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INHERITANCE OF YIELD AND SOME FIBER PROPERTIES OF LINE X TESTER HYBRIDS IN COTTON (*Gossypium hirsutum* L.)

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ABSTRACT

This study was determined the general combining ability (GCA) of parents and specific combining abilities of their hybrid combinations. Furthermore, hybrid vigor of F_1 was evaluated by investigating genetic structure of the lines and testers. A total of 28 F_1 hybrids (4 lines and 7 testers) were used as experimental material, which were developed from line × tester method. Investigated traits, except fiber length were influenced by non-additive gene effect in the created populations. Heterosis values for seed cotton weight per boll, earliness ratio, ginning percentage, fiber length and micronaire were positive, while seed cotton yield was negative. Gloria, TMN 199 and ZN 1018 proved the best parents for seed cotton yield, while TMN 199, GW 2357 and TMN 170 were best for earliness ratio. Similarly, GW 2357 and Gloria were best for seed cotton weight per boll, whereas Ipek 607 proved best for seed index. Likewise, TMN 199, TMD 139 ZN 1018 were best for ginning percentage, while Gloria, Flash, Ipek 607 and UA 48 proved best for fiber length. In the same way, Ipek 607 and TMD 139 were best parents for fiber fineness, whereas Gloria and UA 48 proved best for fiber strength. These parents had the highest overall combining abilities for respective traits. The hybrid combinations, i.e., TMN 199 × Ipek 607, TMN 199 × UA 48, Flash × GW 2357, Gloria × Ipek 607, Gloria × UA 48 and ST 468 × ADN 712 had the highest combining abilities for seed cotton yield. Similarly, TMN 199 × TMN 170 exhibited higher combining ability for earliness ratio, whereas Flash × GW 2357 and Gloria × Ipek 607 had better combining ability for seed cotton weight per boll. Likewise, TMN 199 × GW 2357 and Gloria × ADN 712 resulted in higher combining ability for seed index, while Gloria × TMD 139, TMN 199 × TMN 170, Flash × ZN 1018 and ST-468 × TMN 139 proved better for ginning percentage. Nonetheless, Flash × ADN 712 and ST-468 × Ipek 607 had better combining ability for fiber length, whereas ST-468 × Ipek 607 exhibited better combining ability for fiber micronaire. In the same way, TMN 199 × UA 48, Flash × Ipek 607, ST-468 × GW 2357 and ST-468 × UA 48 had better combine ability for fiber strength. The study identified the most promising hybrids for respective traits and overall combining abilities.

Keywords: Combining ability, fiber quality, ginning percentage, line-tester, seed cotton yield

INTRODUCTION

Cotton is the most important fiber source for Turkey and other countries in the world. It provides the most important material for textile, ginning, oil, feed, and paper industries. Community awareness has rapidly increased on cotton products, and many features of the fiber are used to assess the quality. For instance, fiber fineness affects string quality by 20-35%, fiber length by 35%, and fiber strength by 30-35% (Guvercin et al., 2019). These circumstance force breeders to develop new cultivars with more productive and high quality fibers and explore the gene effects of both parents and hybrids on the desired traits. Line × Tester is a statistical method that can fulfill this necessity. It was first used by Kempthorne in 1957. Hybrid potency is a method that compares the traits of hybrids with their parents in the early generation. It is known as heterosis and heterobeltiosis. While heterosis is a method of determining that a hybrid is closer to which of the parents, heterobeltiosis is a method of determining the status of the hybrid versus superior parent

Several earlier studies have reported that many traits are managed by non-additive gene effects. Boyaci (2011) reported that fiber fineness, boll seed weight and earliness characteristics showed negative heterosis, while both positive and negative heterosis could be seen in other characteristics. In addition, many researchers determined that non-additive genes, in other words, dominant, epistatic or dominant × epistatic genes were effective in the management of yield, ginning percentage, earliness, single boll seed weight, 100 seed weight, fiber fineness and fiber strength traits in Line × Tester populations (Ashokkumar et al., 2010; Saravanan et al., 2010; Kalpande et al., 2014; Sawarkar et al., 2015; Sajjad et al., 2016; Guvercin, 2016; Patil et al., 2018; Ullah et al., 2020; Unay et al., 2020).

Basal et al. (2009) and Karademir et al. (2009) reported that fiber length is managed by additive genes. In addition, Babar et al. (2001), Lakho et al. (2001) and Karademir (2004) indicated high heterosis in ginning percentage, whereas Karademir (2004) and Boyaci (2011) reported high heterosis for 100-seed weight.

The aim of this study was to determine the general combining abilities (GCA) of parents and specific combining abilities (SCA) of hybrids, genetic influence affecting traits in populations as well as the hybrid powers of the crossed lines (Heterosis and Heterobeltiosis) in accordance with the Line × Tester analysis method among the cotton varieties developed recently in Turkey

MATERIALS AND METHODS

The study was carried out in Nazilli-Aydin province (37° 54′ 45″ N, 28° 19′ 14″ E, altitude: 64 m) during 2015 and 2016. Gloria, TMN 199, TMN 170 and ST 468 cotton varieties were used as homozygote lines, whereas GW 2357, ZN 1018, GW 2357, UA 48, ADN 712, Ipek 607 and TMN 139 were used as testers.

The crosses were made in accordance with the Line × Tester analysis method and 28 hybrid combinations were obtained during 2015. The hybrid combinations and their 11 parents were planted at Nazilli Cotton Research Institute on 11 May 2016. The experiment was laid out according to Randomized Complete Block Design (RCBD) with 3 replications. Parents and hybrids were planted in plots of replications as 1 row with length of 12 m, inter-row spacing of 0.70 m and intra-row spacing of 0.10 m. The soil of the experimental area is rich in phosphorus (3.5 ppm) and potassium (350 ppm), poor in organic matter (1.4%), medium calcareous (20.98%), alkaline (pH: 7.95) and saline (0.036%) (Anonymous, 2018). During 2016, 90 kg ha^{-1} of pure nitrogen (46% urea) was applied, followed by the first irrigation (4 furrow irrigations in total). Harvesting was performed manually twice on 8 October 2016 and 1 November 2016.

