

COMBINING ABILITY AND HYBRID VIGOR IN INTERSPECIFIC (*Gossypium hirsutum* L. x *Gossypium barbadense* L.) LINE X TESTER HYBRIDS OF COTTON

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ABSTRACT

Cotton is most important fiber plant having different fiber properties in the world. This study was carried out to increase yield and ginning outturn of seven interspecific (*G hirsutum* L. x *G barbadense* L.) pure (F₉) lines of cotton. For this, lines were hybridized with Stoneville 468 and Claudia cultivars which belonging to *G hirsutum* L. genus, in 2018, by Line x Tester mating design. Then, 14 F₁ Hybrids were sown with 9 parents according to Randomized Complete Block Design with three replications, in 2019, in Kahramanmaras.

In the results of study, BGKM-3 x Stoneville 468 and BGKM-5 x Claudia F₁ hybrids had been found very significant for yield and acceptable ginning outturn with good fiber properties. Moreover, while BGKM-3 x Stoneville 468 hybrid showed positive for specific combination ability (SCA) in seed cotton yield and ginning outturn, BGKM-3 line showed very important for general combination ability (GCA) in terms of yield and fiber length. Also, Stoneville 468 tester showed important GCA both fiber fineness and ginning outturn.

Inheritance for seed cotton yield have been found higher than other traits and determined both environmental and dominant genes are effective on the seed cotton yield. Besides, contribution of lines on total variance were found higher than both testers and lines x testers interaction, excluding fiber fineness.

Keywords: Cotton, fiber properties, interspecific hybrids, Line x Tester, seed cotton yield

INTRODUCTION

Cotton is a fiber plant having genetic diverse, which produced in the 33.7 million ha area in the world, while in 477 800 ha area of Turkey (Anonymous, 2019). 90% of world cotton production is made with *G hirsutum* L. (Upland), whilst 3% with extra long fiber (ELS) *G barbadense* L. species cotton. *G barbadense* L genus is known for having fibers which strength, fineness and uniform with longer than 34 mm, in contrast to low seed cotton yield and ginning outturn.

Cotton is very important for Turkish economy and social life. While cotton is production with upland (*G hirsutum* L.) cultivars in Turkey, ELS cotton is importing from abroad. Because ELS cultivars hasn't adapt to Turkey's conditions. However, because of demand of textile sector continues about quality fiber, breeders have been led to interspecies crosses as a solution. However, although the hybridization between *G hirsutum* L. and *G barbadense* L. species began over years ago, there was no success. Because, the ability to combine yield with fiber quality in F₁ crosses depends on the genetic potentials and combining ability of the parents (Zhang et al., 2016). The interspecific hybridization studies in Turkey last twenty

years have been intensified. Because, interspecific hybrids showed positive heterosis in fiber length, fiber strength (Unay et al., 2018), seed cotton yield (Adsare et al., 2017) and fiber yield (Zhang et al., 2016). However, negative heterobeltiosis was determined for boll number, boll weight (Malathi et al., 2019) and fiber fineness (Gungor and Efe, 2017).

Line x Tester analysis, help to determine of genetic potential of varieties, is used extensively in Turkey. This analysis method explains the total contribution (GCA) of one parent to crossbreed, while at same time explains the importance of the relationship (SCA) with each of the other parents in crossbreed (Kempthorne, 1957). In addition, parents with high general combination ability are important for pure line development, whereas crosses with high specific combination ability are important in terms of F₁ hybrid breeding. Because, F₁ hybrids can be more superior from mean of parents (heterosis) and superior parent (heterobeltiosis) because of the influence of dominant genes. Previous studies have reported that F₁ hybrids showed positive heterosis (Naquibullah et al., 2000) and heterobeltiosis in terms of seed cotton yield, ginning outturn, boll weight (Malathi et al., 2019), earliness and some fiber properties. BGKM-3 x Stoneville 468 hybrid

showed positive heterosis in cotton yield, fiber yield, earliness, fiber length, strength and fineness, but negative heterobeltiosis except for ginning outturn. This situation has been found important for combining high seed cotton yield with good fiber properties in F₁ hybrids.

This study was aimed to increase seed cotton yield and ginning outturn of seven pure cotton genotypes (F₉) which developed by interspecific crossing between *G. hirsutum* L. and *G. barbadense* L. and having thin, long and strength fibers in new hybridization program.

