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Combining ability, heterosis studies for yield, its component traits and fibre properties through Line x Tester mating design in upland cotton

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ABSTRACT : The present experiment was under taken to assess the magnitude of combining ability for yield, its components and fibre properties in upland cotton. The experimental material comprising of sixty seven genotypes was evaluated for fourteen characters in randomized block design with two replications during winter 2017-2018. The analysis of variance indicated substantial variability in the experimental materials for yield, its components and fibre quality traits. Preponderance of non-additive gene action was obtained for seed cotton yield /plant, majority of its component traits and fibre quality traits. Four parents namely; RB 602, SCS 1207, TCH 486-7 and TCH 486-2, were identified as very good general combiners for seed cotton yield /plant. The cross combinations *viz.,* BGDS 1033 x GSHV 177, CO14 x CNH 19, SVPR 5 x Suraj, SVPR 2 x SCS 1207 and SVPR 2 x TCH 486-7 were identified as the best hybrids for seed cotton yield /plant and bolls /plant since these recorded significant *per se*, *sca* effects and standard heterosis for traits as mentioned and well suited for exploitation through heterosis breeding. Whereas, the hybrids, RB 602 x TCH 486-7 and RB 602 x TCH 486-2 may be exploited for development of varieties through transgressive segregation due to its non-significant *sca* effects and involving parents with high *gca* effects for seed cotton yield/plant and bolls /plant traits.

Key words **:** Combining ability, cotton, fibre properties, line x tester, yield

Cotton (*Gossypium* spp.) the white gold is the world's leading natural textile fibre and cultivated by about 80 countries in the world. India is the only country in the world that grows not only all the four cultivated species of cotton but also intra and inter specific hybrids on a commercial scale. It occupies a distinctive position in the global trade because it is a very important agricultural and industrial crop. The demand of cotton is increasing at a rapid pace, more than the world's population growth rate, so we have to increase the yield per unit area. In India, cotton was cultivated in 122.35 lakh hactare producing 377 lakh bales (170 kg) with a productivity of 524 kg/ha during 2017-2018 whereas in Tamil Nadu, cotton was cultivated in 1.48 lakh ha producing 6.00 lakh bales (170 kgs) and 689 kg/ha as productivity (AICCIP Annual Report 2017-2018).

In cotton, now the yield levels have

reached a plateau. So, the increased productivity of cotton could be achieved by adopting hybrid cotton cultivars and exploitation of hybrid vigour and selection of parents on the basis of combining ability effects. Application of biometrical techniques like line x tester analysis has appeared to be the best and vastly useful breeding tool, which gives generalized picture of genetics of the characters under study. Combining ability analysis provides the information for selection of the desirable parents and cross combinations for its exploitation. Line x Tester analysis reveals general combining ability (GCA) effects of parents and specific combining ability (SCA) effects of hybrids. Evaluation of breeding materials for general combining ability and specific combining ability as well as to study the extent of heterosis for yield and yield contributing characters are prerequisite for any breeding program aimed in development of hybrids. Study of gene action involved is very crucial for choosing of best parents and crosses for cotton yield improvement and has been reported by many researchers *viz.,* Karademir *et al.* (2009), Babu *et al.* (2017) and Kumbhalkar *et. al.* (2018). Keeping in view the above points, the present investigation was carried out to evaluate general combining ability of parents, specific combining ability and heterosis of hybrids in cotton for yield, its component and fibre quality traits in *Gossypium hirsutum.*

MATERIALS AND METHODS

The present research work was carried out during winter 2017-2018 in the experimental field of Cotton Research Station, Tamil Nadu Agricultural University, Srivilliputtur, Tamil Nadu, India under irrigated condition.

Plant materials : Fifteen parents, among which five lines *viz.,* RB 602, BGDS 1033, CO 14, SVPR 5 and SVPR 2 and ten testers *viz.,* TCH 1819, CNH 19, COD 5-1-2, GSHV 177, SCS 1207, Suraj, African I-2, TCH 482-7, TCH 484-4 and TCH 486-2 were selected for crossing. Each of the line was crossed with all the ten testers individually in a line x tester mating design (Kempthorne, 1957) to develop 50 hybrids during winter, 2016 at Cotton Research Station, Srivilliputtur. Thus the 50 intra *hirsutum* crosses were produced using conventional hand emasculation and pollination method. Hybridization programme was continued for twenty five days to get sufficient number of crossed bolls and there were collected separately and ginned to obtain F_1 seeds. Simultaneously, parental seeds were also produced by selfing selected plants by adopting clay smear method.

Field layout : The fifty hybrids along with fifteen parents and two check hybrids (SVPR 1 Cotton Hybrid and Bunny NBt.) were raised during winter 2017-2018. Experimental materials were raised in two replications in a randomized block design (RBD) with each cross in double rows of 4.5m length and spacing of 100 cm between rows and 45 cm between plants so as to maintain 10 plants in each row. Recommended agronomic practices and need based plant protection measures were followed to obtain good crop stand.

Data recording : Five competitive plants from each genotype were selected in the parents, F_1s and check hybrids at random per replication and were labelled with tags for recording morphological observations. The average values of the observations from these five plants represented the mean of that genotype per replication. Thus, a total of 67 genotypes were evaluated for all the 14 characters *viz.*, plant height (PH) (cm), monopodia /plant (NM/P), sympodia /plant (NSy/P), bolls /plant (NB/P), boll weight (BW) (g), seed index (SI), lint index (SI), ginning percentage (GP) (%), seed cotton yield /plant (SCY/P) (g), 2.5 per cent span length (SL) (mm), bundle strength (BS) (g/tex), fibre fineness (FF) (µ), uniformity ratio (UR) (%) and elongation percentage (EP) (%). Observations on five fibre quality traits in each replication were recorded with ten grams of lint sample in High Volume Instrument (HVI) under ICC mode.

Statistical analysis : The mean values of the characters measured in 67 genotypes in each replication were analysed for Analysis of Variance, estimation of Standard Error and Critical Difference. The Line x Tester analysis of combining ability was performed. The estimation of heterosis was done by calculating the superiority of the F_1 over standard check (Bunny N *Bt*).

RESULTS AND DISCUSSION

Analysis of variance : Analysis of variance showed significant differences due to genotypes for all the traits except elongation percentage, indicating the presence of sufficient variability in the experimental materials (Table 1). Parents and hybrids showed significant differences between all the characters studied except elongation percentage. The mean sum of squares of the combining ability variance (Table 2) revealed significant differences in the lines for all the traits studied except elongation percentage showing significant difference. The testers showed significant differences for traits except sympodia /plant, lint index and elongation percentage, while the interaction between lines and testers had significant differences for a majority of the traits under study which was in accordance with the findings made by Madhuri *et al.* (2015), Sivia *et al.* (2017) and Monicashree *et al.* (2017).

