26 × GSB-45 for days to 50% flowering, AHC-26 × DB-1602 for days to 50% boll bursting, AHC-26 × ABC-1 for plant height, G. Cot-12 × GSB-44 for monopodia per plant, G. Cot-12 × RHcb-1014 for sympodia per plant, AHC-26 × ARBB-27 for bolls per plant and lint yield per plant, AHC-50 × DB-1602 for boll weight, G. Cot-20 × GSB-43-1 for ginning outturn and lint index, AHC-26 × GSB-41 for fiber fineness, AHC-26 × GSB-43-1 for fiber strength, G. Cot-12 × GSB-41 for fiber length, AHC-1 × DB-1602 for uniformity index and AHC-1 × GSB-45 for seed index.

Table 1: Analysis of variances (mean squares) for combining ability and estimates of variance components for various traits in cotton

No.	Sources of variation	df	DFF	DFBB	PH	MPP	SPP	BPP	BW	GOT
1	Replications	2	4.82	26.74	680.47	0.23	3.70	234.13**	0.08	1.75
2	Lines	4	278.50**	291.56**	2412.54**	3.77**	38.41**	423.44	2.71**	50.48**
3	Testers	8	91.68**	625.50**	1257.21**	4.82**	14.65	728.94*	0.36	12.13**
4	Lines × Testers	32	18.50**	73.48**	444.53**	1.05**	7.37**	294.18**	0.24**	2.57**
5	Error	118	3.32	14.21	223.46	0.08	1.69	43.86	0.04	1.15
6	σ^2_{gca}		7.93**	18.34**	66.21**	0.15**	0.91**	13.43**	0.06**	1.37**
7	σ^2_{sca}		5.06**	19.76**	73.69**	0.32**	1.89**	83.44**	0.07**	0.47**
8	$\sigma^2_{gca}/\sigma^2_{sca}$		1.57	0.93	0.90	0.48	0.48	0.16	0.92	2.89
9	σ^2_A		31.73	73.34	264.83	0.62	3.65	53.71	0.25	5.47
10	σ^2_D		20.24	79.03	294.76	1.30	7.58	333.76	0.27	1.89

Table 1 Cont…

No.	Sources of variation	df	FF	FS	FL	UI	SI	LI	LYPP	SCYPP
1	Replications	2	0.01	1.17	1.14	3.05	0.60	0.01	178.87	2996.33**
2	Lines	4	1.55**	27.18**	13.69*	3.57	40.22**	3.84**	664.59	6775.95
3	Testers	8	0.44**	7.46**	8.85	7.97**	3.10**	1.02**	946.66*	10885.33*
4	Lines × Testers	32	0.09**	2.73**	4.76**	2.03	0.52**	0.22**	383.83**	4323.12**
5	Error	118	0.02	0.61	0.71	1.87	0.24	0.11	59.60	625.48
6	σ^2_{gca}		0.04**	0.69**	0.31**	0.18**	1.01**	0.11**	20.09**	214.64**
7	σ^2_{sca}		0.02**	0.71**	1.35**	0.05	0.09**	0.04**	108.08**	1232.55**
8	$\sigma^2_{gca}/\sigma^2_{sca}$		1.95	0.98	0.23	3.32	10.76	2.77	0.19	0.17
9	σ^2_A		0.17	2.78	1.24	0.71	4.03	0.42	80.34	858.58
10	σ^2_D		0.09	2.83	5.39	0.21	0.37	0.15	432.31	4930.19

*, ** Significant at 0.05 and 0.01 levels of probability, respectively
(DFF – Days to 50% flowering, DFBB – Days to 50% boll bursting, PH – Plant height, MPP – Monopodia per plant, SPP – Sympodia per plant, BPP – Bolls per plant, BW – Boll weight, GOT – Ginning outturn, FF – Fiber fineness, FS – Fiber strength, FL – Fiber length, UI – Uniformity index, SI – Seed index, LI – Lint index, LYPP – Lint yield per plant, SCYPP – Seed cotton yield per plant)

Table 2: Estimates of general combining ability (gca) effects of parents for various traits in cotton

