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Combining Ability Analysis and Heterotic Effects for Cotton Fiber Quality Traits

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ABSTRACT

Combining ability and gene action can help breeders to select suitable parents and appropriate breeding strategy. In the present study combining ability analysis and heterotic effects for cotton fiber quality traits were studied in a set of diallel crosses involving six cotton genotypes. The aim of this study was to estimate general combining ability of parents, special combining ability of F_1 diallel crosses, heterotic effects of F_1 diallel crosses in in the breeding programme to develop high quality cotton varieties. Randomized complete block design was used to test 15 F_1 diallel crosses, and 6 parents. Analysis revealed significant general combining ability effects for all the investigated traits and additive gene effects were important in the inheritance of the traits. Analysis also revealed significant SCA effects for only fiber fineness and spinning consistency index traits and additive and non-additive gene effects were important in the inheritance of the traits. General combining ability was found significant for all investigated traits, revealing the important role of additive gene effects. Specific combining ability was found significant for the Mic and SCI, revealing that non-additive gene effects, as dominant or epistatic are important, but not for Len, Str and SFI.

Keywords**:** cotton, fiber quality, gene action, diallel analysis

Introduction

Raw cotton and cotton products play an important role in the economy of advanced cotton growing countries. Improvement of fiber quality and cotton fiber quality parameters play a vital role in the cotton price in textile sector.Breeding programs of cotton generally aim to increase fiber quality parameters. The success of cotton breeding programme is based on choice of superior genotypes for hybridization and selection for favorable genes and gene complexes in combination. Since fiber quality traits are quantitatively inherited, a simple genetic model having several genetic parameters needs a lot of work to solve complex relationship of successful breeding (Bolek *et al*., 2010). Over the years fiber traits were significantly improved by the plant breeders by bringing new allelic recombination and subsequent selection of valuable trans-segregants (Ali *et al*., 2010).

Combining ability analysis, to compare the performance of F_1 combinations is used in breeding programs (Griffing, 1956) and allow estimation of different genetic parameters (Verhalen and Murray, 1967). Additive-dominance model can direct plant breeder about the validation of data and design as well as usage of data. Heterosis is useful in determining the most appropriate parents for specific traits (Khan *et al*., 2010).

Cotton fiber quality is expressible by a multitude of measurements (Hake *et al*., 1996). Fiber length, fiber fineness, fiber strength, short fiber index and the spinning consistency index are the most important fiber quality traits. Because of the high potential for cotton fiber quality *G. barbadence* L. still are used in cotton breeding programs. Thus new cotton varieties with high fiber quality can be obtained. The variation in a fiber trait through plant breeding approaches requires knowledge of the cultivar's genetics

(Aguado *et al*., 2010). Heterosis is one of the significant techniques in cotton breeding programs (Khan *et al*., 2010, Bhadate *et al*., 1980, Basbag *et al*., 2007). Little work has been reported on the heterosis of fiber quality traits in cotton breeding (Ashokkumar *et al*., 2013). Estimation of heterotic effects is necessary to identify the new suitable cross combinations.

The aim of this study was to determine the general combining ability of the parents, the specific combining ability of F_1 diallel crosses and the heterotic effects of the hybrids in the breeding programme to develop high quality cotton varieties.

Materials and Methods

The parent genotypes belonged to G. *hirsutum* L. (Sayar-314, Stoneville-453, Nazilli-84S, and Fantom) and G. *barbadense* L. (Giza-45 and Delcerro) species. During first year of experiment, six cotton genotypes were crossed in a half diallel mating design in the experimental fields of Dicle University of Agriculture Faculty in 2011. In second year, all parents (6) and F_1 crosses (15) were planted in the randomized complete block design with three replicates at the same experimental area in 2012. In all experiments, plot length was 12 m, spacing between and within rows was 70x20 cm. Standard cultural practices were applied as suggested by Diyarbakır ecological region. Fertilizers were 160kg ha^{-1} N and 120 kg ha^{-1} P_20_5 and irrigations were total 9 times in about 8-10 days intervals as furrow irrigation during growing seasons. Data were recorded on fiber obtained from randomly selected boll in each of the three replicates as the fiber length (Len.) (mm) (2.5% Span Length), fiber fineness (Mic.)(micronaire), fiber strength (Str) (gtex^{-1}), short fiber index (SFI) and the spinning consistency index (SCI). Investigated fiber quality traits were determined by HVI (High Volume Instruments). The data were analyzed using analysis of variance method by using Dial-98 (Ukai, 2006) and SAS (SAS Institute, Cary, NC). Traits found significant were further analyzed by Griffing's (1956) method-II and model-I. Heterosis (Ht) (%) and heterobeltiosis (Hb) (%) were calculated according to formulas of Hallauer and Miranda (1981).

