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Heterosis and combining ability in intraspecific (*G. hirsutum* L.) and interspecific (*G. hirsutum* L. × *G. barbadense* L.) cotton hybrids

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Abstract
The inheritance of most important economic characters, heterosis and combining ability were studied in six interspecific (*G. hirsutum* L. × *G. barbadnese* L.) and three intraspecific hybrid combinations. There were found different types of inheritance of productivity, boll weight and lint percentage and fiber length in the individual crosses. The genetic variance for productivity and fiber length was mainly non-additive, while for lint percentage it was additive. Although non-additive genetic variance prevailed for productivity and fiber length, only individual crosses showed positive heterosis, outperforming the better parent. Of the female forms, the cultivar Helius was identified as a very good general combiner for productivity. From the male forms the cultivar Ashkabat emerged as a very good general combiner for productivity, boll weight and lint percentage. The cultivars Mytra (female), Karshinski-2 and C-6037 (male) were determined as very good general combiners for fiber length. All these cultivars, with the exception of C-6037, had low SCA variances, their high GCA was mainly due to additive gene effects, and they were very suitable for synthetic selection. The cross Helius × Ashkabat was found to be most valuable for the selection of productivity because of the highest mean performance and the highest level of heterosis with high SCA effects. All intraspecific hybrids were found to be most promising for improving lint percentage. The interspecific cross combinations Mytra × C-6037, Helius × C-6037 and Mytra × Karshinski-2, having the longest fibers, the first two with high SCA effects were most valuable for fiber length improvement.

Key words: genetic control; productivity; fiber length; lint percentage

INTRODUCTION

Cotton is the most important fiber crop in the world, both in distribution area and economic importance. Cotton fiber continues to be the most sought-after raw material because of its irreplaceable qualities as electroneutrality, hygroscopicity and softness. In the European Union, cotton is grown on larger areas only in two countries and these are Greece and Spain. In the two countries, cotton is grown under irrigated conditions and the cultivars grown have a longer growing season, high productivity and high fiber quality.

In Bulgaria also there are good soil and climatic conditions for growing cotton, but at this stage the cotton areas are very limited due to economic reasons. The temperate continental climate suggests normal development of cotton, which is currently grown under non-irrigated conditions.

The basis of the modern Bulgarian varieties is the local cotton, which represents a specific ecological group (*Proles Bulgaricum*) of the *G. hirsutum* L. species and it is distinguished by great early maturity, but with a relatively short fiber (Bozhinov & Dimitrova, 1974).

Selection work with cotton in our country is mainly aimed at increasing the productivity and fiber quality while preserving early maturity.

In recent years, many new cotton varieties having a complex of qualities valuable for cotton production have been created: Denitsa, Philipopolis, Sirius, Tsvetelina, Pirin, Perun (Valkova, 2014a; 2014b; 2017; Koleva & Valkova, 2019, 2023), Aida, Anabel, Tiara and Melani (Dimitrova, 2022a; 2022b; 2023). All these varieties are early maturing and high yielding, Anabel and Melani have improved fiber quality characteristics. Most of these varieties were obtained from intervarietal crosses, Sirius and Tsvetelina were created by experimental mutagenesis, Aida, Tiara and Melani were the result of remote hybridization combined with backcross technology.

A permanent task of cotton breeding in our country is to improve the fiber quality and to increase the genetic potential for seed cotton and lint yield. In addition, Bulgarian varieties must be well adapted to the specific conditions of cotton growing in our country, resistant to abiotic (especially drought in the summer months) and biotic stress factors.

In the selection of cotton in our country, intraspecific hybridization and experimental mutagenesis are the main breeding methods for improving earliness and productivity, interspecific hybridization of *G. hirsutum* L. × *G. barbadense* L. and its combination with intraspecific *G. hirsutum* L. hybridization is used to improve fiber quality. Research work has begun to introduce and use the potential of molecular markers for faster and more efficient selection by integrating classical breeding and biotechnological approaches (Sabev et al., 2020). The classical breeding methods of intra- and interspecific hybridization continue to play an important role in the cotton breeding in our country for transferring valuable economic traits and fiber qualities, creating new genetic diversity and new Bulgarian cotton varieties (Dimitrova et al., 2022).

