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Full Length Research Paper

Combining ability and heritability for yield, yield related and fiber quality traits in cotton (*Gossypium*spp.) at Werer, Ethiopia

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Thirty six genotypes were evaluated for seventeen traits in 2017 at Werer Agricultural Research Center. The experiment was laid out in 6 x 6 simple lattice design. Results of analysis of variance showed the presence of significant differences among genotypes for all traits except stand count and uniformity index. Mean squares of lines for general combining ability was significant for all traits, while specific combining ability was significant for days to initial boll opening, number of bolls per plant, seed cotton yield, lint yield and fiber strength. Line 10 and L16 exhibited positive and significant maximum GCA effects for seed cotton yield and lint yield, while L1 and L2 had positive and significant GCA effects for fiber length, fiber strength and fiber elongation. Hybrids L4 x T2, L13 x T1 and L9 x T2 were identified as good specific combinations for seed cotton yield, lint yield and ginning percentage. High heritability in broad-sense were exhibited for almost traits. Generally, selection high performing lines for lint yield and related traits followed by crossing with testers is possible to obtain commercial cotton hybrids.

Keywords: Combining ability, hybrids, lint yield, seed cotton yield, heritability.

INTRODUCTION

Cotton is the most important natural textile fiber crop and its cultivation has a long history and deep-rooted in the Ethiopian agriculture as spinning and weaving to make clothes from cotton is perhaps as old as the history of the country (Mulat*et al.*, 2004). Cotton is one of the major cash crops in Ethiopia and is extensively grown in the lowlands under large-scale irrigation schemes, while grown also on small-scale farms under rain-fed agriculture (EIA, 2012). Cotton, next to coffee as prioritized strategic export and import substitution commodities in the industrial development of Ethiopia (Alebel *et al.*, 2014). Cotton is sometimes called the white gold which is allotetraploid, often-cross pollinating and indeterminate type of growth habit crop in which varietal crosses are easy by hand emasculation (Kumar, 2007; Kanimozhi, 2012). The major end uses for cotton seeds are vegetable oil for human consumption; whole seed, meal and hulls for animal feed and linters for batting and chemical cellulose (Wakelyn *et al.*, 2007). Carlsson (2009) cited that the oil content of cotton seed is about 20% and account for about 5% of the total plant oil produced in the world. The author also suggested that oil composition of cottonseed are linoleicacid (56%), palmitic (23%) and oleic acid (17%) and other major fatty acids.

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Combining ability provides information for the selection of parents as well as the nature and magnitude of gene action involved in the expression of traits (Sharma, 2006). Combining ability are useful in determining the breeding value of lines by suggesting the appropriate use in a breeding program (Olfati *et al*., 2012). Sharma *et al*. (2014) emphasized knowledge of combining ability is useful to assess differences among the genotypes indicated good prospects for selection of suitable parents and crosses for the development of appropriate varieties and hybrids. Kumar *et al.* (2017) revealed that successful hybridization programme parents should be selected not only on the basis of their diversity but also on the basis of their combing ability. The parents having positive relationship between mean performance and GCA effects had more number of additive gene action, while negative association (either high mean performance with low GCA effect or vice versa) exhibited that the traits is under the influence of non-additive gene action (Monicashree *et al*., 2017).

Heritability is the degree to which the given trait is transmitted to next generation and suitable statistical tool for plant breeder to select the suitable breeding method in order to improve the genetic makeup of cotton plant which determine the effectiveness of selection (Aziz *et al.*, 2014). There are two types of heritability i.e, broad sense and narrow sense heritability. Broad sense heritability is the ratio of the total genetic variance to the phenotypic variance of individuals and expressed in percentage as its importance in plant breeding is limited due to unclear estimate of the fixable genetic variance for selection, while narrow sense heritability is the ratio of additive genetic variance to the total phenotypic variance and it gives the best estimate of heritable variance, which can be fixed by selection (Sleeper and Poehlman, 2006). The knowledge on the inheritance qualitative and quantitative traits are very important for the breeders to improve the plant traits and better estimate the level of heritability involve in enhancing breeding approach through selections from segregating generations (Baloch *et al*., 2010). Therefore, the objectives of this study were to assess magnitude of heritability in cotton hybrids obtained by line x tester mating method, and to determine general and specific combining abilities in cotton hybrids for yield, yield related and fiber quality traits.

MATERIALS AND METHODS

The field experiment was conducted at Werer Agricultural Research Center (WARC) during 2017 main cropping season. WARC is located in Amibara district, Afar National Regional State and placed 280 km from Addis Ababa in the eastern direction. The center is located at 9^0 34'12" N latitude, 40^0 17'22"E longitudes and an altitude of 740m above sea level.

Thirty two F_1 hybrids by crossing of 16 inbred lines (female parent) and two testers (male parent) namely, Deltapine-90 and Werer-50using line x tester mating design following the method of Kempthorne (1957) as presented in Table 1. The experiment was laid out as simple lattice design in 6 x 6 arrangements with two replications. Each block comprises 6 units (plots) having 5m long and 5 row wide with the spacing of 0.90m between rows and 0.20m between plants. Two seeds per hill were placed and later thinned out and left with one healthy seedling per hill after seedlings established well. All cultural practice were done manually throughout the entire growing season as required. Data of 17 qualitative and quantitative traits were collected viz., days to initial squaring, days to initial flowering, days to 50% flowering, days to initial boll opening, days to 65% boll opening, number of bolls per plant, plant height, average boll weight, seed cotton yield, ginning percentage, lint yield, fiber length, fiber strength, uniformity index, micronaire and fiber elongation.

Data Analysis

The data collected for all agronomic and quality traits were subjected to general analysis of variance using PROC GLM procedure in SAS (SAS, 2004). The Line x Tester analysis of combining ability to identify the GCA effects of the parents and SCA effects of the hybrids were estimated as described by Kempthorne (1957). The mean squares for crosses, lines, testers and line x tester interaction GCA and SCA effects were calculated by the statistical procedures developed by Kempthorne (1957) and adopted by Singh and Chaudhary (1985). Broad sense heritability values were estimated using the formula adopted by Falconer and Mackay (1996). The heritability percentage was categorized as low, moderate and high as suggested by Robinson *et al.* (1955).

RESULTS AND DISCUSSION

Analysis of Variance

Analysis of variance showed that mean squares of genotypes were significant at ($P \leq 0.05$) for traits of days to initial squaring, days to initial flowering, days to 50% flowering, days to initial boll opening, days to 65% boll opening, number of bolls per plant, plant height, average boll weight, seed cotton yield, ginning percentage, lint yield, micronaire, fiber length, fiber strength, fiber elongation (Table 2). The differences among the checks were significant for traits of days to initial squaring, average boll weight, seed cotton yield, ginning percentage and lint yield traits studied. Whereas, the mean squares for cross vs check was significant for most studied traits viz. days to initial boll opening, days to 65% boll opening, number of bolls per plant, seed cotton

Table 1. Descriptions of the 36 cotton genotypes in experiment.

