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Research Note

Heterosis and combining ability analysis for yield contributing traits and fibre quality in GMS based *G.hirsutum L.* x *G.barbadense L.* hybrids

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Abstract

An experiment was carried out to evaluate the level of heterosis and combining ability in cotton. Thirty five interspecific hybrids were generated by crossing five lines *viz.,* GMS 14, GMS 17, GMS 19, GMS 21 and GMS 27 with seven testers namely CCB26, CCB51, DB1901, CCB2, CCB6, CO18 and Suvin in line x tester mating fashion. Twelve parents along with 35 hybrids and a standard check (DCH 32) were raised in a randomized block design with two replications to evaluate the combining ability and heterosis to identify good combiners and the best hybrids with high yield and fibre quality. The lines *viz.,* GMS 14 and GMS 17 and the testers *viz.,* CO 18 and Suvin were found to record significant *gca* effects for yield and fibre quality traits. Out of the 35 hybrids, GMS 14 x CO18, GMS 27 x Suvin and GMS 17 x CO18 recorded highly positive significant sca effects for most of the traits. The ratio between additive and dominant genetic variance was less than one for all the traits, indicating the preponderance of dominant gene action or non-additive gene action. The above three crosses also exhibited high heterosis over mid parent, better parent and standard check. Hence, these hybrids could be harnessed after analyzing their performance in yield trials.

Keywords: Cotton, combining ability, heterosis, high yield, fibre quality.

Cotton is the most significant fibre commodity in the world. India ranks first in cotton acreage, with 120.69 lakh ha under cultivation, accounting for around 36% of the world's total area of 333 lakh ha. India ranks 39th in productivity with a yield of 447 kg/ha (ICAC, 2023). Almost 67% of the India's cotton cultivation is taken up in rainfed condition.Cotton (*Gossypium* spp.) belongs to the family *Malvaceae*. There are more than 50 species inthe genus *Gossypium* reported till now (Sahu and Samal, 2020), which are native to Africa, Australia, Central and South America and Asia. Among these, only four species are commercially exploited, out of which, two are diploid species *viz.* ,*G. arboreum* and *G. herbaceum* with 2n = 26 and two are tetraploid (2n = 52) species, namely *G. barbadense* and *G. hirsutum*. Among them, *G.hirsutum* contributes about 90% and *G. barbadense* contributes about 4%of the total cotton production in the world.

In view of the growing demand for quality natural fibre, there is an urgent need to develop high yielding cotton hybrids with better fibre quality. Hence, heterosis breeding offers an opportunity to select the most suitable parental lines for improving specific traits for hybridization (Khan *et al.,* 2010, Basal *et al.,* 2011). In India, during 1999-2000, the area under cultivation of hybrid cotton increased to over 45% (Singh *et al.,* 2000). Genetic Male Sterility (GMS) has emerged as an ideal mechanism to accelerate hybrid breeding. To eliminate the need for time-consuming physical emasculation, GMS has given breeders the freedom to arrange crosses between different cotton lines in a way that has never been done before. In the midst of this innovation, the combination of the hardy *G. hirsutum* and the luxurious *G.barbadense* stands out as a bright spot for crossing these two species to improve yield and quality.

Combining ability refers to the capability of cultivars or parental lines to effectively transfer desired genes or traits to their offspring during the hybridization process(Sprague and Tatum 1942). It denotes the genotype's capacity to carry superior traits to its progeny and gives information about the type of gene action for different traits (Sawarkar *et al.,* 2015). Understanding the type of gene action for yield, yield related traits and fiber quality is very important for adopting suitable breeding methods (Natera *et al*., 2012).General combining ability (GCA) provides information about both additive and additive x additive gene interactions, while specific combining ability (SCA) is concerned with non-additive gene action. In the present investigation, GCA, SCA and heterosis were estimated in cotton hybrids generated byline x tester mating fashion to discern the gene action for yield and fibre quality traits.

During winter 2022, five *G.hirsutum* lines GMS *viz.,* GMS14, GMS17, GMS19, GMS21 and GMS27 received from ICAR- CICR, Nagpur and seven *G.barbadense* tester *viz.,* CCB26, CCB51, DB1901, CCB2, CCB6, CO18 and Suvin were raised in a crossing block and35 GMS based F_1interspecifichybrids were synthesized at Department of Cotton, Center of Plant Breeding and Genetics, Tamil Nadu Agricultural University, Coimbatore. During summer 2023, the 35 GMS based HxB hybrids were evaluated along with their 12 parents and a commercial check (DCH 32) in a Randomized Block Design with two replications. Each entry was raised in two rows adopting a spacing of 90 x 45 cm to maintain 10 plants per row. To get a superior crop, the recommended agronomic practices were followed. Five plants per replication were randomly selected in each genotype and observations on boll weight, number of sympodia per plant, number of bolls per plant, ginning outturn, seed index, lint index and seed cotton yield per plant were recorded while days to first flowering, days to 50% flowering and days to first bursting were recorded on plot basis. Fibre quality parameters *viz.,* upper half mean length, uniformity index, bundle strength, elongation percentage and fiber fineness were estimated using High-Volume Instrument (HVI) 900 classic machine. The mean data of individual replications were used for statistical analyses namely Analysis of Variance (Panse and Sukhatme, 1985), combining ability (Kempthorne, 1957) and heterosis were carried out using TNAUSTAT software (Manivannan, 2014).