In the specialized literature diallel and line × tester crosses and their respective analyses are used for genetic analysis of quantitative traits. In cotton breeding these analyses are also widely advocated.

Based on diallel analysis in intraspecific crosses Khan et al. (2011), Makhdoom (2011) and Khan (2013) reported that seed cotton yield was more strongly influenced by non-additive gene effects. Khan & Hassan (2011) reported non-additive type of gene action for boll weight and in the studies of Bölek et al. (2014), Khan et al. (2017) non-additive gene effects were more important for fiber length. Hosseini (2014) in a complete diallel cross (*G. hirsutum* L. × *G. barbadebse* L.) including 9 cotton genotypes reported that in the F_1 generation the most of traits were influenced by additive gene action. Non-additive gene action in the inheritance of lint percentage and fiber length was reported by Patel et al. (2014) (in interspecific *G. hirsutu*m × *G. barbadebse* hybrids), Bõlek et al. (2014), Munir et al. (2018), Roy et al. (2018) in intra- and interspecific hybrids. Dimitrova et al. (2022) on the basis of summarized results concluded that the genetic control of productivity and its elements in the studied sets of genotypes included in diallel and line × tester crosses was mainly non-additive. As for lint percentage and fiber length both additive and non-additive gene effects were important with predominance of non-additive gene action.

To establish the combining ability of parental forms many authors prefer diallel crosses, according to others the line × tester method is much more effective. According to Dabholkar (1992) the line × tester method gives very useful information about both maternal and paternal forms. Line × tester analysis provides information about combining ability of parental forms and their F_1 hybrids useful for breeding programs (Shakeel et al., 2012, Ali et al., 2013). Chapara & Madugula (2021) shared the same opinion, according to them line × tester analysis provides systematic approach for the detection of appropriate parents and crosses in terms of investigated traits.

The aim of this research was to study the inheritance of most important economic traits related to the productivity and fiber quality in intra- and interspecific hybrids of cotton; to evaluate the combining ability of parental forms and their perspective as parental components for hybridization; to determine the type of gene action in connection with the selection strategy and work with the hybrid generations.

MATERIAL AND METHODS

Six interspecific and three intraspecific F_1 crosses between three *G. hirsutum* L. cultivars - Helius, Darmi (Bulgarian selection) and Mytra (Greek), used as female parents, and three cultivars - Karshinski-2 and C-6037 (Uzbek) of the species *G. barbadense* L. and Ashkabat (*G. hirsutum* L.), used as male parents, were studied.

The experiment was carried out in the experimental field of the Field Crops Institute in town of Chirpan, on leached soil type, by the block method, in three replications. Each F_1 hybrid combination and parental forms were sown in 2 rows, 3 m long, randomized, with a 60×20×1 sowing scheme. Traditional cotton growing practices were applied during the growing season. Ten plants of each replicate were observed. The characters under study were: productivity per plant; boll weight; mean fiber length and fiber lint percentage.

The degree of dominance (d/a) was determined (Ognyanova, 1975). Heterosis was calculated relative to the high parent HP = (F_1 – HP)/HP*100 (%), where: HP – high (better) parent heterosis (%); HP – high parent value; F_1 – mean value of F_1 hybrids.

Methodology of Savchenko (1984) was applied to evaluate the general combining ability (GCA) and specific combining ability (SCA). The crosses sum of squares was divided into variation due to females, variation due to males and variation due to female × male interaction. The main effects of females and males are equivalent to the GCA and of female × male interaction represents the SCA.