Parents	DFF	DFBB	PH	MPP	SPP	BPP	BW	GOT	FF	FS	FL	UI	SI	LI	LYPP	SCYPP
						Females										
AHC-1	-1.74**	-5.12**	6.59*	0.02	1.57**	2.67*	0.25**	-0.87**	-0.03	0.77**	-0.05	0.53*	0.12	-0.17**	5.43**	24.05**
G. Cot-12	0.59	1.55*	-12.97**	0.30**	-1.13**	-0.86	-0.30**	-1.27**	-0.37**	0.72**	-0.43**	-0.02	-0.08	-0.36**	-7.95**	-18.81**
G. Cot-20	5.22**	3.77**	5.06	-0.37**	-0.37	4.05**	-0.24**	0.46*	0.01	0.71**	-0.77**	-0.13	-0.31**	0.01	1.60	2.37
AHC-50	-3.11**	-0.53	-7.06*	-0.37**	-0.99**	0.34	-0.13**	2.16**	0.09**	-1.17**	0.14	0.09	-1.57**	-0.11	1.64	-8.13
AHC-26	-0.96**	0.33	8.38**	0.43**	0.91**	-6.19**	0.42**	-0.47*	0.29**	-1.03**	1.11**	-0.47	1.84**	0.63**	-0.73	0.53
S. Em. ±	0.35	0.73	2.88	0.05	0.25	1.27	0.04	0.21	0.03	0.15	0.16	0.26	0.09	0.06	1.49	4.81
Range Min.	-3.11	-5.12	-12.97	-0.37	-1.13	-6.19	-0.30	-1.27	-0.37	-1.17	-0.77	-0.47	-1.57	-0.36	-7.95	-18.81
Range Max.	5.22	3.77	8.38	0.43	1.57	4.05	0.42	2.16	0.29	0.77	1.11	0.53	1.84	0.63	5.43	24.05
						Males										
ABC-1	-0.82	-0.76	-4.62	-0.30**	0.85**	6.17**	0.01	-0.52	0.27**	0.57**	-0.57*	0.31	-0.07	-0.17*	5.48**	21.89**
ARBB-27	1.44**	4.64**	17.24**	-0.07	-0.25	1.65	0.05	-2.07**	0.12**	0.74**	1.01**	0.71*	0.11	-0.49**	-1.41	9.43
GSB-41	5.18**	11.18**	9.14*	0.54**	-1.01**	-11.40**	0.14**	-0.11	-0.28**	-0.78**	-0.37	-1.49**	0.09	0.001	-9.52**	-32.66**
GSB-43-1	0.78	2.64**	5.11	0.87**	-1.99**	2.85	-0.24**	0.97**	-0.20**	1.22**	1.31**	0.31	-0.09	0.24**	1.06	-1.63
GSB-44	-1.62**	-4.89**	-4.94	-0.45**	0.52	0.52	-0.05	0.41	0.10**	0.06	-0.13	0.71*	0.13	0.15	0.81	-0.23
GSB-45	-0.76	0.58	1.24	-0.45**	1.02**	-0.37	0.24**	-0.01	0.05	-0.16	-0.76**	0.11	1.00**	0.42**	4.23*	14.66*
DB-1502	-2.96**	-10.09**	-12.68**	-0.74**	0.82*	7.36**	0.04	0.78**	0.07	-0.70**	-0.91**	0.11	-0.69**	-0.09	9.40**	26.94**
RHcb-1014	-2.36**	-6.56**	-4.78	-0.09	-0.15	4.75**	0.02	0.30	-0.03	-0.62**	0.15	0.11	-0.15	0.01	5.55**	16.08*
DB-1602	1.11*	3.24**	-5.71	0.68**	0.20	-11.52**	-0.22**	0.26	-0.11**	-0.32	0.26	-0.89*	-0.32*	-0.07	-15.60**	-54.49**
S. Em. ±	0.47	0.97	3.86	0.07	0.34	1.71	0.05	0.28	0.04	0.20	0.22	0.35	0.13	0.08	1.99	6.46
Range Min.	-2.96	-10.09	-12.68	-0.74	-1.99	-11.52	-0.24	-2.07	-0.28	-0.78	-0.91	-1.49	-0.69	-0.49	-15.60	-54.49
Range Max.	5.18	11.18	17.24	0.87	1.02	7.36	0.24	0.97	0.27	0.74	1.31	0.71	1.00	0.42	9.40	26.94