Entries	Stock ID	Pedigree	Code
1	CV142-1	LS-90 x Pima S3 5-7 x Deltapine-90	L1 x T1
2	CV142-2	HTO#052 x LS-90 24-7 x Deltapine-90	L2 x T1
3	CV142-3	HTO#052 x DP-90 21-7 x Deltapine-90	L3 x T1
4	CV142-4	Cucurova1518 X LG-450 35-4 X Deltapine-90	L4 x T1
5	CV142-5	ISA 205H x Beyazealtin/5 16-2 x Deltapine-90	L5 x T1
6	CV142-6	HS-46 x Stonevile 453 19-8 x Deltapine-90	L6 x T1
7	CV142-7	Stam 59 A x Cucurova 1518 30 -2 x Deltapine-90	L7 x T1
8	CV142-8	Delcero x Deltapine90 #F5-5-4-2-2 x Deltapine-90	L8 x T1
9	CV142-9	Nazilli-84 X HS-4 #F5-43-3-3-2 x Deltapine-90	L9 x T1
10	CV142-10	Sidhafage Farm No 3A4 DP-90 F_1#44 x Deltapine-90	L10 x T1
11	CV142-11	Melkawerer Farm 2 Farm no 51 DP-90 F_1#103 x Deltapine-90	L11 x T1
12	CV142-12	Algeta Farm no AM 12c DP-90 F_1#146 x Deltapine-90	L12 x T1
13	CV142-13	Farm no Ago1 DP-90 F_1#334 x Deltapine-90	L13 x T1
14	CV142-14	Weyto Farm no M1 DP-90 F_1#375 x Deltapine-90	L14 x T1
15	CV142-15	Europa x Stam 59A – 04-5 x Deltapine-90	L15 x T1
16	CV142-16	Brazilian x Deltapine-90	L16 x T1
17	CV142-17	LS-90 x Pima S3 5-7 x Werer-50	L1 x T2
18	CV142-18	HTO#052 x LS-90 24-7 x Werer-50	L2 x T2
19	CV142-19	HTO#052 x DP-90 21-7 x Werer-50	L3 x T2
20	CV142-20	Cucurova1518 x LG-450 35-4 x Werer-50	L4 x T2
21	CV142-21	ISA 205H x Beyazealtin/5 16-2 x Werer-50	L5 x T2
22	CV142-22	HS-46 x Stonevile 453 19-8 Werer-50	L6 x T2
23	CV142-23	Stam 59 A x Cucurova 1518 30 -2 x Werer-50	L7 x T2
24	CV142-24	Delcero x Deltapine90 #F5-5-4-2-2 x Werer-50	L8 x T2
25	CV142-25	Nazilli-84 x HS-4 #F5-43-3-3-2 x Werer-50	L9 x T2
26	CV142-26	Sidhafage Farm No 3A4 DP-90 F_1#44 x Werer-50	L10 x T2
27	CV142-27	Melkawerer Farm 2 Farm no 51 DP-90 F_1#103 x Werer-50	L11 x T2
28	CV142-28	Algeta Farm no AM 12c DP-90 F_1#146 x Werer-50	L12 x T2
29	CV142-29	Farm no Ago1 DP-90 F_1#334 x Werer-50	L13 x T2
30	CV142-30	Weyto Farm no M1 DP-90 F_1#375 x Werer-50	L14 x T2
31	CV142-31	Europa X Stam 59A – 04-5 x Werer-50	L15 x T2
32	CV142-32	Brazilian x Werer-50	L16 x T2
33		Sisikuk-02 - OPV	C-1
34		Weyto-07 – OPV	C-2
35		Stam-59A – OPV	C-3
36		Delcero x Deltapine -90 #F5-5-4-2-2- OPV	C-4

yield, lint yield, micronaire and fiber elongation. Mean squares due to crosses exhibited significant difference in all traits except stand count and uniformity index. Stand count and uniformity index was not considered for further genetic analysis but other traits were subjected to genetic analyses. The mean squares due to crosses were further partitioned into lines, testers and line x tester interaction as per the procedures for line by tester analysis (Singh and Chaudhary, 1985). Related finding for analysis of variance are in accordance with Solanki *et al.* (2014) and Kencharaddi *et al*. (2015) as significant differences among the cotton genotypes for the entire yield and yield related traits. Karademir *et al.* (2009) evaluated 21 F_1 hybrids obtained by crossing of seven cotton lines and three testers along with ten genotypes. They found significant difference among genotypes for seed cotton yield and ginning percentage. Sawarkar *et al*. (2015) also reported significant differences among genotypes for yield and yield related traits such as days to 50% flowering, days to initial boll opening, number of bolls per plant, plant height, average boll weight, seed cotton yield and ginning percentage. Sajjad *et al.* (2016) revealed that mean squares for genotypes were significant differences for the traits of plant height, number of boll per plant, average boll weight, ginning percentage, seed cotton yield, micronaire, fiber length and fiber strength. Talpur *et al.* (2016) also reported the presence of significant difference among 19 cotton hybrids and checks for plant height, number of boll per plant, boll weight and seed cotton yield in which the hybrids were developed by line x tester crossing method.

Table 2. Mean squares from analysis of variance for agro-morphological and fiber quality traits of 32 cotton crosses and four check varieties evaluated at Werer in 2017.

Traits	Rep (1)	IB (blk/R) (5)	Gen (35)	Cross(C) (31)	Check (Ch) (3)	ChvsC (1)	Error (35)
Days to initial squaring	2.00	4.62	8.32**	6.61*	21.00*	23.36^{ns}	2.63
Days to initial flowering	3.55	3.71	10.5**	11.11**	1.66^{ns}	18.06^{ns}	1.89
Days to 50% flowering	1.68	3.18	14.09**	13.35**	0.50^{ns}	19.88^{ns}	2.24
Days to initial boll opening	4.01	3.14	33.94**	33.4**	8.46^{ns}	126.56*	2.63
Days to 65% boll opening	0.68	4.63	60.27**	45.68**	29.00^{ns}	606.39**	3.86
Number of bolls per plant	2.85	2.60	13.76**	13.71**	4.94^{ns}	42.14*	1.44
Plant height (cm)	0.028	167.05	428.25**	328.29*	723.57^{ns}	6.22^{ns}	95.3
Average boll weight (g)	8.48	0.49	0.55*	0.58*	0.43*	0.03^{ns}	0.19
Seed cotton yield (t/ha)	0.36	0.48	88.18**	79.99**	63.14*	470.38**	8.85
Ginning percentage (%)	1.18	1.65	15.67**	13.97**	19.22**	1.59^{ns}	0.43
Lint yield (t/ha)	0.03	0.009	15.63**	14.56**	6.75*	79.21**	1.19
Stand count	0.13	12.57	17.86^{ns}	19.18^{ns}	2.33^{ns}	23.77^{ns}	13.75
Micronaire(mg/inch)	0.02	0.06	0.55**	0.56**	0.03^{ns}	0.08**	0.1
Fiber Length (mm)	8.47	0.75	19.63**	21.41**	1.93^{ns}	17.64^{ns}	0.65
Uniformity Index (%)	3.65	39.53	37.47^{ns}	42.21^{ns}	0.15 ^{ns}	2.35^{ns}	29.49
Fiber Strength(g/tex)	32.13	1.68	26.98**	27.39**	16.53 ^{ns}	6.98 ^{ns}	2.33
Fiber elongation (%)	0.18	0.21	1.16**	1.21**	0.14 ^{ns}	2.76*	0.27

ns, * and **, non-significant, significant at ($P \leq 0.05$) and ($P \leq 0.01$), respectively. Numbers in parenthesis represent degree of freedom for the respective to source of variation, Rep= replication, IB (blk/R) = incomplete blocks within replication, Ch vs C= checks versus crosses and Gen= genotypes.