The highest (38.2 ºC) and the lowest (7.1 ºC) temperature in the region was recorded during August and November, respectively. In long-term data, the highest average temperature was observed in July (28.4 ºC), the lowest in December (8.2 ºC), and maximum in July (36.1 ºC).

Data relating to seed cotton yield (SCY; kg ha^{-1}), earliness (ER; %), fiber fineness (FF; mic.), fiber length (FL; mm), fiber strength (FS; g tex^{-1}), ginning percentage (GP; %), 100 seed weight (g) and single boll weight (g) were collected during the study. Fiber properties were determined by USTER HVI 1000.

Values obtained were analyzed according to the Line × Tester method with the statistical package program (TARPOPGEN) developed by Ozcan and Acikgoz (1999) in accordance with Kempthorne (1957) and Sing et al. (1982), and the means were compared with the $LSD_{(0.05)}$ (least significant difference) test. Heterosis (Chiang and Smith, 1967) and heterobeltiosis (Fonseca and Patterson, 1968) values were determined with the following formulas.

Heterosis (%); Ht = (F_1-MP)/MP) ×100, Mean Parents = (Line parent + Tester parent)/2 (1)

Heterobeltiosis (%); Htb = (F_1-Better Parent)/Better Parent) ×100 (2)

RESULTS AND DISCUSSION

The differences between genotypes were significant (p>0.01). Both parents and crosses contributed significantly to variation; however, the contribution of parents was more significant than hybrids (Table 1). These results stem from the significance of parent's GCA and the hybrid's SCA values. However, parents showed negative GCA for seed cotton yield, which indicated that GCA/SCA ratio was negative. This pointed out that dominant genes were effective in seed cotton yield.

Table 1. Variance analysis according to line × tester analysis

Source of variation	DF	SCY	GP	ER	BW	SW	FF	FL	FS
Replication	2	13104.45	0.925	55.466	0.036	0.017	1.991	0.059	5.559
Genotypes	38	42967.24**	18.249**	138.650**	0.954**	4.593**	8.213**	0.240**	16.476**
Parents	10	20213.75**	27.727**	148.103**	0.786**	5.287**	12.375**	0.431**	31.915**
Parents vs Hybrids	1	40318.73**	15.628**	1191.412**	5.526**	70.577**	0.209	0.215**	4.182
Hybrids	27	51492.56**	14.835**	96.157**	0.846**	1.893**	6.968**	0.170*	11.214**
Lines	3	21500.17**	4.019**	422.811**	1.434**	5.066**	6.645**	0.508**	8.787**
Tester	6	18637.41**	59.965**	146.384**	2.582**	1.391*'*	25.291**	0.377**	36.581**
Line × Tester	18	67443.01**	1.595**	24.973**	0.170**	1.531**	0.913**	0.045**	3.163**
Error	76	5269.67	0.424	40.513	0.067	0.041**	0.512	0.032	2.213
δ^2 GCA		-354.454	0.294	1.582	0.015	0.008	0.135	0.003	0.179
$^{\delta 2}$ SCA		20.724.446	0.390	-5.180	0.034	0.496	0.134	0.004	0.519
δ^2GCA/δ^2SCA		-0.017	0.750	-0,3	0.440	0.170	1.007	0.750	0.340

SCY: Seed cotton yield (kg ha^{-1}), GP: Ginning percentage (%), ER (%), FL: Fiber length (mm), FF: Fiber fineness (Micronaire), FS: Fiber strength (g/tex), BW:Boll weight (g), SW: seed weight (g)

In addition, it is clearly understood from GCA/SCA ratio (<1) that dominant genes are effective in other traits except for fiber fineness (1.007). Basal et al. (2009), Karademir et al. (2009), and Ekinci and Gencer (2014) reported that additive gene effect was important in fiber length, and dominant gene effect in other traits were compatible with the results of Ali et al. (2016) and Sajjad et al. (2016).

General Combining Ability of Parents (GCA)

According to parental GCA, TMN 199 was positive to ginning percentage, earliness rate, 100 seed weight, fiber fineness, but negative to seed cotton yield, boll weight, fiber length and fiber strength. Flash variety was positive to seed cotton yield, 100 seed weight and fiber length. Gloria variety was positive to seed cotton yield, boll weight, 100 seed weight, fiber length and fiber strength. The ST 468 was negatively correlated to the traits for which Gloria had possitive correlations, except for fiber strength (Table 2).

On the other hand, ADN 712 variety from the tester contributed positively towards ginning percentage, boll weight, and fiber fineness, and negatively to earliness rate, fiber length and fiber strength. The GW 2357 variety was positive to seed cotton yield, earliness rate, boll weight and fiber fineness, and negative to ginning percentage and fiber strenght (Table 2). Similarly, Ipek 607 variety was positive to seed cotton yield, boll weight, 100 seed weight, fiber length and fiber fineness and negative to ginning percentage, earliness rate and fiber fineness. Likewise, TMD 139 variety was positive to ginning percentage, whereas negative to other traits. The TMN 170 variety was positive to ginning percentage, earliness rate, boll seed weight and 100 seed weight, while negative to seed cotton yield and fiber length. The variety UA 48 was positive to boll weight, 100 seed weight, fiber length and fiber strength, whereas negative to ginnig percentage. The ZN 1018 variety was positive to seed cotton yield, ginning percentage and fiber fineness, while negative to boll weight, 100 seed weight, fiber length and fiber strength (Table 2). These results indicate that crucial new genotypes can be developed if ZN 1018, GW 2357 and Ipek 607 varieties are crossed with a high ginning percentage cultivar.

