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Research Article

Estimation of dominance and heterosis of morpho-economic traits in intraspecific F1 hybrids of upland cotton

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Abstract
The present research was conducted to determine the mean performance of parental variety and lines and heterotic effects in F_1 hybrids of upland cotton. Six parental genotypes were included in the present study: Yulduz, Niso, Guliston, SS-BK, T-1336, and T-1391. All six parents were randomly crossed, and ten F_1 hybrids were developed for evaluation. The experiment was laid out in a randomized complete block design with three replications. The mean squares from the analysis of variance revealed that parents and F_1 hybrids differed significantly in their mean performance regarding all the traits studied, except those hybrids were non-significant for staple length. The importance of heterotic effects was evident from the significant mean squares of parents vs. hybrids. The mean performance revealed that F_1 hybrids performed better over the parents for the traits due to the manifestation of heterotic effects. The crosses Niso x Yulduz among the hybrids formed more bolls per plant. Also, they gave yet Niso x Yulduz maximum lint %, and longer fiber was measured in Yulduz x Guliston and Guliston x Yulduz. Also, T-1391 x Niso va SSB K-1 x Niso o formed a higher boll weight. The parental performance was not reflected in hybrid combinations; therefore, the potentiality of parents per se may not be taken for granted for expecting similar performance in the F_1 hybrids. The heterotic effects of the hybrids revealed that at least three hybrids viz. Niso x Yulduz va Niso x Guliston were identified, and they exhibited relative heterosis above 50% and heterobeltiosis over 45% for bolls per plant. The hybrids also expressed a fair amount of heterosis for boll weight, lint %, and fiber length. The high heterotic effects for bolls per plant, boll weight, lint %, and fiber length highlight the promising potential for heterosis breeding in upland cotton, offering a bright outlook for future research.
Keywords: *G. hirsutum* L., variety, line, genotypes, heterosis, heterobeltiosis, fiber

Introduction
Cotton is considered the world’s most important fiber-producing crop. It not only supports the textile industry by providing fiber but also supports the oil industry by producing high-quality oil. Cotton is engaging approximately 350 million people around the globe for its production, ginning, transportation, and storage. The world cotton market of $20 billion annually is made possible by the uncommon ability of the cotton genus (Gossypium) to produce lint fibers that are single-celled,

epidermal, five to six cm long, and seed-borne (Shavkiev et al., 2023; Narimonov et al., 2023). The top three cotton-producing countries are China, India, and the United States, followed by Pakistan, Brazil, Australia, Uzbekistan, Turkey, Turkmenistan, Burkina, Mali, Greece, and Burma. Cotton (*Gossypium hirsutum* L.) is the major cash crop of tropical and subtropical regions of the world (Shavkiev et al., 2021a, Makamov et al., 2022a; Chorshanbiev et al., 2023). Cotton is the best natural fiber crop, with a large contribution to textiles and an economic impact of 600 billion dollars worldwide (Aslam et al., 2020). In Uzbekistan, cotton is a cash crop and is mainly grown as a source of fiber, food, and feed. Moreover, cotton fibers play a vital role in uplifting the country's economy (Khamdullaev et al., 2021; Makamov et al., 2022b). Globally, Uzbekistan ranks fourth in cotton area and production. However, the yield per unit area in Uzbekistan is very low compared with that in other cotton-growing countries (Sanayev et al., 2021; Ergashev et al., 2021; Shavkiev et al., 2021b, Amanov et al., 2022; Matniyazova et al., 2022; Chorshanbiev et al., 2022). The farmers of Uzbekistan are investigating and developing cotton with high fiber and lint yields (Nabiyev et al., 2020; Shavkiev et al., 2020, 2021c, 2022; Amanov et al., 2022; Makamov et al., 2023). Plant breeding is the art and science of changing and improving the heredity and performance of plants. Breeding can also be defined as the use of techniques involving crossing plants to produce varieties with particular traits, which are carried in the genes of the plants and passed on to future generations (Chaudhry & Guitchounts, 2003).