As Jatoi *et al.* (2011) reported that mean squares due to crosses were significant for number of bolls per plant, seed cotton yield and lint yield.

Mean Performance of Genotypes

The highest seed cotton yield (5.08 t ha^{-1}), which was 63.1% higher than the average mean checks was observed in hybrid L10 x T1 followed by L9 x T2 (4.83 t ha^{-1}) and L16 x T1 (4.76 t ha^{-1}) with good ginning percentage (Table 3). Seventeen hybrids exhibited significantly higher in seed cotton yield than overall mean and hybrid mean value, while 20 hybrids exhibited significantly higher than checks mean (3.11 t ha^{-1}). Other three hybrids, L10 x T2, L16 x T2 and L12 x T1 had seed cotton yield of 4.5, 4.46 and 4.43 t/ha, respectively, in which the mean values had non-significant difference with the former high yielding hybrids but significantly higher than the best yielding check variety in the experiment. Ten hybrids also had yield advantages of 0.81 to 12.47% over the best yielding check variety, nevertheless, except one had yield non-significant difference with the check. Highest mean performance among the genotypes were observed for lint yield in hybrids L9 x T2 (1.91 t ha^{-1}) and L10 x T1 (1.91 t ha^{-1}) in which 16 hybrids exhibited significant than over all mean (1.34 t ha^{-1}) and hybrids mean (1.36 t ha^{-1}), while 19 hybrids than checks mean (1.21 t ha^{-1}) as lint yield most important yield traits and quantitatively inherited. On the other hand, only three top promising crosses for average boll weight were observed than best performed check (Delcero x Deltapine-90#F5-5-4-2-2), whereas 15 hybrids were exhibited low average boll weight than mean overall and hybrids mean.

Crosses namely, L1 x T1, L2 x T1, L3 x T1, L1 x T2 and L2 x T2 were late maturity and had lower mean values than check varieties for seed cotton yield, ginning percentage and lint yield. All most all the crosses evaluated in this experiment showed acceptable levels of ginning percentage except, L1 x T1, L1 x T2, L2 x T1, L2 x T2, L14 x T1 and L3 x T1 which surprisingly exhibited the lowest value from 31.04 to 36.21%. Similarly, only two hybrids registered the highest than the maximum (42.21%) check variety (Sisikuk-02) for ginning percentage. All crosses showed high mean performance for days to 65% boll opening over mean value of checks (127.63 days) as an undesirable traits. Among all hybrids, 13 Crosses showed higher number of bolls per plant than the mean value of the checks, whereas L4 x T2, L16 x T2 and L14 x T2 showed higher average boll weight than best performed check variety (Stam-259A). Since, mean performance is the main criterion in selecting better hybrids, Monicashree *et al*. (2017) and Tuteja and Agrawal (2013) reported that the hybrids with high mean performance would result good hybrids and as well as significant difference were revealed for all the studied traits using line x tester mating design. Samreen *et al.* (2008), Jatoi *et al.* (2011) and Talpur e*t al.* (2016) also reported that good mean performance and significant difference among genotypes for plant height, number of bolls per plant, seed cotton yield and average boll weight

Nineteen and 13 hybrids exhibited significantly maximum and minimum value over checks mean for micronaire, respectively.

Table 3. Mean Performance of F1 crosses and checks varieties of cotton for agro-morphological and fiber quality traits.