The relative estimates of variances due to additive and dominance components are presented in Table 2. The dominance variance is higher than the additive variance for all the biometric traits and fibre properties indicating the preponderance of dominance gene action. The ratio between additive (ä^2 GCA) and

Table 1. Analysis of variance for various yield components and fibre quality traits

Source of Variation	df	PH	NM/P	NSy/P	NB/P	BW	SI	LI	GP	SCY/P	SL	UR	BS	EP	FF
Replication	1	9.6	0.2	0.0	0.2	0.5	2.8	1.2	0.4	0.0001	0.8	0.2	0.2	0.001	0.2
Genotypes	64	74.4*	0.2*	1.9*	67.4*	0.3*	2.4*	0.6*	13.3*	0.0023*	7.6*	9.7*	6.1*	0.016	1.0*
Parents	14	65.1*	0.1*	2.8*	12.6*	0.5*	4.0*	0.9*	17.8*	0.0002*	10.9*	15.7*	5.3*	0.016	0.8*
Crosses	49	57.0*	0.2*	0.7*	70.7*	0.3*	1.9*	0.6*	12.1*	0.0016*	5.7*	7.4*	6.2*	0.016	1.0*
Error	64	32.4	0.0	0.4	4.0	0.1	0.6	0.2	2.0	0.0001	0.4	0.4	0.2	0.116	0.1

* Significance at 5% level

dominance (ä^2 SCA) variance was less than one for fourteen characters studied indicating preponderance of non additive gene action (dominance and epistasis) which is important in exploitation of heterosis through hybrid breeding. Present findings were in accordance with Usharani *et al.* (2016), Khokhar *et. al.* (2018) and Monicashree *et al.* (2017). Contrary to the findings of present study, Lukonge *et al.* (2008) and *Khan et al.* (2013) reported additive type of gene action while Jatoi *et al.* (2010) and Patel *et al.* (2014) reported both additive and non-additive type of gene action for traits under study.

For sympodia /plant and monopodia / plant, bolls /plant, boll weight and seed cotton yield/plant, non-additive genetics effects were appeared to be dominant and this confirms the findings of Sivia *et al.* (2017), Monicashree *et al.* (2017) and Khokhar *et. al.* (2018) whereas Ali and Khan (2007) reported dominance of additive type of gene action for monopodia /plant and sympodia /plant and Natera *et al.* (2012) showed that additive genetic effects for bolls /plant and boll weight, Yanal *et al.* (2013) for seed cotton yield /plant. Fibre strength and fibre length werecontrolled by non additive genetic effects and this confirmed the findings of Monicashree *et al.* (2017) and Khokhar *et. al.* (2018). However, Rauf *et al.* (2006) reported both additive and non-additive type of gene action for the investigated traits. Low heritability had been reported by plant researcher for non additive genetic effects suggesting to postpone the selection in early generations. Thus, selection must be delayed till the genes are established in segregating populations.

Proportional contribution of lines, testers and line x tester interactions : The proportional contribution of the lines, testers and their interactions are presented in Table 3. The proportional contribution of line was higher for ginning percentage and fibre fineness, whereas line x tester interaction was higher for the remaining characters (Monicashree *et al.,* 2017). The testers showed lowest proportional contribution for all the characters.

Evaluation of parents : Selection of parents for improvement of yield and fibre quality traits is a crucial step in breeding programme for the improvement of yield and other advantageous traits. Parents are selected based on their mean performance and also their general combining ability effects.

Information on the *per se* performance and nature of general combining ability of characters is necessary for selection of suitable parents for developing hybrids. Therefore, in the present study a total of fifteen parents were evaluated based on *per se* performance and *gca* effects both individually and in combination. Inferiorly significant genotypes were chosen for the traits seed index and fibre fineness.

Mean performance of parents : Parents with good *per se* performance are expected to yield desirable recombinants in the segregating generation and the potentiality of such genotypes will also reflect in the performance of hybrid in most of the occasions. Parents with high mean performance are generally preferred for all the traits except seed index and fibre fineness. Mean performance of the parents are presented in Table 4. The tester GSHV 177 recorded highest

Table 2. Analysis of variance for combining ability for various yield components and fibre quality traits

Source of Variation	df	PH	NM/P	NSy/P	NB/P	BW	SI	LI	GP	SCY/P	SL	UR	BS	EP	FF
Replication	1	73.96	0.14	0.14	1.44	0.22	1.49	0.85	1.19	0.0001	0.77	0.06	0.30	0.0004	0.10
Crosses	49	57.00*	0.24*	0.73*	70.68*	0.29*	1.90*	0.55*	12.06*	0.0016*	5.65*	7.37*	6.23*	0.0156	1.01*
Lines	4	177.17*	0.46*	0.99*	338.20*	0.46*	4.81*	1.51*	64.60*	0.0064*	12.53*	10.70*	4.14*	0.0106	5.68*
Testers	9	66.28*	0.52*	0.32	80.15*	0.65*	3.80*	0.32	17.18*	0.0017*	3.13*	3.50*	2.28*	0.0123	0.90*
Line × Tester	36	41.33	0.14*	0.80*	38.59*	0.18*	1.10*	0.50*	4.95*	0.0011*	5.52*	7.95*	7.44*	0.0170	0.52*
Error	49	32.67	0.04	0.36	4.32	0.09	0.61	0.21	2.18	0.0001	0.37	0.32	0.19	0.1359	0.07
GCA		0.35	0.00	0.00	0.71	0.00	0.02	0.001	0.16	0.0000	0.003	-0.01	-0.03	0.0000	0.01
SCA		4.33	0.05	0.22	17.13	0.05	0.24	0.146	1.39	0.0005	2.576	3.81	3.63	-0.0594	0.22
GCA/SCA		0.081	0.000	0.000	0.041	0.000	0.083	0.007	0.115	0.000	0.001	-0.003	-0.008	0.0000	0.045

* Significance at 5% level

Table 3. Proportional contribution of lines, testers and their interactions for various yield components and fibre quality traits

Particulars	PH	NM/P	NSy/P	NB/P	BW	SI	LI	GP	SCY/P	SL	UR	BS	EP	FF
Lines	25.4	15.8	11.1	39.1	13.0	20.7	22.4	43.7	32.4	18.1	11.9	5.4	5.5	46.0
Testers	21.4	40.3	8.0	20.8	41.4	36.7	10.7	26.2	19.8	10.2	8.7	6.7	14.4	16.4
Line × Tester	53.3	43.9	81.0	40.1	45.6	42.6	66.9	30.1	47.9	71.7	79.4	87.9	80.1	37.6

per se performance for eight traits namely plant height (111.0), monopodia /plant (1.9), sympodia /plant (15.2), bolls /plant (25.7), boll weight (5.2), lint index (5.9), seed cotton yield /plant (0.07) and 2.5% span length (31.1). This was followed by testers COD 1-5-2 which registered significant mean performance for six traits *viz.,* monopodia /plant (1.7), boll weight (5.2), lint index (6.8), ginning percentage (36.6), uniformity ratio (50.2) and bundle strength (22.9). The testers CNH 19 and TCH 486-2 recorded significant *per se* for five traits each. The former registered significant mean performance for sympodia /plant (16.1), boll weight (5.3), 2.5 per cent span length (30.1), uniformity ratio (48.8) and bundle strength (24.9) while the latter for boll weight (5.1), seed index (7.8), ginning percentage (39.7), seed cotton yield /plant (0.07) and uniformity ratio (49.2). Finally with respect to seed cotton yield /plant one line namely RB 602 (0.07 kg), five testers *viz.,* TCH 486-7 (0.08kg), GSHV 177, SCS 1207, Suraj and TCH 486-2 observed high *per se* performance (0.07kg).

gca effects of parents : The general combining ability effects (*gca*) of parents give useful information on the choice of parents in terms of expected performance of their progenies and suggested that parents with high *gca* would produce transgressive segregants in F_2 or later generations. This method has been widely used by several plant breeders for analysing the parents critically for their ability to transmit superior performance to their progenies. The parents with negatively significant *gca* effects were given importance for seed index and fibre fineness while for other traits, parents with positively significant *gca* effects were taken into consideration.