Breeding research needs to address all possibilities to increase yield, including the use of heterosis (Meredith & Brown, 1998). The use of heterosis has long been one of the objectives of cotton breeders. The yield increase of hybrids over the mid-parent, better-parent, or best commercial cultivar has been documented in numerous reviews. The major limiting factor to using heterosis in cotton is the lack of an efficient, dependable crossing system and the difficulty of producing F_1's seed by hand emasculation and pollination (Wu et al., 2004). Heterosis in cotton has the potential of increasing yield from 10 to 20% and making improvements in fiber quality. A review using more recent data showed an average useful heterosis of 21.4% for F1 hybrids and 10.7% for F_2 hybrids, and both F1 and F2 hybrids can produce significantly higher yields than the current best-yielding parent or commercial cultivar (Meredith and Brown., 1998). Wu et al. 2004 detected that the average yield heterosis of F1's and F2's was 15.9 and 9.2%, respectively. Heterosis refers to the superiority of F1 hybrid performance over parental performance (Wu et al., 2004). Generally, positive heterosis is considered desirable. However, in cotton, negative heterosis is useful for some traits, such as plant height, days to first flowering and maturity, node to first sympodial branch, micronaire, and gossypol content, because hybrids with these traits are superior to their parental lines (Singh et al., 2012). The magnitude of heterosis should be at an acceptable level for the successful development of hybrid cotton. In cotton, heteroses of 50% over the popular variety and 20% over the popular hybrid are considered useful for hybrid development (Batool & Khan, 2012).

Generally, the characteristics of plants and other living creatures result from countless gene interactions. Genotypic variance is a part of total variance that remains after eliminating the environmental variance, and those variances can be observed in homozygous lines and their progenies. F1 hybrids have a hybrid, which manifests heterozygosity and can be regarded as the converse of the deterioration that escorts inbreeding (Khan, 2011). Past studies revealed that heterosis is a multigenic complex trait in plants and can be extrapolated as the total of many physiological and phenotypic traits (Baranwal et al., 2012; Azimov et al., 2023). It enabled the plant and animal breeders to improve their performance for several economic traits (Khan, 2013). Rosas et al. (2010) discussed the role of variation in gene expression between parental species and its effect on phenotype. They concluded that F1 hybrids might be expected to show increased performance in basic physiological traits such as growth.

This study aimed to evaluate the potential of F1 hybrids to compare them with parents for yield contributing traits.

Material and methods

Genetic material

Breeding material comprised six parental genotypes (*Gossypium hirsutum* L.,) and their 30 F1 hybrids generated through 6 × 6 complete diallel crossing and control variety (Namangan-77). The parental cultivars (Yulduz et al., SS-BK, T-1336, and T-1391) have a broad genetic base and the total number of bolls per plant, boll weight, and fiber lint as well as fiber length traits.

Experimental design and field procedures

Experimental design and field procedures (2022-2023). Tashkent, Uzbekistan, lies between 41.389°N and 69.465°E. Experiments were comprised of a crossing block and F_1 populations of upland cotton. The six upland cotton genotypes were hand-sown during April 2022, in a non-replicated crossing block. Plots consisted of five rows, each 25 m in length, with plant and row spacings of 60 and 90 cm, to facilitate hand emasculation and crossing. All the cultivars were crossed in a complete diallel fashion. The F_1 population of a 6 × 6 complete diallel cross with six parents was hand sown during April 2022, and all the traits were studied and allowed to self and advance the generation to have seeds for the F_1 crop. During crop season 2023, the experiment had 30 F_1 hybrids and parents, hand-sewn using a randomized complete block (RCB) design. The F_1 genotypes were planted in a single row measuring 5.30 m (having 25 plants of each F_1 population per replication) with three replications. The plant and row spacings were 20 and 90 cm, respectively. All recommended cultural practices and inputs, including fertilizer, hoeing, irrigation, and pest control, were applied similarly for all entries. The crop was grown under uniform conditions to minimize environmental variability to the maximum possible extent. All the crops were harvested during October- November every year and ginning was done with eight saw-gins.