RESULTS AND DISCUSSIONS

Of the female parents, the cultivar Helius had the highest productivity per plant, while the cultivar Mytra had the lowest (Table 1). The cultivar Mytra under our climatic conditions was late in maturing and did not realize its economic productivity. Of the male parents, *G. barbadense* cultivars have realized low productivity, for the cultivar C-6037 it was very low, while Ashkabat (*G. hirsutum*) has realized good productivity, leveling with Helius.

The degree of dominance (d/a) (Table 1) shows that in the *G. hirsutum* × *G. barbadense* crosses the productivity per plant was inherited overdominantly (in 3 crosses), with partial and incomplete dominance of more productive *G. hirsutum* parent and only in one cross it was with partially dominance of the lower productive *G. hirsutum* parent.

Of the interspecific crosses, the highest productivity per plant was found for the F_1 hybrids Helius × Karshinski-2 and Helius × C-6037 showing overdominant inheritance and manifested heterotic effects, heterosis was 3.2% and 12.1%, respectively. The inheritance of productivity was also overdominant in the cross combination Darmi × Karshinski-2, expressing heterosis of 12.9%. Differences observed in the degrees of dominance and heterosis manifestations were determined by the genotype of maternal components and their combining ability with the paternal forms.

In intraspecific crosses with Ashkabat (*G. hirsutum*) the inheritance of productivity per plant was overdominant, with partially dominance of the lower parent and negative overdominance, depending on the genotype of maternal forms and their combining ability. The productivity per plant was the highest in the intraspecific cross combination Helius × Ashkabat, showing positive overdominant inheritance and heterosis of 17.9%.

Patel et al. (2014) in interspecific crosses of the two tetraploid species (*G. hirsutum* and *G. barbadense*) reported significant higher heterobeltiosis (better parent heterosis) for seed cotton yield up to 35.49%. Positive mid parent heterosis for seed cotton yield was reported by Adzare et al. (2017), Rajeev et al. (2018).

G. barbadense cultivars had smaller boll weight compared to those of the *G. hirsutum* species. Inheritance of this trait was with partial dominance of the higher *G. hirsutum* or the lower *G. barbadense* parent and additively. In intraspecific crosses with the cultivar Ashkabat the larger boll weight of the maternal forms was inherited with positive overdominance (in two crosses) and incomplete dominance. The cross combinations Helius × Ashkabat and Mytra × Ashkabat showed heterosis of 6.0% and 14.0% and had the largest boll weight of 5.3-5.7 g.

G. barbadense cultivars had very low lint percentage. The inheritance of this trait in *G. hirsutum* × *G. barbadense* F_1 hybrids was with partially dominace of the lower or higher parent, depending on the degree of difference between parental cultivars of the two species, and this difference was mainly determined by the genotype of the *G. hirsutum* cultivars (Table 2). In crosses with the Greek cultivar Mytra, having the highest lint percentage of the maternal forms, the lower *G. barbadense* parent partially dominated and in those with the cultivar Helius, having the lowest lint percentage of the

Table 1. Inheritance and heterosis for productivity/plant and boll weight in F_1 intraspecific (*G. hirsutum* L.) and interspecific (*G. hirsutum* L. × *G. barbadense* L.) cotton hybrids