*, ** Significant at 0.05 and 0.01 levels of probability, respectively

Table 3: Classification of parents with respect to general combining ability (gca) effects for various traits

Parents	DFF	DFBB	PH	MPP	SPP	BPP	BW	GOT	FF	FS	FL	UI	SI	LI	LYPP	SCYPP
						Females										
AHC-1	G	G	G	A	G	G	G	P	A	G	A	G	A	P	G	G
G. Cot-12	A	P	P	P	P	A	P	P	G	G	P	A	A	P	P	P
G. Cot-20	P	P	A	G	A	G	P	G	A	G	P	A	P	A	A	A
AHC-50	G	A	P	G	P	A	P	G	P	P	A	A	P	A	A	A
AHC-26	G	A	G	P	G	P	G	P	P	P	G	A	G	G	A	A
						Males										
ABC-1	A	A	A	G	G	G	A	A	P	G	P	A	A	P	G	G
ARBB-27	P	P	G	A	A	A	A	P	P	G	G	G	A	P	A	A
GSB-41	P	P	G	P	P	P	G	A	G	P	A	P	A	A	P	P
GSB-43-1	A	P	A	P	P	A	P	G	G	G	G	A	A	G	A	A
GSB-44	G	G	A	G	A	A	A	A	P	A	A	G	A	A	A	A
GSB-45	A	A	A	G	G	A	G	A	A	A	P	A	G	G	G	G
DB-1502	G	G	P	G	G	G	A	G	A	P	P	A	P	A	G	G
RHcb-1014	G	G	A	A	A	G	A	A	A	P	A	A	A	A	G	G
DB-1602	P	P	A	P	A	P	P	A	G	A	A	P	P	A	P	P

G: Good combiner **A:** Average combiner **P:** Poor combiner

Table 4: Estimation of specific combining ability (sca) effects of hybrids for yield and its component traits

Hybrids	DFF	DFBB	PH	MPP	SPP	BPP	BW	GOT
L1 × T1	2.01	4.39*	-0.88	-0.36*	-0.62	-13.24**	-0.21	0.43
L1 × T2	-0.26	-0.35	11.01	-0.63**	0.95	-15.32**	-0.10	0.37
L1 × T3	-2.99**	-3.88	-3.86	0.33*	0.04	1.87	0.22*	-0.12
L1 × T4	-0.59	-5.35*	-13.36	0.60**	0.23	13.68**	-0.02	-0.54
L1 × T5	0.47	0.52	-5.71	0.25	-2.01**	-7.85*	-0.12	-0.09
L1 × T6	0.94	-0.95	17.18*	0.51**	1.90*	10.04**	0.02	0.29
L1 × T7	0.47	2.39	1.34	0.08	-0.45	9.77*	0.22*	-0.46
L1 × T8	-0.13	-0.81	-5.94	-0.29	-1.55*	5.52	-0.03	0.54
L1 × T9	0.07	4.05	0.21	-0.48**	1.51*	-4.48	0.01	-0.41
L2 × T1	0.67	-0.28	-17.17*	-0.72**	0.15	-7.38	0.22*	-0.37
L2 × T2	0.74	-1.68	-9.49	0.32	0.78	1.14	0.21	-0.65
L2 × T3	3.01**	5.12*	-14.77	0.05	-2.66**	1.53	0.03	1.24*
L2 × T4	-3.26**	-2.68	-6.91	1.18**	-1.27	11.01**	0.12	-1.61*
L2 × T5	0.14	3.19	9.76	-1.30**	0.42	-2.99	0.03	1.31*
L2 × T6	-0.73	-2.28	4.40	-0.22	-1.08	1.43	0.04	-0.25
L2 × T7	-0.19	-0.95	17.94*	-0.34*	0.44	-2.30	-0.27*	1.23*
L2 × T8	-0.46	-3.15	18.77*	0.07	3.69**	-2.35	-0.16	0.22