Results and Discussion

Mean squares of δ^2GCA, δ^2SCA, δ^2GCA/δ^2SCA and GCA for investigated traits in cotton parents are presented in Table1. Mean squares of general combining ability (GCA) were found significant for all investigated traits, revealing the important role of additive gene effects (Table 1). Specific combining ability (SCA) was found significant for the Mic and SCI, revealing that non-additive gene effects, as dominant or epistatic are important, but not for the Len, Str and SFI (Table 2).

Variance of GCA effects were higher than variance of SCA effects ((δ^2GCA)/(δ^2GCA)>1) for the all investigated traits which indicated that additive gene action is prevailing with non-additive gene actions for the expression of these traits (Table 1). The results are in agreement with earlier reported the findings. (Bolek *et al*., 2010; Lukonge *et al*., 2008; Aguiar *et al*., 2007; Cheatham *et al*., 2003; Leidi 2003; Tariq *et al*., 1992; Green and Gulp, 1990;Kanoktip, 1987).

SCA was found highly significant for the Mic. and SCI, revealing an important role of non-additive gene effects (Table1). (Green and Culp 1990; Bhardwaj and Kapoor; 1998;Cheatham *et al*., 2003). Additive genetic effects with enough genetic variability were also noticed for the traits permitting for the effective selection (Lukonge *et al*., 2008). The reason for this difference may be due to different genetic structure of genotypes utilised and the different ecological condition (Bolek *et al*., 2010).

Positive GCA effects for the Len and SCI were ascertained in Giza-45 and Delcerro, whereas a negative GCA effects were ascertained in Sayar-314, Stoneville-453, Nazilli-84S and Fantom. Positive GCA effects for the Str were obtained from Stoneville-453, Fantom and Delcerro, while on the contrary negative GCA effects were obtained from Sayar-314, Nazilli-84S and Giza-45. Negative GCA effects for the Mic. were detected in Giza-45, Delcerro, and Nazilli-84S, while positive GCA effects were detected in Sayar-314, Stoneville-453, and Fantom. Negative GCA effects for the SFI were ascertained in Giza-45, Delcerro, and Fantom inasmuch as positive GCA effects were ascertained in Sayar-314, Stoneville-453, and Nazilli-84S. In order to do genetic crosses within the parents, Giza-45 and Delcerro were selected for the Len, Mic., SFI, SCI.

These genotypes would be more promising to develop higher fiber quality progenies. The GCA effects of parents indicated that the Giza-45 genotype was greatest general combiner for the Len, Mic., and SFI followed by Delcerro which was the best combiner for the Str and SCI.

Significant GCA effects for all the traits determined suggest at least one parent superior to the others, regarding mean performance in hybrid combinations. Giza-45 and Delcerro had affirmative and significant GCA effects on the Len, Mic., and SFI values, respectively, indicating some dominance genes for the Str, Mic., and SFI in the Giza-45 and Delcerro genotypes, which are consistent with the results (Aguiar *et al*., 2007).

Determinated SCA effects, Ht (%) and Hb (%) for the investigated traits in cotton F_1 diallel crosses. (Table 2).

The main aim in cotton breeding is obtain a lower value for the Mic. and SFI, while it is referred a high value for the Len, Str and SCI. In this context, higher negative SCA, negative Ht, and negative Hb values are desirable for the Mic. and SFI in cotton breeding studies.

Among the crosses, the determined SCA effects varied from -0.65 to 0.72 for the Len, -0.10 to 0.03 for the Mic., -1.65 to 0.85 for the Str, -0.44 to 0.78 for the SFI, -1.30 to 2.34 for the SCI. Stoneville-453xGiza-45, Sayar-314xDelcerro, Sayar-314xGiza-45, Stoneville-453xFantom, Nazilli-84SxDelcerro and FantomxDelcerro for the Len were determined to be greater specific combinations. Stoneville-453xDelcerro, Sayar-314xFantom, Sayar-314xDelcerro, Stoneville-453xFantom, Nazilli-84SxDelcerro for Str were found to be the best specific combinations. Significant and positive SCA effects for the SCI were observed in the three of the fifteen cross combinations; Sayar-314xDelcerro, DelcerroxGiza-45, Nazilli-84SxGiza-45. On other hand, Sayar-314xGiza-45, Nazilli-84SxFantom, Stoneville-453x Giza-45, Nazilli-84SxDelcerro for the SFI were found to be the greater specific combinations. Negative and significant SCA effects were determined for FantomxGiza-45, Sayar-314xGiza-45, and Stoneville-453xGiza-45 diallel crosses for the Mic.