Hybrid combination	P_1	P_2	F_1	d/a	Heterosis
	Productivity/plant, g				
Helius × Karshinski-2	15.7	12.0	16.2	1.27	103.2
Helius × C-6037	15.7	5.4	17.6	1.37	112.1
Helius × Ashkabat	15.7	16.2	19.1	12.60	117.9
Darmi × Karshinski-2	14.0	12.0	15.8	2.80	112.9
Darmi × C-6037	14.0	5.4	11.5	0.42	82.1
Darmi × Ashkabat	14.0	16.2	15.0	-0.09	92.6
Mytra × Karshinski-2	11.3	12.0	11.6	-0.14	96.7
Mytra × C-6037	11.3	5.4	11.2	0.97	99.1
Mytra × Ashkabat	11.3	16.2	10.0	-1.53	61.7
GD 5.0%; 1.0%; 0.1%	*1.8; 2.5; 3.2*				
	Boll weight, *g*				
Helius × Karshinski-2	5.0	3.2	4.2	0.11	84.0
Helius × C-6037	5.0	3.2	4.0	-0.11	80.0
Helius × Ashkabat	5.0	4.2	5.3	1.75	106.0
Darmi × Karshinski-2	5.0	3.2	4.0	-0.11	80.0
Darmi × C-6037	5.0	3.2	4.5	0.44	90.0
Darmi × Ashkabat	5.0	4.2	4.9	0.75	98.0
Mytra × Karshinski-2	5.0	3.2	4.2	0.11	84.0
Mytra × C-6037	5.0	3.2	4.1	0.00	82.0
Mytra × Ashkabat	5.0	4.2	5.7	2.75	114.0
GD 5.0%; 1.0%; 0.1%	*0.4; 0.5; 0.7*				

P_1 – mean value of female parent; P_2 – mean value of male parent; F_1 – mean value of F_1 hybrids; HP – better parent heterosis (heterobeltiosis).

females, the higher parent partially dominated. In the crosses with the cultivar Ashkabat the inheritance of this trait was overdominant, with weaker or stronger (3.1–4.3%) pronounced heterosis manifestations. Hybrids with this cultivar had the highest lint percentage of 40.0-40.8%. Karademir & Gencer (2010) reported the same level (5.52%) of heterosis for this trait, but only in one cross.

Inheritance of fiber length in interspecific crosses was overdominant (in one cross), with partial or incomplete dominance of the long-fibered *G. barbadense* parent and partial dominance of the lower parent (in one cross), depending on the genotype of parental forms of both species and their combining ability (Table 2). The hybrids from the cross combinations Mytra × C-6037, Helius × C-6037, showed overdominant inheritance, and Mytra × Karshinski-2 with incomplete dominant inheritance of the longer fiber of the cultivar Karshinski-2 outlined with the longest fiber (32.9 – 34.5 mm).

In the intraspecific crosses with the cultivar Ashkabat, having short fiber, the inheritance of this trait was overdominant however the hybrids had much shorter fiber than that of the interspecific hybrids. Heterosis in interspecific hybrids was most pronounced in the cross combination Mytra × C-6037 (4.5%), in intraspecific hybrids it was 4.5 – 4.9%.

Çoban et al. (2015) and Çoban & Ünay (2017) in interspecific (*G. hirsutum* × *G. barbadense*) crosses reported positive mid parent heterosis for fiber length for all cross combinations from 2.05% to 16.99%. Positive heterosis for fiber length in the two tetraploid species hybridization was reported by Bõlek et al. (2014), Unay et al. (2018). Chapara & Madugula (2021) reported heterosis in Upper Half Mean Length (UHML) and mean length in line ×

tester intraspecific crosses. Out of 20 hybrids evaluated, 9 and 13 hybrids registered positive and significant standard heterosis respectively for UHML and mean length, and the highest values were 21.34% and 25.37%. Heterobeltiosis for UHML ranged between 7.53 to 20.73%, significantly higher than those found in our study.

The superiority of interspecific hybrids in fiber length and the superiority of intraspecific hybrids in lint percentage is evident.

Analysis of variance of combining ability revealed significant differences in the GCA of maternal and paternal forms, and in the SCA, for productivity per plant and fiber length (Table 3). This means that additive and non-additive gene effects were involved in the control of these two traits, and that both maternal and paternal forms differed in GCA and SCA. As for boll weight, only the variances of GCA of males were significant, while the GCA of maternal forms and non-additive gene effects (SCA) were statistically non-significant. The genetic differences between the crosses for this trait were determined only by differences in the GCA of paternal forms. For lint percentage the GCA effects of males and non-additive gene effects (SCA) were significant, the GCA effects of maternal forms were non-significant.