L2 × T9	0.07	2.72	-2.52	0.97**	-0.46	-0.09	-0.23*	-1.13
L3 × T1	1.38	8.83**	1.19	0.30	1.05	2.98	0.63**	-0.34
L3 × T2	1.78	4.10	10.57	0.33*	-0.25	1.10	0.03	-0.91
L3 × T3	-2.62*	-4.10	10.03	-0.28	-0.35	2.35	0.06	-1.14
L3 × T4	2.44*	-1.90	10.82	-0.61**	-1.10	7.63*	0.09	1.63**
L3 × T5	-3.16**	-4.04	7.92	-0.03	0.79	-7.97*	-0.09	-0.10
L3 × T6	2.98**	-0.50	-10.66	-0.29	1.52*	-9.21*	-0.07	0.42
L3 × T7	-2.16*	-0.50	-13.77	0.94**	-0.31	-5.21	-0.11	-0.46
L3 × T8	-3.09**	-5.37*	-13.08	-0.06	-1.21	-5.60	0.04	-0.34
L3 × T9	2.44*	3.50	-3.02	-0.29	-0.15	13.94**	-0.59**	1.23*
L4 × T1	-3.62**	-8.54**	-7.36	0.83**	-0.83	11.89**	-0.42**	0.36
L4 × T2	0.44	2.39	-9.83	0.00	-1.36	-2.79	-0.18	-0.42
L4 × T3	-2.96**	-3.81	-0.39	-0.01	3.41**	4.99	-0.11	1.26*
L4 × T4	0.78	4.73*	5.58	-0.88**	1.92*	-14.39**	0.12	0.66
L4 × T5	2.18*	2.26	-7.54	0.64**	-0.72	12.81**	-0.04	-0.35
L4 × T6	1.31	5.46*	-9.21	-0.03	-1.88*	-1.10	-0.22*	-1.13
L4 × T7	2.18*	-0.54	2.44	-0.20	0.45	-4.97	-0.06	-0.61
L4 × T8	1.24	-0.74	7.80	0.28	-1.85*	6.05	0.11	0.17
L4 × T9	-1.56	-1.21	18.52*	-0.63**	0.87	-12.49**	0.82**	0.06
L5 × T1	-0.44	-4.39*	24.23**	-0.05	0.25	5.75	-0.21	-0.07
L5 × T2	-2.70*	-4.46*	-2.26	-0.01	-0.12	15.87**	0.03	1.61*
L5 × T3	5.56**	6.67**	8.98	-0.09	-0.44	-10.74**	-0.20	-1.24*
L5 × T4	0.63	5.21*	3.87	-0.29	0.23	-17.93**	-0.31**	-0.14
L5 × T5	0.36	-1.93	-4.42	0.43**	1.52*	6.01	0.22*	-0.78
L5 × T6	-4.50**	-1.73	-1.71	0.03	-0.46	-1.17	0.22*	0.67
L5 × T7	-0.30	-0.39	-7.96	-0.47**	-0.13	2.70	0.22*	0.29
L5 × T8	2.43*	10.07**	-7.55	0.00	0.92	-3.62	0.04	-0.58
L5 × T9	-1.04	-9.06**	-13.18	0.44**	-1.77*	3.11	-0.01	0.24
S. Em. ±	1.05	2.18	8.63	0.16	0.75	3.82	0.11	0.62
Range								
Minimum	-4.50	-9.06	-17.17	-1.30	-2.66	-17.93	-0.59	-1.61
Maximum	5.56	10.07	24.23	1.18	3.69	15.87	0.82	1.63
Signi. cross	18	14	06	21	13	18	14	09
Positive	08	08	05	11	07	09	08	07
Negative	10	06	01	10	06	09	06	02

