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Nilesh Parmar
Hybrid Cotton Section, Main Cotton Research Station, Navsari Agricultural University, Surat, Gujarat, India

GO Faldu
Hybrid Cotton Section, Main Cotton Research Station, Navsari Agricultural University, Surat, Gujarat, India

AO Sanghani
Hybrid Cotton Section, Main Cotton Research Station, Navsari Agricultural University, Surat, Gujarat, India

Ritaben R Patel
Department of Genetics and Plant Breeding, N. M. College of Agriculture, N.A.U., Navsari, Gujarat, India

HR Ramani
Hybrid Cotton Section, Main Cotton Research Station, Navsari Agricultural University, Surat, Gujarat, India

Corresponding Author:
AO Sanghani
Hybrid Cotton Section, Main Cotton Research Station, Navsari Agricultural University, Surat, Gujarat, India

Determination of gene action and combining ability for yield, its Attributes, Fiber quality and biochemical parameter in upland cotton [*Gossypium hirsutum* (L.)]

Nilesh Parmar, GO Faldu, AO Sanghani, Ritaben R Patel and HR Ramani

Abstract
The prime objective of this study was to the estimate the general combining ability of the parents and specific combining ability of hybrids for the development of high yielding cultivars in cotton (Gossypium *hirsutum* L.). A line x tester analysis was carried out by using three Bt parental lines and ten testers and their resulting 30 hybrids along with one check during *kharif*, 2020. Randomized block design with three replications. Whereas, both GCA and SCA variances were found significant for bolls per plant, ginning outturn, seed index, which indicated that both additive as well as non-additive types of gene actions were important in the inheritance of these traits. The estimates of GCA effects of parents indicated that the GSHV 95/216, SCS 1062, BB-1 and GTHV 02/45 were good general combiner. The crosses G. ot 16 BG II x GSHV 172, G. Cot 16 BG II x GTHV 02/45, BC 68-2 BG II x GTHV 02/45, G. Cot 10 BG II x GSHV 95/216 and G. Cot 10 BG II x H 1452 were found promising hybrids having high SCA effects for seed cotton yield per plant.

Keywords: Cotton, general and specific combining ability, line x tester, gene action

Introduction
Cotton is one of the most important and major fiber crop and has a proud place among the cash crop exercising significant influence on economics and social affairs of the world from the earliest times. Cotton possessing great importance as a multipurpose crop like fiber, oil, and protein yielding crop of global significance and that supplies five basic products seed, lint, oil, hulls and linters. Cotton breeders mainly emphasized on to develop cultivars in early maturity, high yield and good fiber quality traits. Knowledge of combining ability plays an important role in selection of parents for exploitation of hybrid and transgressive expression. Combining ability studies also explain nature and magnitude of gene action. Generally, the selection of parents based on combining ability as well as the *per se* performance but in the presence of non-additive gene action *per se* performance may not produce desirable hybrids. In this context combining ability play important role for parental selection. Line x tester analysis is the simplest method for identification of parents and hybrids by GCA and SCA, respectively and further evaluate heterotic effect for direct exploitation or whether isolate transgressive sergeant from subsequent generation.

Materials and Methods
The present experiment was carried out during *kharif* 2020 using thirteen different genotypes of cotton at Main Cotton Research Station, Navsari Agricultural University, Surat. The experimental materials comprised of thirteen diverse genotypes of cotton including three female Bt parents *viz*., G. Cot 10 BG II, G.Cot 16 BG II, BC 68-2 BG II as well as ten male parents *viz*., GSHV 95/216, GTHV 02/45, GJHV 152, H 1452, BWR 25, GSHV 172, SCS 1062, GSHV 213, BB-1, TCH 1705 and their 30 crosses (line x tester) along with G.Cot Hy-10 BG II as standard check. Thirty hybrids were obtained during kharif, 2019 from Main Cotton Research Station, Navsari Agricultural University, Surat using three females and ten diverse pollinators in a line x tester mating design. The hybrid (F_1) seeds were produced by Dock's (1934) method. One plant of each parent was also selfed to obtain selfed parental seeds used for final evaluation. All the F_1's and selfed seeds of parents were stored properly in seed packets for sowing in the next season. Five random competitive representative plants, excluding border plant, of each genotype in each replication were selected to record the observation for various characters as described below.