Based on the estimate of *gca* effects (Table 5), the line BGDS 1033 recorded high significant *gca* effects for seven traits *viz.,* plant height (2.58), bolls /plant (5.36), seed index (-0.43), ginning percentage (1.60), seed cotton yield /plant (0.03), uniformity ratio (1.11) and fibre fineness (-0.36). The line CO 14 registered significant *gca* effects for monopodia /plant (0.14), boll weight (0.21), uniformity ratio (0.31), bundle strength (0.24) and fibre fineness (-0.54) where as SVPR 2 had significant *gca* values for plant height (3.33), seed index (-0.45), ginning percentage (1.95), 2.5 per cent span length (0.76), and bundle strength (0.41). Among the testers, TCH 1819 had significant *gca* effects for seed index (-0.73), ginning percentage (1.15), 2.5 per cent span length (0.99), bundle strength (0.53) and fibre fineness (-0.19) where as TCH 486-7 registered significant *gca* effects for bolls /plant (4.55), ginning percentage (2.34), seed cotton yield/plant (0.02), uniformity ratio (0.70), and fibre fineness (-0.25). Three testers namely COD 1-5-2, SCS 1207 and TCH 486-2 recorded significant *gca* effects for four traits each.

***Per se* and *gca* effects :** Evaluation of parents based on mean and *gca* separately might result in identification of different sets of parents as promising ones. Kumar *et al.,* (2014) has reported that *per se* performance and *gca* effects of parents were directly related to each other. Khan (2013) also reported parallelism between *per se* performance and *gca* effects and reported that identification of parents for breeding programme based on either *per se* performance or *gca* effects alone was misleading in selection programme. The knowledge on general

Table 4. Mean performance of parents for yield components and fibre quality traits

Parents	PH	NM/P	NSy/P	NB/P	BW	SI	LI	GP	SCY/P	SL	UR	BS	EP	FF
RB 602	108.0	1.4	13.2	23.6	4.4	10.7	4.9	31.5	0.07*	27.1	46.1	20.9	5.7	4.6
BGDS 1033	103.3	1.1	13.7	22.8	3.9	8.2*	5.3	39.5*	0.06	25.3	51.8*	21.2	5.8	4.1
CO 14	103.5	1.4	14.5	20.9	4.5	10.6	5.8*	35.2	0.05	33.3*	42.0	23.6*	5.8	3.5*
SVPR 5	98.0	1.0	13.8	25.2*	4.0	9.1*	4.9	35.1	0.06	27.1	47.2	21.9	5.7	3.3*
SVPR 2	116.0*	1.1	14.5	24.6	4.9	9.9	5.2	34.5	0.06	28.2	49.6*	22.2	5.9	4.2
Mean	**105.8**	**1.2**	**13.9**	**23.4**	**4.3**	**9.7**	**5.2**	**35.1**	**0.06**	**28.2**	**47.3**	**22.0**	**5.8**	**3.9**
TCH 1819	93.0	1.2	12.4	18.4	5.5*	9.9	5.8*	37.1*	0.05	28.3	48.1	22.4	5.8	3.0*
CNH 19	107.5	1.3	16.1*	21.6	5.3*	12.6	5.5	30.4	0.06	30.1*	48.8*	24.9*	5.8	4.1
COD 5-1-2	105.5	1.7*	13.5	22.5	5.2*	11.9	6.8*	36.6*	0.06	28.3	50.2*	22.9*	5.9	4.2
GSHV 177	111.0*	1.9*	15.2*	25.7*	5.2*	11.0	5.9*	34.7	0.07*	31.1*	46.0	22.1	5.9	5.5
SCS 1207	107.0	1.2	16.4*	28.2*	4.9	10.5	5.3	33.6	0.07*	26.3	49.4*	20.7	5.7	4.5
Suraj	99.5	1.4	13.5	24.5	4.6	9.8	5.3	34.9	0.07*	30.1*	41.9	20.0	5.6	3.3*
African I-2	104.0	1.2	14.7*	20.3	4.1	8.4*	4.0	32.3	0.05	31.4*	47.5	25.1*	5.9	4.8
TCH 486-7	98.0	1.4	12.7	22.7	4.9	7.9*	4.9	38.4*	0.08*	26.3	49.8*	21.9	5.8	4.2
TCH 484-4	101.0	1.2	13.2	21.1	5.3*	9.5	6.3*	40.1*	0.05	26.6	48.1	19.8	5.8	4.1
TCH 486-2	104.0	1.2	13.1	20.7	5.1*	7.8*	5.1	39.7*	0.07*	26.2	49.2*	20.3	5.8	4.3
Mean	**103.1**	**1.4**	**14.1**	**22.6**	**5.0**	**9.9**	**5.5**	**35.7**	**0.06**	**28.5**	**47.9**	**22.0**	**5.8**	**4.2**
Grand mean	**104.0**	**1.3**	**14.0**	**22.9**	**4.8**	**9.8**	**5.4**	**35.5**	**0.06**	**28.4**	**47.7**	**22.0**	**5.8**	**4.1**
SEd	5.69	0.21	0.65	2.01	0.30	0.74	0.42	1.40	0.01	0.60	0.60	0.44	0.34	0.25
CD (P=0.05)	11.27	0.41	1.28	3.98	0.59	1.47	0.84	2.77	0.02	1.20	1.19	0.88	0.68	0.49

* Significance at 5% level

Table 5. Estimates of *gca* effects of parents for yield components and fibre quality traits