Analysis of variance indicated that the mean square due to genotypes were significant for all the traits under study. It was further partitioned into mean square due to lines, testers and their interactions. The parents and their hybrids showed positive significance for the seven traits *viz.,* number of sympodia per plant, number of bolls per plant, seed cotton yield per plant, ginning outturn, upper half mean length, uniformity index and bundle strength. These results agree with the conclusions of prior researchers *viz.,* Natera *et al*., 2012, Patel *et al.,* 2018, Premalatha *et al.,* 2020, Richika *et al.,*2021 and Mudhalvan *et al.,* 2022 (**Table 1**). The selection of the parents is one of the prerequisite steps in the breeding to improve the yield attributing traits and fibre quality traits. Based on the *per se* performance along with high GCA, the parents are to be selected to develop the hybrids. Also, the choice of the parents in terms of the predictable performance of their offspring depends on the general combining effects of the parents. Hence, all the crosses and their parents were subjected to combining ability analysis to identify the suitable parents and best cross combinations for the hybrid development.

Two lines *viz.,* GMS 14 and GMS 17 showed positive significant gca effects for number of bolls per plant and seed cotton yield per plant followed by GMS 27 which exhibited good gca effect for seed cotton yield per plant (**Table 2**). Among the testers, CO 18 showed positive gca effect for seven traits *viz.,* number of sympodia per plant, boll weight, seed cotton yield/ plant, upper half mean length, uniformity index, elongation percentage and fibre fineness. The tester, Suvin exhibited positive significant gca effect for boll weight and all the fibre quality traits while CCB 51 showed positive gca effect for boll weight and bundle strength. Similar results were reported by Roy *et al.,* 2018 and Sukrutha *et al.,*2023.In the present investigation, based on the gca effect, the three lines *viz.,* GMS 14, GMS 17 and GMS 27 and the two testers *viz.,* CO 18 and Suvin were identified as desirable parents for developing high yielding hybrids with improved fibre quality traits.

Among the 35 hybrids, the crosses GMS 14 x DB 1901, GMS 14 x CO 18, GMS 17 x CCB 26, GMS 17 x CCB 51, GMS 17 x CO 18, GMS 19 x CCB 26, GMS 21 x CCB 26, GMS 21 x DB 1901, GMS 21 x CCB2, GMS 21 x CCB 6, GMS 27 x CCB 51 and GMS 27 x Suvin showed highly positive significant SCA effect for seed cotton yield per plant. Similar findings were reported by Manonmani *et al.,* 2020, Saleh *et al,* .2012 and Abro *et al.,*2021. The hybrids *viz.,* GMS 14 x CCB 26, GMS 14 x Suvin, GMS 17 x CCB 26, GMS 17 x CCB 51, GMS 17 x CO 18, GMS 19 x CCB 2,GMS 21 x CCB 26, GMS 21 x CCB 51, GMS 27 x CO 18 and GMS 27 x Suvin recorded highly significant positive SCA effect for number of bolls per plant. Nine hybrids *viz.,* GMS 14 x CO 18, GMS 17 x CCB 2, GMS 17 x CCB 6, GMS 17 x CO 18, GMS 19 x CCB2, GMS 19 x CCB 6, GMS 21 x CCB 26, GMS 21 x CCB 51 and GMS 27 x Suvin were found to be best combiners for boll weight and four hybrids *viz.,* GMS 14 x CO 18, GMS 17 x CO 18, GMS 19x DB 1901 and GMS 27 x Suvin excelled with superior SCA effects for ginning outturn (**Table 3**).

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Table 1. Mean squares from analysis of variance for various characters of cotton

Source	df	NSPP	NBPP	BW	SCYPP	GOT	LI	SI	UHML	UI	BS	EP	MIC
Replication	1	0.00	8.3404*	1.16	52.8001*	0.06	0.00	0.23	0.14	0.45	0.90	0.00	0.0613
Genotype	46	65.9646*	492.605*	1.36	1593.7757*	180.5537*	1.15	2.659*	36.3953*	14.571*	70.0076*	0.55	1.6107
Cross	34	20.7372*	295.5227*	1.16	1227.8223*	195.3111*	0.76	2.2328*	35.6479*	15.6017*	68.5298*	0.58	1.4058
Line	4	4.0288*	238.4071*	0.12	815.5886*	35.6774*	0.47	3.5556*	17.7955*	9.9155*	17.4825*	0.15	0.5977
Tester	6	17.1193*	691.2952*	1.55	1546.5587*	234.2609*	1.38	2.00	45.1626*	29.1443*	53.4265*	1.18	2.6016*
LxT	24	24.4264*	206.0988*	1.23	1216.8439*	5092.3017*	0.65	2.07	36.2446*	13.1638*	80.8135*	0.50	1.2416
Parent	11	6.3678*	214.678*	1.97	2286.8587*	129.0654*	1.39	0.89	38.8621*	12.6028*	78.8813*	0.50	2.3725*
Line (p)	4	7.8553*	251*	1.05	2755.4028*	123.9733*	1.34	0.79	3.7203*	3.529*	22.3725*	0.20	0.8161
Tester (p)	6	2.4129*	5.4048*	0.09	16.8396*	72.3732*	0.53	0.40	65.7824*	16.0531*	97.5567*	0.32	3.6438*
L vs T(P)	1	24.147*	1325.0298*	17.0088*	14032.7972*	489.5867*	6.804*	4.2117*	17.9084*	28.1967*	192.8646*	2.73	0.9704
Cross vs Parent	1	2259.2593*	10250.6*	1.32	6412.2781*	245.1749*	11.5324*	36.647*	34.6703*	1.18	22.6436*	0.07	0.1973
Error	46	2.76	9.73	0.05	9.37	46.59	0.28	0.79	1.90	3.24	3.22	0.11	0.3125