MATERIALS AND METHODS

This study was conducted in 2018 and 2019 years in Kahramanmaraş to improvement seed cotton yield and ginning outturn in seven interspecific (*G. hirsutum* L. x *G. barbadense* L.) pure lines (F₉). While interspecific lines (BGKM-1 and BGKM-2 were developed from Sayar 314 x Giza 45, BGKM-3 and BGKM-4 were developed from Maras 92 x Giza 45, BGKM-5, BGKM-6 and BGKM-7 were developed from Ersan 92 x Giza 45) were used as female, Stoneville 468 and Claudia were used as tester parents, and hybridizations were made according to Line x Tester mating design. Stoneville 468 is preferred by farmers for its high seed cotton yield, while Claudia is

preferred for fiber quality. Then, 23 genotypes (7 parents and 14 F₁ hybrids) were planted at East Mediterranean Transitional Zone Agricultural Research Institute's experimental area according to Randomized Complete Block Design with three replicates in May 22nd, 2019. The genotypes were sown four rows and 6 m long in every plot. The inter-row and intra-row of the plants were 0.70 m and 0.15 m respectively. 180 kg ha⁻¹ nitrogen (N) and 60 kg ha⁻¹ phosphorus (P₂O₅) were applied to experiment area. While first fertilization was applied dose as 60-60-0 NPK kg ha⁻¹ in the form of 20.20.0 composed fertilizer before sown, remaining nitrogen (120 kg ha⁻¹) was applied before first irrigation as ammonium nitrate (% 33 N). The all cultural practices were applied according to cotton growing practices of Kahramanmaraş. The experimental area was irrigated with 8 times. Harvests were done twice with by hand at October 16th, 2019 and November 6th, 2019. Fiber characteristics were analyzed with High Volume Instruments (HVI), also. Data of investigated properties were analyzed according to Line x Tester mating design. Then, means of investigated properties were compared via LSD_{0.05}. Furthermore, after the calculated GCA and SCA, heterosis (Chang and Smith, 1967) and heterobeltiosis (Fonseca and Patterson, 1968) were determined by formulas below.

$$\text{Heterosis (\%)}; \quad Ht = ((F_1 - MP) / MP) * 100, \quad MP = (\text{Line parent} + \text{Tester parent}) / 2 \quad (1)$$

$$\text{Heterobeltiosis (\%)}; \quad Htb = (F_1 - \text{Better Parent}) / \text{Better Parent} * 100 \quad (2)$$

RESULTS AND DISCUSSION

Line x Tester Analysis and ratio of GCA/SCA

Results of variance analysis showed that genetic differences among genotypes are important for all properties except fiber strength and uniformity (Table 1). Parents (lines and testers) and hybrids showed important variation for seed cotton yield, ginning outturn, earliness, fiber fineness and fiber length. The significant parents and hybrids indicated that these characters were controlled by both additive and non-additive gene effects. In addition, the variations between lines and testers were positively affected to line x tester interaction. Furthermore, the negative $\delta^2_{GCA} / \delta^2_{SCA}$ ratios on investigated properties have determined as dominant gene/s effects (Table 1). Previous studies reported that different gene effects in the traits examined. Unay et al. (2019) reported the dominant gene effects on seed cotton yield, ginning outturn fiber length and strength, in contrast, Prakash et al. (2018) and Roy et al. (2018) reported that the additive gene effects are more important.