Genotypes	DIS	DIF	DF	DIBO	DBO	NBPP	PH	ABW	SCY	GP	LY	M	FL	FS	FE
L1 x T1	34.5^{abc}	55.5^{abc}	65^{a}	105.5^{ab}	146^{ab}	25.8^{a}	127^{a}	4.13^{d-h}	3.93^{defg}	31.04^{n}	1.22^{efgh}	3.34^{d}	38.52^{a}	37.40^{ab}	8.70^{ab}
L2 x T1	35^{ab}	55^{bcd}	63.5^{ab}	104^{bc}	145.5^{ab}	19.53^{bc}	100.53^{b-f}	3.98^{fgh}	3.05^{i-m}	32.37^{nm}	0.99^{iklm}	3.79^{dc}	37.77^{a}	36.25^{abc}	8.55^{abc}
L3 x T1	34.5^{abc}	56.5^{ab}	64.5^{a}	107^{ab}	148^{a}	20.13^{b}	76.6^{f-k}	4.65^{a-f}	2.42^{lmn}	36.21^{ij}	0.88^{ilm}	3.78^{dc}	35.30^{b}	39.00^{a}	7.65^{b-i}
L4 x T1	30^{def}	50^{f}	57^{ef}	97.5^{efg}	134.5^{c-g}	14.77^{hijk}	76.2^{g-k}	4.88^{a-f}	2.58^{klmn}	39.01^{c-g}	1.01^{ilkm}	4.68^{ab}	28.24^{defg}	26.90^{gh}	7.35^{c-i}
L5 x T1	30.5^{def}	50^{f}	57.5^{ef}	97.5^{efg}	136.5^{cde}	17.87^{b-g}	70.67^{ijk}	4.92^{a-f}	2..63^{klmn}	39.33^{cdef}	1.04^{i-m}	4.68^{ab}	28.82^{defg}	26.60^{gh}	8.70^{ab}
L6 x T1	29^{efg}	50.5^{f}	57.5^{ef}	97^{efg}	135.5^{cdef}	18.63^{bcd}	87.63^{b-j}	4.73^{a-f}	3.06^{i-m}	38.42^{d-h}	1.17^{i-k}	5.09^{ab}	28.94^{defg}	24.35^{h}	7.25^{d-i}
L7 x T1	28^{gf}	49.5^{f}	57^{ef}	95.5^{fgh}	134.5^{c-g}	18.43^{bcd}	79.73^{d-k}	5.28^{abc}	3.93^{defg}	39.7^{cde}	1.56^{bcd}	5.08^{ab}	27.98^{gf}	26.75^{gh}	8.35^{abcd}
L8 x T1	31.5^{b-f}	51^{ef}	58^{def}	95.5^{fgh}	137^{cd}	16.27^{d-g}	74.63^{hijk}	4.38^{b-h}	2.84^{klmn}	38.77^{c-g}	1.09^{i-m}	5.02^{ab}	28.90^{defg}	27.85^{efgh}	7.60^{c-i}
L9 x T1	32^{a-e}	51.5^{ef}	59^{cdef}	95^{fgh}	135.5^{cdef}	17.5^{b-i}	88.43^{b-i}	4.55^{a-g}	3.19^{h-k}	39.99^{cd}	1.28^{efgh}	4.57^{ab}	29.66^{def}	27.25^{efgh}	7.85^{b-g}
L10 x T1	31^{cdef}	52.5^{cdef}	59^{cdef}	98^{defg}	135.5^{cdef}	18.03^{b-f}	93.63^{b-i}	5.12^{a-e}	5.08^{a}	37.58^{ghi}	1.91^{a}	4.82^{ab}	29.79^{def}	29.10^{efg}	8.00^{b-g}
L11 x T1	32.5^{a-e}	51.5^{ef}	58^{def}	100.5^{cde}	137^{cd}	17.1^{c-i}	99.3^{b-g}	4.75^{a-f}	4.15^{b-f}	39.08^{c-g}	1.62^{bcd}	4.86^{ab}	29.50^{def}	27.50^{fgh}	8.00^{b-g}
L12 x T1	31^{cdef}	51.5^{ef}	58^{def}	98.5^{def}	135^{c-g}	14.93^{g-k}	88.8^{b-i}	5.35^{abc}	4.43^{a-e}	38.91^{c-g}	1.73^{ab}	5.09^{ab}	28.86^{defg}	27.60^{efgh}	8.20^{a-g}
L13 x T1	30^{def}	54^{bcde}	61.5^{abcd}	97^{efg}	136.5^{cde}	18.5^{bcd}	82.5^{c-k}	4.7^{a-f}	4.12^{b-e}	37.21^{hij}	1.54^{bcd}	4.43^{bc}	29.23^{def}	29.60^{efg}	7.70^{b-h}
L14 x T1	31.5^{b-f}	52^{def}	57.5^{ef}	101.5^{cd}	138^{c}	10.53^{l}	59.87^{k}	5.2^{abcd}	3.29^{g-k}	35.89^{jk}	1.19^{e-k}	4.56^{ba}	28.65^{defg}	27.30^{efgh}	6.85^{ghij}
L15 x T1	30^{def}	50.5^{f}	59^{cdef}	96^{fgh}	133.5^{c-h}	14.57^{hijk}	104.43^{bc}	4.1^{efgh}	3.66^{f-j}	43.27^{ab}	1.58^{bcd}	4.98^{ab}	28.21^{defg}	29.50^{efg}	9.35^{a}
L16 x T1	31^{cdef}	49.5^{f}	57.5^{ef}	98^{defg}	135.5^{cdef}	15.83^{d-j}	82.2^{c-k}	5.08^{a-e}	4.76^{abc}	39.63^{cde}	1.89^{a}	5.22^{a}	29.81^{defg}	29.50^{efg}	8.25^{a-e}
L1 x T2	35.5^{a}	56.5^{ab}	63.5^{ab}	109^{a}	144.5^{ab}	20.13^{b}	103.6^{bcd}	3.53^{gh}	3.05^{i-m}	31.57^{n}	0.96^{ilkm}	3.57^{d}	38.62^{a}	37.25^{ab}	8.00^{b-g}
L2 x T2	35^{ab}	58.5^{a}	65^{a}	108.5^{a}	147.5^{a}	18.2^{bcde}	107.4^{ab}	3.47^{h}	4.07^{cdef}	33.7^{lm}	1.37^{defg}	3.58^{d}	37.18^{a}	37.70^{ab}	8.30^{abcd}
L3 x T2	34.5^{abc}	55.5^{abc}	65^{a}	106.5^{ab}	143^{b}	16.4^{d-g}	64.5^{jk}	5.02^{a-f}	2.25^{n}	37.12^{hij}	0.84^{im}	3.49^{d}	33.47^{c}	35.30^{bc}	7.40^{c-i}
L4 x T2	32^{a-e}	52^{def}	58^{def}	95^{fgh}	133.5^{c-h}	14.3^{ijk}	105.4^{abc}	5.52^{a}	3.76^{e-i}	38.38^{efgh}	1.44^{ecd}	4.50^{ab}	28.49^{defg}	27.90^{efgh}	6.40^{ij}
L5 x T2	30^{def}	50^{f}	57.5^{ef}	96^{fgh}	129.5^{hi}	16.43^{d-i}	69.77^{ijk}	4.47^{a-h}	2.94^{j-n}	40.31^{c}	1.19^{e-k}	4.88^{ab}	28.51^{defg}	29.10^{efg}	7.90^{b-g}
L6 x T2	31.5^{b-f}	52.5^{cdef}	59^{cdef}	96.5^{fg}	131.5^{fghi}	16.3^{d-i}	97.13^{b-h}	4.47^{a-h}	4.09^{cdef}	38.82^{c-g}	1.59^{bcd}	4.89^{ab}	28.84^{defg}	28.75^{efg}	7.45^{b-i}
L7 x T2	31^{cdef}	51^{ef}	58.5^{cdef}	97.5^{efg}	134.5^{c-g}	15.07^{g-k}	96.7^{b-h}	5.33^{abc}	3.09^{ijkl}	39.06^{c-g}	1.21^{e-k}	5.15^{ab}	28.54^{defg}	30.15^{defg}	7.65^{b-i}
L8 x T2	31^{cdef}	51.5^{ef}	58^{def}	98.5^{dfe}	133.5^{c-h}	14.7^{hijk}	84.77^{b-j}	5.32^{abc}	3.72^{fghi}	38.23^{efgh}	1.42^{cdef}	4.89^{ab}	29.81^{def}	29.35^{efg}	7.00^{e-j}
L9 x T2	31^{cdef}	52.5^{cdef}	60.5^{bcde}	96^{fgh}	135^{c-g}	15.07^{g-k}	97.23^{b-h}	5.3^{abc}	4.83^{ab}	39.56^{cde}	1.91^{a}	4.97^{ab}	28.78^{defg}	29.20^{efg}	7.60^{c-i}
L10 x T2	32.5^{a-e}	52.5^{cdef}	62^{abc}	100.5^{cde}	135^{c-g}	15.33^{e-k}	87.2^{b-j}	4.52^{a-g}	4.5^{abcd}	39.19^{cdef}	1.76^{ab}	5.08^{ab}	29.15^{defg}	29.05^{efg}	6.45^{hij}
L11 x T2	33.5^{abcd}	52.5^{cdef}	59.5^{cdef}	97.5^{efg}	136.5^{cde}	15.13^{f-k}	82.23^{c-k}	5.07^{a-e}	3.19^{hijk}	39.54^{cde}	1.26^{efgh}	5.19^{ab}	30.12^{d}	30.95^{de}	6.8^{ghij}

