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A Line × Tester analysis for some seed cotton yield and fiber quality traits in upland cotton

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ABSTRACT

The objective of the present study was to estimate general combining ability (GCA) of the parents and specific combining ability (SCA) of crosses for the development of high yielding cotton varieties. The study was carried out at the experimental area of Department of Plant Breeding and Genetics, University of Agriculture, Faisalabad. A line × tester analysis was made to identify the superior general and specific combiners for seed cotton yield and fiber quality traits in upland cotton. Five lines/females (FH-114, FH-1000, CIM-448, CIM-707, NIAB-111) and three testers/males (TH-41-83, Cocker-307 and Allepo-41) were crossed to develop 15 F1 hybrids. These genotypes were evaluated along with parents in RCBD with three replications. The general combining ability (GCA) and specific combining ability (SCA) mean squares for seed cotton yield, lint percentage, fiber fineness, fiber strength and fiber length were significant. The fiber fineness showed greater importance of additive gene effect while seed cotton yield, lint percentage, fiber strength and fiber length exhibited non additive genetic effects. Parents FH-114 and NIAB-111 among lines and COKER-307 from testers were found as good general combiners for most of the traits. Hence, these parents proved worth to be used in hybridization and selection program for extracting desirable plants from segregating population. F_1 crosses CIM-707 × COKER-307, CIM-707 × ALLEPO-41 and FH-1000 × COKER-307, by and large, exhibited their superiority for all traits studied and were noted as the best specific combiners. Therefore, these crosses may be preferred to improve several traits simultaneously by selection or may be used for hybrid cotton crop development.

Key word: Fiber, cotton, yield, variety, lint, genotypes.

INTRODUCTION: Cotton is a cash crop and plays an important role in strengthen the economy of Pakistan. It is an important textile fiber crop and ranked second important oil seed crop after soybean in the world (Ullah *et al.*, 2019). It occupies a unique position in the global trade as it is major agricultural and industrial crop. Cotton is a multipurpose crop that supplies five basic products: lint, oil, meal, seed hull and linters. The lint is the most important product of the cotton plant and provides much of the high quality fiber for textile industry. The other most important by-product of seed is oil, which is used primarily for cooking. It contributes about 78% in the total indigenously produced vegetable oil. Its contribution in the agriculture is 5.2% and in the GDP is 1% (Ashraf *et al.*, 2018). The basic objective of any breeding program is to develop varieties with desirable traits. The knowledge about gene action and combining ability effects help the plant breeders in the selection of suitable parents for the hybridization program (Ahmed *et al.*, 2020).

Combining ability is the ability of a parent to produce superior offspring's when combined with another parent. General combining ability (GCA) deals with the additive gene action while specific combining ability deals with dominant gene action. Scientists, Khokhar *et al.* (2018) studied additive and non-additive type of gene action for seed cotton yield per plant. Other scientists (Wang *et al.*, 2016; Bakhsh *et al.*, 2019) studied the Combining ability effect in cotton (*G. hirsuitum*). They found that general combining ability effects were significant for lint percentage while the specific combining ability effects were significant for seed cotton yield and fiber length. They concluded that an additive type of gene action was predominant for ginning out-turn%. The advantage of the present research work was to identify the various genotypes and comparing their combining ability for seed cotton yield and various fiber quality traits. Raza *et al.* (2013) studied gene action and results revealed that there were additive gene action for lint percentage, fibre length, strength and fineness. The findings of Ullah *et al.* (2019) revealed that both types of gene actions (additive and non-additive) were important for lint percentage.

The variances due to SCA were more than GCA variances for various fiber quality parameters which indicates the preponderance of non-additive nature of gene action (Simon *et al.*, 2013). The results of Shaukat *et al.* (2013) showed a higher additive gene effect in the hybrid population (first generation) due to higher GCA variances for fiber strength and fineness whereas lint percentage presented higher SCA variances, pointing towards the gene action of non-additive in nature controlling the various traits. Non-additive gene action for fiber strength and fiber uniformity percentage was also reported by Raza *et al.* (2013).

Samreen *et al.* (2008) studied the combining ability effects in upland cotton genotypes by using analysis related to line × tester and results revealed that GCA and SCA variances for all the traits were significant. However, the higher GCA variance than SCA variance revealed gene action of additive in nature. The previous results (Munawar and Malik, 2013; Raza *et al.*, 2013) revealed that there were significant differences of SCA and GCA for various fiber parameters.