Performances of Lines

The averages of lines in seed cotton yield is 3743.0 kg ha⁻¹, in ginning outturn 36.72%, in fiber yield 1373.8 kg ha⁻¹, in earliness 70.88%, in fiber length 33.64 mm, in fiber fineness 4.24 micronaire, in fiber strength 36.25 g tex⁻¹ and in fiber uniformity 86.71% has been found (Table 2). Differences among lines more effected to variations of fiber yield (97.67%), seed cotton yield (96.28%), earliness (93.30%), ginning outturn (89.25%), fiber length (82.42%), fiber uniformity (53.74%), fiber strength (50.72%) than testers and lines x testers interaction (Table 4). BGKM-3 line has the highest (3951.0 kg ha⁻¹), but BGKM-1 line has the lowest seed cotton yield (3564.3 kg ha⁻¹) in the study. Moreover, BGKM-3 exceeds the effect of low ginning outturn with its high yield potential and came first in fiber yield. The earliness ratios of lines changed from 69.16% to 71.97%, and BGKM-6 was determined as earliest genotype. On the other hand, while fiber fineness of lines were varied from 4.16 (BGKM-5) to 4.31 micronaire (BGKM-1), the fiber length 32.87 mm (BGKM-6) to 34.26 mm (BGKM-3), the fiber strength 37.77 g tex⁻¹ (BGKM-4) to 35.64 g tex⁻¹ (BGKM-3) and the fiber uniformity 86.22% (BGKM-5) to 87.60% (BGKM-4) varied.

Table 1. Variance analysis of Line x Testers for combining effects of different cotton characters

Sources	Degree of freedom	Seed cotton yield (kg ha ⁻¹)	Ginning outturn (%)	Fiber yield (kg ha ⁻¹)	Earliness (%)	Fiber fineness (micronaire)	Fiber length (mm)	Fiber strength (g tex ⁻¹)	Uniformity ratio (%)
Replications	2	117.71	0.22	5.6	0.50	0.007	1.42	3.315	0.84
Genotypes	22	4530.35 **	13.47 **	1332.86 **	117.24 **	0.0491 **	3.93 **	6.99	33.24
Parents (P)	8	6953.44 **	27.04 **	2853.61 **	210.57 **	0.051 **	4.52 *	8.61	28.51
Hybrids (H)	13	3277.85 **	4.68 **	441.086 *	22.51 *	0.043 *	3.79 *	2.44	4.02
P versus H	1	1428.06	19.26 **	760.02 *	602.06 **	0.11 *	1.05	53.4 **	0.71
Lines	6	6838.05 **	9.05 **	933.41 **	45.51 **	0.035 *	6.76 **	2.68	2.16
Testers	1	986.70 *	4.11 *	12.86	12.29 *	0.32 **	5.54 *	11.21 **	1.01 *
Lines x Testers	6	99.51	0.405	20.13	1.22	0.007	0.52	0.73	0.86
Error	44	868.30	1.82	174.87	10.82	0.017	1.55	3.98	84.66
δ^2_{GCA}		1470.72	2.04	196.25	0.11	0.02	1.6	0.93	0.11
δ^2_{SCA}		-256.26	-0.47	-51.58	-0.59	-0.0004	0.34	-1.09	-0.59
$\delta^2_{GCA}/\delta^2_{SCA}$		-5.74	-4.33	-3.80	-0.18	-5.21	4.66	-0.86	-0.18

Table 2. Values Line x Tester crosses and parent investigated properties.