Parents	PH	NM/P	NSy/P	NB/P	BW	SI	LI	GP	SCY/P	SL	UR	BS	EP	FF
RB 602	-3.12*	0.01	-0.19	3.24 **	0.00	0.22	0.13	-0.01	0.01 **	0.24	-0.49 **	0.15	-0.01	-0.24 **
BGDS 1033	2.58 *	0.05	0.21	5.36 **	-0.02	-0.43 *	0.10	1.60 **	0.03 **	-1.33 **	1.11 **	-0.76 **	-0.04	-0.36 **
CO 14	-2.82 *	0.14 **	-0.27 *	-4.43 **	0.21 **	0.72 **	0.05	-1.39 **	-0.01 **	0.02	0.31 *	0.24 *	0.02	-0.54 **
SVPR 5	0.03	-0.26 **	0.07	-2.25 **	-0.21 **	-0.06	-0.48 **	-2.15 **	-0.02 **	0.32 *	-0.23	-0.04	0.00	0.55 **
SVPR 2	3.33 *	0.04	0.20	-1.93 **	0.03	-0.45 *	0.20	1.95 **	0.00	0.76 **	-0.72 **	0.41 **	0.01	0.59 **
SE	**1.81**	**0.06**	**0.19**	**0.66**	**0.09**	**0.25**	**0.14**	**0.47**	**0.00**	**0.19**	**0.18**	**0.14**	**0.12**	**0.08**
TCH 1819	1.08	-0.15 *	0.05	-3.59 **	0.07	-0.73 **	-0.14	1.15 *	-0.01 **	0.99 **	-0.68 **	0.53 **	0.02	-0.19 *
CNH 19	1.38	-0.12	-0.11	0.50	0.42 **	0.88 **	-0.02	-2.13 **	0.01	-0.39 *	0.26	-0.53 **	-0.04	0.28 **
COD 5-1-2	-4.52 *	0.06	-0.21	-2.27 **	0.30 **	0.85 **	0.33 *	-0.73	-0.02 **	0.25	0.62 **	0.27	0.02	-0.20 *
GSHV 177	-0.52	0.54 **	0.25	-2.00 **	-0.15	0.15	0.00	-0.20	-0.01 **	-0.83 **	-0.08	-0.95 **	-0.08	-0.26 **
SCS 1207	2.48	0.09	-0.01	3.82 **	-0.04	0.73 **	0.04	-1.50 **	0.01 **	0.09	0.40 *	0.37 **	0.02	0.06
Suraj	1.88	-0.15 *	0.19	-1.26	-0.36 **	-0.43	-0.25	0.01	0.00	0.19	-0.86 **	0.25	0.00	0.13
African I-2	0.18	-0.31 **	0.11	-2.85 **	-0.17	-0.04	-0.09	-0.39	0.00	0.07	-0.24	0.01	0.00	-0.29 **
TCH 486-7	1.18	-0.01	0.03	4.55 **	0.06	-0.47	0.28	2.34 **	0.02 **	-0.69 **	0.70 **	-0.19	-0.02	-0.25 **
TCH 484-4	-4.72 *	-0.05	-0.33	1.76 **	-0.31 **	-0.55 *	-0.07	0.93	0.00	0.59 **	-0.70 **	-0.24	0.00	0.11
TCH 486-2	1.58	0.06	0.07	1.32 *	0.17	-0.35	-0.06	0.54	0.01 *	-0.25	0.54 **	0.47 **	0.04	0.64 **
SE	**2.56**	**0.09**	**0.27**	**0.93**	**0.13**	**0.35**	**0.20**	**0.66**	**0.00**	**0.27**	**0.25**	**0.20**	**0.16**	**0.12**

* Significance at 5% level; ** Significance at 1% level

combining ability coupled with *per se* performance of parents would be fruitful in selecting suitable parents with good reservoir of superior genes for hybridization programme. In the present study, considering *per se* performance and *gca* effects for seed cotton yield and fibre properties, one line BGDS 1033 and three testers COD 1-5-2, SCS, 1207 and TCH 486-7 were registered significant mean and *gca* effect for three characters each. The line BGDS 1033 obtained good mean and *gca* effects for seed index, ginning percentage and uniformity ratio. The tester COD 1-5-2 have significant value for both mean and *gca* effects for boll weight, lint index and uniformity ratio, SCS 1207 for bolls / plant, seed cotton yield and uniformity ratio and TCH 486-7 for ginning percentage, seed cotton yield /plant and uniformity ration. Finally for seed cotton yield /plant four parents *viz.,* RB 602, SCS 1207, TCH 486-7 and TCH 486-2 had significant *per se* and *gca* effects. The parents possessing positive relationship between mean performance and *gca* effects may have more additive genes and could contribute for the accumulation of favourable genes in a varietal development programme. The lack of association between mean performance and the *gca* effects of parents, either high mean with low *gca* effect or *vice versa* signifies that the particular trait is probably under the influence of non additive gene action. An attempt could be made for selecting desirable hybrids through multiple crosses for yield and fibre quality traits in the segregating generations, as no parent was found to be a good combiner for all the traits as reported by Sawarkar *et al.* (2015), Madhuri *et al.* (2015), Usharani *et al.* (2016), Sivia *et al.* (2017), Monicashree *et al.* (2017) Anjum *et al.* (2018) khokhar *et al.* (2018) and Kumbhalkar *et. al.,*(2018).

Evaluation of hybrids : The prime objective of hybridization is to congregate the desirable genes present in two or more different parents into a single genetic background and also to create new variability. The hybrids obtained are analyzed for their mean, specific combining ability effects and heterosis over a standard check (Bunny N *Bt*) in order to suggest them for heterosis and /plant or recombination breeding procedures. Top performing hybrids for mean performance, *sca* effects and standard heterosis for yield components and fibre quality traits are tabulated in Table 6a, 6b and 6c. Inferiorly significant genotypes were chosen for the traits seed index and fibre fineness.

Mean performance of hybrids : The mean performance of hybrids is the primary criterion for selection of hybrids as it is real value obtained from them. Shimna and Ravikesavan (2008) suggested that *per se* of hybrids appeared to be useful index in judging the hybrids.

Among the fifty hybrids evaluated, the hybrid namely BGDS 1033 x TCH 486-7 recorded significant *per se* performance for nine traits studied namely for plant height (119.0), monopodia /plant (1.8), bolls /plant (35.0), boll weight (5.2), seed index (7.9), ginning percentage (40.8), seed cotton yield /plant (0.15), bundle strength (22.2) and fine fineness (2.8). The cross combination BGDS 1033 x GSHV 177 registered significant *per se* for eight traits namely monopodia /plant (1.9), sympodia /plant (16.2), bolls /plant (36.8), seed index (8.3), ginning percentage (39.6), seed cotton yield /plant (0.15), uniformity ratio (51.4) and fibre fineness (3.8). This was followed by two hybrids RB 602 x Suraj and BGDS 1033 x CNH 19 for seven traits each. The former hybrid registered significant *per se* for sympodia /plant, bolls /plant, seed cotton yield /plant, 2.5 per cent span length, uniformity ratio, bundle strength and fibre fineness and latter for plant height, sympodia /plant, bolls / plant, boll weight, lint index, seed cotton yield / plant and uniformity ratio. The crosses RB 602 x TCH 486-7, RB 602 x TCH 484-4, BGDS 1033 x TCH 1819, BGDS 1033 x 486-2 and SVPR 2 x TCH 486-7 registered highest mean performance for six traits each.

***sca* effects of hybrids :** The next major criterion for judging the hybrids is by studying their specific combining ability (*sca*) effects. *sca* is defined as the deviation from *per se* performance, predicted based on the general combining ability. Sprague and the *sca* effects are due to non-additive genetic interaction and observed that specific combining ability effects not only involved dominance and epistasis, but also a considerable amount of genotype and environment (G × E) interaction. The *sca* value of any cross is helpful in predicting the performance of the hybrids far better than the *gca* of parents. Negative *sca* effects were taken into consideration for seed index and fibre fineness.

Based on *sca* effects (Table 6b), the hybrids namely RB 602 x Suraj and RB 602 x TCH 484-4 recorded significant *sca* effects for five traits each. The former hybrid recorded significant *sca* effects for boll weight (0.42), 2.5 per cent span length (2.34), uniformity ratio (2.59), bundle strength (4.41) and fibre fineness (-0.57) where as latter for monopodia /plant (0.35), sympodia /plant (0.89), lint index (1.29), ginning percentage (2.74), seed cotton yield /plant (0.02). The hybrids namely BGDS 1033 x TCH 486-2, SVPR 5 x Suraj, SVPR 2 x CNH 19, SVPR 2 x TCH 486-7 and SVPR 2 x TCH 486-2 registered significant *sca* effect for four traits each. The *sca* effect obtained by the above hybrids is a clear indication of the presence of dominance gene action and such hybrids are highly suitable for heterosis breeding to fully exploit the dominance gene action and to improve the yield and fibre quality traits. Significant *sca* effects were also reported by Jatoi *et al.* (2010), Natera *et al.* (2012), Javaid *et al.* (2014), Madhuri *et al.* (2015), Sivia *et al.* (2017) and Monicashree *et al.* (2017).