Table 3. Continued

Genotypes	DIS	DIF	DF	DIBO	DBO	NBPP	PH	ABW	SCY	GP	LY	M	FL	FS	FE
L12 x T2	32.5^{a-e}	49.5^{f}	56.5^{f}	97^{efg}	134 $^{c-h}$	14.23^{ijk}	74.7^{hijk}	5.15^{a-e}	4.1^{cdef}	39.48^{cdef}	1.62^{bcd}	4.79^{ab}	30.05^{d}	28.15^{efg}	7.55^{b-i}
L13 x T2	31.5^{b-f}	50.5^{f}	56.5^{f}	97.5^{efg}	133.5^{c-h}	15.37^{e-k}	91.8^{b-i}	4.78^{a-f}	2.47^{lmn}	37^{hij}	0.91^{ilm}	4.64^{ab}	28.85^{ed}	30.75^{def}	6.4^{ij}
L14 x T2	32^{a-e}	51.5^{ef}	57^{ef}	96^{fgh}	132^{e-i}	17.73^{b-g}	78.7^{e-k}	5.5^{a}	2.71^{klmn}	37.93^{fgh}	1.03^{i-m}	5.06^{ab}	28.98^{defg}	29.25^{efg}	5.95^{j}
L15 x T2	31.5^{b-f}	49.5^{f}	57^{ef}	98^{defg}	135.5^{cdef}	15.77^{d-j}	103.9^{bc}	4.82^{a-f}	3.81^{d-h}	43.95^{a}	1.67^{abc}	4.77^{ab}	27.18^{g}	30.3^{defg}	8.35^{abcd}
L16 x T2	31^{cdef}	50^{f}	58.5^{cdef}	97^{defg}	132.5^{d-i}	15.3^{e-k}	89.1^{b-i}	5.52^{a}	4.46^{a-e}	38.77 $^{c-g}$	1.73^{ab}	4.99^{ab}	29.44^{def}	30.1^{efg}	6.8^{ghij}
C1	25.5^{g}	49.5^{f}	58.5^{cdef}	92.5^{h}	122^{j}	12.8^{kl}	64.47^{jk}	4.28 $^{c-g}$	2.35^{mn}	42.21^{b}	0.99^{ilkm}	4.78^{ab}	28.03^{fg}	27^{fgh}	6.9^{ghij}
C2	30.5^{def}	50^{f}	57.5^{ef}	95^{gh}	128.5^{i}	14.63^{jkl}	99.9^{b-j}	5.12^{a-f}	3.17^{hijk}	36.3^{kl}	1.16^{g-l}	4.56^{ab}	28.12^{efg}	28.5^{efg}	6.8^{ghij}
C3	33^{abcd}	51^{ef}	57.5^{ef}	97.5^{efg}	129.5^{hi}	16.1^{d-g}	106.53^{ab}	5.42^{ab}	3.25^{g-k}	39.08^{c-g}	1.27^{efgh}	4.85^{ab}	30.1^{de}	33.4^{cd}	6.95^{ghij}
C4	31.5^{b-f}	51.5^{ef}	57.5^{ef}	95^{fgh}	130.5^{ghi}	15 $^{g-k}$	101.5^{bcde}	4.87^{a-f}	3.69^{fghi}	38.32^{efgh}	1.42^{cdef}	4.79^{ab}	29.22^{def}	27.85^{efgh}	7.4^{c-i}
Mean over all	31.63	51.94	59.26	98.64	135.72	16.46	88.85	4.81	3.52	38.19	1.35	4.65	30.27	30.07	7.57
Hybrids mean	31.81	52.09	59.42	99.09	136.73	16.68	88.32	4.8	3.57	38.09	1.36	4.64	30.44	30.18	7.64
Checks mean	30.13	50.75	58	95	127.63	14.63	93.1	4.92	3.11	38.98	1.21	4.74	28.87	29.19	7.01
LSD (5%)	3.34	2.83	3.08	3.35	4.05	2.48	20.11	0.91	0.61	1.35	0.22	0.65	1.66	3.15	1.07
CV (%)	5.13	2.65	2.52	1.65	1.45	7.32	11.03	9.15	8.46	1.71	8.09	6.88	2.67	5.08	6.84

Mean values followed by similar letter(s) in each column are not significant different each other. LSD (5%)= least significant difference at $P \leq 0.05$, CV (%)= coefficient of variation in percent, DIS= days to initial squaring, DIF= days to initial, flowering, DF= days to 50% flowering, DIBO= days to initial boll opening, DBO= days to 65% boll opening, NBPP= number of bolls per plant, PH = plant height, ABW = average boll weight, SCY= seed cotton yield, GP= ginning percentage and LY= lint yield, M= micronaire, FL= fiber length, FS= fiber strength and FE= Fiber elongation

Moreover, 16, 21 and 22 hybrids recorded significantly higher mean performance over best check (C3), mean overall and hybrids mean for micronaire, respectively. Hybrid L16 x T1 (5.22 mg/inch) gave higher micronaire value followed by hybrids L11 x T2 (5.19 mg/inch) and L7 x T2 (5.15 mg/inch), whereas hybrids L1 x T1 (3.34 mg/inch) and L3 x T2 (3.49 mg/inch) recorded lower mean value in which lower value of micronaire is desirable traits in cotton breeding. Only 18.75% hybrids showed maximum fiber length over both hybrids mean and checks mean in which hybrid L1 x T2 (38.62mm) followed by L1 x T1 (38.52mm) andL2 x T1 (37.77 mm) recorded higher mean value as long fiber lengthsproduce smoother and stronger fabrics which are finer, stronger and more flexible than fiber of short staple length.Other fiber character which more important in textile processing, varies greatly among varieties due to genetic bases and as well quantitatively inherited, fiber strength, ranged from 24.35 g/tex (L6 x T1) to 39 g/tex (L3 x T1) and 28.13, 34.38 and 53.13% of hybrids exceeded over hybrids mean, mean overall and checks mean, respectively.

Mean performance among the genotypes for fiber strength were observed higher in crosses namely, L3 x T1 (39g/tex), L2 x T2 (37.70g/tex), L1 x T1 (37.40 g/tex), L1 x T2 (37.25 g/tex), L2 x T1 (36.25 g/tex) and L3 x T2 (35.30 g/tex), while hybrids L7 x T1 (26.75 g/tex), L5 x T1 (26.60 g/tex) and L6 x T1 (24.35 g/tex) were among lowest value of mean performance. Seventeen, 19, 22 and 24 hybrids manifested maximum fiber elongation over hybrid mean, mean over all, best check (C4) and checks mean, respectively, in which hybrids L15 x T1, L1 x T1 and L5 x T1 were among the highest, as the trait ranged from 5.95 (L14 x T2) to 9.35% (L15 x T1). Generally, crosses involving L1 x T2 and L1 x T1 performed better in all most studied of fiber traits except micronaire in which had great contribution for spinning efficiency. The results of mean performance for fiber quality were supported by earlier researcher, Kaleri, *et al.* (2015) and Monicashree *et al.* (2017).

Combining Ability Analysis of Variance and Heritability

Analysis of variance for combining ability revealed that both GCA and SCA mean squares were significant ($P \leq 0.05$) for days to initial boll opening, number of boll per plant, seed cotton yield, lint yield and fiber strength that suggesting the importance of both additive and non-additive gene actions in determining the inheritance of these characters (Table 4). In agreement with this study results, Monicashree *et al*. (2017) and Sivia *et al*. (2017) reported the significant GCA and SCA mean squares for days to initial boll opening, number of boll per plant, seed cotton yield and lint yield.Jatoi*et al.* (2011) and Samreen *et al.* (2008) also reported that GCA of lines and SCA of interaction were significant different for number of boll per plant, seed cotton yield and lint yield, while GCA of testers were significant different for number of boll per plant, on the hand, similar result reported by Samreen *et al*. (2008) as additive and non-additive gene action were governed the traits of number of boll per plant and seed cotton yield. For phenological traits, Basbag *et al*. (2007) unveiled the significant of GCA of line for days to initial squaring, days to initial flowering and days to 65% boll opening.