Crosses	Seed cotton yield (kg ha ⁻¹)	Ginning outturn (%)	Fiber yield (kg ha ⁻¹)	Earliness (%)	Fiber fineness (mic.)	Fiber length (mm)	Fiber strength (g tex ⁻¹)	Uniformity ratio (%)	
BGKM-1 x Stoneville 468	3702.4 e	38.32 c	1420.0	77.93 d	4.36 abcd	32.40 bcd	32.30	86.03	
BGKM-1 x Claudia	3666.7 e	39.26 c	1438.6	77.70 d	4.23 d	33.11 abc	33.50	86.27	
BGKM-2 x Stoneville 468	4392.9 abc	37.84 c	1659.7	84.93 bc	4.35 bcd	33.18 abc	32.60	85.40	
BGKM-2 x Claudia	4333.3 a-d	38.13 c	1652.9	82.71 cd	4.20 d	33.41 abc	33.63	85.93	
BGKM-3 x Stoneville 468	4750.0 a	38.45 c	1826.9	85.58 abc	4.59 a	33.58 abc	33.57	86.07	
BGKM-3 x Claudia	4500.0 ab	38.53 c	1735.2	84.20 bc	4.29 bcd	34.84 a	34.10	86.40	
BGKM-4 x Stoneville 468	3773.8 de	39.00 c	1469.2	78.06 d	4.41 abcd	33.56 abc	32.07	85.97	
BGKM-4 x Claudia	3726.2 e	39.30 c	1463.2	77.88 d	4.26 cd	34.32 ab	34.40	86.10	
BGKM-5 x Stoneville 468	4023.8 b-e	41.69 ab	1679.7	81.44 cd	4.58 a	32.18 bcd	34.23	86.33	
BGKM-5 x Claudia	4000.0 b-e	41.90 a	1679.1	81.23 cd	4.35 bcd	32.31 bcd	35.53	86.47	
BGKM-6 x Stoneville 468	3952.4 b-e	38.85 c	1533.1	80.88 cd	4.48 abc	31.90 cd	33.50	85.87	
BGKM-6 x Claudia	3845.2 cde	40.10 abc	1542.1	78.71 d	4.37 bcd	32.17 bcd	34.17	85.80	
BGKM-7 x Stoneville 468	4226.2 a-e	38.26 c	1617.6	82.88 cd	4.49 ab	30.41 d	33.83	85.63	
BGKM-7 x Claudia	4071.4 b-e	39.57 bc	1617.6	81.71 cd	4.33 bcd	32.13 cd	34.00	86.50	
<i>Lines</i>									
BGKM-1	3564.3 b	38.50 b	1372.8 bc	71.27 e	4.31 b	33.79 a	35.83 a	86.27	
BGKM-2	3906.0 b	36.10 c	1410.7 bc	70.93 e	4.27 b	33.91 a	36.40 a	86.62	
BGKM-3	3951.0 b	36.76 bc	1450.9 b	71.74 e	4.21 b	34.26 a	37.77 a	86.87	
BGKM-4	3637.6 b	37.36 bc	1359.8 bc	70.88 e	4.26 b	33.66 ab	35.64 a	87.60	
BGKM-5	3717.9 b	35.27 c	1310.7 c	69.16 e	4.16 b	33.74 a	36.47 a	86.22	
BGKM-6	3650.0 b	35.78 c	1305.0 c	71.97 e	4.24 b	32.87 ab	35.83 a	86.82	
BGKM-7	3774.5 b	37.27 bc	1406.5 bc	70.24 e	4.25 b	33.23 ab	35.80 ab	86.59	
<i>Testers</i>									
Stoneville 468	4904.8 a	42.53 a	2085.5 a	90.72 a	4.61 a	30.45 c	32.11 c	83.73	
Claudia	4675.0 a	43.75 a	2044.1 a	88.80 ab	4.34 b	31.76 bc	33.43 bc	85.63	
Means of crosses	4068.9	39.23	1595.4	81.13	4.38	32.82	33.67	86.06	
Means of lines	3743.0	36.72	1373.8	70.88	4.24	33.64	36.25	86.71	
Means of testers	4789.9	43.14	2064.8	89.76	4.48	31.11	32.77	84.68	
Means of parents	4266.5	39.93	1719.3	80.32	4.36	32.37	34.51	85.70	
Means of genotypes	4167.7	39.58	1657.3	80.59	4.37	32.6	34.09	85.88	
LSD _{Hybrids}	60.08**	2.28*	26.91 _{ns}	5.35**	2.17*	0.22*	3.91 _{ns}	2.42 _{ns}	
LSD _{Parents}	33.18**	2.31**	13.12**	4.96	0.22*	1.93**	2.34**	2.32 _{ns}	
CV (%)	12.81	3.51	10.96	3.81	2.91	3.38	3.81	1.56	

LSD: Least significant degrees, CV: Coefficient of variation, *: $P < 0.05$, **: $P < 0.01$, ns: Non-significant

Performances of Testers

The averages of testers have found as 4789.9 kg ha⁻¹ in seed cotton yield, 43.14% in ginning outturn, 2064.8 kg ha⁻¹ in fiber yield, 89.76% in earliness, 31.11 mm fiber length, 4.48 micronaire in fiber fineness, 32.77 g tex⁻¹ in fiber strength and 84.68% in fiber uniformity. The variation

among testers contributed 55.97% to fiber fineness, 35.42% to fiber strength, 25.00% to fiber uniformity, 11.26% to fiber length, 6.76% to ginning outturn, 4.20% to earliness, 2.32% to seed cotton yield and 0.22% to fiber yield (Table 4). In the study, while Stoneville 468 was determined as more productive with earliness and coarse fiber, Claudia

was found other important tester in terms of ginning outturn and fiber properties (Table 2).