Standard heterosis per cent : Among the three kind of heterosis, the interpretation of test hybrids based on standard, useful or economic heterosis reflecting the actual superiority over the best existing cultivar to be replaced appears to be more relevant and practical. Therefore, heterosis over the standard hybrid Mallika NBt. was chosen as the best hybrid in the present study (Table 6c). Negative standard heterosis was taken into consideration for seed index and fibre fineness.

Based on standard heterosis (Table 6c), three hybrids namely RB 602 x Suraj, BGDS 1033 x African I-2 and SVPR 2 x TCH 486-7 had recorded significant standard heterosis for eight traits each. The cross combination RB 602 x Suraj had significant standard heterosis for monopodia /plant (75.00), bolls /plant (28.26), seed index (-16.74), ginning percentage (13.24), seed cotton yield /plant (23.81), uniformity ratio (9.59), bundle strength (7.85) and fibre fineness

Table 6a. Mean performance of top performing crosses for yield and fibre quality traits

Crosses	PH	NM/P	NSy/P	NB/P	BW	SI	LI	GP	SCY/P	SL	UR	BS	EP	FF
RB 602 x SCS 1207	107.0	1.6	14.7	38.9*	4.5	10.3	5.7	35.8	0.13*	27.4*	46.4	20.9	5.7	3.8*
RB 602 x Suraj	108.5	1.4	16.0*	32.5*	4.8	9.0	5.1	36.4	0.13*	29.6*	50.3*	26.1*	5.9	3.5*
RB 602 x TCH 486-7	107.5	1.7	15.5	37.5*	4.9	9.2	5.6	37.8*	0.15*	27.7*	50.2*	22.4*	5.8	4.2
RB 602 x TCH 484-4	100.0	1.9*	15.8	36.0*	4.8	10.0	6.6*	39.8*	0.15*	28.0*	46.8	20.4	5.7	4.7
RB 602 x TCH 486-2	111.0	1.8*	15.1	35.0*	4.8	9.6	5.8*	37.6*	0.14*	24.2	49.6	19.6	5.8	4.8
BGDS 1033 x TCH 1819	115.5	1.1	16.1*	29.1	4.6	8.1*	5.1	38.5*	0.13*	25.1	50.6*	19.4	5.6	3.8*
BGDS 1033 x CNH 19	118.5*	1.6	16.0*	35.3*	5.5*	10.5	5.9*	36.1	0.15*	24.9	51.4*	19.1	5.7	4.5
BGDS 1033 x GSHV 177	115.0	1.9*	16.2*	36.8*	4.7	8.3*	5.4	39.6*	0.15*	23.3	51.1*	18.3	5.6	3.8*
BGDS 1033 x SCS 1207	113.5	1.8*	15.7	34.0*	4.5	9.1	4.8	34.7	0.14*	25.5	52.5*	20.5	5.8	4.7
BGDS 1033 x Suraj	115.5	1.4	15.5	30.0	4.4	9.4	5.3	36.4	0.13*	24.0	50.0*	20.1	5.7	3.9*
BGDS 1033 x African I-2	104.5	1.6	15.7	35.2*	4.7	9.0	6.1*	40.4*	0.15*	25.5	49.4	20.4	5.7	3.5*
BGDS 1033 x TCH 486-7	119.0*	1.8*	15.1	35.0*	5.2*	7.9*	5.4	40.8*	0.15*	27.0	47.8	22.2*	5.7	2.8*
BGDS 1033 x TCH 484-4	111.5	1.8*	14.6	39.3*	4.4	8.6	4.8	36.1	0.16*	26.9	48.0	21.2	5.8	3.8*
BGDS 1033 x TCH 486-2	111.5	1.5	15.3	38.0*	4.7	8.7	5.5	38.8*	0.16*	28.2*	48.9	23.5*	5.8	3.9*
CO 14 x CNH 19	103.0	1.5	13.9	30.0	5.6*	11.1	4.9	30.7	0.13*	25.7	45.9	18.6	5.6	3.6*
SVPR 5 x Suraj	114.0	1.5	16.0*	33.3*	4.3	9.5	4.6	32.6	0.13*	28.4*	44.4	20.9	5.7	4.7
SVPR 2 x CNH 19	119.5*	1.3	16.6*	23.2	5.2*	9.4	5.0	34.5	0.13*	29.0*	47.6	23.8*	5.8	4.3
SVPR 2 x SCS 1207	122.5*	2.1*	15.3	34.8*	4.9	9.4	5.3	36.1	0.15*	27.2	46.7	20.8	5.7	4.7
SVPR 2 x TCH 486-7	112.5	1.2	15.2	38.2*	4.6	8.4*	6.3*	42.7*	0.15*	25.9	50.2*	21.6	5.8	4.4
SVPR 2 x TCH 484-4	114.0	1.4	14.6	30.7*	4.4	7.5	5.0	40.0*	0.13*	25.9	47.5	19.4	5.6	5.1
Mean	**110.7**	**1.6**	**15.4**	**28.3**	**4.7**	**9.3**	**5.3**	**36.1**	**0.11**	**26.8**	**49.1**	**21.3**	**5.8**	**4.2**
SEd	5.7	0.2	0.6	2.1	0.3	0.8	0.5	1.5	0.01	0.6	0.6	0.4	0.4	0.3
Range	97.0to	1.6to	13.9to	17.9to	4.0to	7.5to	4.3to	30.7to	0.05to	23.3to	44.4to	18.3to	5.6to	2.8to
	122.5	2.6	16.6	39.3	5.6	11.3	6.7	42.8	16.0	29.9	53.2	26.1	5.9	5.9

* Significance at 5% level

Table 6b. *sca* effects of top performing crosses for yield and fibre quality traits