* = Significant at 5% level, ** = Significant at 1% level, df = Degrees of Freedom

Table 2. General combining ability effects of parents for yield attributing major traits and span length

Parents	NSPP	NBPP	BW	SCYPP	GOT	LI	SI	UHML	UI	BS	EP	MIC
Lines												
GMS 14	0.07	4.99**	0.09	7.82**	2.23	0.19	0.06	1.71**	1.12*	-0.45	0.05	0.17
GMS17	0.76	1.91*	-0.08	5.58**	0.79	-0.14	-0.42	0.38	0.57	1.63**	0.15	0.12
GMS19	-0.74	-6.23**	0.04	-7.36**	-0.18	-0.25	-0.59*	-0.32	-0.5	-0.94	-0.05	-0.35*
GMS21	-0.15	-0.87	0.06	-8.87**	-1.92	0.13	0.62*	-1.32**	-0.99	0.66	-0.1	-0.02
GMS27	0.07	0.2	-0.11	2.83**	-0.92	0.07	0.33	-0.44	-0.19	-0.9	-0.05	0.08
Testers												
CCB26	0.92	-0.56	-0.72**	-2.68**	-6.43*	-0.38*	0.38	-1.56**	-0.2	0.54	-0.03	-0.46*
CCB51	-0.05	-1.06	-0.19*	-3.41**	-1.13	-0.1	-0.07	-1.79**	-1.17	-2.09**	-0.3*	-0.41*
DB1901	1.15	13.44**	0.09	-5.64**	-1.73	-0.03	0.15	-2.07**	-2.06**	1.36*	-0.45**	-0.23
CCB2	-1.55*	-11.66**	-0.01	1.95*	-0.53	-0.46*	-0.84**	0.55	-0.49	-2.32**	-0.1	0.1
CCB6	-1.38*	-7.16**	0	-1.38	-1.91	0.13	0.56	-0.7	-0.74	-1.87**	0.02	-0.31
CO 18	1.75**	0.74	0.52**	4.7**	0.21	0.63**	-0.07	3.49**	2.72**	0.32	0.56**	0.93**
Suvin	-0.85	0.24	0.31**	-14.54**	2.52	0.22	-0.11	2.05**	1.91**	4.07**	0.3*	0.38*

* = Significant at 5% level, ** = Significant at 1% level

NSPP – number of sympodia per plant
GOT – ginning outturn
UI – uniformity index
NBPP – number of bolls per plant
LI – lint index
BS – bundle strength
BW – boll weight
SI – seed index
EL – elongation percentage
SCYPP- seed cotton yield per plant
UHML – upper half mean length
MIC fibre fineness

Table 3. Specific combining ability effects of hybrids for yield contributing major traits and fibre quality traits