*, ** Significant at 0.05 and 0.01 levels of probability, respectively

Table 4 Cont…

Hybrids	FF	FS	FL	UI	SI	LI	LYPP	SCYPP
L1 × T1	-0.07	-0.10	0.01	0.47	-0.62*	-0.13	-16.36**	-59.01**
L1 × T2	-0.02	-0.37	0.63	0.07	-0.43	-0.07	-17.00**	-63.10**
L1 × T3	0.18*	-0.25	-4.48**	-0.73	0.23	0.06	3.58	13.98
L1 × T4	0.00	-0.45	0.63	0.47	-0.01	-0.17	12.58**	46.38**
L1 × T5	0.10	0.20	0.97*	0.07	-0.07	-0.05	-10.69*	-35.59*
L1 × T6	-0.05	0.03	1.21*	-0.33	0.75**	0.38*	12.74**	43.13**
L1 × T7	-0.27**	-0.23	-0.05	-1.33	0.16	-0.05	10.98*	42.54**
L1 × T8	0.03	-0.41	0.59	-0.33	-0.07	0.12	8.38	25.50
L1 × T9	0.11	1.59**	0.49	1.67*	0.06	-0.09	-4.20	-13.85
L2 × T1	-0.13	0.45	-0.01	1.02	-0.13	-0.13	-4.15	-11.47
L2 × T2	0.01	-0.12	-0.99*	0.62	0.57*	0.05	1.57	11.23
L2 × T3	0.22**	-1.30**	2.50**	-0.18	-0.21	0.23	5.37	11.09
L2 × T4	0.10	-0.60	-0.39	-0.98	-0.32	-0.55**	9.33*	42.50**
L2 × T5	-0.06	-0.04	0.15	0.62	-0.28	0.24	-2.18	-14.63
L2 × T6	0.09	0.28	-0.22	1.22	-0.02	-0.11	0.55	3.08
L2 × T7	0.07	0.92*	0.03	0.22	-0.11	0.28	-4.18	-21.55
L2 × T8	-0.13	-0.26	-1.03*	-0.78	0.34	0.21	-4.87	-17.58
L2 × T9	-0.15	0.64	-0.04	-1.78*	0.17	-0.21	-1.45	-2.66
L3 × T1	-0.01	-2.14**	0.03	-0.87	0.65*	0.19	11.66*	42.21**
L3 × T2	0.03	0.59	-0.05	0.73	0.22	-0.15	-0.44	5.90
L3 × T3	0.24**	0.51	1.00*	-0.07	0.23	-0.20	2.08	15.09
L3 × T4	-0.05	0.31	0.15	0.13	0.01	0.44*	13.28**	29.63*
L3 × T5	-0.17*	0.90*	0.99*	-0.27	-0.06	-0.04	-9.94*	-32.50*
L3 × T6	-0.09	-0.51	-2.68**	-0.67	-1.21**	-0.41*	-9.65*	-35.77*
L3 × T7	-0.11	0.93*	0.07	0.33	0.05	-0.11	-7.96	-24.31
L3 × T8	-0.01	0.25	0.01	0.33	0.06	-0.06	-5.41	-15.65
L3 × T9	0.17*	-0.85	0.50	0.33	0.05	0.34	6.39	15.39

L4 × T1	0.11	0.90*	-0.68	-0.09	-0.25	-0.03	4.61	11.33
L4 × T2	0.16	0.67	0.54	-0.49	-0.45	-0.26	-5.09	-16.02
L4 × T3	-0.17*	1.59**	0.03	0.71	0.06	0.39*	7.26	18.53
L4 × T4	0.08	-1.21**	0.74	-0.09	0.34	0.31	-11.83**	-40.26**
L4 × T5	-0.02	-0.46	-0.62	-0.49	-0.14	-0.15	14.46**	47.88**
L4 × T6	-0.07	0.37	0.72	-0.89	0.65*	0.01	-5.26	-11.56
L4 × T7	0.11	-0.79	0.06	0.11	-0.07	-0.23	-5.58	-16.36
L4 × T8	0.01	0.03	-0.20	1.11	-0.02	0.02	6.11	17.41
L4 × T9	-0.21*	-1.07*	-0.60	0.11	-0.12	-0.06	-4.68	-10.94
L5 × T1	0.11	0.90*	0.65	-0.53	0.35	0.10	4.25	16.94
L5 × T2	-0.18*	-0.77	-0.13	-0.93	0.10	0.43*	20.96**	61.98**
L5 × T3	-0.47**	-0.55	0.96	0.27	-0.32	-0.48*	-18.29**	-58.70**
L5 × T4	-0.13	1.95**	-1.13*	0.47	-0.02	-0.03	-23.35**	-78.25**
L5 × T5	0.15	-0.60	-1.49**	0.07	0.56*	0.01	8.34	34.84*
L5 × T6	0.13	-0.17	0.98*	0.67	-0.17	0.13	1.63	1.13
L5 × T7	0.21*	-0.83	-0.11	0.67	-0.02	0.11	6.73	19.67
L5 × T8	0.11	0.39	0.63	-0.33	-0.32	-0.28	-4.21	-9.68
L5 × T9	0.09	-0.31	-0.34	-0.33	-0.16	0.01	3.94	12.06
S. Em. ±	0.08	0.45	0.49	0.79	0.28	0.19	4.46	14.44
Range								
Minimum	-0.47	-2.14	-4.48	-1.78	-1.21	-0.55	-23.35	-78.25
Maximum	0.24	1.95	2.50	1.67	0.75	0.44	20.96	61.98
Signi. cross	11	12	12	02	07	07	16	17
Positive	05	08	06	01	05	04	08	09
Negative	06	04	06	01	02	03	08	08