The phenological characters *viz*., days to 50% flowering, sympodia per plant, bolls per plant, boll weight (g), seed cotton yield per plant (g), ginning outturn (%), seed index (g), fiber length (mm), fiber strength (g/tex), fiber fineness (mv), oil content (%), gossypol content (mg/100g), protein content (mg/g), phenol content (%) and proline content (mg/g). The average value of data from these plants was computed and used for statistical analysis.

Results and Discussion

The concept of combining ability is becoming increasingly important in plant breeding, it provides guidelines for an early assessment of the relative breeding worth of the parental material. Utilizing this technique, the breeder can choose the best general combining parents as well as specific cross combinations for further exploitation. The GCA is attributed to additive genetic effects which are theoretically fixable. On the other hand, SCA attributed to non-additive gene action may be due to dominance, additive x dominance and dominance x dominance or higher order gene interaction and is unfixable.

Analysis of variance

Analysis of variance for combining ability for all the characters was presented in Table 1. According to the line x tester analysis proposed by Kempthorne (1966) [21].

The estimated variances due to line σ^2l significant for ginning outturn. Whereas estimated variances due to line σ^2m were significant for seed index. The estimates of σ^2 gca were significant for bolls per plant, ginning outturn, seed index, gossypol content and other traits was non-significant. The significant values for gca variances were also noted by Patel *et al*. (2012) [22] for bolls per plant, boll weight, seed cotton yield and ginning outturn; Sawarkar *et al*. (2015) [23] for days to 50% flowering, boll weight, fiber Strength, fiber fineness and oil content; Roy *et al*. (2018) [16] for bolls per plant, boll weight, seed cotton yield, ginning outturn and seed index; for a number of bolls per plant, boll weight and seed cotton yield per plant. The estimates of σ^2 sca were significant for all the characters. The ratio of σ^2 gca /σ^2 sca revealed that all the characters manifested values less than unity, which indicates importance of dominant variance. The estimates of components of variances (GCA and SCA) and their ratio (σ^2 gca/σ^2 sca) indicated that both additive and non-additive variances were important in inheritance of those traits. However, the variance due to SCA was higher in magnitude than their respective GCA variances indicating preponderance of non-additive gene effects for all the characters. Almost similar results have been reported by Sawarkar *et al*. (2014) [23] for analysis of variance for combining ability indicated the predominance of non-additive gene action for all the characters under study except plant height, 2.5% span length and oil content. For all the characters were higher SCA variance than their respective GCA variance. Similar results have been repoted by Basal *et al*. (2011) [4], Patel *et al*. (2012) [22], Usharani *et al*. (2016) [18], Makhdoom *et al*. (2019) [13], Udaya and Patil (2020) [17], Gnanasekaran and Thiyagu (2021) [9].

General combining ability (GCA) and Specific combining ability (SCA) effects The GCA and SCA effects of parents and their crosses for different yield contributing traits were presented in Table 2 and Table 3, respectively. The combining ability provides useful information for the choice of parents in terms of expected performance of the hybrids and progenies (Dhillon, 1975). Combining ability also useful in deciding breeding methodology aiming at exploitation of fixable (additive) and nonfixable (non-additive) genetic variances.

Days to 50% flowering

Estimate of GCA effects revealed that among the three lines, none of the female parents showed negative and significant gca effect for days to 50% flowering. Out of ten testers one tester BWR 25 (-2.00) showed significant and negative gca effect for days to 50% flowering. A perusal of SCA effects estimation of days to 50% flowering for hybrids ranged between -2.47 (GCot 10 BG II x GSHV 213) to 2.63 (GCot 10 BG II x BWR 25). Out of thirty crosses, only three crosses *viz*., GCot 10 BG II x GSHV 213 (-2.47), BC 68-2 BG II x SCS 1062 (-2.07) and G Cot 16 BG II x GSHV 95/216 (-2.00) had significant and negative sca effects, which is desirable for earliness.

Sympodia per plant

Among parents, the magnitude of GCA effects none of the lines exhibited significant and positive gca effect for sympodia per plant. But two testers named by BB-1 (1.33) and H 1452 (1.04) were good general combiners as they exhibited and significant and positive gca effect for sympodia per plant. Among crosses magnitude of SCA varied from -3.68 (GCot 10 BG II x GSHV 95/216) to 3.17 (GCot 10 BG II x SCS 1062). Out of thirty crosses, only five crosses showed significant and positive SCA effects for number of sympodia per plant.