Crosses	NSPP	NBPP	BW	SCYPP	GOT	LI	SI	UHML	UI	BS	EP	MIC
GMS 14 x CCB26	-1.63	5.91*	0.06	-31.79**	-0.47	-0.22	-0.58	-3.92**	-1.33	-3.31*	0.04	0.42
GMS 14 x CCB51	-1.67	-6.59**	-0.38*	-9.89**	-9.07	-0.29	1.27	1.51	-3.16*	2.22	-0.14	0.11
GMS 14 x DB1901	0.13	0.41	-0.15	10.02**	-1.49	-0.21	-0.3	1.39	-2.52	2.47	-0.19	-0.52
GMS 14 x CCB2	0.33	-10.99**	0.05	2.35	-16.25**	-1.03*	0.96	-2.78*	-0.14	-2.6	-0.29	-0.91*
GMS 14 x CCB6	-0.33	2.51	-0.52**	-0.59	1.71	0.18	-0.11	-2.38*	-0.94	-3.65*	0.14	-0.61
GMS 14 x CO18	7.53**	3.61	1.87**	53.14**	23.2**	1.06*	-1.7*	3.33**	5.65**	4.26**	0.75**	1.9**
GMS 14 x SUVIN	-4.37**	5.11*	-0.93**	-23.23**	2.35	0.51	0.46	2.82**	2.41	0.61	-0.29	-0.39
GMS 17 x CCB26	2.68*	7.49**	0.26	6.11**	-2.12	-0.19	-0.1	-1.34	-3.18*	0.01	-0.01	-0.15
GMS 17 x CCB51	-1.36	5.49*	-0.38*	9.67**	-5.68	0.09	1.4*	1.19	1.49	-3.46*	0.06	-0.67
GMS 17 x DB1901	0.44	1.99	-0.71**	-11.44**	-1.01	0.32	0.83	-0.08	0.18	1.34	-0.09	0.07
GMS 17 x CCB2	-2.86*	-11.91**	-0.68**	-3.36	-0.7	-0.5	-1.13	-1.25	-0.94	3.87*	-0.14	0.16
GMS 17 x CCB6	-3.2*	-5.41*	0.66**	-9.74**	-3.52	-0.29	-0.08	-0.9	0.91	-0.58	-0.36	-0.4
GMS 17 x CO18	4.84**	5.69*	1.05**	28.04**	17.79**	0.78	-1.37*	7.76**	3.6*	10.13**	0.9*	1.49**
GMS 17 x SUVIN	-0.56	-3.31	-0.2	-19.28**	-4.75	-0.19	0.44	-5.4**	-2.09	-11.32**	-0.34	-0.5
GMS 19 x CCB26	2.02	-6.87**	-0.23	25.04**	-1.21	0.07	0.42	1.06	0.99	0.38	-0.16	-0.14
GMS 19 x CCB51	3.14*	-2.37	0.3	1.14	2.17	0	-0.48	2.99**	0.51	7.56**	0.56*	0
GMS19 x DB1901	-4.06**	2.13	-0.32	-7.84**	3.17	-0.32	-1.55*	1.82	1.35	-2.39	0.11	0.28
GMS 19 x CCB2	-0.36	18.23**	0.8**	2.69	13.67**	0.81	-0.42	0.35	0.18	3.09*	-0.04	0.33
GMS 19 x CCB6	-0.02	4.73	0.39*	1.26	2.81	0.42	0.39	1.1	1.13	3.24*	0.19	0.88*
GMS 19 x CO18	-0.66	-13.17**	-0.73**	-11.36**	-16.33**	-0.69	1.44*	-2.24*	-1.93	-4.5**	-0.2	-1.18**
GMS 19 x SUVIN	-0.06	-2.67	-0.21	-10.93**	-4.28	-0.28	0.21	-5.1**	-2.22	-7.4**	-0.49*	-0.16
GMS 21 x CCB26	-1.43	14.77**	-0.19	12.96**	0.76	0.2	0.56	3.96*	3.13*	3.03*	0.24	0.06
GMS 21 x CCB51	1.55	8.27**	0.58**	-10.43**	8.95	0.37	-0.99	-6.86**	-0.05	-9.59**	-0.54*	0.48
GMS 21 x DB1901	2.35	-1.73	0.59**	6.49**	3.02	0.45	0.49	-2.13*	-0.26	3.51*	-0.04	-0.04
GMS 21 x CCB2	0.05	-7.13**	0.09	8.99**	5.63	0.43	-0.32	2.35*	1.32	-6.76**	0.31	0.43
GMS 21 x CCB6	2.88*	1.87	-0.34	19.31**	0.34	-0.26	-0.54	1.55	-0.13	-1.96	-0.06	0.07
GMS 21 x CO18	-5.25**	-8.03**	-0.78**	-29.5**	-10.48	-0.46	0.71	1.21	-2.69	0.2	-0.05	-1.55**
GMS 21 x SUVIN	-0.15	-8.03**	0.04	-7.81**	-8.22	-0.75	0.08	-0.05	-1.33	11.6**	0.16	0.55
GMS 27 x CCB26	-1.63	-21.3**	0.1	-12.33**	3.05	0.14	-0.3	0.23	0.38	-0.11	-0.11	-0.18
GMS 27 x CCB51	-1.67	-4.8	-0.11	9.52**	3.62	-0.17	-1.2	1.16	1.2	3.27*	0.06	0.09
GMS 27 x DB1901	1.13	-2.8	0.58**	2.77	-3.69	-0.24	0.53	-1.01	1.24	-4.93**	0.21	0.22
GMS 27 x CCB2	2.83*	11.8**	-0.26	-10.67**	-2.35	0.29	0.91	1.32	-0.43	2.4	0.16	-0.01
GMS 27 x CCB6	0.67	-3.7	-0.19	-10.24**	-1.34	-0.05	0.34	0.62	-0.98	2.95	0.09	0.06
GMS 27 x CO18	-6.47**	11.9**	-1.41**	-40.32**	-14.19**	-0.7	0.92	-10.07**	-4.64**	-10.09**	-1.4*	-0.66
GMS 27 x SUVIN	5.13**	8.9**	1.29**	61.26**	14.89**	0.71	-1.19	7.72**	3.22*	6.51**	0.96*	0.49

* = Significant at 5% level, ** = Significant at 1% level

Table 4. Genetic components for six biometrical traits

Variance	NSPP	NBPP	BW	SCYPP	GOT	LI	SI	UHML	UI	BS	EP	MIC
Additive	-0.216	5.242	-0.004	0.644	-0.989	0.006	0.010	-0.035	0.143	-0.720	0.005	0.010
Dominant	10.501	97.309	0.587	604.510	76.984	0.161	0.617	17.039	4.489	38.305	0.194	0.449
A / D	-0.021	0.054	-0.007	0.001	-0.013	0.039	0.015	-0.002	0.032	-0.019	0.024	0.021

* = Significant at 5% level, ** = Significant at 1% level

NSPP – number of sympodia per plant
SCYPP- seed cotton yield per plant
SI – seed index
BS – bundle strength
NBPP – number of bolls per plant
GOT – ginning outturn
UHML – upper half mean length
EL – elongation percentage
BW – boll weight
LI – lint index
UI – uniformity index
MIC fibre fineness

Table 5. Relative heterosis, heterobeltosis and standard heterosis for Numberofsympodiaper plant (NSPP), Numberofbollsperplant(NBPP), Bollweight(BW) and Seed cotton yield per plant (SCYPP)