Table 2. GCA effects of parents for investigated properties

Lines and Testers	SCY	GP	ER	BW	100 SW	FF	FL	FS
Lines								
TMN 199	-14.747	0.53**	4.564*	-0.096**	0.537**	0.186**	-0.520**	-0.683**
Flash	35.11**	0.12	-2.004*	0.053	0.070**	0.038	0.093**	-0.421
Gloria	16.40**	-0.50**	-5.297*	0.331**	0.047**	-0.188	0.752**	0.569**
ST 468	-36.77**	-0.15**	2.737*	-0.288	-0.654**	-0.036	-0.324**	0.536**
Testers								
ADN 712	-2.11	0.21**	-4.542*	0.066*	-0.027	0.056**	-0.439**	-0.785**
GW 2357	36.64**	-0.40**	5.729*	0.293**	-0.013	0.124**	-0.877	-0.935**
Ipek 607	26.94**	-4.06**	-3.032*	0.588**	0.260**	-0.340**	2.664**	1.774**
TMD 139	-16.65	3.38**	-1.658	-0.766**	-0.286**	-0.101**	-0.905**	-1.168**
TMN 170	-39.86**	1.05**	2.654*	0.120**	0.352**	0.017	-0.663**	0.215
UA 48	-4.847	-0.66**	-0.016	0.173**	0.294**	0.036	1.390**	2.882**
ZN 1018	73.17**	0.48**	0.864	-0.473**	-0.579**	0.207**	-1.199**	-1.985**

Specific Combining Ability of Hybrids (SCA)

A total of 12 hybrids displayed negative SCA for seed cotton yield, 13 for ginning percentage and fiber length, 15 for earliness rate and fiber fineness, 14 for boll seed weight, 16 for 100 seed weight, 15 for fiber fineness, 13 for fiber length and fiber strength unlike other combinations (Table 3).

It has been reported that fiber length is managed by both additive (Ekinci and Gencer, 2014) and non-additive (dominant and epistatic) (Basal et al., 2009) gene effects. Fiber fineness and strength is managed by additive (Karademir and Gencer, 2010), and fiber fineness by both additive and non-additive (Ekinci and Gencer, 2014) gene effects. Basal et al. (2009) reported that fiber strength is governed by non-additive genes. Among studied traits, TMN 199 × Ipek 607, TMN 199 × UA 48, TMN 199 × ZN 1018, Flash × GW 2357, Flash × TMN 170, Gloria × Ipek 607, Gloria × UA 48, ST 468 × ADN 712, ST 468 × TMD 139 and ST 468 × TMN 170 were significant for seed cotton yield. Similarly, Flash × ADN 712 and Flash × ZN 1018 remained significant for ginning percentage, whereas Flash × ADN 712 and Gloria × TMD 139 for boll weight. Likewise, TMN 199 × GW 2357, TMN 199 × Ipek 607, Flash × TMN 170, Flash × UA 48, Gloria × ADN 712, ST 468 × GW 2357, ST 468 × Ipek 607 and ST 468 × UA 48 proved significant for 100 seed weight, while Flash × TMN 170, Gloria × GW 2357 and Gloria × Ipek 607 were significant for fiber fineness. In the same way, Flash × ADN 712 and ST 468 × GW 2357 remained significant for fiber length, whereas Flash × Ipek 607 and ST 468 × GW 2357 hybrids were significant for fiber strength. The hybrids with the highest special adaptability for seed cotton yield in the current study were Gloria × Ipek 607, whereas ST 468 × GW 2357 had the highest special adaptability for fiber length and strength (Table 3).

Table 3. SCA effects of hybrids for investigated characteristics

F_1 Hybrids	SCY (kg ha^{-1})	GP (%)	ER (%)	BW(g)	100 SW(g)	FF (mic)	FL (mm)	FS (g tex^{-1})
TMN 199 × ADN 712	55.71	-0.016	-0.26	-0.039	-0.516**	-0.025	0.25	0.408
TMN 199 × GW 2357	-119.28**	0.256	-1.214	0.094	1.253**	-0.052	0.002	-0.642
TMN 199 × Ipek 607	97.88**	0.0272	1.847	-0.118	0.568**	0.074	-0.39	-0.617
TMN 199 × TMD 139	3.38	0.355	-2.102	-0.044	-0.690**	-0.067	-0.006	0.592
TMN 199 × TMN 170	-26.37	-0.269	3.594	-0.168	0.046	-0.002	-0.279	-0.092
TMN 199 × UA 48	160.60**	-0.063	0.31	0.168	-0.718**	-0.025	0.042	0.008
TMN 199 × ZN 1018	149.27**	-0.335	-2.175	0.106	0.057	0.098	0.23	0.342
Flash × ADN 712	5.694	0.643**	0.553	0.253**	-0.306**	0.059	0.781**	0.246
Flash × GW 2357	124.51**	-0.353	1.288	0.045	-0.224**	-0.058	-0.838**	-1.53**
Flash × Ipek 607	-207.92**	-0.207	-0.001	-0.18	-0.535**	0.005	0.318	1.665**
Flash × TMD 139	-12.44	-0.652**	-1.238	-0.143	0.047	-0.026	-0.136	0.163
Flash × TMN 170	86.66**	-0.378	2.176	0.316	0.483**	0.129**	0.305	-0.487
Flash × UA 48	-22.56	0.238	1.17	-0.024	0.691**	0.133	-0.421	-0.12
Flash × ZN 1018	-20.03	0.690**	-3.949	-0.267**	-0.156	-0.241	-0.009	0.08
Gloria × ADN 712	-236.34**	0.602	0.272	-0.141	1.398**	-0.054	-0.968**	0.456
Gloria × GW 2357	-41.1	0.685	2.033	-0.003	-1.254**	0.085**	-0.273	0.039
Gloria × Ipek 607	260.38**	0.447	-3.423	0.133	-0.175	0.098**	-0.131	-1.202
Gloria × TMD 139	-66.85	-2.015	2.851	0.516**	0.670**	0.07	0.402	-0.927
Gloria × TMN 170	-130.74**	0.174	-1.303	-0.259**	-0.383**	-0.232**	0.536	0.623
Gloria × UA 48	174.32**	-0.248	-4.173	-0.233**	-0.356**	-0.094	0.14	-0.044
Gloria × ZN 1018	40.34	0.356	3.744	-0.013	0.1	1.121	0.295	1.056
ST 468 × ADN 712	128.93**	0.057	-0.564	-0.073	-0.576**	0.02	-0.063	-1.111
ST 468 × GW 2357	35.87	-0.588	-2.107	-0.137	0.226**	0.026	1.109**	2.139**
ST 468 × Ipek 607	-150.33	-0.312	1.577	0.164	0.142**	-0.178	0.052	0.164
ST 468 × TMD 139	70.80**	1.007	0.49	-0.329	-0.027	0.017	-0.259	0.173
ST 468 × TMN 170	70.45**	0.473	-4.467	0.111	-0.17**	0.106	-0.562	-0.044
ST 468 × UA 48	8.84	0.074	2.692	0.089	0.383**	-0.013	0.239	0.156
ST 468 × ZN 1018	-169.57	-0.71	2.379	0.175	-0.001	0.022	-0.516	-1.477