Crosses	PH	NM/P	NSy/P	NB/P	BW	SI	LI	GP	SCY/P	SL	UR	BS	EP	FF
RB 602 x SCS 1207	-3.08	-0.09	-0.53	3.52 *	-0.20	0.05	0.28	1.12	0.00	0.24	-2.57 **	-0.91 **	-0.07	-0.20
RB 602 x Suraj	-0.98	-0.05	0.57	2.20	0.42 *	-0.14	-0.08	0.22	0.01	2.34 **	2.59 **	4.41 **	0.15	-0.57 **
RB 602 x TCH 486-7	-1.28	0.11	0.23	1.39	0.10	0.10	-0.11	-0.66	0.00	1.32 **	0.93 *	1.15 **	0.07	0.51 **
RB 602 x TCH 484-4	-2.88	0.35 *	0.89 *	2.68	0.37	1.03	1.29 **	2.74 *	0.02 *	0.34	-1.07 *	-0.80 *	-0.05	0.60 **
RB 602 x TCH 486-2	1.82	0.14	-0.21	2.17	-0.16	0.43	0.43	0.88	0.01	-2.62 **	0.49	-2.31 **	0.01	0.22
BGDS 1033 x TCH 1819	1.12	-0.39 **	0.41	-0.94	-0.19	-0.04	-0.11	-0.42	0.00	-1.39 **	1.11 **	-1.66 **	-0.14	0.17
BGDS 1033 x CNH 19	3.82	0.08	0.47	1.12	0.36	0.75	0.57	0.51	0.00	-0.21	0.97 *	-0.90 **	0.02	0.40 *
BGDS 1033 x GSHV 177	2.22	-0.28 *	0.31	5.12 **	0.13	-0.72	0.05	2.03	0.02 **	-1.37 **	1.01 *	-1.28 **	-0.04	0.24
BGDS 1033 x SCS 1207	-2.28	0.07	0.07	-3.50 *	-0.23	-0.55	-0.64	-1.59	-0.01	-0.09	1.93 **	-0.40	0.06	0.82 **
BGDS 1033 x Suraj	0.32	-0.09	-0.33	-2.37	-0.01	0.91	0.20	-1.34	0.00	-1.69 **	0.69	-0.68 *	-0.02	-0.10
BGDS 1033 x African I-2	-8.98 *	0.27	-0.05	4.42 **	0.10	0.17	0.79 *	3.01 **	0.01	-0.07	-0.53	-0.14	-0.02	-0.03
BGDS 1033 x TCH 486-7	4.52	0.17	-0.57	-3.23 *	0.37	-0.55	-0.23	0.68	-0.01	2.19 **	-3.07 **	1.86 **	0.00	-0.77 **
BGDS 1033 x TCH 484-4	2.92	0.21	-0.71	3.91 *	-0.01	0.23	-0.48	-2.62 *	0.01	0.81	-1.47 **	0.91 **	0.08	-0.18
BGDS 1033 x TCH 486-2	-3.38	-0.20	-0.41	3.05 *	-0.19	0.18	0.21	0.48	0.01	2.95 **	-1.81 **	2.50 **	0.04	-0.56 **
CO 14 x CNH 19	-6.28	-0.11	-1.15 **	5.66 **	0.23	0.20	-0.38	-1.91	0.02 **	-0.76	-3.73 **	-2.40 **	-0.14	-0.32
SVPR 5 x Suraj	1.37	0.32 *	0.31	8.54 **	0.08	0.64	0.08	-1.39	0.04 **	1.06 *	-3.57 **	-0.60	-0.06	-0.16
SVPR 2 x CNH 19	4.07	-0.26	1.08 *	-3.64 *	0.01	-0.33	-0.48	-1.45	0.01	1.80 **	-1.00 *	2.63 **	0.07	-0.80 **
SVPR 2 x SCS 1207	5.97	0.38 *	-0.32	4.59 **	0.17	-0.23	-0.24	-0.55	0.03 **	-0.48	-2.04 **	-1.27 **	-0.09	-0.13
SVPR 2 x TCH 486-7	-2.73	-0.42 **	-0.46	7.31 **	-0.23	-0.03	0.52	2.28 *	0.02 **	-1.00 *	1.16 **	0.09	0.05	-0.17
SVPR 2 x TCH 486-2	3.87	-0.14	0.80	1.39	0.46 *	0.05	-0.09	-0.29	0.00	1.26 **	0.82 *	2.23 **	0.09	-0.31
SE	5.72	0.20	0.60	2.08	0.29	0.78	0.46	1.47	0.01	0.61	0.57	0.44	0.37	0.27
Range	-8.98to 7.12	-0.51to 0.51	-0.89to 0.89	-7.56to 8.54	0.62to 0.70	-1.89to 1.83	-0.65to 1.29	-2.62to 3.10	-0.05to 0.04	-2.62to 3.58	-3.73to 4.11	-2.46to 4.41	-0.17to 0.13	-0.90to 0.90

* Significance at 5% level; ** Significance at 1% level

Table 6c. Standard heterosis of top performing crosses for yield and fibre quality traits

Crosses	PH	NM/P	NSy/P	NB/P	BW	SI	LI	GP	SCY/P	SL	UR	BS	EP	FF
RB 602 x SCS 1207	-0.93	100.00 **	-5.77	53.56 **	-15.09 **	-4.19	12.87	11.37 *	28.57 **	-16.72 **	1.09	-13.64 **	-5.00	-28.97 **
RB 602 x Suraj	0.46	75.00 **	2.56	28.26 **	-9.43	-16.74 *	0.00	13.24 **	23.81 *	-10.03 **	9.59 **	7.85 **	-1.67	-34.58 **
RB 602 x TCH 486-7	-0.46	112.50 **	-0.64	48.02 **	-7.55	-14.88 *	9.90	17.76 **	42.86 **	-15.81 **	9.37 **	-7.44 **	-3.33	-21.50 **
RB 602 x TCH 484-4	-7.41	137.50 **	1.28	42.09 **	-9.43	-6.98	30.69 **	23.99 **	38.10 **	-14.89 **	1.96	-15.70 **	-5.00	-13.08 **
RB 602 x TCH 486-2	2.78	125.00 **	-3.21	38.34 **	-10.38	-10.70	13.86	16.98 **	38.10 **	-26.44 **	8.06 **	-19.01 **	-3.33	-10.28 *
BGDS 1033 x TCH 1819	6.94	37.50	3.21	15.02	-13.21 *	-24.65 **	0.99	19.78 **	23.81 *	-23.71 **	10.24 **	-19.83 **	-6.67	-28.97 **
BGDS 1033 x CNH 19	9.72	100.00 **	2.56	39.33 **	3.77	-2.33	16.83	12.46 **	42.86 **	-24.32 **	11.98 **	-21.07 **	-5.00	-15.89 **
BGDS 1033 x GSHV 177	6.48	137.50 **	3.85	45.26 **	-11.32 *	-22.79 **	6.93	23.21 **	42.86 **	-29.18 **	11.33 **	-24.38 **	-6.67	-28.97 **
BGDS 1033 x SCS 1207	5.09	125.00 **	0.64	34.19 **	-16.04 **	-15.81 *	-5.94	7.94	38.10 **	-22.49 **	14.38 **	-15.29 **	-3.33	-12.15 *
BGDS 1033 x Suraj	6.94	75.00 **	-0.64	18.58 *	-17.92 **	-13.02	4.95	13.40 **	28.57 **	-27.05 **	8.93 **	-16.94 **	-5.00	-28.04 **
BGDS 1033 x African I-2	-3.24	100.00 **	0.64	39.13 **	-12.26 *	-16.28 *	19.80 *	25.70 **	42.86 **	-22.49 **	7.63 **	-15.70 **	-5.00	-34.58 **
BGDS 1033 x TCH 486-7	10.19	125.00 **	-3.21	38.14 **	-2.83	-26.98 **	6.93	26.95 **	42.86 **	-17.93 **	4.14 **	-8.26 **	-5.00	-47.66 **
BGDS 1033 x TCH 484-4	3.24	125.00 **	-6.41	55.34 **	-16.98 **	-20.47 **	-4.95	12.31 **	52.38 **	-18.24 **	4.58 **	-12.40 **	-3.33	-29.91 **
BGDS 1033 x TCH 486-2	3.24	87.50 **	-1.92	50.20 **	-11.32 *	-19.07 **	8.91	20.72 **	52.38 **	-14.29 **	6.54 **	-2.89	-3.33	-27.10 **
CO 14 x CNH 19	-4.63	87.50 **	-10.90 **	18.58 *	5.66	3.26	-2.97	-4.36	23.81 *	-21.88 **	0.00	-23.14 **	-6.67	-32.71 **
SVPR 5 x Suraj	5.56	87.50 **	2.56	31.62 **	-19.81 **	-12.09	-8.91	1.56	23.81 *	-13.68 **	-3.27 *	-13.64 **	-5.00	-12.15 *
SVPR 2 x CNH 19	10.65 *	56.25 *	6.41	-8.30	-1.89	-12.56	-1.98	7.48	14.29	-11.85 **	3.70 **	-1.65	-3.33	-20.56 **
SVPR 2 x SCS 1207	13.43 *	162.50 **	-1.92	37.35 **	-7.55	-13.02	3.96	12.31 **	47.62 **	-17.33 **	1.74	-14.05 **	-5.00	-12.15 *
SVPR 2 x TCH 486-7	4.17	50.00 *	-2.56	50.99 **	-13.21 *	-22.33 **	23.76 **	33.02 **	47.62 **	-21.28 **	9.37 **	-10.74 **	-3.33	-18.69 **
SVPR 2 x TCH 486-2	10.65 *	93.75 **	5.77	14.82	1.89	-20.47 **	4.95	19.47 **	9.52	-13.07 **	8.28 **	0.83	-1.67	-4.67
SE	3.96	0.14	0.42	1.48	0.20	0.55	0.32	1.03	0.01	0.44	0.41	0.31	0.26	0.19
Range	-10.19to 13.43	25.03to 225.00	-10.93to 6.41	-29.25to 55.34	-24.50to 5.66	-30.23to 11.63	15.84to 35.68	-4.36to 29.65	-52.38to 9.12	-29.18to 122.5	-3.27to 15.90	-24.38to 7.85	-6.67to -1.67	-47.66to 9.38