Crosses	NSPP			NBPP			BW			SCYPP		
	di	dii	Diii	di	dii	diii	di	dii	diii	di	dii	diii
GMS 14 x CCB26	68.13**	67.86**	95.83**	115.94**	115.94**	122.39**	-27.4**	-45.36**	16.23	-19.98**	-39.78**	9.53**
GMS 14 x CCB51	74.08**	61.23**	87.5**	76.98**	75.718**	83.58**	-20.78**	-43.61**	19.96*	-4.96	-27.98**	30.98**
GMS 14 x DB1901	89.2**	82.73**	112.5**	151.52**	140.58**	147.76**	-5.39	-32.99**	42.54**	6.84*	-18.12**	48.92**
GMS 14 x CCB2	84.33**	64.82**	91.67**	38.81**	34.78**	38.81**	-7.52**	-30.93**	46.93**	5.73*	-18.17**	48.83**
GMS 14 x CCB6	80.32**	61.23**	87.5**	81.69**	76.71**	92.54**	-23.61**	-42.478**	22.37**	2.13	-21.66**	42.48**
GMS 14 x CO18	163.21**	140.06**	179.17**	132.12**	130.43**	137.31**	66.42**	17.53**	150**	60.93**	23.39**	124.41**
GMS 14 x SUVIN	46.41**	36.15**	58.33**	119.12**	115.94**	122.39**	-24.4**	-44.43**	18.2	-24.66**	-41.62**	6.18*
GMS 17 x CCB26	123.53**	103.57**	137.5**	45.27**	10.61*	117.91**	-23.71**	-41.32**	17.11	2.59	-24.18**	45.68**
GMS 17 x CCB51	100.9**	97.56**	95.83**	39.6**	6.82	110.45**	-22.18**	-43.52**	12.72	3.91	-22.7**	48.54**
GMS 17 x DB1901	116.33**	103.85**	120.83**	67.18**	23.48**	143.28**	-23.44**	-44.73**	10.31	-13.59**	-35.01**	24.89**
GMS 17 x CCB2	82.22**	78.26**	70.83**	-13.71**	-35.61**	26.87**	-29.45**	-46.15**	7.46	-3.51	-26.74**	40.78**
GMS 17 x CCB6	80.67**	76.74**	69.37**	4.39	-18.94*	59.7**	8.35	-16.59**	66.45**	-9.49**	-31.86**	30.93**
GMS 17 x CO18	173.91**	173.91**	162.5**	57**	18.94*	134.33**	43.51**	3.3	106.14**	36.04**	2.36	96.69**
GMS 17 x SUVIN	100**	95.83**	95.83**	26.63**	-4.55	88.06**	-4.83	-28.57**	42.54**	-26.13**	-43.84**	7.91**
GMS 19 x CCB26	91.64**	88.21**	119.58**	21.69**	4.12	50.75**	-24.82**	-37.48**	1.32	39.9**	21.32**	51.76**
GMS 19 x CCB51	108.7**	96.3**	120.83**	30.54**	12.37*	62.69**	17.22**	-8.8	47.81**	15.85**	1.35	26.78**
GMS19 x DB1901	54.72**	51.85**	70.83**	83.75**	51.55**	119.4**	6.04	-18**	32.89**	3.98	-7.74**	15.42**
GMS 19 x CCB2	75.51**	59.26**	79.17**	59.26**	32.99**	92.54**	33.33**	9.88	78.07**	19.06**	6.95*	33.79**
GMS 19 x CCB6	79.59**	62.96**	83.33**	30.59**	14.43*	65.67**	18.86**	-1.08	60.31**	16.05**	3.09	28.96**
GMS 19 x CO18	96**	81.48**	104.17**	24.85**	6.19	53.73**	6.94	-17.59*	33.55**	29.33**	14.81**	43.62**
GMS 19 x SUVIN	76.47**	66.67**	87.5**	35.37**	14.43*	65.67**	12.8	-8.8	47.81**	-8.25	-17.45**	3.26
GMS 21 x CCB26	64.81**	61.97**	95.71**	86.75**	59.79**	131.34**	-20.03**	-31.75**	3.73	35.85**	24**	37.98**
GMS 21 x CCB51	93.22**	75.86**	112.5**	68.86**	45.36**	110.45**	32.97**	5.92	60.96**	10.72**	2.01	13.52**
GMS 21 x DB1901	100**	89.66**	129.17**	87.5**	54.64**	123.88**	44.58**	14.43	73.9**	23.37**	15.4**	28.42**
GMS 21 x CCB2	76.47**	55.17**	87.5**	9.88	-8.25	32.84**	15.02*	-2.74	47.81**	31.46**	24.59**	38.65**
GMS 21 x CCB6	100**	75.86**	112.5**	36.47**	19.59**	73.13**	-0.34	-14.86	29.39**	39.84**	30.97**	45.74**
GMS 21 x CO18	57.69**	41.38**	70.83**	50.3**	27.84**	85.07**	10.52	-12.84	32.46**	18.78**	11.16**	23.7**
GMS 21 x SUVIN	73.58**	58.62**	91.67**	35.37**	14.43*	65.67**	26.72**	5.05	59.65**	-0.7	-5.74*	4.9
GMS 27 x CCB26	51.61**	38.24**	95.83**	3.66	-10.53	26.87**	-11.41	-21.36**	8.99	16.5**	2.34	24.21**
GMS 27 x CCB51	55.74**	32.35**	87.5**	41.82**	23.16**	74.63**	7.38	-11.39	22.81**	35.38**	19.98**	45.62**
GMS 27 x DB1901	76.67**	55.88**	120.83**	89.87**	57.89**	123.88**	45.75**	19.46**	65.57**	25.09**	12.49**	36.52**
GMS 27 x CCB2	82.14**	50**	112.5**	61.25**	35.79**	92.54**	2.07	-10.28	24.34**	18.17**	7.6**	30.59**
GMS 27 x CCB6	67.86**	38.24**	95.83**	27.38**	12.63	59.7**	4.01	-7.59	28.07**	16.83**	5.17*	27.64**
GMS 27 x CO18	36.84**	14.71	62.5**	103.68**	74.74**	147.76**	-14.34	-30.06**	-3.07	14.11**	2.66	24.59**
GMS 27 x SUVIN	96.55**	67.65**	137.5**	81.48**	54.74**	119.4**	73.16**	49.05**	106.58**	68.77**	53.91**	86.79**