OBJECTIVES: In climate change scenario, the present research was carried out to examine the genetic variation in cotton genotypes.

MATERIALS AND METHODS: The present studies on the combining ability effects of different plant characters of *Gossypium hirsutum* L. were carried out in the experimental area of the Department of Plant Breeding and Genetics, University of Agriculture, Faisalabad. The experimental material was developed by crossing 8 varieties namely FH-114, FH-1000, CIM-448, CIM-707, NIAB-111, TH-41-83, Cocker-307 and Allepo-41, according to line × tester method. These varieties were grown in 12" × 12" earthen pots during in the green house. At flowering stage five lines i.e. FH-114, FH-1000, CIM-448, CIM-707, NIAB-111 were used as seed parents, and were pollinated by TH-41-83, Cocker-307 and Allepo-41 (testers) following line × tester fashion. The temperature in the greenhouse was maintained between 60°F and 100°F using steam as well as electric heaters. The seed parents were hand emasculated in the evening and pollinated the following morning to produce enough F_1 hybrid seed. Extreme precautionary measures were taken to avoid pollen contamination of the genetic material during selfing and crossing operation. The list of complete sets of parents and their crosses is given in table 1. The seeds of 15 Crosses and their 8 parents were sown in the field in a Randomized Complete Block Design with three repeats. The seeds were sown in single row plot having ten plants spaced 30 cm within the row and 75 cm between the rows. Normal agronomic practices and plant protection measures were adopted during growth and development of the plant. The data were taken on five consecutive middle plants, while one plant at both the end of each row was left as non-experimental. The mature bolls of each plant were picked and seed cotton was obtained. The total produce of each plant was obtained by picking seed cotton twice and added up to record the seed cotton yield of that plant. Picking was done when the dew had evaporated. The harvesting was weighed by electrical balance and mean seed cotton yield was calculated. Clean and dry sample of seed cotton of each plant was weighed and ginned separately with single roller electric gin in the laboratory. The lint obtained from each sample was weighed and ginning % was calculated by the following formula.

$$\text{Lint percentage} = \frac{\text{Weight of lint in a sample}}{\text{Weight of seed cotton in a sample}} \times 100$$

Parents: Lines	Parents: Testers	Crosses
FH-114	TH-41-83	FH-114 × TH-41-83
	Cocker-307	FH-114 × Cocker-307
	Allepo-41	FH-114 × Allepo-41
FH-1000	TH-41-83	FH-1000 × TH-41-83
	Cocker-307	FH-1000 × Cocker-307
	Allepo-41	FH-1000 × Allepo-41
CIM-448	TH-41-83	CIM-448 × TH-41-83
	Cocker-307	CIM-448 × Cocker-307
	Allepo-41	CIM-448 × Allepo-41
CIM-707	TH-41-83	CIM-707 × TH-41-83
	Cocker-307	CIM-707 × Cocker-307
	Allepo-41	CIM-707 × Allepo-41
NIAB-111	TH-41-83	NIAB-111 × TH-41-83
	Cocker-307	NIAB-111 × Cocker-307
	Allepo-41	NIAB-111 × Allepo-41

Table 1: The list of complete set of parents and their crosses.

Fiber length, fiber strength and fiber fineness of each plant were measured using Spin able HVI-900. HVI-900 is a computerized high volume instrument which provides a comprehensive profile of raw fiber. It measured the most important fiber characteristics such as strength, length, fineness, uniformity, elongation and others within a quick period of time according to the international trading standards. Mean values of these characters were then calculated. The data on the above mentioned parameters were statistically analyzed following the analysis of variance technique (Steel *et al.*, 1997) in order to see whether genotypic differences for each of the characters are significant. Combining ability analysis was performed by using line × tester analysis (Kempthorne, 1957).

RESULTS: The analysis of variance following line × tester analysis for each trait was conducted separately. Mean squares were differed significantly among the traits (table 1 & 2).