Among the crosses the determinate Ht values varied from -1.77% to 3.81% for the Len, -3.43% to 10.58% for the Mic., -1.33% to 7.85% for the Str, -10.48% to 24.86% for the SFI, -12.82% to 7.06% for the SCI. In addition among the crosses the estimated Hb values varied from -7.87% to -0.03% for the Len, -17.98% to 5.19% for the Mic., -5.06% to 3.80% for the Str, -26.51% to 19.24% for the SFI, -18.22% to 4.63% for the SCI. Similar results were reported by Rauf *et al*., (2005). High and positive Hb (%) values were determined for the crosses Sayar-314xGiza-45, Sayar-314xDelcerro, Stoneville-453xGiza-45 and Nazilli-84SxGiza-45 for the Len, Sayar-314xDelcerro, Stoneville-453xFantom, Stoneville-453xDelcerro, Nazilli-84SxDelcerro for the Str, FantomxGiza-45, Stoneville-453xGiza-45, Sayar-314xGiza-45 for the SCI, while high and negative Ht values were determined for the crosses DelcerroxGiza-45, FantomxGiza-45, Nazilli-84SxGiza-45, Stoneville-453xGiza-45, Sayar-314xGiza-45 and Stoneville-453xDelcerro for the Mic., Sayar-314xGiza-45 Stoneville-453xGiza-45 and Nazilli-84SxGiza-45 for the SFI. The lower Hb values were determined for the crosses Sayar-314xGiza-45 (-17.98%) for the Mic, and Sayar-314xGiza 75 for the SFI (-26.51%) (Table. 2). Performance of parents and crosses could vary widely with genetic background and growing conditions (Ashokkumar *et al*., 2013; Bolek *et al*., 2010;Ehsan *et al*., 2008; Copur, 2006).

Conclusion

As a result of this study it may be concluded that additive genetic effects were noticed for the Len, Str, SFI. On the other hand, both additive and non-additive genetic effects were defined for the Mic. and SCI. Hence, selection in early generations may be more preferred for the Len, Str, SFI, while selection in the late generations may be more preferable for the Mic. and SCI. Suitable parents were determined to improve fiber quality traits of cotton. Namely Giza-45 for the Len, Mic., and SFI; Delcerro for the Str and SCI were selected as the thriving parents. These results implyed that Stoneville-453xGiza-45, Sayar-314xDelcerro, Sayar-314xGiza-45, Stoneville-453xFantom, Nazilli-84SxDelcerro and FantomxDelcerro for the Len; FantomxGiza-45, Sayar-314xGiza-45, Stoneville-453xGiza-45 for the Mic, Stoneville-453xDelcerro, Sayar-314xFantom, Sayar-314xDelcerro, Stoneville-453xFantom, Nazilli-84SxDelcerro for the Str; Sayar-314xDelcerro, DelcerroxGiza-45, Nazilli-84SxGiza-45 for the SCI may be proposed as the utmost promising cross combinations.

Table 1. Values of δ2GCA, δ2SCA, δ2GCA/δ2SCA and GCA for investigated traits in cotton parents (Griffing, 1956).

Parameters	**Genotypes**		**Len**	**Mic.**	**Str**	**SFI**	**SCI**
GCA	1	Sayar-314	-1,28**	0,62**	-0,281	0,58**	-8,39**
	2	Stoneville-453	-0,82**	0,0004	0,054	0,23*	-0,03
	3	Nazilli-84S	-0,81**	-0,15**	-1,302**	0,4**	-5,54**
	4	Fantom	-0,75**	0,26**	1,171**	-0,03	-2,66**
	5	Delcerro	1,20**	-0,30**	**1,841****	-0,35**	**10,00****
	6	Giza-45	**2,44****	**-0,43****	-1,484**	**-0,85****	6,62**
	δ^2 GCA		52,42**	3,65**	41,97**	6,68**	1210,13**
	δ^2 SCA		0,64	0,07**	1,8	0,54	112,96**
	(δ^2GCA)/(δ^2GCA)		81,16	51,51	23,32	12,18	10,71

σ^2GCA: variance of general combiningability, σ^2SCA: variance of specificcombiningability * and **: significant at $P \leq 0.05$ and $P \leq 0.01$ respectively; Len: Fiber Length (mm), Mic: Fiber Fineness (micronaire), Str: Fiber Strength (g/tex), SFI: Short Fiber Index, SCI: SpinningConsistency Index

Table 2. Determinated SCA effects, Ht (%) and Hb (%) for the investigated traits in cotton F_1 diallel crosses.