The genetic variance components estimates for productivity per plant were: σ^2_{GCA}=0.331 (at F=0, σ^2_{GCA}=1.324; at F=1, σ^2_{GCA}=0.662); σ^2_{SCA}=1.093 (at F=0, σ^2_{SCA}=4.372; at F=1, σ^2_{SCA}=1.093). The contributions of σ^2_{GCA} and σ^2_{SCA} to the genetic variance revealed that non-additive gene effects were of greater importance for the inheritance of productivity per plant. The results obtained are similar to those of previous studies by Ahuja & Dhayal (2007), Basal et al. (2009), Senthilkumar et al. (2010), Munir et al. (2018), Çoban & Ünay (2017), Roy et al. (2018), who also found predominance of non-additive gene effects for seed cotton yield applying the line × tester

Table 2. Inheritance and heterosis for lint percentage and fiber length in F_1 intraspecific (*G. hirsutum* L.) and interspecific (*G. hirsutum* L. × *G. barbadense* L.) cotton hybrids

Hybrid combination	P_1	P_2	F_1	d/a	Heterosis
	Lint percentage, %				
Helius × Karshinski-2	36.7	34.9	36.3	0.56	98.9
Helius × C-6037	36.7	33.1	36.4	0.83	99.2
Helius × Ashkabat	36.7	39.1	40.3	2.00	103.1
Darmi × Karshinski-2	38.4	34.9	36.5	-0.09	95.1
Darmi × C-6037	38.4	33.1	36.4	0.25	94.8
Darmi × Ashkabat	38.4	39.1	40.8	5.86	104.3
Mytra × Karshinski-2	39.9	34.9	37.3	-0.04	93.5
Mytra × C-6037	39.9	33.1	35.8	-0.21	89.7
Mytra × Ashkabat	39.9	39.1	40.0	1.25	100.3
GD 5.0%; 1.0%; 0.1%	*0.7; 0.9; 1.2*				
	Fiber length, *mm*				
Helius × Karshinski-2	25.8	33.6	30.6	0.23	91.1
Helius × C-6037	25.8	33.0	33.2	1.06	100.6
Helius × Ashkabat	25.8	26.5	27.8	4.71	104.9
Darmi × Karshinski-2	25.9	33.6	30.7	0.25	91.4
Darmi × C-6037	25.9	33.0	28.9	-0.15	87.6
Darmi × Ashkabat	25.9	26.5	27.5	4.33	103.8
Mytra × Karshinski-2	27.6	33.6	32.9	0.77	97.9
Mytra × C-6037	27.6	33.0	34.5	1.56	104.5
Mytra × Ashkabat	27.6	26.5	28.8	3.18	104.3
GD 5.0%; 1.0%; 0.1%	*1.4; 1.9; 2.5*				

Table 3. Analysis of combining ability variance for productivity/plant, boll weight, lint percentage and fiber length in F_1 intraspecific (*G. hirsutum* L.) and interspecific (*G. hirsutum* L. × *G. barbadense* L.) cotton hybrids

Source of variation	Degrees of freedom	Sum of squares	Mean square	F-experienced
		Productivity/plant, *g*		
GCA - females	2	59.401	29.705	151.261**
GCA - males	2	2.145	1.073	5.462**
SCA	4	13.901	3.475	17.696**
Errors	9		0.196	
Variance components		σ^2_{GCA}=0.331; σ^2_{SCA}=1.093;		
		F=0. σ^2_A*=1.324;* σ^2_D*=4.372*		
		F=1. σ^2_A*=0.662;* σ^2_D*=1.093*		
		Boll weight, *g*		
GCA - females	2	0.080	0.040	1.455
GCA - males	2	3.742	1.871	68.037**
SCA	4	0.142	0.035	1.293
Errors	9		0.027	
		Lint percentage, %		
GCA - females	2	0.090	4.492	0.679
GCA - males	2	31.341	15.670	236.849**
SCA	4	1.860	0.465	7.029**
Errors	9		0.066	
Variance components		σ^2_{GCA}=0.205; σ^2_{SCA}=0.133		
		F=0. σ^2_A*=0.820;* σ^2_D*=0.532*		
		F=1. σ^2_A*=0.410;* σ^2_D*=0.133*		
		Fiber length. mm		
GCA - females	2	13.702	6.851	35.510**
GCA - males	2	29.336	14.668	76.030**
SCA	4	7.499	1.875	9.720**
Errors	9		0.193	
Variance components		σ^2_{GCA}=0.247; σ^2_{SCA}=0.561		
		F=0. σ^2_A*=0.988;* σ^2_D*=2.242*		
		F=1. σ^2_A*=0.494;* σ^2_D*=0.561*		