* = Significant at 5% level, ** = Significant at 1% level

di- Relative heterosis; dii- Heterobeltosis; diii-standard heterosis

NSPP – number of sympodia per plant; NBPP – number of bolls per plant; BW – boll weight; SCYPP- seed cotton yield per plant

Table 6. Relative heterosis, heterobeltosis and standard heterosis for Ginning outturn (GOT), Lint index (LI) and Seedindex(SI) and Upper Half Mean Length (UHML)

Crosses	GOT			LI			SI			UHML		
	di	dii	diii	di	dii	diii	di	dii	diii	di	dii	diii
GMS 14 x CCB26	-7.94	-27.45*	-14.58	7.69	-21.35	0	20.54	8.48	16.23	-13.62**	-15.46**	7.34
GMS 14 x CCB51	-17.22	-33.58*	-21.79	10.45	-16.85	5.71	36.63**	25.45*	34.42**	20.93**	4	26.42**
GMS 14 x DB1901	-1.25	-20.63	-6.55	10	-13.48	10	12.15	9.09	16.88	13.08**	2.79	24.95**
GMS 14 x CCB2	-30.58*	-45.77**	-36.15*	-22.96	-41.57*	-25.71	17.41	12.42	20.45	1.21	-1.89	19.27**
GMS 14 x CCB6	-3.22	-15.03	0.04	17.33	-1.12	25.71	22.06*	16.36	24.68**	-1.52	-4.45	16.15**
GMS 14 x CO18	66.06**	45.41**	71.21**	58.49**	30	65.29**	-3.91	-10.61	-4.22	11.81**	0.85	52.48**
GMS 14 x SUVIN	2.04	-5.64	11.1	21.38	8.43	37.86*	19.12	15.15	23.38*	31.18**	19.55**	45.32**
GMS 17 x CCB26	-12.89	-30.24*	-21.34	0	-26.44	-8.57	19.17	6.29	16.23	-10.95**	-11.85**	11.93*
GMS 17 x CCB51	-10.38	-26.89*	-17.56	13.64	-13.79	7.14	30.55**	18.76	29.87*	13.59**	-3.24	20.37**
GMS17 x DB1901	-0.88	-19.01	-8.67	17.39	-6.9	15.71	18.99	14.61	25.32*	2.46	-7.82	14.68**
GMS 17 x CCB2	5.73	-16.08	-5.37	-15.79	-35.63*	-20	-16.09	-20.43	-12.99	0.62	-3.54	20**
GMS 17 x CCB6	-15.29	-24.21	-14.54	-2.7	-17.24	2.86	15.09	8.67	18.83	-2.23	-6.19	16.7**
GMS 17 x CO18	55.29**	38.55**	56.24**	43.75**	18.97	47.86*	-6.83	-14.13	-6.1	18.91**	8.37*	63.85**
GMS 17 x SUVIN	-13.1	-18.02	-7.55	-3.18	-12.64	8.57	11.66	6.89	16.88	-1.72	-11.36**	10.28**
GMS19 x CCB26	10.55	5.78	-21.47	50.56*	39.58*	-4.29	36.26**	31.91*	20.78	-4.17	-6.94	18.17**
GMS19 x CCB51	34.03*	31.3	-2.52	52.69*	47.92*	1.43	13.98	12.77	3.25	20.11**	3.99	24.4**
GM19 x DB1901	34.95*	32.47*	-1.65	33.33*	29.41	-5.71	-4.38	-8.97	-7.79	8.71*	-0.46	19.08**
GMS 19 x CCB2	76.38**	66.87**	23.89	70.21**	66.67**	14.29	-0.68	-3.97	-5.84	5.49	3.07	23.3**
GMS 19 x CCB6	19.05	9.18	-2.83	54.13**	37.7*	20	30.08**	26.34	22.73*	3.84	1.53	21.47**
GMS 19 x CO18	-2.07	-9.93	-20.33	37.14*	26.32	2.86	39.58**	39.08**	28.25*	-7.99*	-17.6**	24.59**
GMS 19 x SUVIN	4.87	-8.63	-8.63	22.03	2.86	2.86	16.61	11.69	11.69	-0.92	-9.05*	8.81*
GMS 21 x CCB26	-4.09	-18.49	-20.98	31.62*	1.32	10	40.59**	24.56*	38.31**	0.52	-1.45	25.14**
GMS 21 x CCB51	28.98	11.85	8.45	42.15*	13.16	22.86	11.97	1.17	12.34	-19.26**	-30.68**	-15.41*
GM 21 x DB1901	11.85	-2.83	-5.78	40.16*	17.11	27.14	26.61*	21.05*	34.42**	-8.86*	-17.29**	0.92
GMS 21 x CCB2	25.65	5.74	2.52	31.15*	5.26	14.29	6.21	0	11.04	7.54*	4.06	26.97**
GMS 21 x CCB6	-5.37	-9.25	-12.02	13.87	2.63	11.43	21.27*	13.68	26.23*	1.09	-2.11	19.45**
GMS 21 x CO18	-4.42	-8.61	-11.39	26.32	10.53	20	32.27**	21.05*	34.42**	-2.22	-11.65**	33.58**
GMS 21 x SUVIN	-19.82	-21.04	-21.04	-4.11	-7.89	0	19.08	13.16	25.65*	11.4**	1.35	23.67**
GMS 27 x CCB26	6.43	-8.45	-13.79	31.05	2.33	6.71	25.83*	11.76	23.38*	-3.77	-9.68*	14.68*
GMS 27 x CCB51	19.75	5.16	-0.98	25.42	1.37	5.71	5.84	-4.12	5.84	17.9**	5.27	17.25*
GMS 27 x DB1901	-1.3	-13.17	-18.24	19.35	1.37	5.71	23.93*	18.82	31.17**	2.7	-2.8	8.26*
GMS 27 x CCB2	8.87	-7.28	-12.69	27.73	4.11	8.57	18.38	11.76	23.38*	12.12**	10.77*	26.42**
GMS 27 x CCB6	-5.55	-8.14	-13.5	20.9	10.96	15.71	29.16*	21.41*	34.03**	5.69	4.33	19.27**
GMS 27 x CO18	-9.41	-12.16	-17.29	20	6.85	11.43	31.67**	20.82	33.38**	-27.32**	-36.89**	-4.59
GMS 27 x SUVIN	35.54*	31.58*	31.58*	36.92*	34.11*	39.86*	0.25	-4.47	5.45	47.05**	39.54**	55.41**