Both lines and testers GCA mean squares were highly significant for days to 65% boll opening, plant height, number of boll per plant, ginning percentage, fiber strength and fiber elongation, while SCA mean squares were highly significant for the traits of seed cotton yield, days to initial boll opening, number of boll per plant, lint yield and fiber strength. For lines GCA, all traits were showed highly significant differences. Memon e*t al.* (2017) reported GCA of line were significant for days to initial flowering and days to 65% boll opening. In case of testers GCA, significant difference mean squares observed for the traits of days to 65% boll opening, number of boll per plant, plant height and ginning percentage while, the non-significant difference testers mean squares observed for days to initial squaring, days to initial flowering, days initial boll opening, average boll weight, seed cotton yield and lint yield in which the traits suggest that the testers used for the current study had no contribution and comparable potential for the aforementioned traits, respectively. Generally, the results of analysis of combining abilities obtained from this study indicated the importance of both additive and non-additive gene actions in controlling traits of cotton. Therefore, both additive and non-additive variances are important in determining for the exploitation breeding behavior of the genetic potential of the cotton inbred lines in variety development program through selection and hybrid development. Related with above result Kumar *et al.* (2017) reported that mean sum of squares due to GCA effects of lines and testers were significant for plant height, average boll weight, seed cotton, ginning percentage and number of bolls per plant, while SCA effect of line x tester were significant for number of boll per plant and seed cotton yield. On the hand, Prakash, (2018)revealed that mean squares due to GCA of line were significant for days to 50% flowering and initial boll opening. Other result also reported by many other authors (Swakar *et al*., 2015; Monicashree *et al*., 2017; Sivia *et al*., 2017) also indicated the importance of additive and non-additive gene actions in controlling agronomic and fiber quality traits of cotton.

In the present study, the broad sense heritability estimates ranged from 48.65% for average boll weight to 94.66% for ginning percentage (Table 4). High heritability (>60%) exhibited for days to initial flowering (69.49%), days to 50% flowering (72.57%), days to initial boll opening (85.62%), days to 65% boll opening (87.96%), number of bolls per plant (81.05%), plant height (63.59%), seed cotton yield (81.76%), ginning percentage (94.66%), lint yield(85.87%), micronaire (69.23%), fiber length (93.59%), fiber strength (84.10%), fiber elongation (62.24%). On the hand, moderate heritability values were also recorded for days to initial squaring (51.96%) and average boll weight (48.65%).This result showed that selection could be easy and improvement is possible using selection breeding. In agreement with the current result, Khan *et al.* (2009) reported high heritability for plant height, number boll per plant and seed cotton yield. The obtained results were also in accordance with results of Rauf *et al.* (2006) who reported high heritability was observed for studied characters such as lint yield, fiber length, seed cotton yield and number of bolls per plant.On contrary, Meena and Meena (2017) reported moderate heritability for ginning percentage and number of boll per plant, while low heritability were exhibited for average boll weight, seedcotton yield and lint yield.

Table 4. Mean squares from combining ability analysis of variance and heritability for yield, yield related and fiber quality traits in 32 crosses evaluated at Werer in 2017.

Traits	GCA, Line (15)	GCA Tester (1)	SCA Line x tester (15)	Error (17)	h^2(b) (%)
Days to initial squaring	9.85**	7.34^{ns}	1.55^{ns}	2.19	51.96
Days to initial flowering	19.56**	1.49^{ns}	2.87^{ns}	2.45	69.49
Days to 50% flowering	26.15**	0.22 ^{ns}	3.71 ^{ns}	2.29	72.57
Days to initial boll opening	56.53**	0.15 ^{ns}	5.99**	2.21	85.62
Days to 65% boll opening	81.16**	63.59**	6.76 ^{ns}	3.97	87.96
Number of bolls per plant	18.26**	32.90**	7.83**	1.56	81.05
Plant height (cm)	515.83**	324.98**	141.25 ^{ns}	83.41	63.59
Average boll weight (g)	0.76**	0.75 ^{ns}	0.14 ^{ns}	0.23	48.65
Seed cotton yield (t/ha)	1.62**	0.001^{ns}	0.88**	0.08	81.76
Ginning percentage (%)	26.56**	2.29**	0.65^{ns}	0.44	94.66
Lint yield (t/ha)	0.32**	0.003^{ns}	0.12**	0.01	85.87
Micronaire(mg/inch)	1.11**	0.03^{ns}	0.07^{ns}	0.04	69.23
Fiber length(mm)	42.51**	0.37 ^{ns}	0.59 ^{ns}	0.32	93.59
Fiber strength(g/tex)	51.39**	27.04**	3.42**	0.27	84.10
Fiber elongation(%)	1.64**	9.53**	0.23^{ns}	0.12	62.24

ns,* and **, non-significant, significant at ($P \leq 0.05$) and ($P \leq 0.01$) respectively, numbers in parenthesis represent degree of freedom for the respective source of variation, broad sense heritability (h^2b).

Estimates of General Combining Ability Effects

Based on the results from analysis of variance for combining ability, the GCA effects of parents on yield, yield related and quality traits were estimated in table 5. The result showed that, out of 16 lines four and five line exhibited positive and negative significant GCA effects, respectively, for seed cotton yield. Line L10 exhibited the maximum GCA effect (1.22 t ha^{-1}) followed by L16 (1.05 t ha^{-1}) and L12 (0.70 t ha^{-1}), whereas L3 exhibited the minimum GCA effect (-1.23 tha^{-1}) followed by L5 (-0.78 t ha^{-1}), as indicating the existence of best and poorest general combiners in group of lines for seed cotton yield studied, respectively. GCA effect ranged -0.02 to 0.47t ha^{-1} and significant and positive GCA effect were exhibited for L9 (0.23 t/ha^{-1}), L10 (0.47t ha^{-1}), L15 (0.27 t ha^{-1}), L16 (0.45 t ha^{-1}) and L12 (0.31 t ha^{-1}), while 7 lines had negative and significant GCA for lint yield. These findings in agreement to the findings of Ashokkumar *et al.* (2010), Alkuddsi *et al.* (2013), Khan *et al.* (2015) and Kumar *et al.* (2017) for seed cotton yield. For ginning percentage, eight line revealed positive and significant GCA effect, among them, L15 (5.24%) gave desirable significant positive GCA effect and was the best general combiner line for this trait. On the other hand, five line showed negative and significant GCA effect ranged -0.96 (L13) to -6.42 (L1) for lint yield. Only two line, L4 (0.51gm) and L14 (0.53gm) revealed positive and significant GCA effects, whereas L1 (-0.97gm) and L2 (-0.98gm) showed negative and significant GCA effect for average boll weight in which 12 line are recorded as non-significant. Similar findings were reported by Kumar *et al.* (2017), Alkuddsi *et al* (2013), Lakho *et al.* (2016) and Memon *et al.* (2016). Plant height contributed more for seed cotton yield increment as line namely, L1, L2 and L15 recorded positive and significant GCA effect and equally important to be used in parental combination for plant height as good general combiner whereas L3, L5, L8 and L14 showed negative and significant GCA effect as poorest general combiners. From present study, line L1, L6, L3 and L2 showed positive and significant GCA for number of boll per plant for improvement of seed cotton yield programs, while five line recorded as negative and significant GCA for this traits. Significant genetic effects due to GCA for plant height were noticedby Alkuddsi *et al*. (2013), Khan *et al*. (2015) and Kumar *etal*. (2017).