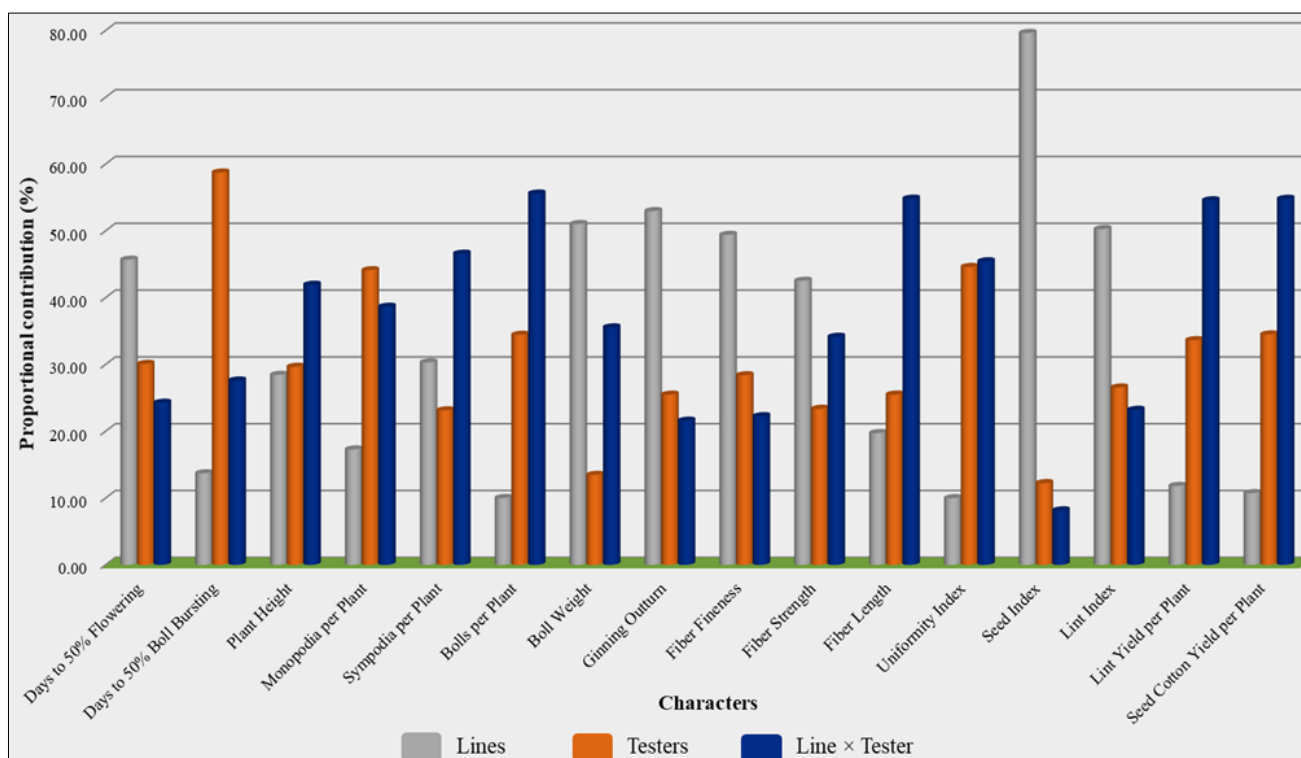*, ** Significant at 0.05 and 0.01 levels of probability, respectively