Performances of Line x Tester Hybrids

Averages of hybrids were determined as 4068.9 kg ha⁻¹ in seed cotton yield, 39.23% ginning outturn, 1595.4 kg ha⁻¹ in fiber yield, 81.13% in earliness, 4.38 micronaire in fiber fineness, 32.82 mm in fiber length, 33.67 g tex⁻¹ in fiber strength, and 86.06% in fiber uniformity. Furthermore, Line x Tester interaction contributed to the variations 1.40% in seed cotton yield, 4.00% in ginning outturn, 2.10% in fiber yield, 2.50% in earliness, 7.07% in fiber fineness, 6.32% in fiber length, 13.86% in fiber strength and 21.27% in fiber uniformity (Table 4). Among the hybrid, BGKM-3 x Stoneville 468 F₁ has obtained high cotton yield (4750.0 kg ha⁻¹), fiber yield (1826.9 kg ha⁻¹) and earliness (85.58%). Moreover, BGKM-5 x Claudia F₁ was getting highest ginning outturn (41.90%), while BGKM-3 x Claudia F₁ for fiber length (34.84 mm) and BGKM-5 x Claudia F₁ for fiber strength (35.53 g tex⁻¹) and uniformity (86.47%) had been found very important. Basal et al. (2017) were reported that interspecies (*G barbadense*

L. x G hirsutum L.) crosses showed negative GCA in fiber quality, while positive GCA in seed cotton yield.

GCA of Parents

According to Table 3, lines showed positive GCA on some properites. While BGKM-2 shows significant GCA in seed cotton yield (29.42*) and BGKM-5 in ginning outturn (2.57**), BGKM-3 is showed very significant and positive GCA in seed cotton yield (55.61**), in fiber yield (18.57**), in earliness (3.76**) and in fiber length (1.39**). While BGKM-3 line would be most important parent due to positive contribution to six traits, showing insignificant and negative GCA (-0.74) in term of ginning outturn had been attracted attention. On the other hand, testers showed negligible GCA in other traits, except fiber fineness. Stoneville 468 showed positive GCA in seed cotton yield (4.85), in fiber yield (0.55), in earliness (0.54) and in fiber fineness (0.09**), while Claudia had been showed positive GCA in term of ginning outturn, fiber length, fiber strength, and fiber uniformity properties.

Table 3. The combining ability Line x Tester crosses (SCA) and parents (GCA) in studied traits

Crosses	Seed cotton yield (kg ha ⁻¹)	Ginning outturn (%)	Fiber yield (kg ha ⁻¹)	Earliness (%)	Fiber fineness (mic.)	Fiber length (mm)	Fiber strength (g tex ⁻¹)	Uniformity ratio (%)
BGKM-1 x Stoneville 468	-3.06	-0.16	-1.48	-0.42	0.01	-0.02	-0.08	0.04
BGKM-1 x Claudia	3.06	0.16	1.48	0.42	-0.01	0.02	0.08	-0.04
BGKM-2 x Stoneville 468	-1.87	0.17	-0.22	0.57	0.25	-0.01	0.00	-0.11
BGKM-2 x Claudia	1.87	-0.17	0.22	-0.57	-0.25	0.01	0.00	0.11
BGKM-3 x Stoneville 468	7.65	0.27	4.03	0.15	-0.27	0.06	0.25	-0.01
BGKM-3 x Claudia	-7.65	-0.27	-4.03	-0.15	0.27	-0.06	-0.25	0.01
BGKM-4 x Stoneville 468	-2.47	0.16	-0.26	-0.45	-0.02	-0.01	-0.65	0.09
BGKM-4 x Claudia	2.47	-0.16	0.26	0.45	0.02	0.01	0.65	-0.09
BGKM-5 x Stoneville 468	-3.66	0.21	-0.52	-0.43	0.30	0.03	-0.13	0.09
BGKM-5 x Claudia	3.66	-0.21	0.52	0.43	-0.30	-0.03	0.13	-0.09
BGKM-6 x Stoneville 468	0.51	-0.31	-1.00	0.54	0.23	-0.03	0.18	0.19
BGKM-6 x Claudia	-0.51	0.31	1.00	-0.54	-0.23	0.03	-0.18	-0.19
BGKM-7 x Stoneville 468	2.89	-0.34	-0.55	0.05	-0.49	-0.01	0.43	-0.28
BGKM-7 x Claudia	-2.89	0.34	0.55	-0.05	0.49	0.01	-0.43	0.28
<i>Lines</i>								
BGKM-1	-38.44	-0.44	-16.61	-3.32	-0.08	-0.07	-0.77	0.10
BGKM-2	29.42 *	-1.25	6.1	2.69	-0.10	0.48	-0.56	-0.39
BGKM-3	55.61 **	-0.74	18.57**	3.76**	0.06	1.39**	0.16	0.18
BGKM-4	-31.89	-0.08	-12.92	-3.16	-0.04	1.12*	-0.44	-0.02
BGKM-5	-5.70	2.57**	8.40	0.21	0.09	-0.58	1.21	0.35
BGKM-6	-17.01	0.25	-5.77	-1.33	0.05	-0.79	0.16	-0.22
BGKM-7	7.99	-0.31	2.23	1.16	0.03	-1.55	0.24	0.01
<i>Testers</i>								
Stoneville 468	4.85	-0.31	0.55	0.54	0.09**	-0.36	-0.52	-0.15
Claudia	-4.85	0.31	-0.55	-0.54	-0.09	0.36	0.52	0.15