Seed cotton yield: Regarding general combining ability for seed cotton yield, among the lines CIM-707 (7.54) showed maximum positive and significant GCA, so marked as a good general combiner followed by CIM-448 (5.67), whereas FH-114 (-10.95) has a maximum and negative GCA which revealed that it is a poor general combiner for this character. Among the testers Coker-307 (9.36) has a maximum and significant GCA for this character which showed that it is a good general combiners, whereas Coker-307 (-10.47) having negative significant GCA, showed that it is a poor general combiner for the character under study (table 3). The cross combinations CIM-707 × Coker-307 (60.19) and CIM-448 × Coker-307 (22.60) respectively showed maximum positive and significant SCA so revealed as good specific combiners, while CIM-448 × Allepo-41 (-31.32) showed maximum negative SCA value for this character followed by FH-114 × Allepo-41 (-30.21) which revealed that these crosses are poor specific combiner for the character (table 4). This trait is governed by non-additive genes (table 5).

Fiber length: General combining ability effects for fiber length are given in table 3. Among the lines FH-114 (1.06) showed maximum positive and significant GCA, so marked as a good general combiner for fiber length, whereas FH-1000 (-1.106) has maximum negative and significant GCA which revealed that it is a poor general combiner for this character. Among the testers TH-41-83 (0.56) has a maximum and significant GCA for this character which showed that it is a good general combiners, whereas Allepo-41 (-0.88) having negative GCA, showed that it is a poor general combiner for the character under study. Specific combining ability effects for this character are given in table. 4. FH-114 × Coker-307 (2.26) and CIM-707 × TH-41-83 (2.07) respectively showed max positive and significant SCA so revealed as good specific combiners while FH-1000 × Allepo-41 (-2.93) showed maximum negative SCA value for this character followed by CIM-448 × Allepo-41 (-2.81) which revealed that these crosses are poor specific combiner for the character . The value of ratio of dominant to additive (σ^2H /σ^2D) is more than one i.e. 7.79 so that trait is governed by dominant genes (table. 5).

Fiber strength: Regarding fiber strength NIAB-111 (1.48) showed maximum positive and significant GCA whereas FH-1000 (-0.986) has maximum negative and significant GCA. Among the testers Allepo-41 (-0.69) having significant negative GCA. The combinations NIAB-111 × Coker-307 (3.94) and NIAB-

S.O.V	DF	SCY	FL	FS	FF	LP
Rep.	1	0.09^{ns}	2.26 ^{ns}	0.35 ^{ns}	0.08 ^{ns}	0.70 ^{ns}
Gen.	22	732.73**	2.70**	0.77*	0.15*	22.29**
Parents (P)	7	469.42**	1.27 ^{ns}	3.89*	0.15 ^{ns}	32.64**
P vs C	1	3415.52**	3.56*	2.12 ^{ns}	0.01^{ns}	15.86**
Crosses	14	672.75**	3.36**	3.82*	0.16*	17.58**
Lines (L)	4	334.79**	3.87**	5.38*	0.22*	9.30**
Testers (T)	2	992.45**	6.07**	3.57 ^{ns}	0.32**	37.21**
L × T	8	761.81**	2.42 ^{ns}	3.11 ^{ns}	0.09 ^{ns}	16.81**
Error	22	0.49	0.88	1.57	0.07	0.24

Table 2: Mean square values of line × tester analysis for various studied traits.
Significant = *, highly significant = **, DF = degree of freedom, Rep = replications, Gen = genotypes, SCY = Seed cotton yield
FL = Fiber length, FS = fiber strength, FF = fiber fineness, LP = lint percentage

Genotypes	Seed cotton yield	Fiber length	Fiber strength	Fiber fineness	Lint percentage
Lines					
FH-114	-10.953*	1.060*	-0.436	-0.160	1.338*
FH-1000	1.250*	-1.106*	-0.986*	0.256*	0.620*
CIM-448	5.687*	-0.256	0.313	0.156	0.333*
CIM-707	7.542*	0.393	-0.370	-0.110	-0.343*
NIAB-111	-3.526*	-0.090	1.480*	-0.143	-1.948*
S.E. (GCA lines)	0.29	0.38	0.51	0.10	0.19
Testers					
TH-41-83	1.118*	0.56*	0.35	0.093	-1.827*
Coker-307	9.356*	0.33	0.34	-0.206*	2.016*
Allepo-41	-10.474*	-0.89*	-0.69*	0.113	-0.189
S.E. (GCA testers)	0.22	0.30	0.39	0.08	0.15

Table 3: General combining ability estimate of 5 lines and 3 testers for various traits.

