PLANT BREEDING AND SEED SCIENCE
Volume 62 2010

DOI: 10.2478/v10129-011-0001-6

Yuksel Bolek[1], Hatice Cokkızgın[2], Adem Bardak[3]

Kahramanmaras Sutcu Imam University, Faculty of Agricultural, Department of Field Crops[1,2],
Bingol University, Faculty of Agricultural, Department of Field Crops[3]

COMBINING ABILITY AND HETEROSIS FOR FIBER QUALITY TRAITS IN COTTON

ABSTRACT

Combining ability analysis and heterosis for cotton fiber quality traits were studied in a set of diallel crosses involving eight cotton (*Gossypium* sp.) genotypes. Randomized complete block design was used to test 56 F_1 and 8 parents for fiber quality traits; length (Len), strength (Str), micronaire (Mic), uniformity (Unf), elongation (Elg), spinning consistency index (Sci) and short fiber index (Sfi). Analysis revealed significant general combining ability (GCA) and specific combining ability (SCA) effects for all the traits and additive gene effects were important in the inheritance of the traits. Giza-45 had the highest GCA effects for Len, Sci, Unf and Elg while Is-4 had the highest Str value. Mic and Sfi values were lowest for Askabat-100 and Giza-45, respectively. The cross Cukurova-1518 × 108-F and Nazilli-84S × Askabat-100 had the lowest SCA effects for Mic and Sfi, respectively. The highest values for Len (Askabat-100 × 108-F), for Str (Acala Prema × 108-F), for Sci (Is-4 × Giza-45), for Unf (Stoneville-453 × Askabat-100) and for Elg (108-F × Is-4) were also obtained. Hybridizations among Askabat-100 × Nazilli-84S, Is-4 × Giza-45, Askabat-100 × Stoneville-453, Askabat-100 × Giza-45, Is-4 × 108F, Giza-45 × 108F, Giza-45 × Acala Prema, Nazilli-84S × Giza-45, Is-4 × Nazilli-84S and Acala Prema × Askabat-100 crosses yielded the best heterosis and heterobeltiosis values. Aforementioned parents and crosses could be utilized for further selection of high fiber quality and applying 3-way crosses or modified backcross or recurrent selection to genotypes having good combining ability would improve fiber quality.

Key words: Cotton, diallel analysis, heterosis, heterobeltiosis, general and specific combining ability

INTRODUCTION

Cotton is used in many different areas having economical importance. Most of the breeding programs of cotton aim to increase fiber quality parameters that are important in textile industry. For this purpose the most important step is to select suitable parents. 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. Combining ability analysis, to compare the performance of lines in hybrid combinations is used in breeding

Communicated by Henryk J. Czembor

programs (Griffing 1956) and allow estimation of different genetic parameters (Verhalen and Murray 1967).

In previous studies in cotton, Sprague and Tatum (1942) used the terms of general (GCA) and specific combining ability (SCA) to designate the average performance of line, tester and hybrid combinations. Combining ability analysis is an important tool for the selection of desirable parents together with the information regarding nature and magnitude of gene effects controlling quantitative traits. GCA effects reflect performance of parental lines in combination with all other lines, so parents with the highest GCA effects should have greater impact on trait improvement and it may be possible to utilize additive variance through natural selection.

The success of the hybridization program depends on the ability of the parents having greater potential in the hybridization to yield desirable segregants/recombinants (Hallauer and Miranda 1981;Goyal and Kumar 1991; Ahuja and Dhayal 2007).

Fiber elongation had approximately equal additive and dominance genetic effects while fiber strength exhibited primarily additive genetic effects. Micronaire and length showed primarily dominance genetic effects (Cheatham *et al.* 2003). Lukonge *et al.* (2008) and Meredith and Bridge (1972) reported that micronaire, length and strength are controlled by additive genes. Moreover, fiber parameters, micronaire, fiber strength, fiber length, uniformity index, short-fiber index, fiber elongation etc. showed additive gene effects (Aguiar *et al.* 2007).

The phenomenon of heterosis of F_1 hybrids can also reflect SCA and GCA of parental lines. Heterotic studies can also provide the basis for exploitation of valuable hybrid combinations and their commercial utilization in future breeding programs (Khan *et al.* 2009).

Heterosis or hybrid vigour is the increment in performance of a hybrid (F_1 generation) in relation to the parental average and can assume positive or negative values (Aguiar *et al.* 2007). Regarding previous studies on heterosis in cotton, researchers reported different heterosis values for yield components and fiber quality parameters. The amount of exploitable heterosis for seed cotton yield ranged from 15.50% (Al-Rawi and Kohel 1969) to 35% (Thomson and Luckett 1988). The amount of heterosis for fiber properties was usually lower (5-10%) than that for yield and its components (Turan 1979; Luckett 1989; Kaynak 1990; Meredith and Brown 1998). Estimated heterosis and heterobeltiosis values were published for different cotton cultivars (Basal and Turgut 2003; Wu *et al.* 2004; Temiz and Gencer 2005; Karademir *et al.* 2007; Basbag *et al.* 2008).

To determine combining abilities of parents and to select appropriate parents and crosses the diallel analysis has been widely used by plant breeders. Superior combining parents were identified on the basis of combining abilities and subsequently used in the breeding program with good results (Braden *et al.* 2003). Thus, the main objective of this experiment was to identify the best parents and their crosses, on the basis of their general and specific abilities as well as heterosis and heterobeltiosis performance, yielding high fiber quality.