* = Significant at 5% level, ** = Significant at 1% level

di- Relative heterosis; dii- Heterobeltosis; diii-standard heterosis

GOT – ginning outturn; LI – lint index; SI – seed index; UHML – upper half mean length

Table 7. Relative heterosis, heterobeltosis and standard heterosis for Uniformity ratio(UR), Bundle strength (BS), Elongation percentage (EP)and Fibrefineness(FF)

Crosses	UI			BS			EP			FF		
	di	dii	diii	di	dii	diii	di	dii	diii	di	dii	diii
GMS 14 x CCB26	1.67	0.19	-0.74	2.17	1.43	9.26	11.3*	6.67	-2.29	5.75	-18.48	20.81
GMS 14 x CCB51	-2.47	-4.46	-4.17	0.22	-8.43	19.21*	-0.42	-7.75	-9.16	-11.67	-24.08*	12.52
GMS 14 x DB1901	-2.66	-4.54	-4.48	42.41**	22.45**	31.9**	-3.77	-10.85*	-12.21*	-16.77	-33.69**	-1.72
GMS 14 x CCB2	2.54	0.8	0.37	1.19	-5.41	1.89	-0.41	-8.4	-8.4	-14.37	-34.85**	-3.44
GMS 14 x CCB6	0.81	-1.28	-0.92	-4.28	-7.32	-0.17	8.26	-0.76	0	-26.33*	-37.06**	-6.73
GMS 14 x CO18	8.58	2.19	11.41	4.67	-9.89*	34.48**	19.84**	4.76	17.56**	20.97*	5.23	110.8**
GMS 14 x SUVIN	8.51	6.44	6.44	29.81**	25.16**	34.82**	6.22	-2.29	-2.29	-1.77	-17.74	21.91
GMS 17 x CCB26	-3.03	-3.27	-3.68	8.21	-1.72	27.79**	10.73*	7.5	-1.53	15.82	6.93	1.41
GMS 17 x CCB51	0.92	0.55	0.86	-17.86*	-17.92**	6.86	3.31	-3.1	-4.58	-13.75	-18.5	-13.15
GMS 17 x DB1901	-1.66	-1.9	-1.84	30.25**	3.96	35.16**	-1.65	-7.75	-9.16	26.54	21.95	15.65
GMS 17 x CCB2	-0.86	-0.86	-1.29	17.33*	0.92	31.22**	2.46	-4.58	-4.58	49.45**	35.64	28.64
GMS 17 x CCB6	0.71	0.31	0.67	1.78	-9.63*	17.5**	0.41	-6.82	-6.11	-1.49	-6.26	-1.56
GMS 17 x CO18	3.76	-0.73	8.22	15.85*	8.39*	61.75**	22.31**	8.16	21.37**	33.3*	-1.8	96.71**
GMS 17 x SUVIN	0.46	0.25	0.25	-12.16*	-22.3**	1.03	5.74	-1.53	-1.53	20.16	17.06	17.06
GMS 19 x CCB26	1.18	1.05	0.12	-0.36	-11.04*	20.24**	1.24	0.83	-6.87	-15.89	-31.27*	-12.99
GMS 19 x CCB51	-1.23	-1.96	-1.66	2.39	0.51	35.85**	4.8	1.55	0	-20.27	-26.58	-7.04
GMS19 x DB1901	-1.17	-1.78	-1.72	6.77	-15.99**	13.55*	-4.8	-7.75	-9.16	-0.07	-15.33	7.2
GMS 19 x CCB2	-0.43	-0.8	-1.23	4.65	-11.42*	19.73**	-2.38	-6.11	-6.11	16.96	-5.81	19.25
GMS 19 x CCB6	0.03	-0.73	-0.37	3.2	-9.9*	21.78**	2.77	-1.52	-0.76	6.89	-2.22	23.79
GMS 19 x CO18	-3.66	-8.16	0.12	-27.74**	-31.15**	2.74	-0.75	-9.52*	1.53	-39.97**	-51.02**	-1.88
GMS 19 x SUVIN	-0.65	-1.23	-1.23	-10.14*	-21.83**	5.66	-3.17	-6.87	-6.87	-0.28	-10.75	12.99
GMS 21 x CCB26	2.46	1.83	2.15	12.29*	0.64	34.82**	4.88	2.38	-1.53	8.97	-5.7	3.6
GMS 21 x CCB51	-3.24	-3.24	-2.94	-37.53**	-38.41**	-17.5**	-15.29**	-16.28**	-17.56**	9.47	7.83	18.47
GMS 21 x DB1901	-4.47	-4.59	-4.29	31.71**	3.97	39.28**	-9.8*	-10.85*	-12.21*	8.7	-2.14	7.51
GMS 21 x CCB2	-0.37	-0.73	-0.43	-19.67*	-31.75**	-8.58	0.39	-1.53	-1.53	41.97*	20.94	32.86
GMS 21 x CCB6	-2.84	-2.87	-2.52	-6.79	-18.31**	9.43	-3.88	-6.06	-5.34	1.24	-1	8.76
GMS 21 x CO18	-5.8	-9.57	-1.41	-12.17*	-16.67**	24.36**	-1.1	-8.16	3.05	-37.54**	-51.64**	-3.13
GMS 21 x SUVIN	-0.89	-1.04	-0.74	50.73**	31.63**	76.33**	4.28	2.29	2.29	38.7**	32.48*	45.54*
GMS 27 x CCB26	1.43	0.68	-0.25	-0.72	-10.71*	18.7**	3.36	2.5	-6.11	-3.65	-20.97	-0.94
GMS 27 x CCB51	0.62	-0.73	-0.43	-7.82	-8.77	21.27**	-2.02	-6.2	-7.63	-5.8	-12.86	9.23
GMS 27 x DB1901	-0.31	-1.53	-1.47	-0.24	-21.03**	4.97	-2.02	-6.2	-7.63	11.37	-5.24	18.78
GMS 27 x CCB2	-0.19	-1.17	-1.6	3.71	-11.61*	17.5**	2.01	-3.05	-3.05	20.31	-2.75	21.91
GMS 27 x CCB6	-1.58	-2.93	-2.58	3.45	-9.03	20.93**	2.4	-3.03	-2.29	-3.4	-11.24	11.27
GMS 27 x CO18	-5.94	-10.86	-2.82	-40.67**	-43.91**	-16.3*	-17.74**	-25.85**	-16.79**	-21.48	-36.17*	27.86
GMS 27 x SUVIN	7.11	5.83	5.83	31.81**	15.48**	53.52**	21.29**	15.27**	15.27**	30*	16.85	46.48*