* Significance at 5% level; ** Significance at 1% level

(-34.58) where as the hybrid between BGDS 1033 x African I-2 had significant standard heterosis monopodia /plant (100.0), bolls /plant (39.13), seed index (16.28), lint index (19.80), ginning percentage (25.70), seed cotton yield /plant (42.86), uniformity ratio (7.63) and fibre fineness (-34.58). The F_1 between SVPR 2 x TCH 486-7 had recorded significant heterosis for monopodia /plant (50.0), bolls /plant (50.99), seed index (22.33), lint index (23.76), ginning percentage (33.02), seed cotton yield /plant (47.62), uniformity ratio (9.37) and fibre fineness (-12.15). Five hybrids *viz.,* RB 602 x TCH 486-7, BGDS 1033 x GSHV 177, BGDS 1033 x TCH 486-7, BGDS 1033 x TCH 484-4 and BGDS 1033 x TCH 486-2 were registered significant standard heterosis for seven traits each followed by six hybrids namely RB 602 x TCH 484-4, RB 602 x TCH 486-2, BGDS 1033 x CNH 19, BGDS 1033 x SCS 1027, BGDS 1033 x Suraj and SVPR 2 x SCS 1207 which recorded significant standard heterosis for six traits each. Therefore, these hybrids could be selected based on standard heterosis for improvement in yield and fibre quality traits. Positive and significant standard heterosis has been reported for yield and fibre quality traits by Jyotiba *et al.* (2010), Geddam *et al.* (2011), Ashokkumar *et al.* (2013), Madhuri *et al.* (2015), Sivia *et al.* (2017), Monicashree *et al.* (2017), Kumbhalkar *et. al.,* (2018) and Khokhar *et. al.,* (2018)

Crosses chosen for heterosis breeding : Hybrids for heterosis breeding were selected based on three criteria *viz.*, mean performance, *sca* effects and standard heterosis. In this perspective, the hybrids BGDS 1033 x GSHV 177, CO14 x CNH 19, SVPR 5 x Suraj, SVPR 2 X SCS 1207 and SVPR 2 x TCH 486-7 for seed cotton yield /plant and bolls /plant were identified as the best hybrids and these are well suited for exploitation through heterosis breeding for trait as mentioned. Since cotton is an often-cross pollinating crop, varietal crosses are easy by hand emasculation and hence, these hybrids could be utilized in heterosis breeding programme. Hybrids with high *per se* performance, significant *sca* and heterosis for yield and fibre quality traits have also been reported (Kumar *et al.* (2014); Madhuri *et al.* (2015); Monicashree *et al.* 2017); Khokhar *et al.* (2018); Kumbhalkar *et al.* (2018)

Crosses chosen for recombination breeding : Recombination breeding procedures allow further combination of alleles in segregating generations, so that we could obtain genotypes with favourable combination of alleles for the traits under improvement. Selection of such genotypes will not mislead if such characters and genotypes are under the control of additive genetic effects. Hence, the hybrids suitable for recombination procedures were selected based on the presence of additive genetic effects *i.e.* significant *gca* effects of the parents and absence of non additive genetic effects *i.e.* non significant *sca* effects of the corresponding hybrids. Such hybrids are believed to throw suitable segregants with favourable combination of alleles for the selected traits. Thus the hybrids RB 602 x TCH 486-7 and RB 602 x TCH 486-2 could be recommended for recombination breeding as they satisfied for seed cotton yield /plant and bolls /plant. The cross combinations CO 14 x CNH 19 and CO 14 x COD 1-5-2 for Boll weight and the hybrid between SVPR 2 x TCH 1819 for ginning percentage, 2.5

per cent span length and bundle strength could also recommended for recombination breeding. By exploiting this cross the best transgressive segregants for yield, other yield contributing traits and fibre quality parameters can be selected in further generations. High *per se* performance, significant standard heterosis and highly significant gca effects for one of the parents for seed cotton yield but non-significant sca effect for seed cotton yield may be due to the lack of co-adaptation between favourable alleles of the parents involved for this trait. Similar results were also recorded by Hussain *et al.* (2010), Sawarkar *et al.* (2015), Solanki *et al.* (2015), Usharani *et al.* (2016), Babu *et al.* (2017), Monicashree *et al.* (2017), Anjum *et al.* (2018) and Munir *et al.* (2018).

CONCLUSION

The results signify the importance of non-additive genetic effects for attaining maximum improvement in quantitative traits. Parents having high *gca* values *i.e.,* TCH 486-7,RB 602, SCS 1207 and TCH 486-2 were detected with higher general combining ability for seed cotton yield /plant and should be given due consideration in developing superior hybrid or recombinant in the segregating generation. The hybrids BGDS 1033 x GSHV 177, CO14 x CNH 19, SVPR 5 x Suraj, SVPR 2 X SCS 1207 and SVPR 2 x TCH 486-7 for seed cotton yield /plant and bolls /plant were chosen for heterosis breeding as it recorded significant *per se*, *sca* effects and standard heterosis for trait as mentioned. Besides, the hybrids RB 602 x TCH 486-7 and RB 602 x TCH 486-2 could be recommended for recombination breeding as they satisfied significant *gca* effects of the parents and non significant *sca* effects of the corresponding hybrids for seed cotton yield /plant and bolls / plant.

REFERENCES

Ali, M.A., and Khan, I.A. 2007. Assessment of genetic variation and inheritance mode of some metric traits in cotton (*Gossypium hirsutum* L.). 2007. *J. Agric. Soc. Sci.* **3 :** 112-16.