Trait measurement and statistical analyses

Data were recorded for the total number of bolls per plant, weight (g), lint %, and fiber length (mm). The mean data were subjected to analysis of variance according to Steel et al. (1997) to test the null hypothesis of no differences among various F_1 hybrid populations and their parental cultivars. In this case, the Fisher criterion (F), the standard deviations (SD), the standard error (SE), and the degree of significant differences (P≤0.05*, P≤0.01**, and P≤0.001***) determined the reliability of the differences among the genotypes for each trait.

The dominance coefficient in F_1 hybrids determination was according to Griffing (1950):

$$hp = \frac{F_1 - MP}{P - MP}$$

Where:
hp – dominance coefficient;
F_1 – the evaluated arithmetic mean of the hybrid;
MP – the evaluated arithmetic mean of both parents;
P – the evaluated arithmetic mean of the best parents
The heterosis coefficient in F_1 hybrids determination was according to o Mather and Jinks (1982):
Average heterosis(%H)= [(F_1-MP)/MP] X 100
F1 is the mean value of F1 and MP is the mean value of two parents involved in the cross.
Heterobeltiosis (%Hb)= [(F_1-BP)/BP] X 100
Where BP is the mean value (over replications) of the better parents of the particular cross.

The correlation coefficient was also determined among the various variables (Snedecor &Cochran, 1981). In this case, when r was less than 0.3, the correlation between the traits was weak; when r = 0.3–0.7, then it was average, and when r was higher than 0.7, it revealed a strong association.

Results

In the experiment, when the indicators of the number of bolls per plant of varieties and lines of cotton and their F1 hybrids obtained based on diallel hybridization were studied, the high was at Yulduz (17.3± 2.15 units) variety compared to the control variety. Low was the Niso variety (15.8±1.66 units) compared to the control variety. Among the lines, this indicator was higher than the control. Among F1 hybrid combinations, the highest values of the number of bolls per plant were found in Yulduz x T-1336, Niso x Yulduz, and Niso x Gulistan hybrids. It was noted that they have more than 20 number bolls per plant. T-1336 x Yulduz, T-1336 x Yulduz, Yulduz x Gulistan, SSB K-1 x T-1391, SSB K-1 x T-1336, SSB K-1 x Niso and Gulistan x Yulduz hybrids in plant is number of bolls per plant was at the lowest level, i.e. below 16. In genotypes of Yulduz x T-1391, Niso x T-1336, Niso x Yulduz, and Niso x SSB K-1 F1 hybrids, when the traits of the number of bolls are high positive dominance, T-1336 x T-1391 and SSB K-1 x Yulduz negative dominance was evident (Table 1).

When the best and average heterosis was studied in the traits of the number of pods in the plants of the F1 generations compared to the parental forms, heterosis was from 20% to 50% in F1 hybrids of Yulduz x T-1336, Niso x Yulduz, and Niso x Guliston. According to the analysis of the results of this trait, it was noted that Niso x Yulduz and Niso x Guliston F1 hybrids have a higher number of bolls per plant, the superiority of the trait, and higher heterosis efficiency compared to other hybrids.

Table 1. Degrees of dominance and heterosis of the number of bolls per plant of parental and F1 hybrid genotypes