Mean performance of parents and F_1 crosses

The values of the studied traits of the parents (line and tester) are given in Table 4. Seed cotton yield of the lines ranged from 7035.7 to 5496.0 kg ha^{-1}, ginning percentage from 42.03 to 40.25%, earliness rate from 78.86 to 66.50%, boll seed weight from 6.23 to 5.44 g, 100 seed weight from 10.43 to 9.90 g, fiber fineness from 5.17 to 5.57 micronaire, fiber length from 32.01 to 28.96 mm, and fiber strength from 37.33 to 30.80 g tex^{-1}. Seed cotton yield of the testers ranged from 621.82 to 462.30. kg da^{-1}, ginning percentage from 42.10 to 32.19%, earliness rate from 87.90 to 70.31%, boll seed weight from 6.40 to 4.79 g, 100 seed weight from 13.86 to 8.90 g, fiber fineness from 4.47 to 5.62 micronaire, fiber length from 35.26 to 28.43 mm, and fiber strength from 40.13 to 29.46 g tex^{-1} (Table 4).

On the other hand, seed cotton yield of hybrids of these parents ranged from 8261.9 kg ha^{-1} (Gloria × Ipek 607) to 3003.39 kg ha^{-1} (Gloria × ADN 712), ginning percentage from 44.99% (TMN 199 × TMD 139) to 36.19% (ST 468 × Ipek 607), earliness rate from 91.93% (TMN 199 × TMN 170) to 69.36% (Gloria × Ipek 607), boll seed weight from 7.38 g (Gloria × Ipek 607) to 4.94 g (ST 468 × TMD 139), 100 seed weight from 13.59 g (TMN 199 × GW 2357) to 10.58 g (ST 468 × ZN 1018), fiber fineness from 4.78 micronaire (ST 468 × Ipek 607) to 5.82 micronaire (TMN 199 × ZN 1018), fiber length from 34.09 mm (Flash × Ipek 607) to 28.90 mm (ST 468 × ZN 1018) and fiber strength from 37.30 g tex^{-1} (ST 468 × UA 48) to 30.80 g tex^{-1} (ST 468 × ZN 1018). The ST 468 × ZN 1018 had low 100 seed weight, fiber length and fiber strength; however, low 100 seed weight had not affected the seed cotton yield and ginning percentage.

Among the lines, TMN 199 had the highest ginning percentage (42.03%) and earliness rate (78.86%), whereas Gloria had the highest seed cotton yield (7035.7 kg ha^{-1}), boll seed weight (6.23 g), 100 seed weight (10.30 g), fiber length (32.01 mm) and fiber strength (37.33 g tex^{-1}). Among testers, ZN 1018 had the highest seed cotton yield (6218.82 kg ha^{-1}), whereas TMD 139 resulted in the highest ginning percentage (42.97%). Likewise, GW 2357 had the highest earliness rate (79.89%) and single boll seed weight (6.50 g), Ipek 607 had the highest fiber length (35.26 mm), fiber strength (34.73 g tex^{-1}) and fiber fineness (4.47 micronaire) (Table 4).

Among hybrids, Gloria × Ipek 607 produced the highest seed cotton yield (8261.9 kg ha^{-1}), while TMN 199 × TMD 139 and Flash × TMD 199 resulted in the highest ginning percentage (44.99% and. 44.89%). Similarly, TMN 199 × TMN 170 recorded the highest earliness rate (91.93%), Gloria × Ipek 607 had the highest boll weight (7.38 g), TMN 199 × Ipek 607 observed the highest 100 seed weight, Flash × Ipek 607 resulted in the highest fiber length and strength, and the thinnest fibers were recorded for ST 468 × Ipek 607 (Table 4).