Fig 1: Proportional contribution of lines, testers and their interactions toward the total variance
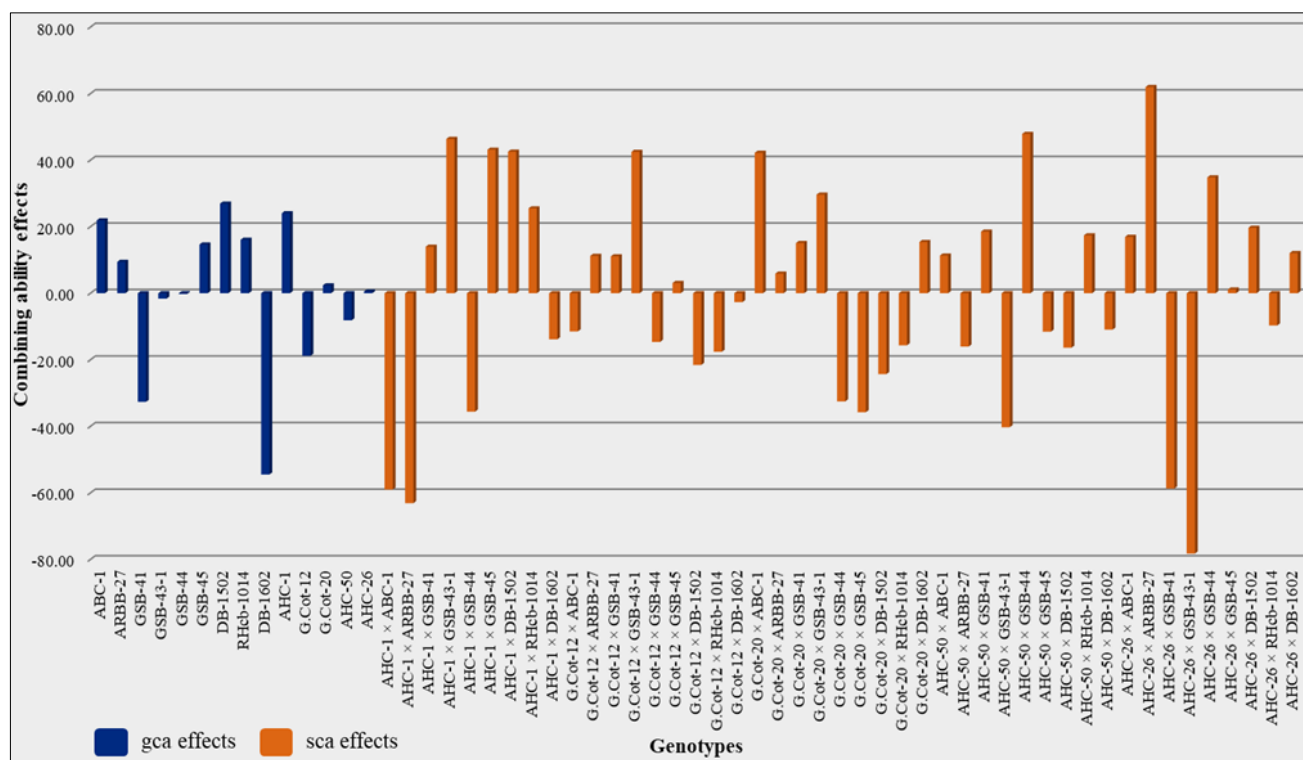
Fig 2: GCA effect of parents and SCA effect of hybrids for seed cotton yield per plant

Conclusions

The hybrids of parental lines having desirable gca effects for various attributes may be advanced for identification of desirable transgressive segregants in segregating generations. Looking to the significance of both additive and non-additive gene effects for seed cotton yield per plant and majority of yield components, it is suggested that initial selection of parents could be done on the basis of *per se* performance and gca effects and then biparental mating or recurrent selection should be employed so that both additive as well as non-additive gene effects could be exploited simultaneously for further improvement of the traits in the population. However, considering the predominance of non-additive gene effects and for seed cotton yield and some of its component traits emphasizing that the exploitation of hybrid vigour on commercial scale through development of hybrids could be viable and profitable option.

Acknowledgement

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