Genotypes of cotton parents and F1 hybrids	Mean ± SE	hp	%H	%Hb
Namangan-77 (andoza)	16,1±1,88			
Yulduz	17,3±2,15			
Niso	15,8±1,66			
Guliston	16,2±2,06			
SS-BK	16,2±2			
T-1336	17,2±2,01			
T-1391	17,9±1,89			
T-1391x T-1336	18,1±1,91	1,7	3,4	1,1
T-1391 x Yulduz	18,1±1,95	0,4	2,8	1,1
T-1391 x Niso	17,2±2,12	0,1	2,4	-3,9
T-1391 x SSB K-1	17,1±1,91	-0,6	0,3	-4,5
T-1391 x Guliston	16,5±1,55	1,5	-3,2	-7,8
T-1336 x T-1391	18,1±2,04	-15,0	3,4	1,1
T-1336 x Yulduz	15,7±1,33	2,6	-8,7	-9,2
T-1336 x Niso	18,3±1,74	1,0	10,9	6,4
T-1336 x SSB K-1	17,2±2,13	-0,8	3,0	0,0
T-1336 x Guliston	16,3±2,30	-1,0	-2,4	-5,2
Yulduz x T-1391	17,3±1,59	34,0	-1,7	-3,4
Yulduz x T-1336	20,6±1,94	-0,5	19,8	19,1
Yulduz x Niso	16,1±1,81	1,3	-2,4	-6,9
Yulduz x SSB K-1	17,5±2,26	-1,5	4,8	1,2
Yulduz x Guliston	15,8±1,80	0,2	-5,4	-8,7
Niso x T-1391	17,03±1,63	4,1	1,4	-4,9
Niso x T-1336	19,4±2,30	10,5	17,6	12,8
Niso x Yulduz	24,9±3,01	10,2	50,9	43,9
Niso x SSB K-1	18,03±1,88	37,5	12,7	11,3
Niso x Guliston	23,5±3,45	-1,6	46,9	45,1
SSB K-1 x T-1391	15,7±0,92	-1,6	-7,9	-12,3
SSB K-1 x T-1336	15,9±0,99	0,8	-4,8	-7,6
SSB K-1 x Yulduz	17,2±2,11	-5,5	3,0	-0,6
SSB K-1 x Niso	14,9±1,12	0	-6,9	-8,0
SSB K-1 x Guliston	17,8±1,79	0,1	9,9	9,9
Guliston x T-1391	17±1,92	3,0	0,3	-4,5
Guliston x T-1336	18,2±1,80	-1,3	9,0	5,8
Guliston x Yulduz	15,9±2,32	0,5	-4,8	-8,1
Guliston x Niso	16,6±1,95	0	3,8	2,5
Guliston x SSB K-1	16,9±2,76	1,7	4,3	4,3

Yulduz and Guliston varieties were higher than the control in traits of boll weight indicators in the parent forms and their F1 hybrid. A similar result was observed between the lines. In this case, it was found that boll weight is higher than 6 g in varieties and lines. Indicators in the boll weight were up to 6 g among hybrid combinations T-1391x T-1336, T-1336 x Yulduz, Yulduz x SSB K-1, and SSB K-1 x T-1391 F1. In the remaining hybrids, it was found that it is higher than 6 g (table 2).

T-1391x T-1336, when the sign of cotton weight in the boll of T-1391 x Niso, Niso x Yulduz, Niso x SSB K-1 and SSB K-1 x Niso F1 generations is extremely positive dominance, T-1391 x Guliston, T-1336 x Yulduz, Yulduz x Guliston, SSB K-1 x T-1336 and Guliston x T-1391 extreme negative dominance was evident. When the best and average heterosis was studied in the characteristics of the number of bolls per plant of the F1 hybrids compared to the parental forms, the heterosis effect was up to 10% in T-1391 x Niso and SSB K-1xNiso F1 hybrids. According to the analysis of the results of this trait, it was noted that the T-1391 x Niso and SSB K-1 x Niso F1 hybrids have a higher number of bolls per plant, superiority of the trait, and higher heterosis efficiency.

Table 2. Degrees of dominance and heterosis of the boll weight of parental and F1 hybrid genotypes.