MATERIAL AND METHODS

Plant material:

Eight cotton genotypes were crossed in a full diallel mating design. The parent genotypes belonged to *G. hirsutum* L. (Is-4, 108-F, Acala Prema, Cukurova-1518, Nazilli-84S, Stoneville-453) and *G. barbadense* L. (Giza-45, Askabat-100) species.

Field evaluations:

Experiment was conducted in the experimental fields of Kahramanmaras Agricultural Research Institute during 2005-2007. Total of 159 cotton genotypes (*G. hirsutum* L., *G. barbadense* L. and *G. herbaceum* L.) were planted on April 7, 2005. Resulting fiber measurements, 8 genotypes were mainly selected for important fiber characteristics (Table 1). Genotypes Giza-45, Askabat-100, Is-4 and 108-F have quality fibers and they are also verticillium wilt resistant. Acala Prema is both verticillium wilt resistant and high yielding cultivar. Cukurova-1518 adapted to Mediterranean Region of Turkey, and Nazilli-84S adapted to Egean Region of Turkey with high ginning turnout (45%). Stoneville-453 is a commercial cultivar developed at Stoneville Pedigree in USA and adapted to Southest of Turkey. Selected parents were planted on May 16, 2006 in the field to form diallel cross combinations among them (Fig. 1). The following year, all F_1s (28), reciprocals (28) and parents (8) were planted on May 15, 2007.

Table 1

Significant fiber characteristics of the cotton genotypes used in the experiment

Genotypes	Micronarie	Length [mm]	Strength [g/tex]	Spinning Consistancy Index	Uniformity [%]	Short Fiber Index	Elongat [%]
Giza-45	-	36.3	42.7	215.5	87.5	3.4	6.7
Askabat-100	3.4	35.6	43.0	-	85.6	3.4	-
Is-4	3.8	36.4	45.1	223.0	88.1	3.4	-
108-F	-	32.0	40.4	197.5	87.7	3.4	-
Acala Prema	-	-	40.0	188.0	86.7	3.4	-

Mic: Micronaire, Len: Length, Str: Strength, Sci: Spinning Consistancy Index , Unf: Uniformity, Sfi: Short Fiber Index , Elg: Elongation

Fig. 1. Experiment planted in the field in 2006

In all experiments, plot length was 12 m, spacing between and within rows was 70 × 20 cm. Completely randomized block design with 3 replications was applied. Standard cultural practices were applied as suggested by Kahramanmaras Agricultural Research Institute. Shortly, fertilizers were 14 kg N and 12 kg P_2O_5 and irrigations were total 8 times in about 8-10 days intervals as needed during growing seasons. Field was received total 642.1 mm, 658.8 mm, 680.6 mm amount of rain during 2005, 2006 and 2007 respectively (Anonymous 2007).

Bolls were sampled from the first position of the middle fruiting branches of each genotype. Fiber characteristics; length (Len) (mm) (2.5% Span Length), strength (Str) (g/tex) micronaire (Mic), uniformity (Unf) (%), elongation (Elg) (%), spinning consistency index (Sci) and short fiber index (Sfi) were determined by HVI (High Volume Instruments).

Statistical analysis:

The data were analyzed using analysis of variance method (SAS, Tukey). Traits found significant were further analyzed by Griffing's method (1956). Heterosis and heterobeltiosis values were calculated according to formulas of Hallauer and Miranda (1981).

$$Heterosis = \frac{F_1 - Means\ of\ parents}{Means\ of\ parents} \times 100$$

$$Heterobeltiosis = \frac{F_1 - Better\ parent}{Better\ parent} \times 100$$

RESULTS

Parents were selected for fiber quality traits in 2005. Fiber length ranged from 36.37 mm to 35.28 mm for *G. barbadense* genotypes while it ranged from 37.95 mm to 27.74 mm for *G. hirsutum* genotypes. Fiber strength ranged from 42.7 g/tex to 35.6 g/tex for *G. barbadense* genotypes while it was 42.6 g/tex to 31.3 g/tex for *G. hirsutum* genotypes. Fiber micronaire was between 4.78 and 3.94 for *G. barbadense* genotypes while it was between 4.95 and 3.82 for *G. hirsutum* genotypes. On the other hand, fiber uniformity and fiber elongation varied from 87.0% to 85.6% and 7.6% to 7.2% for *G. barbadense* genotypes while it varied from 87.8% to 82.5% and from 8.2% to 5.4% for *G. hirsutum* genotypes, respectively. Spinning consistency index ranged from 146 to 130 for *G. barbadense* genotypes while it ranged from 151 to 83 for *G. hirsutum* genotypes. Short fiber index ranged from 6.5 to 5.9 for *G. barbadense* genotypes while it ranged from 7.5 to 5.7 for *G. hirsutum* genotypes (data is not shown).

Variance analysis for general (GCA) and specific combining abilities (SCA) showed significant(p=0.05) effects for the fiber characters (Len, Str, Mic, Unf, Elg, Sci, Sfi) of the genotypes and their crosses (Table 2). Broad sense heritability values ranged from 0.57 to 0.83 while narrow sense heritability values ranged from 0.12 to 0.39 (Table 2).