Table 5. Estimates of GCA effects in agro-morphological and fiber quality traits for Cotton lines and testers studied at Werer in 2017

Line	DIS	DIF	DF	DIBO	DBO	NBPP	PH	ABW	SCY	GP	LY	M	FL	FS	FE
L1	3.13**	3.90**	4.82**	7.99**	8.51**	6.28**	28.95**	-0.97**	-0.08	-6.42**	-0.27**	-1.16**	8.13**	7.15**	0.71**
L2	2.47**	4.63**	4.72**	7.39**	9.73**	2.18**	17.31**	-0.98**	-0.01	-4.96**	-0.18**	-0.96**	7.01**	6.80**	0.79**
L3	3.24**	3.91**	5.34**	7.71**	8.78**	1.58*	-17.05**	0.1	-1.23**	-1.34**	-0.51**	-1.01**	3.93**	6.97**	-0.11
L4	-0.73	-1.09*	-1.89*	-2.66*	-2.72**	-2.15**	4.08	0.51*	-0.40**	0.6	-0.13*	-0.06	-2.09**	-2.78**	-0.76**
L5	-2.18**	-2.11*	-2.08**	-2.76*	-3.88**	0.47	-15.09**	0.01	-0.78**	1.94**	-0.25**	0.16	-1.75**	-2.33**	0.66**
L6	-1.16	-0.58	-1.13	-2.64*	-3.32**	0.78*	2.3	-0.3	0.01	0.19	0.02	0.33**	-1.58**	-3.63**	-0.29
L7	-2.09**	-1.82*	-1.66*	-2.07*	-2.14*	0.07	2.04	0.41	-0.06	1.11**	0.02	0.46**	-2.21**	-1.73**	0.36*
L8	-0.27	-0.82	-1.33	-2.32*	-1.51	-1.2	-9.81*	0.03	-0.31*	0.16	-0.11	0.30**	-1.10**	-1.58**	-0.34
L9	-0.71	-0.13	0.28	-3.72*	-1.48	-0.4	2	0.04	0.44**	1.68**	0.23**	0.13	-1.22**	-1.95**	0.09
L10	-0.18	0.4	1.07	0.06	-1.44	0	0.72	0	1.22**	0.49*	0.47**	0.33**	-0.93**	-1.10**	-0.41**
L11	1.60*	-0.08	-0.63	-0.09	0.01	-0.57	0.2	-0.01	0.1	1.25**	0.08	0.38**	-0.60*	-0.95**	-0.24
L12	-0.17	-1.60*	-2.14**	-1.14	-2.13*	-2.10**	-5.05	0.42	0.70**	1.23**	0.31**	0.31**	-1.01**	-2.30**	0.24
L13	-1.29	0.14	-0.46	-1.72*	-1.73	0.25	-0.26	0.11	-0.27	-0.96**	-0.14*	-0.09	-1.41**	0	-0.59**
L14	-0.34	-0.37	-2.22**	-0.41	-1.76	-2.55**	-20.93**	0.53*	-0.57**	-1.29**	-0.26**	0.16	-1.57**	-1.90**	-1.24**
L15	-0.95	-2.08*	-1.4	-2.39*	-2.27*	-1.52*	12.17*	-0.35	0.17	5.24**	0.27**	0.25**	-2.77**	-0.28	1.21**
L16	-0.38	-2.30**	-1.29	-1.25	-2.65*	-1.12	-1.58	0.45	1.05**	1.08**	0.45**	0.46**	-0.85**	-0.38	-0.11
SE(±)	0.74	0.78	0.76	0.74	1	0.62	4.57	0.24	1.42	0.33	0.53	0.51	3.16	3.47	0.62
SE (gi – gj) lines	1.05	1.11	1.07	1.05	1.41	0.88	6.46	0.34	0.2	0.47	0.07	0.1	0.28	0.27	0.17
Tester															
Tester 1	-0.31	-0.15	-0.05	0.04	1.04	0.72	-1.72	-0.11	0.03	-0.24	-0.07	-0.02	0.07	-0.65**	0.39**
tester 2	0.31	0.15	0.05	-0.04	-1.04	-0.72	1.72	0.11	-0.03	0.24	0.02	0.02	-0.07	0.65**	-0.39**
SE(±)	0.26	0.28	0.27	0.26	0.35	0.22	1.61	0.09	0.5	0.12	0.19	0.02	0.07	0.65	0.39
SE (gi – gj) testers	0.37	0.39	0.38	0.37	0.5	0.31	2.28	0.12	0.07	0.17	0.03	0.04	0.1	0.09	0.06

Traits *and** significant at ($P < 0.05$) and ($P < 0.01$) respectively, SE (m±)= standard error of the mean, SE (gi – gj) testers= standard error of difference, DIS= days to initial squaring, DIF= days to initial flowering, DF= days to 50% flowering, DIBO= days to initial boll opening, DBO= days to 65% boll opening, NBPP= number of bolls per plant, PH= plant height, ABW= average boll weight, SCY = seed cotton yield, GP= ginning percentage, LY= lint yield, M= micronaire, FL= fiber length, FS= fiber strength and FE= Fiber elongation.

In general combining ability of fiber quality traits, lines, L6, L8, L16, L7, L10, L12, L15 and L11 exhibited positive and significant GCAeffects for micronaire, while L1, L2 and L3 exhibited desirable and significant GCA for this traits. Line, L1, L2 and L3 recorded positive and significant GCA effects for fiber length and fiber strength. Moreover, L1, L2, L5, L7 and L15 had significant and positive GCA effects for fiber elongation. The parents having high GCAeffects for fiber quality traits could be useful in quality improvement of cotton breeding programs by practicing early generation selections, since the GCAeffect was due to additive gene action which is fixable. Sawarkar *et al*. (2015) reported positive and significant GCA were observed for fiber length and micronaire. Other authors supported previous results are Karademir *et al*. (2009), Ali *et al.* (2016) and Sajjad *et al.* (2016). Among the testers, tester1 (Deltapine-90) were found to be good general combiners for fiber elongation and while tester2 (Werer-50) for fiber strength and two of the tester were non-significant for the traits of microniare and fiber length, Karademir *et al*. (2009), Srinivas, *et al*. (2014) and Ali *et al.* (2016) reported as testers were non-significant for micronaire, while contradictory reported were for fiber length.

Estimates of Specific Combining Ability Effects

Crosses evaluated in the current study showed considerable variation in SCA effects for different traits (Table 6). Significant estimates of SCA effects were observed for some substantial of crosses and nine hybrids namely, L1 x T1, L7 x T1, L11 x T1, L13 x T1, L2 x T2, L4 x T2, L6 x T2,L8 x T2 and L9 x T2were exhibited specific combiners in which the among the highest positively significant SCA effect were 8.19 (L13 X T1) while, hybrids L9 x T1, L13 x T2 and L4 x T1 had minimum negative SCA effect as poorest specific combiners for seed cotton yield. Positive and negative SCA were observed as author Sajjad*et al*. (2016) for seed cotton yield.