Genotypes of cotton parents and F1 hybrids	Mean ± SE	hp	%H	%Hb
Namangan-77 (andoza)	5,53±0,41			
Yulduz	6,61±0,46			
Niso	5,92±0,55			
Guliston	6,47±0,48			
SS-BK	5,71±0,49			
T-1336	6,15±0,50			
T-1391	6,26±0,48			
T-1391x T-1336	5,93±0,53	-2,0	-3,3	-4,8
T-1391 x Yulduz	6,23±0,44	0,0	0,0	-1,6
T-1391 x Niso	6,30±0,48	1,7	4,1	1,6
T-1391 x SSB K-1	5,97±0,50	0,0	0,0	-4,8
T-1391 x Guliston	6,15±0,76	-2,0	-3,2	-4,7
T-1336 x T-1391	6,25±0,43	1,0	1,6	0,0
T-1336 x Yulduz	5,88±0,74	-4,0	-6,5	-7,9
T-1336 x Niso	6,04±0,55	0,4	0,7	-1,0
T-1336 x SSB K-1	6,10±0,51	1,0	3,4	0,0
T-1336 x Guliston	6,23±0,47	0,0	0,0	-3,1
Yulduz x T-1391	6,25±0,67	0,0	0,0	-1,6
Yulduz x T-1336	6,37±0,76	1,0	1,6	0,0
Yulduz x Niso	6,30±0,59	1,0	3,3	0,0
Yulduz x SSB K-1	5,93±0,64	-0,3	-1,7	-6,3
Yulduz x Guliston	6,37±0,52	-2,0	-3,1	-1,6
Niso x T-1391	5,82±0,57	-1,7	-4,1	-6,5
Niso x T-1336	6,10±0,42	1,0	1,7	0,0
Niso x Yulduz	6,40±0,50	1,5	4,9	1,6
Niso x SSB K-1	6,02±0,48	2,2	3,8	2,0
Niso x Guliston	6,14±0,55	0,0	0,0	-4,7
SSB K-1 x T-1391	5,72±0,51	-0,7	-3,4	-8,1

SSB K-1 x T-1336	5,49±0,45	-2,5	-8,5	-11,5
SSB K-1 x Yulduz	6,35±0,5,3	1,0	5,0	0,0
SSB K-1 x Niso	6,21±0,50	4,0	6,9	8,8
SSB K-1 x Guliston	6,31±0,54	0,7	4,1	-1,6
Guliston x T-1391	6,11±0,50	-2,0	-3,2	-4,7
Guliston x T-1336	6,01±0,52	-1,0	-3,1	-6,1
Guliston x Yulduz	6,41±0,52	1,0	1,6	0,0
Guliston x Niso	6,35±0,60	0,7	3,3	-1,6
Guliston x SSB K-1	6,50±0,51	1,3	7,4	1,6

There was a non-significant difference in the reduction and increase of fiber length in plants compared to the control in varieties and lines. According to fiber length in plants, in hybrids with Niso, Yulduz, SSB K-1, and Guliston cotton varieties as mothers, the parameters of the control variety were equal or slightly higher. Yulduz x SSB K-1, Nisa x Yulduz, SSB K-1 x Gulistan, Yulduz x Gulistan, and Gulistan x Yulduz F1 hybrids, when the fiber length traits in plants are extremely positive dominant, T-1336 x T-1391 negative dominance has become apparent. When the best and average heterosis was studied in traits of fiber length in plants of the F1 hybrids compared to the parental, the heterosis effect in Yulduz x Guliston, SSB K-1 x Guliston, and Guliston x Yulduz F1 hybrids found up to 1% to 3 %. According to the analysis of the results of this trait, it was noted that Yulduz x Guliston and Guliston x Yulduz F1 hybrids have a higher fiber length, superiority of the trait, and high heterosis efficiency compared to other hybrids.

Table 3. Degrees of dominance and heterosis of fiber length of parental and F1 hybrid genotypes.