Table 4. Mean values of observed characters

Parents and F_1 Hybrids	SCY (kg ha^{-1})	GP (%)	ER (%)	BW (g)	SW (g)	FF (mic)	FL (mm)	FS (g tex^{-1})
Lines								
TMN 199	6992.0	42.03	78.86	5.61	9.90	5.57	30.84	32.66
Flash	5496.0	40.25	66.50	5.99	10.43	5.42	30.30	34.10
Gloria	7035.7	40.41	67.36	6.23	10.30	5.17	32.01	37.33
ST 468	5698.4	41.74	71.03	5.44	9.93	5.42	28.96	30.80
Testers								
ADN 712	4623.0	40.04	70.31	5.59	9.23	5.14	30.09	31.86
GW 2357	4726.1	39.21	79.89	6.50	9.86	5.48	29.93	29.30
Ipek 607	5757.9	32.19	66.90	6.24	13.86	4.47	35.26	34.73
TMD139	5123.0	42.97	68.80	4.79	8.90	4.60	30.76	32.23
TMN 170	5103.1	42.10	87.90	6.40	9.46	5.27	29.85	33.73
UA 48	5234.1	36.99	77.02	6.02	9.56	5.42	33.74	40.13
ZN 1018	6218.2	41.09	79.72	5.48	9.56	5.62	28.43	29.46
Mean$_{(Parents)}$	5638.0	39.80	75.70	5.70	10.60	5.10	30.80	33.20
LSD$_{(0.05)}$	1178.0	1.28	15.80	0.40	0.36	0.30	1.01	2.28
Crosses								
TMN 199 × ADN 712	5613.1	41.45	80.83	6.26	11.81	5.55	30.30	32.66
TMN 199 × GW 2357	3517.8	41.11	90.20	6.62	13.59	5.59	29.60	31.46
TMN 199 × Ipek 607	6325.3	37.26	84.50	6.70	13.18	5.25	32.90	34.20
TMN 199 × TMD 139	4944.4	44.99	81.92	5.42	11.38	5.35	29.50	32.46
TMN 199 × TMN 170	4414.6	42.04	91.93	6.18	12.75	5.53	29.50	33.16
TMN 199 × UA 48	3422.6	40.53	85.98	6.57	11.93	5.53	31.90	35.93
TMN 199 × ZN 1018	7301.5	41.40	84.37	5.86	11.83	5.82	29.50	31.40
Flash × ADN 712	6071.4	40.41	75.12	6.70	11.55	5.48	31.40	32.76
Flash × GW 2357	6454.3	40.10	86.13	6.72	11.65	5.43	29.30	30.83
Flash × Ipek 607	3765.8	36.58	76.08	6.79	11.61	5.03	34.09	36.73
Flash × TMD 139	5285.7	44.89	76.22	5.47	11.65	5.24	30.07	32.30
Flash × TMN 170	6043.6	41.53	83.94	6.82	12.72	5.51	30.70	33.03
Flash × UA 48	5301.5	40.43	80.27	6.53	12.87	5.54	32.08	36.06
Flash × ZN 1018	6107.1	42.02	76.03	5.40	11.15	5.33	29.90	31.40
Gloria × ADN 712	3003.9	41.03	71.55	6.58	13.10	5.14	30.30	33.96
Gloria × GW 2357	4611.1	40.50	83.58	6.95	10.60	5.35	30.60	33.40
Gloria × Ipek 607	8261.9	36.60	69.36	7.38	11.95	4.90	34.30	34.86
Gloria × TMD 139	4553.5	41.59	77.01	6.41	12.25	5.12	31.20	32.20
Gloria × TMN 170	3682.5	41.45	77.17	6.52	11.83	4.93	31.60	35.13
Gloria × UA 48	7083.3	39.31	71.63	6.60	11.80	5.08	33.30	37.13
Gloria × ZN 1018	6523.5	41.05	80.43	6.17	11.38	5.47	30.80	33.36
ST 468 × ADN 712	6125.0	40.84	78.75	6.03	10.56	5.37	30.10	32.36
ST 468 × GW 2357	4849.2	39.59	87.48	6.19	11.37	5.44	30.90	35.46
ST 468 × Ipek 607	3623.0	36.19	82.40	6.79	11.35	4.78	33.40	36.20
ST 468 × TMD 139	5448.4	44.96	82.69	4.94	10.85	5.21	29.50	33.26
ST 468 × TMN 170	5162.6	42.10	82.04	6.27	11.37	5.42	29.50	34.43
ST 468 × UA 48	4896.8	39.99	86.53	6.30	11.84	5.32	32.30	37.30
ST 468 × ZN 1018	3892.8	40.34	87.10	5.74	10.58	5.52	28.90	30.80
Mean$_{(crosses)}$	5220.0	40.10	81.00	6.20	11.77	5.20	31.03	33.70
LSD$_{(0.05)}$	1200	0.92	7.00	0.80	1.00	0.28	1.24	2.36

Hybrid vigor (Heterosis and Heterobeltiosis)

Heterosis values of hybrids for seed cotton yield ranged between -48.46% (Gloria × ADN 712) and 29.15% (Gloria × Ipek 607), whereas the values for ginning percentage varied between 6.16% (ST 468 × TMD 139) and -2.59% (ST 468 × ZN 1018). Likewise, heterosis values for earliness rate ranged between 19.48% (ST 468 × Ipek 607) and -0.77% (Gloria × UA 48), whereas the values for boll seed weight varied between 18.4% (Gloria × Ipek 607) and -3.4% (ST 468 × TMD 139). Similarly, heterosis values for 100 seed weight ranged from 37.6% (TMN 99 × GW 2357) to -4.6% (ST 468 × Ipek 607), whereas the values for fiber fineness varied between 5.21% (TMN 199 × TMD 139) and -5.65% (Gloria × TMN 170). In the same way, heterosis values for fiber length were in the range of 5.03% (ST 468 × GW 2357 and 3.94% (TMN 199 × TMD 199), whereas the values for fiber strength differed from 18.02% (ST 468 × GW 2357) to -8.38% (TMN 99 × ADN 712) (Table 5).

Gloria × Ipek 607 and Flash × GW 2357 hybrids showed significant positive heterosis for boll weight and 100 seed weight, and contributed to seed cotton yield, while TMN 199 × TMN 170 hybrid exhibited high positive and significant heterosis for seed cotton yield and 100 seed weight. The hybrids TMN 199 × UA 48, Flash × Ipek 607, Gloria × ADN 712, Gloria × GW 2357 and ST 468 × ZN 1018 exhibited high and positive heterosis for boll weight and 100 seed weight, and negative heterosis for seed cotton yield, possibly due to insufficient number of bolls (Table 5).