Table 2

Analysis of Variance for Fiber Quality Traits for GCA and SCA

Parameter	Mean Squares			
	GCA	SCA	H^2	h^2
Micronaire	0.47*	0.17*	0.77	0.37
Length [mm]	67.80*	5.37*	0.83	0.33
Strength [g/tex]	78.44*	27.92*	0.65	0.14
Spinning Consistancy Index	4147.54*	566.84*	0.81	0.12
Uniformity [%]	7.32*	2.70*	0.57	0.16
Short Fiber Index	0.98*	0.21*	0.60	0.18
Elongation [%]	1.28*	0.40*	0.60	0.39

*, Significant at 0.05. GCA: General Combining Ability, SCA: Specific Combining Ability, H2: Broad Sense Heritability, h2: Narrow Sense Heritability

Of the parents, Giza-45 had the highest GCA effects for Len (2.61), Sci (22.02), Unf (1.16) and Elg (0.45) while Is-4 had the highest Str (2.70)value. Mic (-0.25) and Sfi (-0.38) values were lowest for Askabat-100 and Giza-45, respectively (Table 3).

Table 3

Estimates of GCA Effects for Fiber Traits

Parents Name	Mic	Len [mm]	Str [g/tex]	Sci	Unf [%]	Sfi	Elg [%]
Giza-45	-0.17	2.61	2.69	22.02	1.16	-0.38	0.45
Askabat-100	-0.25	2.57	1.18	15.20	0.75	-0.20	0.32
Is-4	-0.17	2.19	2.70	19.14	0.32	-0.20	0.15
108-F	0.24	-2.02	-0.39	-10.73	-0.41	0.09	-0.37
Acala Prema	0.05	-1.64	0.34	-4.42	-0.07	-0.05	-0.02
Cukurova-1518	0.08	-1.32	-2.45	-14.70	-0.58	0.32	-0.21
Nazilli-84S	0.11	-1.02	-3.43	-17.14	-0.56	0.22	-0.23
Stoneville-453	0.11	-1.38	-0.63	-9.36	-0.61	0.21	-0.09

Mic: Micronaire, Len: Length, Str: Strength, Sci: Spinning Consistancy Index , Unf: Uniformity, Sfi: Short Fiber Index , Elg: Elongation

Table 4

Estimates of SCA Effects for Fiber Traits

Crosses	Mic	Len [mm]	Str [g/tex]	Sci	Unf [%]	Sfi	Elg [%]
Askabat-100 × Giza-45	0.24	-2.21	-3.60	-25.95	-0.95	0.21	0.39
Is-4 × Giza-45	0.10	-1.06	5.31	34.11	1.05	-0.04	-0.10
108-F × Giza-45	-0.63	1.34	3.14	14.23	-0.29	0.00	0.07
Acala Prema × Giza-45	-0.21	1.64	0.26	10.17	1.30	-0.34	0.04
Cukurova-1518 × Giza-45	-0.10	0.55	-0.95	-5.80	-0.64	-0.11	-0.21
Nazilli-84S × Giza-45	-0.26	2.11	-2.74	-1.61	0.39	-0.04	0.08
Stoneville-453 × Giza-45	0.03	0.88	1.04	10.36	0.98	-0.28	-0.01
Giza-45 × Askabat-100	-0.13	0.35	-0.60	0.75	0.13	0.05	-0.33
Is-4 × Askabat-100	0.16	-3.28	-0.31	-8.58	-2.83	0.71	0.16
108-F × Askabat-100	0.01	-0.72	-0.17	-2.45	0.10	-0.10	-0.33
Acala Prema × Askabat-100	0.03	1.32	6.03	18.98	0.01	-0.09	-0.10
Cukurova-1518 × Askabat-100	-0.22	2.26	4.24	18.27	0.10	-0.26	-0.43
Nazilli-84S × Askabat-100	-0.41	2.95	0.87	19.70	1.80	-0.54	0.51
Stoneville-453 × Askabat-100	0.01	2.23	-0.73	15.42	3.17	-0.53	-0.28
Giza-45 × Is-4	-0.04	-0.58	-1.68	-29.75	0.05	0.10	0.03
Askabat-100 × Is-4	0.38	-1.58	-4.00	-0.25	-0.40	0.23	0.35
108-F × Is-4	-0.22	0.43	-5.67	-15.64	0.37	-0.23	0.84
Acala Prema × Is-4	0.06	0.94	-2.97	-9.45	0.49	-0.04	-0.44
Cukurova-1518 × Is-4	0.02	1.36	2.30	9.08	0.82	-0.23	-0.62
Nazilli-84S × Is-4	-0.07	0.43	3.45	8.77	0.30	-0.11	-0.58

Mic: Micronaire, Len: Length, Str: Strength, Sci: Spinning Consistancy Index , Unf: Uniformity, Sfi: Short Fiber Index , Elg: Elongation