method in intra- and interspecific (*G. hirsutum* × G. *barbadense*) crosses. Patel et al. (2014) found σ^2_{GCA} > σ^2_{SCA} indicating preponderance of additive gene effects in inheritance of this trait.

The estimated components of genetic variance for lint percentage and fiber length (Table 3) and the ratio $\sigma^2_{GCA}/\sigma^2_{SCA}$ reveal that additive gene effects were of greater importance for the inheritance of lint percentage, while non-additive gene action more strongly influenced fiber length. Patel et al. (2014), Bölek et al. (2014), Khan et al. (2017), Munir et al. (2017), Çoban & Ünay (2017), Roy et al. (2018) also concluded that non-additive gene effects were more important for fiber length, in intra- and interspecific (*G. hirsutum* × *G. barbadense*) hybrids.

Results from the analysis show that additive and non-additive genes controlled the variation in productivity per plant, lint percentage and fiber length, which is consistent with that reported by other authors. Ashokkumar et al. (2010), Azam et al. (2013), Linga et al. (2013), Memon et al. (2017) in line × tester analyzes reported that both additive and non-additive variances were important and involved in the control of seed cotton yield and its components. Non-additive gene effects were of greater importance and essential for the inheritance of productivity per plant and fiber length. The presence of non-additive gene action in the expression of many traits related to yield and fiber properties was reported by Karademir et al. (2016), Sajjad et al. (2016), Memon et al. (2017), Sivia et al. (2017) in line × tester analyses in Upland Cotton (*Gossypium hirsutum* L.).

GCA effects for the studied traits are indicated in Table 4. Of the maternal forms, the cultivar Helius had positive GCA for productivity per plant, the cultivars Darmi and Mytra had positive but non-significant GCA for boll weight. Of the paternal forms, the cultivar Ashkabat had positive GCA for productivity per plant and for boll weight. The cultivar Karshinski-2 had positive, but non-significant, GCA for productivity per plant, and negative GCA for boll weight, the cultivar C-6037 possessed negative GCA for both traits.

GCA is determined by additive genes and it can be considered, of the maternal forms, the cultivar Helius possessed the most additive genes for productivity per plant and of the paternal forms the cultivar Ashkabat possessed the most additive genes for productivity per plant and for boll weight.

Of the maternal forms, the cultivars Helius and Mytra had positive, but non-significant, GCA for lint percentage. Of the paternal forms, the cultivar Ashkabat had positive and significant GCA for this trait. The cultivar Darmi of the females and the two *G. barbadense* cultivars of the males had negative GCA for lint percentage.

Of the females, the cultivar Mytra showed positive GCA for fiber length, of the males, the *G. barbadense* cultivars Karshinski-2 and C-6037 had high and positive GCA for this trait. The cultivars Helius and Darmi of the maternal forms and the cultivar Ashkabat from the males exhibited negative GCA for fiber length.