Bolls per plant

The GCA effects for number of bolls per plant was observed for one male parent GCot 10 BG II (1.46) and one female GTHV 02/45 (20.36) were identified as good general combiners as they expressed significant positive gca effect for bolls per plant. Hybrids varied in the estimates of sca effects from -9.75 (GCot 16 BG II x GSHV 95/216) to 11.73 (GCot 16 BG II x GTHV 02/45). Significant and positive sca estimates for number of bolls per plant was recorded by eight crosses.

Boll weight (g)

The significant and positive gca effects were recorded by female GCot 16 BG II (0.17) and males GSHV 95/216 (0.22), GJHV 152 (0.25), SCS 1062 (0.12), BB-1 (0.40) and BWR 25 (0.15). An examination of SCA estimation for boll weight the value fluctuated from -0.90 (BC 68-2 BG II x GSHV 172) to 0.61 (BC 68-2 BG II x BWR 25). Out of thirty hybrids, only ten hybrids exhibited significant and positive SCA effect.

Seed cotton yield per plant (g)

A perusal of GCA estimates of seed cotton yield per plant for parents ranged from -23.44 (BWR 25) to 67.23 (GTHV 02/45). Out of three lines, none of the showed significant and positive gca effect for seed cotton yield per plant. While from ten male parents, GTHV 02/45 (67.23), GSHV 95/216 (20.85) and SCS 1062 (15.81) showed positive significant gca effect for seed cotton yield per plant. A perusal of SCA effect, it ranged between -72.48 (GCot 10 BG II x GTHV 02/45) and 47.29 (GCot 16 BG II x GSHV 172). Out of thirty hybrids, eight hybrids showed significant and positive SCA effects for seed cotton yield per plant.

Ginning outturn (%)
The results of ginning outturn revealed that among thirteen parents, one lines GCot 10 BG II (1.18) showed significant and positive gca effect for ginning outturn, In case of ten testers, the four testers SCS 1062 (2.01), GTHV 02/45 (0.81), GSHV 95/216 (0.74) and GSHV 213 (0.56) identified as good general combiners and positive significant for ginning outturn. The spectrum of difference in SCA effects ranged from -2.40 (GCot 16 BG II x H 1452) to 1.90 (BC 68-2 BG II x H 1452). Out of thirty hybrids, five hybrids showed significant and positive SCA effects for ginning outturn.

Seed index (g): The magnitude of gca effects varied from -1.04 (H 1452) to 0.63 (BB-1). Only one line G.Cot 16 BG II (0.21) and four testers *viz*., BB-1 (0.66), GJHV 152 (0.63), GSHV 95/216 (0.63) and GTHV 02/45 (0.42) emerged as good general combiners for incorporating bold seed size. The spectrum of difference in SCA effects were ranged from -1.41 (GCot 16 BG II x GSHV 95/216) to 0.77 (GCot 10 BG II x GSHV 95/216). Out of thirty hybrids, one hybrid GCot 10 BG II x GSHV 95/216 showed significant and positive SCA effects for seed index.

Fiber length (mm): The general combining ability effects of parents for fiber length ranged from -0.97 (BWR 25) to 0.86 (BB-1). The parent GCot 10 BG II (0.38) showed significant and positive gca effect for fiber length. Out of ten testers, two testers BB-1 (0.86) and GJHV 152 (0.52) showed significant and positive GCA effects among the parents. Specific combining ability effect ranged from -1.67 (GCot 16 BG II x GSHV 172 to 2.78 (BC 68-2 BG II x GSHV 172). Three hybrids, BC 68-2 BG II x GSHV 172 (2.78), GCot 16 BG II x BWR 25 (0.99) and GCot 10 BG II x GSHV 213 (0.95) showed significant and positive SCA effects for fiber length.