Table 4

Continued

Crosses	Mic	Len [mm]	Str [g/tex]	Sci	Unf [%]	Sfi	Elg [%]
Stoneville-453 × Is-4	-0.04	1.53	5.16	10.48	-0.70	-0.10	0.16
Giza-45 × 108-F	-0.07	0.18	6.03	18.50	-0.03	0.13	0.03
Askabat-100 × 108-F	-0.33	3.02	3.55	23.50	0.85	-0.10	-0.15
Is-4 × 108-F	-0.07	-1.29	-2.93	-21.25	-2.30	0.38	-0.30
Acala Prema × 108-F	-0.14	0.26	7.06	25.42	0.39	-0.15	0.03
Cukurova-1518 × 108-F	0.41	-0.40	-0.82	-6.30	-0.12	0.56	-0.20
Nazilli-84S × 108-F	0.09	-0.84	-2.84	-12.86	-0.79	0.10	0.09
Stoneville-453 × 108-F	0.34	-0.71	-3.99	-15.39	-0.10	-0.14	-0.12
Giza-45 × Acala Prema	-0.09	-0.09	-1.83	-5.75	-0.25	0.05	0.00
Askabat-100 × Acala Prema	0.02	0.22	-0.28	4.75	1.10	-0.08	-0.18
Is-4 × Acala Prema	0.11	0.51	-3.80	-10.75	0.05	0.03	0.23
108-F × Acala Prema	-0.30	-0.25	-3.10	-8.75	-0.48	0.15	0.23
Cukurova-1518 × Acala Prema	0.22	-0.92	-1.20	-9.86	-0.89	0.02	-0.43
Nazilli-84S × Acala Prema	0.32	-0.58	-2.79	-8.92	0.27	-0.04	-0.21
Stoneville-453 × Acala Prema	0.18	-0.39	-0.19	-3.20	-0.29	0.00	0.05
Giza-45 × Cukurova-1518	-0.07	0.93	3.43	11.50	-0.15	-0.20	-0.40
Askabat-100 × Cukurova-1518	-0.11	0.05	-0.10	0.75	0.03	-0.03	0.10
Is-4 × Cukurova-1518	-0.21	1.73	1.68	12.00	0.38	-0.10	-0.35
108-F × Cukurova-1518	0.25	-0.33	-3.13	-13.75	-0.35	-0.08	-0.20
Acala Prema × Cukurova-1518	0.19	-0.23	0.93	-2.50	-0.63	-0.10	0.28
Nazilli-84S × Cukurova-1518	0.01	-0.73	2.47	5.11	-0.39	0.20	-0.21
Stoneville-453 × Cukurova-1518	0.21	-1.69	-3.57	-14.92	-0.07	0.08	0.15
Giza-45 × Nazilli-84S	0.06	-0.97	1.60	2.25	0.00	0.03	-0.23
Askabat-100 × Nazilli-84S	0.00	-0.02	3.60	12.25	0.40	0.00	-0.28
Is-4 × Nazilli-84S	0.23	-3.18	1.85	-5.75	-0.58	0.28	-0.18
108-F × Nazilli-84S	-0.21	-0.35	0.68	-1.75	-1.10	0.48	-0.03
Acala Prema × Nazilli-84S	-0.17	0.73	-0.50	3.00	0.45	-0.20	-0.38
Cukurova-1518 × Nazilli-84S	0.05	-0.30	0.63	-3.75	-0.93	0.30	-0.13
Stoneville-453 × Nazilli-84S	-0.11	-1.72	2.96	2.02	-1.09	0.47	0.09
Giza-45 × Stoneville-453	-0.13	1.79	0.38	6.00	0.90	0.03	0.63
Askabat-100 × Stoneville-453	-0.09	-0.01	2.90	9.25	-0.03	0.00	-0.08
Is-4 × Stoneville-453	-0.03	-0.82	0.85	-6.25	-1.58	0.08	0.60
108-F × Stoneville-453	0.40	-0.80	-0.68	-8.00	-0.20	-0.03	-0.75
Acala Prema × Stoneville-453	-0.06	-0.03	-3.80	-11.50	-0.20	0.08	-0.43
Cukurova-1518 × Stoneville-453	0.28	-0.44	-3.28	-16.50	-0.75	0.08	-0.48
Nazilli-84S × Stoneville-453	-0.21	-0.35	2.08	7.00	-0.10	0.28	-0.25

Mic: Micronaire, Len: Length, Str: Strength, Sci: Spinning Consistancy Index , Unf: Uniformity, Sfi: Short Fiber Index , Elg: Elongation