Genotypes	Seed cotton yield	Fiber length	Fiber strength	Fiber fineness	Lint percentage
FH-114 × TH-41-83	17.517*	-1.210*	-0.483	-0.110	-0.424
FH-114 × Coker-307	-19.501*	2.256*	-0.683	-0.526*	2.724*
FH-114 × Allepo-41	-30.213*	0.756	-0.083	-0.376*	4.905*
FH-1000 × TH-41-83	0.237	-0.893	-0.700	0.290	-1.692*
FH-1000 × Coker-307	-7.289*	-2.310*	-2.900*	0.223	4.982*
FH-1000 × Allepo-41	6.149*	-2.930*	-1.073	0.690*	1.161*
CIM-448 × TH-41-83	-16.769*	1.086	2.426*	0.323*	-3.950*
CIM-448 × Coker-307	22.604*	0.936	0.026	0.773*	-0.128
CIM-448 × Allepo-41	-31.321*	-2.813*	-1.490	0.930*	-1.581*
CIM-707 × TH-41-83	-17.902*	2.070*	-2.790*	0.523*	-1.311*
CIM-707 × Coker-307	60.199*	-0.310	1.656*	-0.480*	1.757*
CIM-707 × Allepo-41	5.150*	1.006	1.006	-0.346*	-3.124*
NIAB-111 × TH-41-83	12.034*	0.856	2.606*	-0.446*	-1.947*
NIAB-111 × Coker-307	0.124	1.406*	3.940*	-0.530*	2.764*
NIAB-111 × Allepo-41	-1.017*	0.090	-1.460	0.303	-4.135*
S.E.(SCA)	0.50	0.66	0.89	0.18	0.34

Table 4: Specific combining ability estimate of 15 crosses for various traits.

-111 × TH-41-83 (2.60) respectively, showed maximum positive and significant SCA while FH-1000 × Coker-307 (-2.90) showed a maximum negative SCA value for this character followed by CIM-707 × TH-41-83 (-2.79).

Fiber fineness: Among the lines FH-1000 (0.256) showed maximum positive and significant GCA, so marked as a poor general combiner. Among the testers, Coker-307 (-0.206) having negative significant GCA, showed that it is a good general combiner for the character under study. CIM-448 × Allepo-41 (0.93) and CIM-448 × Coker-307(0.77) respectively showed maximum positive and significant SCA so revealed as poor specific combiners, while NIAB-111 × Coker-307 (-0.53) showed maximum negative SCA value for this character followed by FH-114 × Coker-307 (-0.52) which revealed that these crosses are good specific combiner for the character.

Lint percentage: General combining ability effects for lint percentage are given in table 3. Among the lines FH-114 (1.338) showed maximum positive and significant GCA, so marked as a good general combiner for lint percentage followed by FH-1000 (0.62), whereas NIAB-111 (-1.948) has a maximum and negative GCA which revealed that it is a poor general combiner for this character. Among the testers, Coker-307 (2.02) has a maximum and significant GCA was showing good general combiners whereas TH-41-83 (-1.827) having negative GCA, showed that it is poor general combiner for the character under study. FH-1000 × Coker-307 (4.982) and FH-114 × Allepo-41 (4.905) respectively showed maximum positive and significant SCA so revealed as good specific combiners ,while NIAB-111 × Allepo-41 (-4.135) showed maximum negative and significant SCA value for this character followed by CIM-448 × TH-41-83 (-3.95) which revealed that these crosses are poor specific combiner for the character (table 4). The value of ratio of dominant to additive (σ^2H /σ^2D) is more than one i.e. 101.80 so that trait is governed by dominant genes (table 5).

Traits	Genetic components					
	σ^2GCA	σ^2D	σ^2SCA	σ^2H	σ^2SCA /σ^2GCA	σ^2H /σ^2D
Seed Cotton Yield	-4.72	-9.44	380.66	380.66	-80.65	-40.32
Fiber length	0.0495	0.0990	0.7710	0.7710	15.58	7.79
Fiber strength	0.0380	0.0760	0.7668	0.7668	20.18	10.08
Fiber fineness	0.038	0.076	0.0106	0.0106	0.279	0.139
Lint percentage	0.0407	0.0814	8.2862	8.2862	203.59	101.80

Table 5: Estimation of variances due to GCA (σ^2GCA), SCA (σ^2SCA), additive (σ^2D), dominant (σ^2H), ratio of SCA to GCA (σ^2SCA/ σ^2GCA) and degree of dominance (σ^2H/ σ^2D) for various traits.