Fiber strength (g/tex)
The general combining ability effects of parents for fibre strength ranged from -1.15 (BWR 25) to 1.01 (GSHV 95/216). One line G Cot 10 BG II (0.50) showed significant and positive gca effects, on other hand three testers *viz*., GSHV 95/216 (1.01), GJHV 152 (0.61) and SCS 1062 (0.55) exhibited significant positive gca effects. Specific combining ability effect ranged from -1.95 (GCot 16 BG II x GSHV 172) to 2.05 (BC 68-2 BG II x GSHV 172). Six hybrids showed significant and positive SCA effect for fiber strength.

Fiber fineness (mv)
Fiber fineness values in the range of 3.5 to 4.5 mv are more preferable than higher or lower value of fiber fineness. An examination of GCA estimates revealed that data ranged from -0.15 (H 1452) to 0.21 (GSHV 95/216). None of the lines and testers displayed significant and negative GCA effect for fiber fineness. From examination of SCA estimation data ranged from -0.68 (BC 68-2 BG II x GSHV 95/216) to 0.54 (G Cot 10 BG II x GSHV 95/216). Two hybrids *viz*., BC 68-2 BG II x GSHV 95/216 (0.68) and GCot 10 BG II x BB-1 (-0.63) displayed significant and negative SCA effect for fiber fineness.

Oil content (%)
Positive values for the combining ability effects are preferred for this trait. An examination of GCA estimates revealed that data ranged from -0.41 (GTHV 02/45) to 0.27 (TCH 1705). In lines and testers, none of the showed significant and positive GCA effect for oil content. An examination of sca effects of crosses revealed that one cross BC 68-2 BG II x H 1452 (1.14) exhibited highly significant and positive sca effects for oil content. The estimates of sca effects for oil content varied from -0.86 (G Cot 16 BG II x H 1452) to 1.14 (BC 68-2 BG II x H 1452).

Gossypol content (mg/100g)
Negative value for the combining ability effect is preferred when gossypol derived from seeds. One line BC 68-2 BG II (-5.50) showed significant and negative GCA for gossypol content. Whereas three testers *viz*., TCH 1705 (-6.47), GSHV 213 (-4.75) and BB-1 (-2.25) showed significant and negative GCA for gossypol content. From examination of SCA estimation data ranged from -16.64 (BC 68-2 BG II x BB-1) to 17.60 (BC 68-2 BG II x GSHV 172). Twelve hybrids displayed significant and negative SCA effect for gossypol content.

Protein content (mg/g)
Positive values for the combining ability effects are preferred for this trait. An examination of GCA estimates revealed that data ranged from -2.82 (SCS 1062) to 3.60 (H-1452). In lines not anyone showed significant and positive GCA effect and in testers H-1452 (3.60), BB-1 (2.64) and GSHV 95/216 (1.04) showed significant and positive GCA effect for protein content. An examination of sca effects of crosses revealed that eleven crosses exhibited highly significant and positive sca effects for protein content. The estimates of sca effects for protein content varied from -4.80 (GCot 16 BG II x GSHV 213) to 5.13 (GCot 10 BG II x SCS 1062).

Phenol content (%)
Out of three lines, only one female G.Cot 16 BG II (0.01) had significant and positive GCA effect for phenol content. In case of testers, three testers *viz*., SCS 1062 (0.05), GSHV 95/216 (0.04) and GTHV 02/45 (0.04) were identified as good general combiners for this trait as they had significant and positive gca effect for phenol content. Out of 30 crosses, 10 crosses reported the highest positive sca effect by the cross GCot 10 BG II x GTHV 02/45 (0.13) followed by GCot 16 BG II x SCS 1062 (0.09), G Cot 10 BG II x GSHV 95/216 (0.05), BC 68-2 BG II x GSHV 213 (0.05).

Proline content (mg/g)
Out of three females, none of the female was significant and positive GCA effect for proline content. In case of testers, five testers *viz*., GSHV 95/216 (0.27), GSHV 172 (0.26), BB-1 (0.18), H 1452(0.17) and SCS 1062 (0.14) were identified as good general combiners for this trait as they had significant and positive gca effect for proline content. Out of 30 crosses, 9 crosses reported the highest significant and positive sca effect.

Table 1: Mean sum of square for combining ability and variance components for different characters in *G. hirsutum* L.