Table 5

Heterosis and Heterobeltiosis for Fiber Traits

Crosses	Sci		Unf		Sfi		Elg		Mic		Len		Str	
	H[%]	HB[%]	H[%]	HB[%]	H[%]	HB[%]	H[%]	HB[%]	H[%]	HB[%]	H[%]	HB[%]	H[%]	HB[%]
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Askabat-100 × Giza-45	1.39	1.39	0.41	0.41	-4.24	-9.60	11.64	10.14	-11.26	-11.26	1.83	1.83	-3.16	-4.79
Is-4 × Giza-45	67.25	66.09	2.32	1.55	-9.32	-9.32	-2.06	-5.30	-14.53	-14.53	6.58	0.75	24.17	22.08
108-F × Giza-45	-1.05	-1.05	0.00	0.00	-4.24	-8.87	-6.85	-6.85	-20.74	-22.93	-0.63	-0.63	-6.61	-8.18
Acala Prema × Giza-45	17.42	17.42	2.49	2.49	-11.02	-20.46	-2.06	-7.14	-15.47	-15.47	2.04	2.04	6.94	5.14
Cukurova-1518 × Giza-45	-12.89	-12.89	-0.46	-0.46	3.39	-5.43	-2.74	-13.42	-13.05	-13.05	-2.97	-2.97	-15.04	-16.47
Nazilli-84S × Giza-45	-5.23	-5.23	0.58	0.58	-0.85	-9.30	-1.37	-1.37	-18.32	-20.90	7.58	7.58	-17.30	-18.69
Stoneville-453 × Giza-45	5.92	5.92	0.17	0.17	-5.09	-20.00	-12.33	-12.33	-8.21	-8.21	-4.64	-4.64	1.24	-0.47
Giza-45 × Askabat-100	13.08	2.44	1.16	0.70	-8.00	-8.00	1.35	1.35	0.00	-16.84	2.05	2.05	10.17	-7.59
Is-4 × Askabat-100	23.85	11.42	-1.69	-2.87	-1.60	-1.60	-6.08	-7.95	-8.35	-8.35	1.31	1.31	32.17	24.87
108-F × Askabat-100	-12.69	-12.69	-0.58	-0.58	-4.80	-4.80	-12.84	-12.84	16.08	-6.14	-15.98	-15.98	2.93	-12.85
Acala Prema × Askabat-100	23.08	23.08	-0.58	-0.58	-7.20	-12.12	-4.73	-8.44	2.91	2.91	-1.52	-1.52	32.87	32.87
Cukurova-1518 × Askabat-100	17.69	17.69	0.18	0.18	-4.80	-7.75	-15.54	-23.78	0.38	0.38	2.42	2.42	19.64	19.64
Nazilli-84S × Askabat-100	8.08	8.08	1.75	1.75	-11.20	-13.95	2.03	2.03	-6.20	-22.00	5.37	5.37	-2.79	-2.79
Stoneville-453 × Askabat-100	13.08	13.08	3.78	3.78	-11.20	-20.71	-9.46	-9.46	6.71	6.71	2.34	2.34	2.51	-3.03
Giza-45 × Is-4	24.91	24.91	1.67	1.67	-2.63	-5.93	-4.64	-4.64	1.40	-16.11	-2.33	-2.33	28.68	14.25
Askabat-100 × Is-4	11.07	11.07	-3.79	-3.79	15.79	5.60	1.33	1.33	11.58	11.01	-11.01	-11.01	3.82	3.82
108-F × Is-4	3.11	3.11	1.67	1.67	-6.14	-13.71	0.66	0.66	6.36	-14.43	-5.73	-5.73	3.82	-6.96
Acala Prema × Is-4	4.50	4.50	-0.52	-0.52	0.88	-12.88	-18.54	-20.13	4.33	4.33	-8.14	-8.14	15.13	15.13
Cukurova-1518 × Is-4	-5.54	-5.54	-1.09	-1.09	6.14	-6.20	-15.89	-22.56	11.96	11.96	-9.40	-9.40	7.24	7.24

Table 5

Continued

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Nazilli-84S × Is-4	4.84	4.84	-0.58	-0.58	0.00	-11.63	-17.88	-17.88	-0.76	-20.49	1.96	1.96	7.24	7.24
Stoneville-453 × Is-4	11.77	11.77	-0.63	-0.63	3.51	-15.71	-16.56	-16.56	6.62	6.62	-2.33	-2.33	21.71	21.71
Giza-45 × 108-F	41.50	24.74	0.94	-0.06	-4.84	-4.84	23.42	-6.16	-25.90	-25.90	18.30	0.39	21.11	19.98
Askabat-100 × 108-F	26.88	23.46	1.93	1.40	-7.26	-8.00	10.81	-16.89	-19.75	-19.75	20.70	0.72	3.89	3.89
Is-4 × 108-F	-15.81	-26.30	-1.93	1.67	-1.61	-1.61	26.13	-7.29	-17.40	-17.40	9.00	-12.57	-20.76	-20.76
Acala Prema × 108-F	21.74	21.74	0.88	0.88	-6.45	-12.12	9.91	-20.78	-3.69	-3.69	0.83	0.83	17.93	17.93
Cukurova-1518 × 108-F	-7.51	-7.51	-0.47	-0.93	14.52	10.08	9.91	-25.61	-2.97	-2.97	0.00	-1.07	-7.19	-7.19
Nazilli-84S × 108-F	-24.11	-24.11	-0.35	-0.35	-3.23	-6.98	11.71	-3.88	0.31	0.31	-0.43	-0.43	-23.23	-23.23
Stoneville-453 × 108-F	-15.02	-15.02	-0.64	-0.64	0.81	-10.71	23.42	6.20	-6.86	-6.86	0.33	-1.34	-16.16	-16.16
Giza-45 × Acala Prema	52.43	9.41	4.20	1.91	-18.94	-18.94	-7.14	-7.14	-2.04	-19.05	28.70	1.55	20.38	-3.39
Askabat-100 × Acala Prema	64.56	30.39	3.79	1.98	-14.39	-14.39	-12.99	-12.99	4.71	4.05	28.47	-0.33	37.26	31.34
Is-4 × Acala Prema	25.73	-10.38	2.61	-0.40	-12.12	-12.12	-14.29	-14.29	9.81	9.67	26.83	-5.41	5.24	-4.87
108-F × Acala Prema	32.52	7.91	1.01	-0.23	-7.58	-7.58	-14.94	-14.94	4.71	-15.87	6.69	-0.81	27.51	3.30
Cukurova-1518 × Acala Prema	5.34	-24.91	0.59	-1.11	-2.27	-2.27	-25.33	-29.88	12.61	12.61	6.72	-1.84	3.79	3.79
Nazilli-84S × Acala Prema	-1.46	-7.73	0.71	0.71	-3.03	-3.03	-14.29	-14.29	25.10	0.10	5.55	-1.02	0.44	0.44
Stoneville-453 × Acala Prema	25.73	16.14	0.77	0.77	-6.82	-12.14	-8.44	-8.44	18.60	18.60	7.65	-1.58	25.76	13.83
Giza-45 × Cukurova-1518	34.55	3.14	-0.29	-0.81	-11.63	-11.63	-23.17	-23.17	3.63	-15.94	19.20	2.25	31.08	-0.47
Askabat-100 × Cukurova-1518	40.46	18.85	0.29	0.23	-8.53	-8.53	-21.34	-21.34	-2.72	-4.94	21.76	2.70	31.54	19.08
Is-4 × Cukurova-1518	45.91	11.07	1.05	-0.23	-9.30	-9.30	-31.10	-31.10	3.11	1.27	23.09	-0.20	35.69	16.05
108-F × Cukurova-1518	-18.64	-29.25	-1.75	-1.75	7.75	7.75	-30.49	-30.49	35.49	7.06	-3.23	-3.23	1.85	-21.93