Genotypes			LEN			MIC			STR			SFI			SCI		
			SCA	**Ht (%)**	**Hb (%)**	**SCA**	**Ht (%)**	**Hb (%)**	**SCA**	**Ht (%)**	**Hb (%)**	**SCA**	**Ht (%)**	**Hb (%)**	**SCA**	**Ht (%)**	**Hb (%)**
1	x	2	-0.12	0.17	-2.25	0.01	2.84	-8.43	-0.028	0.89	-0.16	0.78	**24.86**	13.25	-7.07**	-12,82	**-18,22**
1	x	3	-0.18	0.45	-1.56	0.16**	5.84	-8.43	-0.304	-1.29	-1.68	-0.05	2.07	1.72	-9.31**	-12,72	-15,76
1	x	4	-0.11	0.29	-2.28	0.25**	8.43	1.12	0.388	-0.84	-4.79	0.16	9.30	-1.89	-0.73	-5,65	-7,27
1	x	5	0.60	3.11	-4.78	-0.01	0.77	-14.42	0.684	4.16	-0.76	0.19	9.31	-7.06	**5.29****	1,45	-5,84
1	x	6	0.63	**3.81**	-6.60	-0.07**	-1.57	**-17.98**	0.044	-0.62	-2.15	**-0.44**	**-10.48**	**-26.51**	-4.73**	5,47	1,36
2	x	3	-0.27	-0.78	-1.21	-0.04	0.62	-2.64	-0.607	**-1.33**	-2.74	0.57	17.90	7.28	-4.77*	**-12,48**	-15,03
2	x	4	0.10	0.12	**-0.03**	0.34**	**10.58**	**5.19**	0.419	5.32	2.16	0.45	20.64	19.24	-5.43**	-5,67	-10,04
2	x	5	-0.65	**-1.77**	-7.17	-0.07	-1.77	-6.95	**0.848**	**7.85**	**3.80**	0.03	11.14	3.38	-5.64**	-10,88	-11,90
2	x	6	**0.72**	3.20	-5.05	-0.06*	-2.46	-9.59	-0.025	1.04	-1.53	-0.43	-7.09	-16.91	-4.31**	3,19	0,63
3	x	4	0.008	0.25	-0.33	-0.003	2.58	-5.41	-0.557	0.34	-4.01	-0.29	-2.41	-12.13	-1.30	-11,11	-12,74
3	x	5	0.30	1.68	-4.30	0.03	0.39	-1.79	0.372	3.93	-1.34	-0.14	-0.61	-15.25	0.47	-6,11	-9,85
3	x	6	0.12	2.94	-5.67	-0.06	-2.95	-7.18	-1.642	0.33	-0.83	0.09	-6.53	-23.05	4.97*	2,39	1,93
4	x	5	0.27	1.25	-4.18	-0.10	-1.32	-10.82	0.132	1.76	0.94	0.26	11.85	5.19	2.34	-6,34	-11,65
4	x	6	-0.36	0.00	**-7.87**	**-0.15****	-3.42	-14.50	0.025	0.91	-4.53	0.01	-1.80	-11.26	-5.06*	**7,06**	**4,63**
5	x	6	0.01	1.49	-1.35	-0.01	**-3.43**	-5.63	-0.229	1.12	**-5.06**	0.06	-1.54	-5.65	0.96*	2,50	-1,16
S. Error			**0.37**	**1.55**	**2.46**	**0.13**	**4.19**	**5.90**	**0.59**	**2.55**	**2.47**	**0.33**	**10.42**	**12.72**	4.24	**6.91**	**7.02**
Means			**0.07**	**1.08**	**-3.64**	**0.01**	**1.01**	**-7.16**	**-0.03**	**1.57**	**-1.51**	**0.08**	**5.11**	**-4.64**	-2.29	**-4.11**	**-7.39**
Max.			**0.72**	**3.81**	**-0.03**	**0.34**	**10.58**	**5.19**	**0.85**	**7.85**	**3.80**	**0.78**	**24.86**	**19.24**	5.29	**7.06**	**4.63**
Min.			**-0.65**	**-1.77**	**-7.87**	**-0.15**	**-3.43**	**-17.98**	**-1.64**	**-1.33**	**-5.06**	**-0.44**	**-10.48**	**-26.51**	-9.31	**-12.82**	**-18.22**

Where: SCA: variance of specific combining ability, Ht: Heterosis (%), Hb: Heterobeltiosis (%), * and **: significant at $P \leq 0.05$ and $P \leq 0.01$ respectively; LEN: Fiber Length (mm), MIC: Fiber Fineness (micronaire), STR: Fiber Strength (g/tex), SFI: Short Fiber Index, SCI: Spinning Consistency Index 1: Sayar-314, 2: Stoneville-453, 3: Nazilli-84S, 4: Fantom, 5: Delcerro, 6: Giza-45

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