Table 4. Contribution of genotypes to the total variance of the traits studied (%)

Properties	Lines	Testers	Lines x Testers
Seed cotton yield	96.28	2.32	1.40
Ginning outturn	89.25	6.76	4.00
Fiber yield	97.67	0.22	2.10
Earliness	93.30	4.20	2.50
Fiber fineness	36.96	55.97	7.07
Fiber length	82.42	11.26	6.32
Fiber strength	50.72	35.42	13.86
Uniformity ratio	53.74	25.00	21.27

SCA of Hybrids

In the study, BGKM-1 x Stoneville 468 F₁ and BGKM-1 x Claudia F₁ showed significant and positive SCA in two and six traits, respectively (Table 3). BGKM-2 x Stoneville 468 F₁ had positive SCA in ginning outturn (0.17), earliness (0.57) and fiber length, while BGKM-2 x Claudia F₁ showed positive SCA in seed cotton yield (1.87), in fiber yield (0.22), in fiber fineness (0.01) and in fiber uniformity (0.11). The BGKM-3 x Stoneville 468 F₁ having most seed cotton yield had been showed positive SCA in seed cotton yield (7.65), in ginning outturn (0.27), in fiber yield (4.03), in earliness (0.15), in fiber fineness (0.06) and in fiber length. Moreover, BGKM-3 x Stoneville 468 F₁ had combined seed cotton yield, fiber yield and earliness with fiber properties. Besides, dominant gen effects on traits indicated the importance of the BGKM-3 x Stoneville 468 F₁ for develop both hybrid and conventional variety, while the BGKM-3 x Claudia F₁ had been found important for development of conventional cultivars. In the study, BGKM-4 x Claudia F₁ was showed positive SCA in seed cotton yield (2.47), in fiber yield (0.26), in earliness (0.45), in fiber fineness (0.01), in fiber length (0.02) and in fiber strength (0.65), while BGKM-4 x Stoneville 468 F₁ was showed insignificant but positive SCA in ginning outturn (0.16) and in fiber uniformity. BGKM-5 x Stoneville 468 and BGKM-5 x Claudia F₁ having the highest ginning outturn were showed positive SCA at four traits, and are found important for develop conventional cultivars. BGKM-6 x Stoneville 468 F₁ was found to be more important than BGKM-6 x Claudia F₁ with having positive SCA in five traits. BGKM-7 x Claudia F₁ had been determined more important than BGKM-7 x ST 468 F₁. BGKM-7 x Claudia F₁ showed insignificant-positive SCA in fiber yield (0.55), in ginning outturn (0.34), in fiber length (0.49), in fiber uniformity (0.19) and fineness (0.01), while BGKM-7 x Stoneville 468 F₁ had been showed insignificant-positive SCA in cotton yield (2.89), in fiber strength (0.43) and in earliness (0.05).