Table 5. Heterosis values (%) of cross combinations for investigated traits

Hybrids	SCY	GP	ER	BW	SW	FF	FL	FS
TMN 199 × ADN 712	-3.34	1.01	8.37	11.7**	23.5**	3.64	-0.51	1.23
TMN 199 × GW 2357	-39.95**	5.37**	13.63**	9.3**	37.6**	2.44	-2.52**	-8.34*
TMN 199 × Ipek 607	-0.77	0.4	15.94**	13.1**	11.0**	4.65	-0.39	1.48
TMN 199 × TMD 139	-18.37*	5.86**	10.96*	4.3	21.1**	5.21**	-3.94*	0.051
TMN 199 × TMN 170	27.01**	-0.05	10.25*	2.9	31.7**	2.06	-2.51	-0.1
TMN 199 × UA 48	-44.01**	2.57*	10.31*	13.0**	22.6**	0.64	-1.11	-1.28
TMN 199 × ZN 1018	10.54	-0.39**	6.41	5.7*	21.6**	4.05	-0.36	1.07
Flash × ADN 712	20	0.66*	9.82	15.7**	17.5**	3.85	4.17*	-0.65
Flash × GW 2357	26.28*	0.91	17.67**	7.6*	14.8**	-0.37	-2.39	-2.73
Flash × Ipek 607	-33.07**	0.97	14.06**	11.1**	-4.4**	1.79	4.00*	6.73*
Flash × TMD 139	-0.48	7.86**	12.66**	1.5	20.5**	4.59	-1.51	-2.61
Flash × TMN 170	14.03	0.85	8.73	10.0*	27.9**	3.12	2.35	-2.6
Flash × UA 48	-1.18	4.66**	11.86*	8.7**	28.7**	2.15	0.19	-2.82
Flash × ZN 1018	4.26	3.30**	3.99	-1.6	11.6**	-3.41	1.83	-1.2
Gloria × ADN 712	-48.46**	2.00**	3.94	11.3**	34.2**	-0.23	-2.21	-1.83
Gloria × GW 2357	-21.59*	1.73**	13.53**	9.2**	5.1**	0.41	-1.13	0.25
Gloria × Ipek 607	29.15**	0.81	3.33	18.4**	-1.1**	1.66	1.99	-3.23
Gloria × TMD 139	-25.09**	-0.24	13.12**	16.4**	27.6**	4.74	-0.37	-7.42*
Gloria × TMN 170	-39.32**	0.46	-0.59	3.2	19.8**	-5.65**	2.4	-1.12
Gloria × UA 48	15.45	1.56**	-0.77	7.8**	18.8**	-4	1.3	-4.13
Gloria × ZN 1018	-1.56	0.73	9.37	5.4	14.7**	1.36	2.15	-0.09
ST 468 × ADN 712	18.68	-0.01	11.43*	9.3**	10.2**	1.7	2.27	3.29
ST 468 × GW 2357	-6.966	-2.2	15.93**	3.7	14.9**	-0.18	5.03*	18.02**
ST 468 × Ipek 607	-36.75**	-2.08	19.48**	16.2	-4.6**	-3.4	4.05*	10.47
ST 468 × TMD 139	0.69	6.16**	18.27**	-3.4	15.2**	3.99	-1.1	5.55
ST 468 × TMN 170	-4.4	0.43	3.24	5.8*	17.2**	1.31	0.32	6.71
ST 468 × UA 48	-10.41	1.57**	16.90**	9.9**	21.5**	-1.91	3.12	5.16
ST 468 × ZN 1018	-34.66**	-2.59**	15.55**	5.1	8.6**	0.03	1	2.21
Mean	-3.7	10.62	8.2	5.2	17.41	1.3	0.15	0.6

According to populations' average, positive hybrid vigor (heterosis) for boll weight and 100 seed weight were not reflected in yield due to earliness; thus, the hybrids produced less number of bolls and seed cotton yield. However, heterosis in ginning percentage (10.62%) partially reduced the reflection and decreased fiber production. While hybrid powers in fiber properties caused coarseness in fiber fineness, heterosis in fiber length and strength found weak. Our findings differed with Boyaci (2011) in terms of seed cotton yield and 100 seed weight, and exhibit similarities with Karademir (2004) in terms of ginning percentage, with Basbag et al. (2007) in terms of earliness, with Ali et al. (2016) in terms of boll seed weight, with Ashokkumar et al. (2013) in terms of fiber fineness and strength, and with Coban and Unay (2013) in terms of fiber length.

The heterobeltiosis values of the hybrids differed between 17.43% (Flash × GW 2753) and -57.30% (Gloria × ADN 712) for seed cotton yield, 4.70% (TMN 199 × TMD 139) and -13.28% (ST 468 × Ipek 607) for ginning percentage, 16.42% (ST 468 × TMD 139) and -12.21% (Gloria × TMN 170) for earliness rate, 18.3% (Gloria × Ipek 607) and -9.2% (ST 468 × TMD 139) for boll seed weight, 37.3% (TMN 99 × GW 2357) and -18.1% (ST 468 × Ipek 607) for 100 seed weight, 3.56% (TMN 199 × ZN 1018) and -11.92% (ST 468 × Ipek 607) for fiber fineness, 5.26% (ST 468 × Ipek 607) and 4.91% (Flash × UA 48) for fiber length, and 5.75% (Flash × Ipek 607) and -15.15% (ST 468 × GW 2357) for fiber strength (Table 6).

Table 6. Heterobeltiosis values (%) of cross combinations for yield and fiber properties