Source of variation	df	Days to 50% flowering	Sympodia per plant	Bolls per plant	Boll weight (g)	Seed cotton yield per plant (g)	Ginning outturn (%)	Seed index (g)
Replications	2	3.63	0.83	17.07	0.00	208.62	0.25	0.82
Hybrids	29	9.26**	10.64**	352.11**	0.67**	4550.91**	8.74**	2.22**
Line effect	2	0.03	10.10	59.91	0.84	772.95	45.63**	1.24
Tester effect	9	12.86	11.23	587.40	0.69	7129.96	8.61	4.18*
Line x Tester effect	18	8.49**	10.40**	266.93**	0.64**	3681.16**	4.70**	1.35**
Error	58	2.59	1.58	15.39	0.03	179.49	0.49	0.33
σ^2_l		-0.08	0.28	1.48	0.03	19.78	1.50**	0.03
σ^2_m		1.14	1.07	63.55	0.07	772.27	0.90	0.43*
σ^2_{gca}		0.19	0.46	15.81*	0.04	193.43	1.36**	0.12**
σ^2_{sca}		1.97**	2.93**	83.85**	0.20**	1167.22**	1.40**	0.34**
$\sigma^2_{gca}/\sigma^2_{sca}$		0.10	0.16	0.19	0.18	0.16	0.97	0.36

Table 1: Continue…….

Source of variation	df	Fiber length (mm)	Fiber strength (g/tex)	Fiber fineness (mv)	Oil content (%)	Gossypol content (mg/100g)	Protein content (mg/g)	Phenol content (%)	Proline content (mg/g)
Replications	2	0.56	5.47**	0.88*	0.09	1.68	5.70**	0.00	0.001
Hybrids	29	3.22**	5.35**	0.34	0.66*	494.67**	32.97**	0.01**	0.59**
Line effect	2	4.11	13.12	0.10	0.77	907.45	1.55	0.01	0.02
Tester effect	9	2.69	5.78	0.16	0.34	460.35	37.45	0.01	0.56
Line x Tester effect	18	3.39**	4.27**	0.47*	0.81**	465.97**	34.23**	0.01**	0.67**
Error	58	0.62	0.55	0.23	0.35	1.36	0.62	0.00	0.02
σ^2_l		0.12	0.42	0.00	0.01	30.20	0.03	0.00	0.00
σ^2_m		0.23	0.58	-0.01	0.00	51.00	4.09	0.00	0.06
σ^2_{gca}		0.14	0.46	-0.01	0.01	35.00*	0.97	0.00	0.01
σ^2_{sca}		0.92**	1.24**	0.08*	0.15**	154.87**	11.20**	0.003**	0.22**
$\sigma^2_{gca}/\sigma^2_{sca}$		0.15	0.37	-0.07	0.07	0.23	0.09	0.15	0.06

* and ** indicates significance at 5% and 1% levels of probability, respectivel

Table 2: General combining ability effect of parents for different characters in *G. hirsutum* L.

Sr. No.	Parents	Days to 50% flowering	Sympodia per plant	Bolls per plant	Boll weight(g)	Seed cotton yield per plant(g)	Ginning outturn (%)	Seed index (g)
Lines								
1	G Cot 10 BG II	0.03	-0.53*	1.47*	-0.16**	0.38	1.19**	-0.19
2	G Cot 16 BG II	0.00	0.62	-0.12	0.17**	4.87	0.09	0.22*
3	BC 68-2 BG II	-0.03	-0.09	-0.35	-0.01	-5.26*	-1.27**	-0.03
	SE(g_i)	0.29	0.23	0.72	0.03	2.45	0.13	0.10
Testers								
1	GSHV 95/216	0.33	0.72	2.54	0.23**	20.86**	0.75**	0.63**
2	GTHV 02/45	2.33**	-0.19	20.37**	-0.28**	67.23**	0.81**	0.42*
3	GJHV 152	-0.78	-0.98*	-7.37**	0.25**	-21.16**	-0.89**	0.63**
4	H 1452	-0.33	1.04*	-1.91	-0.29**	-18.78**	-0.75**	-1.05**
5	GSHV 172	0.00	0.43	-0.99	-0.42**	-13.97**	-0.77**	-0.68**
6	SCS 1062	-0.89	0.83	2.13	0.12*	15.82**	2.01**	0.35
7	GSHV 213	0.44	-0.43	0.40	0.01	0.88	0.57*	-0.22
8	BB-1	-0.33	1.33**	-7.28**	0.40**	-14.77**	-0.48*	0.67**
9	BWR 25	-2.00**	-2.38	-6.97**	0.15**	-23.44**	-0.83**	-0.98**
10	TCH 1705	1.22*	-0.38	-0.90	-0.17**	-12.66**	-0.41	0.21
	SE(g_j)	0.54	0.42	1.31	0.05	4.46	0.23	0.19

Tables 2: Continue…….