Heterotic Effects (Heterosis and Heterobeltiosis)

In the study, one hybrid in fiber yield, two hybrid in fiber strength, three hybrid in seed cotton yield and ginning outturn, eight hybrid in earliness and fiber fines, ten hybrid in fiber length, and eleven hybrid combinations in fiber

uniformity have been showed positive heterosis. In addition, while two hybrids showed positive both heterosis and heterobeltiosis for fiber length, one hybrid showed positive both heterosis and heterobeltiosis in fiber uniformity. BGKM-3 x Stoneville 468 and BGKM-5 x Stoneville 468 F₁ showed positive heterosis in six properties. The four combinations of BGKM-3 and BGKM-5 lines with testers showed positive heterosis in earliness, fiber fineness, fiber length and fiber uniformity, while differentiated in seed cotton yield and ginning outturn. In addition, hybrids of BGKM-3 and BGKM-4 with Claudia showed positive both heterosis and heterobeltiosis in fiber length. Heterosis values of hybrid in seed cotton yield between -11.66% (BGKM-4 x Stoneville 468) and 7.29% (BGKM-3 x Stoneville 468), in ginning outturn between -5.43% (BGKM-1 x Stoneville 468) and 7.26% (BGKM-5 x Stoneville 468), between in fiber yield of -15.75% (BGKM-1 x Claudia) and 3.35% (BGKM-3 x Stoneville 468), in earliness between -3.44% (BGKM-1 x Stoneville 468) 5.38% (BGKM-3 x Stoneville 468), in fiber fineness between -2.35% (BGKM-1 x Stoneville 468) and 4.59% (BGKM-5 x Stoneville 468), in fiber length between -4.49% (BGKM-7 x Stoneville 468) and 5.54% (BGKM-3 x Claudia), in fiber strength between -5.25% (BGKM-4 x Stoneville 468) and 1.82% (BGKM-5 x Claudia), in fiber uniformity between -0.60% (BGKM-4 x Claudia) and 1.60% (BGKM-5 x Stoneville 468) were changed (Table 5). Adsare et al. (2017) found positive heterosis in seed cotton yield, whereas Gungor and Efe (2017) determined positive heterosis in fiber length, fiber strength, fiber fineness and fiber uniformity. Moreover, Coban and Unay (2017) reported positively-significant useful heterosis for fiber strength and length whereas mostly low-negative values for fiber quality parameters were determined by Dhamayanthi (2011). In addition, the heterobeltiosis values of the hybrids have been found positive, in contrast to others, as 1.76% (BGKM-3 x Claudia) and 1.93% (BGKM-4 x Claudia) in fiber length, as 0.39% in fiber fineness and as 0.32% (BGKM-5 x Claudia) in uniformity. In previous studies, Gohil et al. (2017) was detected significant heterobeltiosis in terms of seed cotton yield (-28.59% and 31.64%) and fiber yield (-37.27% and 27.04%), while Gungor and Efe (2017) detected in terms of in fiber length (1.39%) and fiber uniformity (-0.62%).

Table 5. Heterosis and heterobeltiosis values of line x tester crosses (%)