Variations	SCY	GP	ER	BW	SW	FF	FL	FS
TMN 199 × ADN 712	-19.72**	-1.38**	2.5	11.5**	19.3**	-0.36	-1.73	0.00
TMN 199 × GW 2357	-49.68**	-2.18**	12.90**	1.9	37.3**	0.36	-3.96*	-3.67
TMN 199 × Ipek 607	-9.53	-11.30**	7.15	7.4*	-4.9**	-5.69	-.6.64**	-1.53
TMN 199 × TMD 139	-29.28**	4.70**	3.88	-3.4	15.0**	-3.95	-4.07*	-0.61
TMN 199 × TMN 170	-36.86**	-0.13	4.58	-3.4	28.8*	-0.66	-4.07*	-1.67
TMN 199 × UA 48	-51.04**	-3.56**	9.02	9.2**	20.5**	-0.72	-5.36**	-10.46**
TMN 199 × ZN 1018	4.42	-1.50**	5.83	4.5	19.5**	3.56	-4.26*	-3.87
Flash × ADN 712	10.46	0.39	6.85	11.9**	10.8**	1.11	3.81*	-3.91
Flash × GW 2357	17.43	-0.39	7.81	3.4	11.7**	-0.91	-2.98	-9.57**
Flash × Ipek 607	-34.59**	-9.13**	13.72**	8.8**	-16.2*	-7.19	-3.32*	5.75
Flash × TMD 139	-3.82	4.4**	10.78*	-8.6**	11.7**	-3.38	-2.24	-5.27
Flash × TMN 170	9.96	-1.3**	-4.5	6.4**	22.0**	1.66	1.6	-3.12
Flash × UA 48	-3.53	0.42	4.22	8.4**	23.4**	2.09	-4.91**	-10.13**
Flash × ZN 1018	-1.78	2.24**	-4.63	-5.8	6.9**	-5.1	-1.31*	-7.91*
Gloria × ADN 712	-57.30**	1.52**	1.76	5.6	27.2**	-0.58	-5.13**	-9.01**
Gloria × GW 2357	-34.46**	0.21	4.62	6.9**	2.9*	-2.43	-4.33*	-10.53**
Gloria × Ipek 607	17.42**	-9.44**	2.98	18.3**	-13.8*	-5.28	-2.72	-6.60*
Gloria × TMD 139	-35.27**	-3.21**	11.94*	2.9	18.9**	-1.1	-2.31	-13.75**
Gloria × TMN 170	-47.65**	-1.54**	-12.21**	1.8	14.9**	-6.51	-1.04	-5.89
Gloria × UA 48	0.67	-2.73**	-6.99	6.0*	14.6**	-6.15	-1.29	-7.47**
Gloria × ZN 1018	-7.27	-0.098	0.89	-0.9	10.6**	-2.67	-3.56	-10.62**
ST 468 × ADN 712	7.48	-2.055	10.87*	7.9*	6.3**	-0.98	0.34	1.56
ST 468 × GW 2357	-14.9	-5.16**	9.5	-4.7	14.5*	-0.73	3.32	15.15**
ST 468 × Ipek 607	-37.77**	-13.28**	16.01**	8.9**	-18.1**	-11.92	-5.26**	4.22
ST 468 × TMD 139	-4.38	4.64**	16.42**	-9.2**	9.3**	-3.93	-4.00*	3.2
ST 468 × TMN 170	-9.4	0.009	-6.67	-2.1	14.5**	-0.12	-1.18**	2.07
ST 468 × UA 48	-14.06	-4.2**	12.35*	4.6	19.2**	-1.97	-4.19*	-7.05
ST 468 × ZN 1018	-37.39**	-3.34**	9.25	4.7	6.6	-1.72	0.08	0
Mean	-16	-2	5.3	7.1	11.9	-2.3	-2	-3.5

Except Gloria × Ipek 607, positive but non-significant heterobeltiosis values for seed cotton yield of other hybrids indicated that the trait is managed by dominant gene instead of additive genes and environment effect. The Flash × ADN 712 hybrid showed positive heterobeltiosis for all traits except fiber fineness and strength, Flash × GW 2357 for seed cotton yield and 100 seed weight, Flash × TMN 170 for seed cotton yield, boll seed weight, 100 seed weight and fiber length, Gloria × Ipek 607 for seed cotton yield, earliness rate, boll seed weight and 100 seed weight. In addition, positive heterobeltiosis values were observed for boll seed weight and 100 seed weight from the population averages. The positive heterobeltiosis values for earliness trait were not reflected positively on the number of bolls and seed cotton yield. Moreover, due to negative heterobeltiosis (% -2.0) recorded for ginning percentage, negative effect on fiber yield was appeared (Table 6).

CONCLUSION

The parents and hybrids significantly differed for the studied traits. In F_1 generation, dominant genes were more effective in the management of all studied traits, except fiber length. This indicated that plant selections should be started at F_3 and F_4. In addition, parents proved superior to hybrids for the studied traits, except fiber strength necessitates more care in plant selection due to low variation.

The hybrids TMN 199 × Ipek 607, TMN 199 × UA 48, TMN 199 × ZN 1018, Flash × GW 2357, Flash × TMN 170, Gloria × Ipek 607, Gloria × UA 48, ST 468 × ADN 712 proved significant for seed cotton yield. Similarly, Flash × ADN 712, Flash × ZN 1018 were significant for ginning percentage, whereas Flash × ADN 712, Gloria × TMD 139, Gloria × TMN 170 and Gloria × UA 48 remained significant for boll weight. Likewise, TMN 199 × GW 2357, TMN 199 × Ipek 607, Flash × TMN 170, Flash × UA 48, Gloria × ADN 712, ST 468 × GW 2357, ST 468 × Ipek 607 and ST 468 × UA 48100 were significant for 100 seed weight, while Gloria × TMN 170 proved significant for fiber fineness. In the same way, Flash × ADN 712, Gloria × ADN 712, ST 468 × GW 2357 were significant for fiber length, while Flash × Ipek 607 and ST 468 × GW 235 remained significant for fiber strength. Gloria × Ipek 607 proved the most promising hybrid with its F_1 combination in terms of high seed cotton yield, economical ginning percentage and earliness rate as well as superior fiber properties.

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LITERATURE CITED

Anonymous. 2018. Cotton Research Institute soil analysis laboratory results, Nazilli-Aydın.

Ali, I., S. Amir, A. Ali. and B. Sadia. 2016. Genetic basis of variation for within-boll yield components in cotton. Turkish Journal of Agriculture and Forestry 40(1): 18-24.

Ashokkumar, K., R. Ravikesavan and K.S.J. Prince. 2010. Combining ability estimates for yield and fibre quality traits in line x tester crosses of upland cotton (*Gossypium hirsutum*). International Journal of Biology 2(1): 179-189.