Sr. No.	Parents	Fiber length (mm)	Fiber strength (g/tex)	Fiber fineness (mv)	Oil content (%)	Gossypol content (mg/100g)	Protein content (mg/g)	Phenol content (%)	Proline content (mg/g)
Lines									
1	G Cot 10 BG II	0.38*	0.50**	0.06	-0.12	0.02	-0.26	-0.01**	-0.03
2	G Cot 16 BG II	-0.36*	-0.75**	-0.05	-0.06	5.49**	0.17	0.02**	0.03
3	BC 68-2 BG II	-0.02	0.25	-0.02	0.18	-5.51**	0.08	-0.01**	0.002
	SE(g_i)	0.14	0.13	0.09	0.11	0.21	0.14	0.00	0.03
Testers									
1	GSHV 95/216	0.03	1.02**	0.21	-0.02	13.47**	1.05**	0.05**	0.28**
2	GTHV 02/45	-0.04	-0.82**	-0.02	-0.42*	1.27**	-0.44	0.04**	-0.17**

3	GJHV 152	0.53*	0.62*	-0.05	0.08	7.96**	-2.53**	-0.003	0.00
4	H 1452	-0.57*	-0.65*	-0.15	0.10	-0.30	3.61**	-0.003	0.17**
5	GSHV 172	0.09	0.25	-0.09	-0.07	-11.75	0.31	-0.04**	0.27**
6	SCS 1062	-0.04	0.55**	-0.09	0.10	0.36	-2.82**	0.06**	0.14**
7	GSHV 213	-0.37	-0.95**	0.18	0.18	-4.75**	-0.10	-0.03**	-0.20**
8	BB-1	0.86**	0.42	-0.12	-0.14	-2.25**	2.65**	-0.01**	0.19**
9	BWR 25	-0.97**	-1.15**	-0.02	-0.08	2.48**	-1.17**	0.002	-0.46**
10	TCH 1705	0.49	0.72	0.15	0.28	-6.47**	-0.53*	-0.05**	-0.21**
	SE(g_j)	0.26	0.25	0.16	0.20	0.39	0.26	0.00	0.05

* and ** indicates significance at 5% and 1% levels of probability, respectively

Table 3: Specific combining ability effect of crosses for different characters in *G. hirsutum* L.