Crosses	Seed cotton yield (kg ha ⁻¹)		Ginning outturn (%)		Fiber yield (kg ha ⁻¹)		Earliness (%)		Fiber fineness (micronaire)		Fiber length (mm)		Fiber strength (g tex ⁻¹)		Uniformity ratio (%)	
	Htr	Htb	Htr	Htb	Htr	Htb	Htr	Htb	Htr	Htb	Htr	Htb	Htr	Htb	Htr	Htb
BGKM-1 x Stoneville 468	-12.15	-24.30	-5.43	-9.80	-17.47	-31.64*	-3.44	-13.95	-2.35	-5.46	0.95	-4.02	-4.76	-9.69	1.22	-0.25
BGKM-1 x Claudia	-10.99**	-21.48*	-4.44	-10.22	-15.75*	-29.59**	-2.89	-12.48*	-2.18	-2.75	1.13	-1.89	-3.04	-6.26	0.37	-0.53
BGKM-2 x Stoneville 468	-0.21	-10.23	-3.7	-10.97*	-5.15	-20.41*	5.30	-6.19	-1.98*	-5.58	3.22	-1.81	-4.86*	-10.39*	0.27	-1.39
BGKM-2 x Claudia	1.04	-7.18	-4.50	-12.87**	-4.24	-19.1*	3.55	-6.80	-2.35	-4.10	1.84	-1.25	-3.60	-7.47	-0.2	-1.29
BGKM-3 x Stoneville 468	7.29	-3.02	-2.90	-9.51	3.35	-12.25	5.38	-5.56	4.07	-0.31	3.78	-1.99	-3.93	-11.00	0.90	-0.93
BGKM-3 x Claudia	4.48	-3.64	-4.27	-11.86	-0.65	-15.06	4.92	-5.16	0.42	-1.78	5.54	1.76	-4.21	-9.70**	0.20	-0.58
BGKM-4 x Stoneville 468	-11.66	-23.12**	-2.38	-8.25	-14.70*	-29.52**	-3.37	-13.85	-0.68	-4.42	4.73	-0.29	-5.25	-9.78	0.36	-1.86
BGKM-4 x Claudia	-10.09	-20.07	-3.07	-10.10	-13.84	-28.36*	-2.40	-12.36	-0.91	-2.46	4.90	1.93	-0.57	-4.03	-0.60	-1.71
BGKM-5 x Stoneville 468	-6.47	-17.7	7.26	-1.91	-0.88	-19.10	1.94	-10.17	4.59	-0.48	0.28	-4.60	0.06	-5.85	1.60	-0.08
BGKM-5 x Claudia	-4.70	-14.46*	6.04	-4.11	-0.01	-17.89	2.85	-8.48*	2.46	0.39	-1.34	-4.25	1.82	-2.50	0.66	0.32
BGKM-6 x Stoneville 468	-7.54	-19.16	-0.74	-8.61	-9.52	-26.35*	-0.48	-10.80*	1.09	-2.96	0.75	-2.87	-1.41	-6.51**	0.69	-1.08
BGKM-6 x Claudia	-7.56*	-17.68*	0.92	-8.27	-7.93*	-24.57**	-2.07	-11.32*	1.81	-0.68	-0.32	-1.94	-1.37	-4.73	-0.5	-1.18
BGKM-7 x Stoneville 468	-2.60	-13.83	-4.06	-9.99*	-7.28	-22.37*	3.02	-8.57	1.41	-2.52	-4.49	-8.49**	-0.29	-5.47	0.55	-1.10
BGKM-7 x Claudia	-3.45	-12.40	-2.34	-9.58**	-6.13	-20.68	2.75	-7.99**	0.96	-0.10	-1.15	-3.64	-1.84	-5.04	0.47	-0.15

Htr: Heterosis, Htb: Heterobeltiosis

CONCLUSION

The lines had been found very weaker than testers and crosses in terms of seed cotton yield and ginning outturn, but superior from than in terms of fiber properties. Testers have been the most productive varieties. Crosses are placed between parents in terms of yield and fiber quality. Lines were more contributed to the inheritance of traits than the testers and lines x testers interaction, except fiber fineness. While lines gave the highest contribution to fiber yield variation (97.67%), inconstanstr, gave the lowest contribution to fiber fineness variation (36.96%). BGKM-3, one of the lines, is showed very significant and positive GCA in terms of cotton yield, fiber yield, earliness and fiber length except for ginning outturn, while positive GCA showed in fiber fineness, fiber strength and fiber uniformity. Stoneville 468, one of the testers, was showing as smilarity with Unay et al. (2019) for cotton yield, fiber yield and earliness, Claudia is showed smilarity again in term of ginning outturn, fiber length, fiber fineness, fiber strength and fiber uniformity again with Unay et al. (2019). On the other hand, BGKM-3 x Stoneville 468 F₁ hybrid combined seed cotton yield with fiber quality, and was showed positive heterosis in seed cotton yield, fiber yield, earliness, fiber length and fiber uniformity. BGKM-3 x Claudia and BGKM-4 x Claudia F₁ hybrids have been showed positive heterosis and heterobeltiosis with the effect of dominant gene/s in fiber length. As a result, hybrids have higher seed cotton yield and ginning outturn than lines and BGKM-3 x Stoneville 468 F₁ hybrid have been found important not only as F₁ hybrid but also for conventional cultivar development studies. Because, it produced more seed cotton yield and ginning outturn with fiber quality from BGKM-3 parent.

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