Table 5

Continued

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Acala Prema × Cukurova-1518	-5.91	-5.91	-2.56	-2.56	-3.10	-5.30	-23.17	-23.17	24.22	22.17	-3.36	-3.36	15.39	9.17
Nazilli-84S × Cukurova-1518	1.82	1.82	-0.76	-0.76	0.78	-1.52	-25.00	-25.00	14.12	-10.19	1.02	1.02	10.31	10.31
Stoneville-453 × Cukurova-1518	2.27	0.90	-0.64	-0.64	2.33	-5.71	-14.63	-14.63	13.34	13.20	-2.85	-3.44	12.31	-3.82
Giza-45 × Nazilli-84S	58.76	-2.09	3.09	0.58	-8.53	-8.53	4.65	-7.53	-18.45	-18.45	21.42	2.15	20.06	-11.22
Askabat-100 × Nazilli-84S	86.44	26.92	4.75	2.68	-13.95	-13.95	8.53	-5.41	-24.36	-24.36	27.22	5.24	33.02	17.27
Is-4 × Nazilli-84S	58.19	-3.11	1.31	-1.90	-3.10	-3.10	-9.30	-22.52	-11.01	-11.01	6.97	-14.93	40.44	16.97
108-F × Nazilli-84S	4.52	-26.88	-1.48	-2.92	7.75	7.75	-4.65	-4.65	-8.67	-8.67	-1.89	-2.74	7.11	-20.05
Acala Prema × Nazilli-84S	21.47	4.37	2.02	1.78	-6.98	-9.09	-9.30	-24.03	-6.63	-6.63	3.88	3.88	5.85	-2.48
Cukurova-1518 × Nazilli-84S	18.08	-5.00	-1.01	-2.91	10.08	10.08	-8.53	-28.05	-8.26	-8.26	0.99	-0.95	17.22	14.15
Stoneville-453 × Nazilli-84S	16.95	-7.18	-0.65	-2.56	3.88	-4.29	3.88	3.88	-6.63	-6.63	-0.33	-2.84	15.96	-3.29
Giza-45 × Stoneville-453	47.09	14.29	6.71	2.26	-19.29	-19.29	18.61	4.80	6.21	-13.58	22.14	5.40	14.23	1.29
Askabat-100 × Stoneville-453	48.43	27.31	7.73	3.72	-20.71	-20.71	1.55	-11.49	4.40	2.15	20.57	2.31	12.25	12.25
Is-4 × Stoneville-453	33.63	3.11	0.67	-4.25	-13.57	-13.57	16.28	-0.66	6.86	5.09	14.43	-6.66	26.35	26.18
108-F × Stoneville-453	-17.94	-27.67	2.18	-1.11	-11.43	-11.43	-17.05	-17.05	38.42	9.52	-6.55	-6.55	-9.88	-19.34
Acala Prema × Stoneville-453	-4.48	-4.48	2.36	0.30	-10.00	-10.00	-3.88	-19.48	17.46	15.67	-1.74	-1.74	-6.19	-6.19
Cukurova-1518 × Stoneville-453	-28.70	-28.70	1.33	-2.39	-3.57	-3.57	-6.20	-26.22	27.43	27.43	-6.28	-6.28	-21.08	-21.08
Nazilli-84S × Stoneville-453	5.38	5.38	0.91	-0.89	3.57	3.57	-3.88	-3.88	7.50	-15.29	-5.12	-5.12	7.64	7.64
Average	15.97	3.29	0.81	-0.08	-4.35	-7.99	-5.23	-12.19	1.15	-4.88	4.99	-1.66	10.22	2.71

H: Heterosis, HB: Heterobeltiosis, Sci: Spinning Consistancy Index , Unf: Uniformity, Sfi: Short Fiber Index , Elg: Elongation, Mic: Micronaire, Len: Length, Str: Strength

The SCA effects of the crosses for fiber characteristics are presented in Table 4. Cross Cukurova-1518 × 108-F had high (0.41) SCA effects for mic while the cross, Askabat-100 × 108-F was high (3.02) for Len. Str value was highest for Acala Prema × 108-F (7.06) and Sci was highest for Is-4 × Giza-45 (34.11). On the other hand, Stoneville-453 × Askabat-100 had high (3.17) SCA effects for Unf while 108-F × Is-4 was highest for Elg (0.84). Crosses 108-F × Giza-45 and Nazilli-84S × Askabat-100 had lowest Mic (-0.63) and Sfi (-0.54), respectively.

In the reciprocal effect, it was observed that the cross combination of Acala Prema × 108-F (7.06) had the highest value and it was followed by Acala Prema × Askabat-100 (6.03) for Str. On the other hand, crosses Stoneville-453 × Askabat-100 (-0.53) and Stoneville-453 × Giza-45 (-0.28) for Sfi while 108F × Giza-45 (-0.63) and 108-F × Acala Prema (-0.30) for Mic had closer values to each other regarding reciprocal effects (Table 4).