Sr. No.	Crosses	Days to 50% flowering	Sympodia per plant	Bolls per plant	Boll weight (g)	Seed cotton yield per plant (g)	Ginning outturn (%)	Seed index (g)
1	G Cot 10 BG II x GSHV 95/216	0.30	-3.68**	2.55	0.37**	25.81**	-0.13	0.77*
2	G Cot 10 BG II x GTHV 02/45	-0.70	-0.32	-17.55**	-0.10	-72.48**	0.05	0.49
3	G Cot 10 BG II x GJHV 152	0.74	-0.67	4.67*	-0.36**	7.68	-0.20	-0.45
4	G Cot 10 BG II x H 1452	-0.03	-1.66*	8.11**	-0.16	23.219**	0.50	-0.26
5	G Cot 10 BG II x GSHV 172	-0.70	-0.86	-2.04	0.37**	1.68	0.57	0.11
6	G Cot 10 BG II x SCS 1062	0.18	3.17**	-6.96**	0.06	-26.77**	-0.18	-0.22
7	G Cot 10 BG II x GSHV 213	-2.47**	1.92*	-3.73	0.35**	0.63	0.25	0.10
8	G Cot 10 BG II x BB-1	-0.03	0.01	2.28	0.08	12.99	-0.12	-0.58
9	G Cot 10 BG II x BWR 25	2.63**	2.17**	3.70	-0.20*	10.26	0.08	0.64
10	G Cot 10 BG II x TCH 1705	0.07	-0.06	8.96**	-0.40**	16.97*	-0.82*	-0.59
11	G Cot 16 BG II x GSHV 95/216	-2.00*	1.55*	-9.75**	-0.18	-45.93**	1.81**	-1.41**
12	G Cot 16 BG II x GTHV 02/45	-1.66	0.45	11.73**	-0.13	38.04**	-0.66	0.34
13	G Cot 16 BG II x GJHV 152	0.11	-0.67	1.23	0.10	9.86	0.53	-0.01
14	G Cot 16 BG II x H 1452	1.00	0.64	-11.84**	0.30**	-34.56**	-2.40**	0.45
15	G Cot 16 BG II x GSHV 172	-1.66	-0.54	7.44**	0.52**	47.29**	-0.58	0.63
16	G Cot 16 BG II x SCS 1062	1.88*	-2.00**	3.29	0.15	21.42**	-1.16**	0.40
17	G Cot 16 BG II x GSHV 213	0.88	-0.22	10.78**	-0.73**	12.88	0.98*	-0.24
18	G Cot 16 BG II x BB-1	-0.33	0.62	-4.55*	-0.16	-24.78**	-0.52	0.25
19	G Cot 16 BG II x BWR 25	-1.00	-0.63	3.70	-0.40**	4.35	0.52	-0.71*
20	G Cot 16 BG II x TCH 1705	1.11	0.18	-12.05**	0.52**	-28.57**	1.48**	0.31
21	BC 68-2 BG II x GSHV 95/216	1.70	2.12**	7.19**	-0.19*	20.12*	-1.68**	0.64
22	BC 68-2 BG II x GTHV 02/45	2.36*	-0.12	5.82*	0.23*	34.44**	0.61	-0.84*
23	BC 68-2 BG II x GJHV 152	-0.85	1.35	-5.90*	0.26**	-17.54*	-0.32	0.47
24	BC 68-2 BG II x H 1452	-0.96	1.02	3.72	-0.13	11.34	1.90**	-0.18
25	BC 68-2 BG II x GSHV 172	0.70	1.40	-5.40*	-0.90**	-48.98**	0.01	-0.74*
26	BC 68-2 BG II x SCS 1062	-2.07*	-1.17	3.66	-0.21*	5.35	1.34**	-0.17
27	BC 68-2 BG II x GSHV 213	1.58	-1.69*	-7.04**	0.38**	-13.51	-1.24**	0.14
28	BC 68-2 BG II x BB-1	0.36	-0.63	2.26	0.07	11.78	0.64	0.33
29	BC 68-2 BG II x BWR 25	-1.63	-1.54*	-7.40**	0.61**	-14.61	-0.61	0.07
30	BC 68-2 BG II x TCH 1705	-1.18	-0.74	3.08	-0.12	11.60	-0.65	0.28
	SE(S_{ij})	0.93	0.73	2.26	0.09	7.73	0.40	0.33

Table 3: Continue…….

Sr. No.	Crosses	Fiber length (mm)	Fiber strength (g/tex)	Fiber fineness (mv)	Oil content (%)	Gossypol content (mg/100g)	Protein content (mg/g)	Phenol content (%)	Proline content (mg/g)
1	G Cot 10 BG II x GSHV 95/216	-0.04	-0.57	0.54	-0.45	1.98**	-2.89**	0.05**	0.12
2	G Cot 10 BG II x GTHV 02/45	0.22	-0.73	-0.03	0.09	-0.31	-2.61**	0.13**	0.24**
3	G Cot 10 BG II x GJHV 152	-0.94*	0.03	-0.10	-0.02	4.67**	-3.54**	-0.006	0.16
4	G Cot 10 BG II x H 1452	-0.14	0.00	0.20	-0.29	3.00**	0.55	-0.02**	0.14
5	G Cot 10 BG II x GSHV 172	-1.11*	-0.10	0.23	0.59	-12.67*	-0.74	-0.01	-0.17*
6	G Cot 10 BG II x SCS 1062	0.82	1.20**	0.23	0.30	-5.304**	5.13**	-0.09**	-0.04
7	G Cot 10 BG II x GSHV 213	0.95*	0.50	-0.43	-0.18	1.39*	2.94**	-0.01	-0.58**
8	G Cot 10 BG II x BB-1	0.82	-0.77	-0.63*	-0.48	16.36**	0.33	-0.02**	0.10
	continue…….								
9	G Cot 10 BG II x BWR 25	-0.44	-1.00	-0.23	0.24	0.53	2.09**	-0.03**	-0.24
10	G Cot 10 BG II x TCH 1705	-0.11	1.43	0.20	0.21	-9.65**	-1.26**	0.007	0.27
11	G Cot 16 BG II x GSHV 95/216	0.49	0.88*	0.15	0.51	-8.56**	1.89**	-0.03**	-0.90**
12	G Cot 16 BG II x GTHV 02/45	0.16	1.21**	-0.32	-0.16	-13.33**	4.89**	-0.08**	-0.52**
13	G Cot 16 BG II x GJHV 152	0.59	0.28	-0.38	0.14	1.80**	3.47**	-0.03**	-0.44**
14	G Cot 16 BG II x H 1452	0.59	0.55	0.12	-0.86*	5.66**	-0.66	0.008	0.16*
15	G Cot 16 BG II x GSHV 172	-1.67**	-1.95**	-0.15	-0.16	-4.93**	3.73**	-0.02*	0.03