For lint yield, 7 hybrids viz. L13 x T1, L7 x T1, L11 x T1, L4 x T2, L6 x T2, L8 x T2 and L9 x T2 showed highest SCA. In which crosses were combinations of poor x good combining parents and poor x poor combining parents, hence SCA effect of these crosses is due to non-additive with non-fixable effect which among the available genotypes used as parents in hybridization programmes. Moreover, highly significant SCA effects of the crosses indicate significant deviation from what would have been predicted based on their parental performances. Positive and significant SCA effect were observed crosses combination of L7 x T1, L11 x T1, L13 x T1, L2 x T2, L4 x T2, L6 x T2, L8 x T2 and L9 x T2 for seed cotton yield and lint yield. Based on this result, these crosses could be selected for their SCA effect and useful to transgressive breeding for seed cotton yield and lint yield improvement. Two crosses viz., L1 x T1 and L14 x T2 for number of boll per plant recorded positive and significant SCA effects. In agreement with the current study both negative and positive estimates of SCA effects in crosses of cotton lines also reported by Khan *et al.* (2015), Memon *et al*. (2016) and Kumar *et al.* (2017). Non-significant SCA effects were recorded for plant height, average boll weight and ginning percentage which crosses observed as poor specific combiners for respective traits. In case of phenological traits, two crosses viz. L2 x T1 and L14 x T2 for days to initial boll opening and one hybrid (L13 x T2) for days to 50% flowering recorded negative and significant SCA which the result showed good combination of crosses in desired direction. Out of 5 phenological traits, three traits namely, days to initial squaring, days to initial flowering and days to 65% boll opening exhibited non-significant SCA effect in both direction. The SCA effects of the crosses for fiber quality traits were showed Positive and significant specific combining ability effects for fiber strength in crosses L3 x T1, L11 x T2and L6 x T2 cross combinations. Sajjad *et al* (2016)and Ali *et al*. (2016) reported positive and significant SCA forfiber strength.

Proportional Contribution of Line, Tester and Line x Tester

The proportional contributions of lines, testers and their interactions (line x testers) to the total variance for investigated characters were presented in Table 7. The result exhibited maximum line contribution to total variance of all of the characters namely, days to initial squaring, days to initial flowering, days to 50% flowering, days to initial boll opening, days to 65% boll opening, number of bolls per plant, plant height, average boll weight, seed cotton yield, ginning percentage, lint yield, micronaire, fiber length, fiber strength and fiber elongation. This indicated that predominant of maternal (lines) influence for these traits and higher estimates of variance is due to GCA. On the other hand, tester and line x tester interactions not contributed for studied traits. Monicashree *et al.* (2017) reported that proportional contribution of the line was significant for number of bolls per plant, ginning percentage, fiber length and fiber strength, while testers exhibited lowest proportional contribution for all the traits. On the hand, proportional contribution of line for days to initial flowering, days to initial flowering and days 65% boll opening were significantly exhibited (Basbag *et al*., 2007).

Table 6. Estimates of SCA effects of crosses evaluated for agro-morphological and fiber quality.

Crosses	DIBO	NBPP	SCY	LY	FS
L1 x T1	-1.44	2.12*	0.44*	0.14	0.73
L2 x T1	-2.54*	-0.05	-0.51*	-0.18*	-0.08
L3 x T1	0.26	1.15	0.08	0.03	2.50**
L4 x T1	1.64	-0.48	-0.59**	-0.21*	0.15
L5 x T1	0.81	0	-0.16	-0.07	-0.6
L6 x T1	0.2	0.45	-0.52*	-0.20*	-1.55**
L7 x T1	-0.96	0.96	0.42*	0.18*	-1.05
L8 x T1	-1.2	0.07	-0.46*	-0.16*	-0.1
L9 x T1	-0.1	0.5	-0.82**	-0.31*	-0.33
L10 x T1	-1	0.64	0.28	0.08	0.67
L11 x T1	1.47	0.27	0.48*	0.19*	-1.08*
L12 x T1	0.89	-0.37	0.17	0.06	0.38
L13 x T1	-0.5	0.85	0.83**	0.32**	0.07
L14 x T1	2.70*	-4.32**	0.29	0.09	-0.32
L15 x T1	-0.83	-1.32	-0.08	-0.04	0.25
L16 x T1	0.6	-0.45	0.15	0.09	0.35
L1 x T2	1.44	-2.12*	-0.44*	-0.14	-0.73
L2 x T2	2.54*	0.05	0.51*	0.18*	0.08
L3 x T2	-0.26	-1.15	-0.08	-0.03	-2.50**
L4 x T2	-1.64	0.48	0.59**	0.21*	-0.15
L5 x T2	-0.81	0	0.16	0.07	0.6
L6 x T2	-0.2	-0.45	0.52*	0.20*	1.55**
L7 x T2	0.96	-0.96	-0.42*	-0.18*	1.05
L8 x T2	1.2	-0.07	0.46*	0.16*	0.1
L9 x T2	0.1	-0.5	0.82**	0.31**	0.32
L10 x T2	1	-0.64	-0.28	-0.08	-0.67
L11 x T2	-1.47	-0.27	-0.48*	-0.19*	1.08*
L12 x T2	-0.89	0.37	-0.17	-0.06	-0.38
L13 x T2	0.5	-0.85	-0.83**	-0.32**	-0.07
L14 x T2	-2.70*	4.32**	-0.29	-0.09	-0.25
L15 x T2	0.83	1.32	0.08	0.04	0.33
L16 x T2	-0.6	0.45	-0.15	-0.09	-0.35
SE SCA	1.05	0.88	2.01	0.74	0.37
SE (Sji-Skl)	1.49	1.25	2.84	1.05	0.52

Traits* and **significant at ($P \leq 0.05$) and ($P \leq 0.01$) respectively, SE (m±)= standard error of the mean, SE (Sij-Sik), standard error of difference, DIBO= days to initial boll opening, LY= lint yield, NBPP= number of bolls per plant and SCY= seed cotton yield, FS= fiber strength

Table 7. Proportional contribution of line, tester and line x tester to total variance for yield, yield related and fiber quality traits.

Traits	Line (%)	Tester (%)	Line x Tester (%)
Days to initial squaring	82.83	4.11	13.05
Days to initial flowering	86.82	0.44	12.74
Days to 50% flowering	87.54	0.05	12.41
Days to initial boll opening	90.41	0.02	9.58
Days to 65% boll opening	88.06	4.6	7.34
Number of bolls per plant	64.61	7.75	27.64
Plant height (cm)	76	3.19	20.81
Average boll weight (g)	79.83	5.26	14.91
Seed cotton yield (t/ha)	64.82	0.01	35.17
Ginning percentage (%)	97.05	0.56	2.39
Lint yield (t/ha)	72.1	0.05	27.85
Micronaire(mg/inch)	93.7	0.17	6.14
Fiber Length(mm)	98.57	00.06	1.38
Fiber Strength(g/tex)	90.77	3.18	6.04
Fiber elongation (%)	65.42	25.40	9.18

CONCLUSION

The findings of this study indicated the possibility ofpredicting hybrid performances based on the general combining ability of parents. In conventional breeding approach identifying crosses with noticeable good GCA and cross combinations with desirable SCA for the traits have been playing decisive roles in breeding. Likewise, combining ability and performance of parents have been found to be good indicators used in selection of parents for heterosis breeding. Furthermore, promising cross combinations identified in this study could be utilized for future breeding work as well as for direct release after confirming the stability of their performances under multi-location evaluation and over many year due to the present study was conducted at one location and this finding is only an indication and we cannot reach at definite conclusion. Hence, the information for degree of heritability, combining ability and gene action were pivotal role for research activity who would like to develop high yielding varieties of cotton. Furthermore, when selection is effectively done it can yield fruitful hybrids that have the potential to meet the demand of textile industry, seed producers and remain competitive against the synthetic fibers. On the other hand, the information from this studied also useful for advancing these breeding materials for further breeding programmes.

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