Discussion: For any genetic change to occur in a plant character, either through natural or deliberate selection, genetic variation in the character must be present. Thus the availability of information on the relative contribution of different genetic components of variation in a character is essential before subjecting the breeding population to selection. Biometric analysis of the data revealed that variation in seed cotton yield, lint percentage, fiber length, fiber strength and fiber fineness were genetically manifested. The genetic variability in each character was further partitioned into various casual components, i.e. due to general and specific combining ability as outlined by Kempthorne (1957). The relative contribution of general and specific combining ability provided some understanding on the genetic control of the character. It was revealed that non additive genetic effects were important to control seed cotton yield, fiber strength, fiber length and lint percentage as had been discussed (Ali *et al.*, 2016; Kaleem *et al.*, 2016), while additive genetic component appeared to be predominantly for fiber fineness (Khokhar *et al.*, 2018; Mahrous, 2018).

For seed cotton yield non-additive genetic component appeared to be predominant, this confirms the finding of Ali *et al.* (2016) while Munir *et al.* (2016) showed that non additive effects controlled the seed cotton yield. For lint percentage non additive genetic effects were important similar results were found by Ullah *et al.* (2019) while opposite results were shown by Ali *et al.* (2016). For fiber fineness additive genetic effects were important which confirms the finding of Khan *et al.* (2017), while finding of Kamaran *et al.* (2018) reflected it as controlled by additive gene effects. For fiber strength, non-additive genetic components appeared to be predominant this confirms the finding of Kamaran *et al.* (2018), while Nasimi *et al.* (2016) found that additive effects controlled the character. For fiber length non additive genetic components appeared to be predominant this confirms the finding of Kaleem *et al.* (2016), while Coban and Unay (2017) showed that fiber length is controlled by additive gene action.

Among the lines FH-114 proved to be a good general combiner for fiber length and lint percentage, FH-1000 for fiber fineness, CIM-707 for seed cotton yield. Among testers TH-41-83 proved to be a good general combiner for fiber strength and fiber length, COKER-307 for seed cotton yield and lint percentage, ALLEPO-41 for fiber fineness. Thus, on the basis of these results it is concluded that four parental lines i.e. FH-114, FH-1000, COKER-307, NIAB-111 may hold good promise to a breeder for exploiting variability in the characters investigated here. It had been reported that parents having good GCA for a particular character are expected to yield good hybrids (Temiz *et al.*, 2016; Ullah *et al.*, 2019) and this behavior of the parents studied here was found to be valid in the present studies e.g. CIM-707, TH-41-83, COKER-307 which were good combiners for seed cotton yield and produced good hybrids i.e. NIAB-111 × COKER-307 , NIAB-111 × TH-41-83, CIM-707 × ALLEPO-41. For lint percentage FH-114 and COKER-307 exhibited best general combining ability (GCA) and therefore their crosses, i.e. FH-114 × COKER-307 and NIAB-111 × COKER-307 gave the best performance. For fiber length TH-41-83 was the best general combiner and when it was crossed with NIAB-111 the combination yielded the best performance. Variety NIAB-111 being best general combiner for fiber strength nicked well with COKER-307. For fiber fineness CIM-448 best produced varietal combination with ALLEPO-41.

BY contrast, varieties FH-114 and COKER-307 showed poor general combining ability for fiber length, but they produced best cross combination, FH-114 × COKER-307. For fiber strength and fiber length the cross combination NIAB-111 × COKER-307 and NIAB-111 × COKER-307 were the best respectively, and had parents with poor combining ability. For seed cotton yield varietal combination CIM-707 × COKER-307 displayed best, but these crosses had originated from parents those were poor general combiner. For the fiber fineness CIM-448 and CIM-707 were revealed to have a poor general combining ability, but they yielded best cross combination. Thus, from all the results it seems that it is not always necessary that good hybrids are produced by parents having high GCA, sometimes the parents with poor GCA nick well to produce potential hybrids as had been examined in the present case. Similar opinion had been made in previous studies (Imran *et al.*, 2016; Coban and Unay, 2017).

Greater role of lines towards variation in seed cotton, fiber fineness, indicates the predominant maternal influence for these traits. By contrast testers appear to be more important for variation in number of seed cotton yield and revealed the preponderance paternal influence for this trait, the contribution of maternal and paternal influence was relatively higher for variation in lint percentage, fiber strength and fiber length. Similar results were obtained in the previous studies (Khokhar *et al.*, 2018; Bakhsh *et al.*, 2019).

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