From the evaluations of the GCA effects it follows that the parental forms had different manifestation of GCA for fiber length and lint percentage. With a positive GCA for the fiber length they showed negative GCA for lint percentage and vice

Table 4. Evaluation of GCA effects for productivity/plant, boll weight, lint percentage and fiber length in F_1 intra- and interspecific *G. hirsutum* L. × *G. barbadense* L. cotton hybrids

Females	GCA	Males	GCA
Productivity/plant			
Helius	3.267	Karshinski-2	0.178
Darmi	-0.255	C-6037	-0.667
Mytra	-3.011	Ashkabat	0.489
Standard error	0.362		0.362
Boll weight			
Helius	-0.133	Karshinski-2	-0.489
Darmi	0.067	C-6037	-0.042
Mytra	0.067	Ashkabat	0.911
Standard error	0.135		0.135
Lint percentage			
Helius	0.059	Karshinski-2	-1.230
Darmi	-0.141	C-6037	-1.407
Mytra	0.081	Ashkabat	2.637
Standard error	0.210		0.210
Fiber length			
Helius	-0.022	Karshinski-2	0.855
Darmi	-1.500	C-6037	1.655
Mytra	1.520	Ashkabat	-2.511
Standard error	0.359		0.359

versa. These contradictory trends in GCA for the two traits are due to the complex genetic relationship between them. Exceptions were the cultivars Mytra showing positive GCA (non-significant for lint percentage) and Darmi showing negative GCA (non-significant for lint percentage) for both traits. Patel et al. (2014) concluded that in general *G. hirsutum* parents had good general combining ability for yield and yield components while *G. barbadense* parents were found to be good general combiners for fibre quality traits, which is consistent with the results of this study.

Some of the parental forms were emerging as very good general combiners for two and three traits: the cultivar Helius had positive GCA for productivity/plant and lint percentage (non-significant); the cultivar Mytra showed positive GCA for lint percentage (non-significant) and fiber length and the cultivar Ashkabat showed positive GCA for productivity/plant (non-significant), boll weight and lint percentage.

Given that the GCA effects are determined by additive genes, parental forms showing positive GCA for two and three traits had additive genes for these traits and therefore they have great selection value and should be used with preference in selection programs.

Jatoi et al. (2011) concluded that GCA is important for breeding programs for selection of parental cultivars for hybridization, SCA is important for heterosis selection for the use of heterosis.

The SCA effects are given in Table 5. Six crosses showed SCA effects (significant in 4 crosses) for productivity per plant. It is considered that dominant and epistatic interactions occurred in these crosses. The cross combinations Darmi × Karshinsky-2, Helius × Ashkabat, (exceeding the more productive parent) and Mytra × C-6037 (above the mean of both parents) had the highest SCA effects for productivity per plant. The parental forms (the cultivars Helius and Ashkabat) having high GCA for productivity per plant had low SCA variances (s^2_i, s^2_j) and are not recommended for obtaining high-heterosis hybrids. These varieties are suitable for synthetic selection.

Positive SCA for lint percentage was found in crosses Mytra × Karshinski-2, Helius × C-6037 (non-significant) and Darmi × C-6037 and for fiber length in crosses Darmi × Karshinski-2, Helius × C-6037, Mytra × C-6037 and Darmi × Ashkabat. The hybrids of last two crosses were superior in fiber length to better parent exhibiting heterobeltiosis of 4.3-4.5%. The parental forms Helius with positive GCA and Ashkabat with high GCA for lint percentage had low variances of SCA, which makes them suitable for synthetic selection, while the cultivar Mytra having positive GCA and high variance of SCA is more suitable for heterosis selection.

The cultivars Mytra and Karshinski-2 with high GCA for fiber length had low variances of SCA, their high GCA was mainly determined by additive gene effects. It can be considered that these parental forms persistently transmitted their longer fiber in all hybrid progenies. They are not suitable for creating high-heterosis hybrid populations, but can be used successfully in hybridization as parental components. The cultivar C-6037 having high GCA had high SCA variance, and its high GCA was due to both additive and non-additive gene actions and interactions.

The crosses Mytra × Karshinski-2 and Darmi × Karshinski-2 showed positive SCA effects for two traits, the first cross for productivity per plant and lint percentage, while the second one for productivity per plant and fiber length.