Among the crosses the estimated heterosis values varied from -15.98 (108-F × Askabat-100) to 28.7 (Giza-45 × Acala Prema) for Len, -23.23 (Nazilli-84S × 108-F) to 40.44 (Is-4 × Nazilli-84S) for Str, -25.90 (Giza-45 × 108-F) to 38.42 (108-F × Stoneville-453) for Mic, -3.79 (Askabat-100 × Is-4) to 7.73 (Askabat-100 × Stoneville-453) for Unf, -31.10 (Is-4 × Cukurova-1518) to 26.13 (Is-4 × 108-F) for Elg, -28.70 % (Cukurova-1518 × Stoneville-453) to 86.44% (Askabat-100 × Nazilli-84S) for Sci, and -20.71 (Askabat-100 × Stoneville-453) to 15.79 (Askabat-100 × Is-4) for Sfi (Table 5).

On the other hand, the highest heterobeltiosis values were determined for the crosses Nazilli-84S × Giza-45 (7.58%) for Len, Acala Prema × Askabat-100 (32.87%) for Str, Stoneville-453 × Askabat-100 (3.78%) for Unf, Askabat-100 × Giza-45 (10.14%) for Elg, Is-4 × Giza-45 (66.09%) for Sci while the lowest heterobeltiosis values belonged to Giza-45 × 108-F (-25.90%) for Mic, and Askabat-100 × Stoneville-453 for Sfi (-20.71%) (Table 5).

DISCUSSION

In the parental selections to make crosses in 2005, Giza-45 was selected for Len, Sci, Unf, Sfi and Elg while Askabat-100 was better for Mic. On the other hand, Is-4 was selected for Str. 108-F and Acala Prema are high yielding cultivars while others (Nazilli-84S, Cukurova-1518 and Stoneville-453) are adapted to wide range of cotton growing regions.

The general combining ability effects of parents indicated that the genotype Giza-45 was best general combiner for len, str, sci, unf, sfi and elg followed by Askabat-100 which was the best combiner for mic while Is-4 was found best combiner for str. Thus, Giza-45, Askabat-100 and Is-4 parental values and significant positive GCA effects, these genotypes would be better to develop progenies for high fiber quality. Significant GCA effects for all the traits measured suggest at least one parent superior to the others, regarding mean performance in hybrid combinations. GCA/SCA>1 indicates that all of the characters studied were controlled by additive genes (Table 2) as shown by Lukonge *et al.* (2008), Augiar *et al.* (2007) and Meredith and Bridge (1972).

Cross combination of Askabat-100x108-F was found the best combiner for fiber length while for fiber strength Acala Prema × 108-F had high SCA effects. 108-F × Giza-45 and Nazilli-84S × Askabat-100 were best specific combiners for mic and sfi, respectively. Moreover, Stoneville-453 × Askabat-100 had high SCA effects for unf and Is-4 × Giza-45 was better combiner for Sci. Cross 108-F × Is-4 was resulted for high elg value to be selected for good combiner.

Giza-45 × Is-4, 108-F × Stoneville-453 cross had negative and significant SCA effects on Sci and Elg, respectively, indicating some recessive genes for fiber fineness in Is-4 and Stoneville-453 (male parent) genotypes, which is consistent with (Aguiar *et al.* 2007) results.

Some cross combinations for Str, Sfi, and Mic had high reciprocal effects. From the results, it is evident that if these parameters are to be improved single cross performance should be merged to reciprocal effects. Bhatade *et al.* (1980) have demonstrated this approach for the improvement of plant traits. On the other hand, additive genetic effects with enough genetic variability were noticed for the traits permitting for effective selection as shown by Lukonge *et al.* (2008). Noticed contradictions may be due to different genetic backgrounds of cultivars used and different environmental conditions under which the cotton crop is grown (Khan *et al.*, 2009).

Best crosses for heterosis are Giza-45 × Acala Prema for Len, Is-4 × Nazilli-84S for Str, Giza-45 × 108-F for Mic, Askabat-100 × Stoneville-453 for Unf, 108-F × Is-4 for Elg, Askabat-100 × Nazilli-84S for Sci and Askabat-100 × Stoneville-453 for Sfi. When heterobeltiosis values are taken into consideration, the crosses Nazilli-84S × Giza-45 for Len, Acala Prema × Askabat-100 for Str, Stoneville-453 × Askabat-100 for Unf, Askabat-100 × Giza-45 for Elg, Is-4 × Giza-45 for Sci, Giza-45 × 108-F for Mic and Askabat-100 × Stoneville-453 for Sfi should be selected.

When both heterosis and heterobeltiosis values used for selection, the crosses Askabat-100 × Nazilli-84S or Is-4 × Giza-45 for Sci, Askabat-100 × Stoneville-453 for Unf and Sfi, Stoneville-453 × 108-F for Elg, Askabat-100 × Nazilli-84S for Len and Askabat-100 × Acala Prema are the ones that should be selected.

Mean values for heterosis and heterobeltiosis of Str and Sci for most of the hybrids were positive indicating these parents can be used to obtain hybrids with best performance. On the other hand, most of hybrids had negative Elg values for heterosis and heterobeltiosis indicating these parents were not to be used to have better hybrids for those traits.

Estimated heterosis values for the parameters mostly fit to the results published previously. The differences between the estimated heterosis and heterobeltiosis values for all investigated characters in this study and those reported previously might be due to the use of different genetic materials and di fferent environmental conditions.