16	G Cot 16 BG II x SCS 1062	0.06	-0.55	-0.15	0.26	9.26**	-2.75**	0.09**	0.33**
17	G Cot 16 BG II x GSHV 213	-0.90	-0.05	0.28	0.51	13.65**	-4.80**	-0.04**	0.50**
18	G Cot 16 BG II x BB-1	-0.64	-0.92*	0.28	0.28	0.29	-2.13**	0.03**	0.05
19	G Cot 16 BG II x BWR 25	0.99*	1.45**	0.28	-0.47	-13.60**	-1.47**	0.03**	0.49**
20	G Cot 16 BG II x TCH 1705	0.32	-0.91	-0.08	-0.08	9.77**	-2.17**	0.03**	0.30**
21	BC 68-2 BG II x GSHV 95/216	-0.44	-0.31	-0.68*	-0.05	6.57**	1.00*	-0.03**	0.78**
22	BC 68-2 BG II x GTHV 02/45	-0.38	-0.48	0.35	0.06	13.65**	-2.27**	-0.05**	0.29**
23	BC 68-2 BG II x GJHV 152	0.35	-0.31	0.48	-0.11	-6.48**	0.06	0.03**	0.28**
24	BC 68-2 BG II x H 1452	-0.44	-0.55	-0.31	1.14**	-8.67**	0.10	0.01*	-0.31**
25	BC 68-2 BG II x GSHV 172	2.78**	2.05**	-0.08	-0.43	17.60**	-2.98**	0.02**	0.14
26	BC 68-2 BG II x SCS 1062	-0.88	-0.65	-0.08	-0.57	-3.96**	-2.38**	0.00	-0.29**
27	BC 68-2 BG II x GSHV 213	-0.04	-0.45	0.15	-0.33	-15.03**	1.87**	0.05**	0.08
28	BC 68-2 BG II x BB-1	-0.18	1.68**	0.35	0.19	-16.64**	1.80**	-0.01	-0.16
29	BC 68-2 BG II x BWR 25	-0.54	-0.45	-0.05	0.22	13.06**	-0.61	-0.004	-0.25**
30	BC 68-2 BG II x TCH 1705	-0.21	-0.52	-0.12	-0.13	-0.11	3.43**	-0.04**	-0.57**
	$SE(S_{ij})$	0.45	0.43	0.28	0.34	0.67	0.46	0.01	0.08

* and ** indicates significance at 5% and 1% levels of probability, respectively

Conclusion

From the analysis of study both GCA and SCA variances were found significant for bolls per plant, ginning outturn, seed index, which indicated that both additive as well as non-additive types of gene actions were important in the inheritance of these traits. The estimates of GCA effects of parents indicated that the GSHV 95/216, SCS 1062, BB-1 and GTHV 02/45 were good general combiner. The crosses G.Cot 16 BG II x GSHV 172, G.Cot 16 BG II x GTHV 02/45, BC 68-2 BG II x GTHV 02/45, G.Cot 10 BG II x GSHV 95/216 and G.Cot 10 BG II x H 1452 were found promising hybrids having high SCA effects for seed cotton yield per plant.

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