Ashokkumar, K., K.S. Kumar and R. Ravikesavan. 2013. Heterosis Studies for fibre quality of upland cotton in line x tester design. African Journal of Agriculture Research 8(48): 6359-6365.

Babar, S.B., A.R. Soomro, R. Anjum and M.S. Kalwar. 2001. Estimation of heterosis, heterobeltiosis and economic heterosis in upland cotton (*Gossypium hirsutum* L.). Pakistan J. Biol. Sci. 4: 518–20.

Basal, H., A. Unay, O. Canavar and I. Yavas. 2009. Combining ability for fiber quality parameters and within-boll yield components in intraspecific and interspecific cotton populations. Spanish Journal of Agricultural Research 7(2): 364-74.

Basbag, S., R. Ekinci and O. Gencer. 2007. Combining ability and heterosis for earliness characters in line x tester population of *Gossypium hirsutum* L. Hereditas 144(5): 185–190.

Boyaci, K. 2011. A research on the inheritance of agronomical and technological properties of some cotton (*Gossypium* ssp.) in line x tester hybrid. Cukurova University, Department of Field Crops, Institute of Natural and Applied Sciences, Ph.D. Thesis, Adana-Turkey, 137pp (In Turkish).

Chiang, M.S. and J.D. Smith. 1967. Diallel analysis of the inheritance of quantitative characters in grain sorghum I. heterosis and inbreeding depression. Canadian Journal of Genetic Cytology 9: 44–51.

Coban, M. and A. Unay. 2013. Investigation of yield yield component and lint quality traits inheritance in some cotton breeds (*Gossypium hirsutum* L. x *Gossypium barbadense* L.) Adnan Menderes University, Department of Field Crops, Institute of Natural and Applied Sciences, M. Sc. Thesis, Aydin-Turkey, 97 pp (In Turkish).

Ekinci, R. and O. Gencer. 2014. Determination of genetic structure of fiber quality traits in double cross F_1 generation. YYU, Journal of Agriculture Science. 24(3): 290- 299 (In Turkish).

Fonseca, S. and F.L. Patterson. 1968. Hybrid vigor in a seven parent diallel cross in common winter wheat (*Triticum aestivum* L.). Crop Science 8(1): 85–88.

Guvercin, R.S. 2016. Combining ability of some cotton (*Gossypium hirsutum* L.) genotypes in line x tester for Elbistan conditions –II fiber properties. YYU, Journal of Agriculture Science. 26(4): 603–613 (In Turkish).

Guvercin, R.S., S. Candemir and G. Borzan. 2019. Selection success in hybrids (F9) of cotton (*Gossypium* spp.) having natural brown fibers. International Journal of Anatolia Agricultural Engineering (4):1–12.

Kalpande, H., V.N. Chinchane, S.K. Chavan, J.D. Deshmukh, V.S Patil and A. Kumar. 2014 3rd International Conference on Agriculture & Horticulture October 27-29, Hyderabad International Convention Centre, India.

Karademir, C. 2004 Determination of superior parents and hybrid combinations resistant to drought stress in cotton breeding. Cukurova University, Department of Field Crops, Institute of Natural and Applied Sciences, Ph.D. Thesis, Adana-Turkey, 118s (In Turkish).

Karademir C., E. Karademir, R. Ekinci and O. Gencer. 2009. Combining ability estimates and heterosis for yield and fiber quality of cotton in line x tester design. Not. Bot. Hort. Agrobot. Cluj. 37(2): 228–233.

Karademir, E. and O. Gencer. 2010. Combining ability and heterosis for yield and fibre quality properties in cotton (*Gossypium hirsutum* L.) obtained by half diallel mating design. Not. Bot. Hort. Agrobot. Cluj. 38(1): 222–227.

Kempthorne, O. 1957. An introduction to genetic STATISTICS. John Wiley and Sons. Inc., Newyork, U.S.A.

Lakho, A.R., H. Bhutto, M.S. Chang, M.Y. Solangi, G.H. Kalwar and A.H. Bolach. 2001. Estimation of heterosis for yield and economic traits in cotton (*Gossypium hirsutum* L.). Journal of Plant Science 3: 26–30.

Ozcan, K. and N. Acikgoz. 1999. A Statistical program for population genetics. The Symposium of Computer Applications for Agriculture, 3-6 October Cukurova University, Adana-Turkey (In Turkish).

Patil, A.E., D.B. Deosarkar and M.R. Puttawar. 2018. Environmental impact on the stability of gene action for seed cotton yield in cotton (*Gossypium hirsutum* L.). Int. J. Curr. Microbiol. App.Sci. 7(1): 1319–1329.

Sajjad, M., M.T. Azhar and M.U. Malook. 2016. Line × tester analysis for different yield and its attributed traits in Upland Cotton (*Gossypium hirsutum* L.). Agric. Biol. J. N. Am. 7(4): 163–172.

Saravanan, N.A., R. Ravikesaven and T.S Raveendran. 2010. Combining analysis for yield and fibre quality parameters in intraspecific hybrids of *Gossypium hirsutum* L. Electronic Journal of Plant Breeding 1: 856–863.

Sawarkar, M., A. Solanke, G.S. Mhasal and S.B. Deshmukh. 2015. Combining ability and heterosis for seed cotton yield, its components and quality traits in *Gossypium hirsutum* L. Indian Journal of Agricultural Research 49(2):154–159.

Singh. J., S.S. Malhi and T.H. Chanal. 1982. Single tester analysis of seed and fibre characters in upland cotton. Crop Improvement 9(2): 164–166.

Ullah, A., A. Shakel, A. Muhu, M. Ali and Y. Majid. 2020. A line × tester analysis for some seed cotton yield and fiber quality traits in upland cotton. International Journal of Cotton Research and Technology 2(1): 55–59.

Unay, A., N. Ozbek and M. Cinar. 2020. Line x tester analysis for yield and fiber quality in cotton (*Gossypium hirsutum* L.). Turk J. Field Crops. 24(2): 215–220.