ACKNOWLEDGEMENT

This project was supported by The Scientific and Technological Research Council of Turkey (TÜBİTAK) (Project No: 1040537). Fiber analysis was performed in the companies, SANKO HOLDING A.Ş and ISKUR TEKSTIL ENERJI TIC. SAN. A.Ş.

REFERENCES

Aguiar P.A.D,, Penna J.C.V,, Freire E.C., Melo L.C. (2007) Diallel analysis of upland cotton cultivars. Crop Breeding and Applied Biotechnology 7: 353-359.

Ahuja S.L., Dhayal L.S. (2007) Combining ability estimates for yield and fibre quality traits in 4x13 linextester crosses of *Gossypium hirsutum*. Euphytica 153: 87-98.

Al-Rawi K.M., Kohel R.J. (1969) Diallel analaysis of yield and other agronomic characters in *Gossypium hirsutum* L. Crop Sci. 6: 779-783.

Anonymous (2007) http://www.meteor.gov.tr.

Basal H., Turgut I. (2003) Heterosis and combining ability for yield components and fiber quality parameters in a half diallel cotton (*G. hirsutum* L.) population. Turk J Agric For 27. 207-212.

Basbag S., Ekinci R., Gencer O. (2008) Pamukta bazı karakterlere ilişkin heterotik etkiler ve korelasyon analizleri. Ankara Üniversitesi Ziraat Fakültesi. Tarım Bilimleri Dergisi, 14 (2) 143-147.

Bhatade S.S., Shobhane M.R., Unchegaonkar P.K. (1980) Heterosis and combining ability in *G. arboreum* L. Indian J. Agri. Sci., 50: 310–16.

Braden C.W., Thaxton S., Thaxton P. (2003) Combining ability for near extra long fibres in up-land cotton. Beltwide Cotton Conferences, January 6–10, Nashville, TN.

Cheatham C.L., Jenkins J.N., McCarty Jr J.C., Watson C.E., Wu J. (2003) Genetic variances and combining ability of crosses of american cultivars, australian cultivars, and wild cottons. The Journal of Cotton Science 7:16–22.

Goyal S.N., Kumar S. (1991) Combining ability for yield component and oil content in sesame. Indian J. Genet. Plant Breeding 51: 311-314.

Griffing B. (1956) Concept of general and specific combining ability in relation to diallel crossing systems. Aust. J. Biol. Sci. 9:463-493.

Hallauer A.R., Miranda J.B. (1981) Quantitative genetics in maize breeding. Iowa State Uni. Press Ames. U.S.A

Karademir E., Karademir Ç., Ekinci R. (2007) Pamukta erkencilik, verim ve lif teknolojik özelliklerin kalıtımı. Yüzüncü Yıl Üniversitesi, Ziraat Fakültesi, Tarım Bilimleri Dergisi (J. Agric. Sci.), 17(2): 67-72.

Kaynak M.A. (1990) Harran ovası koşullarında, *Gossypium hirsutum* L. türü içindeki 12 pamuk çeşidinin eksik diallel melezlerinde, verim, verim unsurları ve lif özelliklerinin kalıtımı üzerinde araştırmalar. Doktora Tezi. Ç.Ü. Fen Bilimleri Enstitüsü Tarla Bitkileri Anabilim Dalı. Adana.

Khan N.U., Hassan G., Kumbhar M.B., Marwat K.B., Khan M.A., Parveen A., Aiman U., Saeed M. (2009) Combining ability analysis to identify suitable parents for heterosis in seed cotton yield, its components and lint % in upland cotton. Industrial Crops and Products 29. 108–115.

Luckett D.J. (1989) Diallel analysis of yield components, fiber quality and bacterial blight resistance using spaced plants of cotton. Euphytica 44: 11-21.

Lukonge E.P., Labuschagne M.T., Herselman L. (2008) Combining ability for yield and fibre characteristics in tanzanian cotton germplasm. Euphytica (2008) 161 :383-389.

Meredith W.R., Bridge R.R. (1972) Heterosis and gene action in cotton, *Gossypium hirsutum* L. Crop Sci 12:304-310.

Meredith Jr W.R., Brown J.S. (1998) Heterosis and combining ability of cottons originated from different regions of the U.S. Journal of Cotton Science 2: 77-84.

Sprague G.F., Tatum L.A. (1942) General vs specific combining ability in single crosses of corn. - J. Am. Soc.

Agron. 34: 923-952.

Temiz M., Gencer O. (2005) Pamukta (*Gossypium* Spp.) kombinasyon yeteneği ve melez gücü üzerine araştırmalar. Türkiye VI. Tarla Bitkileri Kongresi, 5-9 Eylül 2005, Antalya (Araştırma Sunusu Cilt II, Sayfa 1079-1082).

Thomson N.J., Luckett D.J. (1988) Heterosis and combining ablity effects in cotton. II Heterosis. Aust. Jour. Agric. Res. 39: 991-1002.

Turan Z.M. (1979) Pamuğun bazı agronomik ve tarımsal özelliklerinin diallel analiz yöntemi ile populasyon analizleri. Doktora Tezi. E.Ü. Zir. Fak. Agronomi-Genetik Bölümü. İzmir.

Verhalen LM, Murray JC (1967) A diallel analysis of several fiber properties traits in upland cotton (*Gossypium hirsutum* L.). Crop. Sci. 7:501-505.

Wu Y.T., Yin J.M., Guo W.Z., Zhu X.F., Zhang T.Z. (2004) Heterosis performance of yield and fibre quality in F_1 and F_2 hybrids in upland cotton. Plant Breeding 123, 285—289.