* = Significant at 5% level, ** = Significant at 1% level
di- Relative heterosis; dii- Heterobeltosis; diii-standard heterosis
UI – uniformity index; BS – bundle strength; EL – elongation percentage; MIC : Fibre fineness

For fibre quality traits, the following eight hybrids *viz.,* GMS 14 x CO 18, GMS 14 x Suvin, GMS 17 x CO 18, GMS 19 x CCB 51, GMS 19 x Suvin, GMS 21 x CCB 26, GMS 21 x CCB 2 and GMS 27 x Suvin exhibited significant positive SCA effects for UHML and the four hybrids *viz.,* GMS 14 x CO 18, GMS 17 x CO 18, GMS 21 x Suvin, GMS 27 x Suvinrecorded significant SCA effect for bundle strength. Based on these results, three hybrids, GMS 14 x CO 18, GMS 17 x CO 18 and GMS 27 x Suvin could be recommended as the best cross combinations for fibre quality traits. The ratio between additive and dominant genetic variance was observed to be less than one for all the traits (**Table 4**).Hence it could be concluded that these traits could be under the influence of dominant gene action.

Out of the 35 hybrids evaluated, positive and significant heterosis were recorded for the hybrids GMS 14 x CO18 (124.41), GMS17 x CO18 (96.69) and GMS 27 x Suvin (86.79) for seed cotton yield per plant, GMS 17 x CO 18 (63.85) and GMS 27 x Suvin (55.41) and GMS 14 x CO 18 (52.48) for UHML and GMS 17 x CO 18 (61.75) for bundle strength, elongation percentage (21.37) and fibre fineness (96.71). Similar results for these traits were reported by Aty *et al.*,2023; Balakrishna *et al.,* 2017 and Rajeev *et al*.2018.The highest magnitude of relative heterosis, heterobeltosis and standard heterosis for seed cotton yield per plant and fibre quality traits was exhibited by GMS 17 x CO18 followed by GMS 14 x CO18 and GMS 27 x Suvin. (**Table 5,6&7**).These hybrids could be exploited further after evaluation in yield trials. This study aligns with the findings of Chakholoma *et al.,*2022, Udaya *et al*.,2023, Yehia and El-Hashash, 2019, Isong *et al.,*2019, Imtiaz *et al.,*2022 and Vadodariya *et al.,*2022.

In this study, considering GCA effects, the three lines GMS 14, GMS 17 and GMS 27 and two testers *viz.,* CO 18 and Suvin were identified as desirable parents for developing hybrids with improved yield and fibre quality traits. These parents can be utilized for hybridization programmes to identify superior segregants with high yield and improved fibre quality traits. Out of the 35 F_1 hybrids evaluated, three hybrids *viz.,*GMS 14 x CO18, GMS 17 x CO18, and GMS 27 x Suvin, were selected for heterosis breeding as these hybrids showed high SCA effects and better heterotic behavior.

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