Anjum, R., Baloch, M. J., Baloch, G. M. and Chachar, Q. 2018. Combining ability estimates for yield and fibre quality traits in Bt and non-Bt upland cotton genotypes. *Pure and Applied Biology,***7 :** 389-99.

Annual Report, All India Co-ordinated Research Project on Cotton. 2017 – 18.

Ashokkumar, K., Senthil Kumar, K. and Ravikesavan, R. 2013. Heterosis studies for fibre quality of upland cotton in line x tester design. *Afr. J. Agric. Res.,* **8 :** 6359-65.

Babu, B. J., Satish, Y., Ahamed, M. L and Rao, V. S. 2017. Combining ability analysis for yield and fibre quality traits in cotton (*Gossypium hirsutum* L.). *J. Res. Angrau,* **45 :** 33-43.

Geddam, S.B., Khadi, B.M., Mogali, S., Patil, R.S., Katageri, I.S., Nadaf, H.L. and Patil, B.C. 2011. Study of heterosis in genetic male sterility based diploid cotton hybrids for yield, yield component and fibre quality characters (Gossypium hirsutum L.) *Karnataka J. Agric. Sci.,* **24 :** 118-24.

Hussain, A., Azhar, F. M., Ali, M. A., Ahmad, S and Mahmood, K. 2010. Genetic studies of fibre quality characters in upland cotton. *J. Anim. Plant Sci.*, **20 :** 234-38.

Jatoi, W.A., Baloch, M.J., Khan, N.U., Veesar and Batool, S. 2010. Identification of potential parents and hybrids in intraspecific crosses of upland cotton. *Sarhad J. Agric.,* **26 :** 25-30.

Javaid, A., Azhar, F.M., Khan, I.A. and Rana, S.A. 2014. Genetic basis of some yield components in Gossypium hirsutum L. *Pak. J. Agri. Sci.,* **51 :** 143-46.

Jyotiba, S.S., Patil, B.R., Deshpande, S.K., Patil, S.S. and Patil, R.S. 2010. Heterosis studies in GMS based diploid cotton (Gossypium herbaceum L). *Electronic J. Pl. Breed.,* **1 :** 685-88.

Karademir, C., E. Karademir, R. Ekinci and Gencer, O. 2009. Combining ability estimates and heterosis for yield and fiber quality of cotton in line x tester design. *Bot. Hort. Agrobot. Cluj.,* **37 :** 228-31.

Khan, N.U. 2013. Combining ability analysis in intra specific F_1 Diallel cross of upland cotton. *Agron.,* **6 :** 289-95.

Khokhar, E.S., Shakeel, A., Maqbool, M.A., Abuzar, M.K., Zareen, S., Aamir, S.S and Asadullah, M. 2018. Studying combining ability and heterosis in different cotton (*Gossypium hirsutum* L.*)* genotypes for yield and yield contributing traits. *Pakistan Journal of Agricultural Research,* **31 :** 55-68. http://dx.doi.org/10.17582/journal.pjar/2018/31.1.55.68.

Kumar, K.S., Ashokkumar, K. and Ravikesavan, R. 2014. Genetic effects of combining ability studies for yield and fibre quality traits in diallel crosses of upland cotton (Gossypium hirsutum L). *Afr. J. Biotechnol.,* **13 :** 119-26.

Kumbhalkar, H.B., Gawande, V.L. Vinita Gotmare and Rathod, T.H. 2018. Combining Ability Studies for Yield, its Component Traits and Fibre Properties through Line X Tester Mating Design in Upland Cotton (*Gossypium hirsutum* L.). *Int.J.Curr.Microbiol.App.Sci.* **7 :** 1357-70.

Lukonge, E.P., Labuschagne, M.T. and Herselman, L. 2008. Combining ability for yield and fiber characteristics in Tanzanian cotton germplasm. *Euphytica,* **161 :** 383-89.

Madhuri, S., Solanke, A. Mhasal, G.S. and Deshmukh, S.B. 2015. Combining ability and heterosis for seed cotton yield, its components and quality traits in *Gossypium hirsutum* L. *Indian J. Agric. Res.,* **49 :** 154-59.

Monicashree, C., Amala Balu, P. and Gunasekaran, M. 2017. Combining Ability and Heterosis Studies on Yield and Fibre Quality Traits in Upland Cotton (Gossypium hirsutumL.).*Int. J. Curr. Microbiol. App. Sci.* **6 :** 912-27. https://doi.org/10.20546/ijcmas.2017.608.113

Munir S., Qureshi, M. K. Shahzad, A. N., Manzoor, H. Shahzad, M. A. Aslam, K. and Athar, H. 2018. Assessment of gene action and combining ability for fibre and yield contributing trais in interspecific and intraspecific hybrids of cotton. *Czech J. Genet. Plant Breed. pp*: 1-7.

Natera, J.R.M., Rondan, A., Hernandez, J. and Pinto, J.F.M. 2012. Genetic studies in upland cotton (Gossypium hirsutum L.) II. General and specific combining ability. *J. Agr. Sci. Tech.,* **4 :** 617-27.

Patel, D.H., Patel, D.U. and Kumar, V. 2014. Heterosis and combining ability analysis in tetraploid cotton (*G.hirsutum* L. and *G. barbadense* L.). *Electr. J. Plant Breed.,* **5 :** 408-14.

Rauf, S., Munir., H., Basra., S. M.A., Abdullojon, E. 2006. Combining ability analysis in upland cotton (*Gossypium hirsutum* L.). *International J. Agric. Biol.,* **3 :** 341-43.

Sawarkar, M., Solanke, A Mhasal, G. S. and Deshmukh, S. B. 2015. Combining ability and heterosis for seed cotton yield, its components and quality traits in *Gossypium hirsutum* L. *Indian Journal of Agricultural Research*, **49 :** 154-59. https://doi.org/10.5958/0976-058X.2015.00022.0.

Shimna, B. and Ravikesavan. (2008). Combining ability analysis of yield related traits and fibre quality traits in cotton (*Gossypium* spp.). *J. Cotton Res. Dev.,* **22 :** 23-27.

Sivia, S.S., Siwach, S. S., Sangwan, O., Lingaraja, L. and Vekariya, R.D. 2017. Combining Ability Estimates for Yield Traits in Line x Tester Crosses of Upland Cotton (Gossypium hirsutum). Int. *J. Pure App. Biosci.* **5 :** 464-74. https://doi.org/10.18782/2320-7051.2462

Solanki, H. V., Mehta, D. R. Rathod, V. B. and Vavdiya, P. A. 2015. Heterosis and combining ability for earliness and its related traits in cotton (*Gossypium hirsutum* L.). *The Bioscan,* **10 :** 2075-79.

Usharani, C. V., Manjula, S. M. and Patil S. S. 2016. Estimating combining ability through line × tester analysis in upland cotton. *Research in Environment and Life Sciences,* **9 :** 628-33.

Yanal, A.A., Rao, G., Patil, M.R. Gowda, T.H. and Joshi, M. 2013. Combining ability analysis for seed cotton yield (kapas yield) and its components in intra hirsutum hybrids and forming heterotic boxes for exploitation in cotton. *Gen. Appl. Biol.,* **4 :** 35-49. https://doi.org/10.5376/gab.2013.04.0005.

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