The crosses Helius × C-6037 and Darmi × Ashkabat had positive SCA effects for three traits (productivity/plant, lint percentage and fiber length), which makes them very valuable for heterosis selection. The cultivars having positive GCA and high variances of SCA, suitable for heterosis selection, were: Karshinski 2 - for productivity/plant; Mytra – for lint percentage; C-6037 – for fiber length.

The results obtained show that additive and non-additive gene effects were involved in the inheritance of productivity per plant and fiber length, but non-additive gene effects were more important because the variance of SCA were higher than the variance of GCA. Although non-additive variance predominated (for both traits), only individual crosses showed heterosis, outperforming the better parent. Low levels of heterosis were observed for both traits. For this reason, synthetic populations are of greater importance. Thus, cultivars having positive and high GCA and low or high variances of SCA (the cultivar C-6037 for fiber length) could be used as donors in synthetic selection to increase productivity and improve fiber length.

Table 5. Estimation of SCA effects ($_{Sij}$) and variances ($\sigma^2 s_i$; $\sigma^2 s_j$) for productivity/plant, boll weight, lint percentage and fiber length in F_1 intra- and interspecific *G. hirsutum* L. × *G. barbadense* L. cotton hybrids

Females/Males	Karshinski-2	C-6037	Ashkabat	σ^2_{Si}
Productivity/plant				
Helius	-1.311	0.633	0.978	1.889
Darmi	1.544	-1.944	0.400	3.076
Mytra	0.067	1.311	-1.378	1.724
	MD = 0.362			
σ^2_{Sj}	2.405	2.863	1.419	
Boll weight				
Helius	0.156	-0.044	-0.111	0.007
Darmi	-0.178	0.189	-0.011	0.021
Mytra	0.022	-0.144	0.122	0.006
	MD = 0.135			
σ^2_{Sj}	0.016	0.017	0.015	
Lint percentage				
Helius	-0.159	0.152	0.007	-0.005
Darmi	-0.693	0.319	0.374	0.331
Mytra	0.852	-0.470	-0.381	0.517
	MD = 0.210			
σ^2_{Sj}	0.586	0.143	0.113	
Fiber length				
Helius	-0.778	0.989	-0.211	0.728
Darmi	0.800	-1.768	0.967	2.262
Mytra	-0.022	0.778	-0755	0.502
	MD = 0.359			
σ^2_{Sj}	0.537	2.266	0.689	

CONCLUSIONS

In the studied intraspecific and interspecific hybrids different types of inheritance of productivity per plant, boll weight and lint percentage and fiber length were observed. Low-level heterosis manifestations were found for all studied traits in individual crosses.

Genetic variance for productivity per plant and fiber length was mainly non-additive, for lint percentage it was additive.

The cultivar Ashkabat, from the male parents, has emerged as a very good general combiner for productivity per plant, boll weight and lint percentage having high GCA for these traits. The cultivar Helius was found as a very good general combiner for productivity per plant, it showed high mean performance and high GCA. The cultivar Mytra, from the female parents, Karshinski-2 and C-6037 from the males, were identified as very good general combiners for fibre length. The use of these cultivars as parents in intraspecific and interspecific crosses will help to increase the productivity, lint percentage and fiber length of hybrids.

The cross combination Helius × Ashkabat having high SCA and the highest heterosis appears to be very valuable for the selection of productivity. Both parental forms had high productivity, high GCA and low variances of SCA and are very suitable for synthetic selection.

The intraspecific hybrids Helius × Ashkabat, Darmi × Ashkabat and Mytra × Ashkabat exhibited heterosis for lint percentage and high mean level can be used in breeding programs to improve this trait.

The interspecific hybrids Mytra × C-6037, Helius × C-6037 and Mytra × Karshinski-2 having the longest fiber, the first two high SCA effects, are most valuable for fiber length improvement. The cultivar Mytra had high GCA and low variances of SCA and it is suitable for synthetic selection, while the cultivar C-6037 had high GCA and high variances of SCA and it is suitable for synthetic and heterosis selection.

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