Genotypes of cotton parents and F1 hybrids	Mean ± SE	hp	%H	%Hb
Namangan-77 (andoza)	33,6±1,23			
Yulduz	33,2±1,58			
Niso	34,2±1,05			
Guliston	33,5±1,54			
SS-BK	33,7±1,17			
T-1336	33,4±1,44			
T-1391	34,2±1,38			
T-1391x T-1336	33,6±1,31	-0,5	-0,6	-1,8
T-1391 x Yulduz	33,5±1,51	-0,4	-0,6	-2,0
T-1391 x Niso	34,3±0,98	0	0,3	0,3
T-1391 x SSB K-1	34,03±1,44	0,4	0,4	-0,5
T-1391 x Guliston	34,1±1,45	0,8	0,9	-0,3
T-1336 x T-1391	33,4±1,55	-1,0	-1,2	-2,3
T-1336 x Yulduz	33,3±1,46	0,0	0,0	-0,3
T-1336 x Niso	34,06±1,52	0,7	0,8	-0,4
T-1336 x SSB K-1	33,9±1,22	2,0	1,2	0,6
T-1336 x Guliston	33,6±1,34	2,0	0,6	0,3
Yulduz x T-1391	33,6±1,37	-0,2	-0,3	-1,8
Yulduz x T-1336	33,6±1,06	3,0	0,9	0,6
Yulduz x Niso	34,2±1,26	1,0	1,5	0,0
Yulduz x SSB K-1	34,1±1,02	2,3	2,1	1,2
Yulduz x Guliston	34,3±1,24	5,0	3,0	2,4
Niso x T-1391	34,1±1,21	0	2,7	-0,3
Niso x T-1336	34,2±1,45	1,0	1,2	0,0
Niso x Yulduz	34,4±1,47	1,4	2,1	0,6

Niso x SSB K-1	34,2±1,26	1,0	0,9	0,0
Niso x Guliston	33,7±1,20	-0,2	-0,3	-1,5
SSB K-1 x T-1391	33,8±1,19	-0,3	-0,3	-1,2
SSB K-1 x T-1336	33,7±1,31	1,0	0,6	-1,5
SSB K-1 x Yulduz	33,6±1,35	0,7	0,6	-0,3
SSB K-1 x Niso	34,2±1,32	1,0	0,9	0,0
SSB K-1 x Guliston	34,2±1,52	6,0	1,8	1,5
Guliston x T-1391	33,6±1,56	-0,5	-0,6	-1,8
Guliston x T-1336	34,05±1,14	6,5	1,9	1,6
Guliston x Yulduz	34,3±1,40	5,0	3,0	2,4
Guliston x Niso	34,4±1,28	1,5	1,8	0,6
Guliston x SSB K-1	33,9±1,37	3,0	0,9	0,6

When the indicators of fiber yield in plants of 7 varieties and lines of cotton and their F1 generations obtained based on diallel hybridization were studied, compared to the control variety, Niso variety (40.1±1.60 %) and T-1391(40.3±1.78%) it was noted that it is high in the range. Among the F1 hybrid combinations, the highest indicators of fiber yield in plants were determined in T-1391 x Yulduz, T-1391 x Guliston, Yulduz x T-1336, Guliston x Niso, Niso x Yulduz and Niso x Guliston hybrids. Their fiber yield was close to 40% and higher. T-1336 x SSB K-1, Guliston x T-1391, and Guliston x SSB K-1 combinations had the lowest indicators of fiber output, i.e. close to 36%. In the plants of Niso x Yulduz and Guliston x Yulduz F1 generations, the traits of fiber yield are extremely positive dominance. At the same time, T-1391 x Niso, Niso x T-1391, and Guliston x SSB K-1 are extremely negative dominance. When studying the best and average heterosis in the characteristics of fiber yield in the plants of the F1 generations compared to the parental forms, the effect of heterosis in the hybrid combinations of Niso x Yulduz, Yulduz x T-1336 and Niso x Guliston F1 is 1% to 4% was determined. According to the analysis of the results of this trait, it was noted that the Niso x Yulduz F1 hybrid has a higher fiber yield, superiority of the trait, and higher heterosis efficiency compared to other hybrid combinations.

Table 4. Degrees of dominance and heterosis of fiber lint of parental and F_1 hybrid genotypes.

Genotypes of cotton parents and F_1 hybrids	Mean ± SE	hp	%H	%Hb
Namangan-77 (andoza)	38,4±1,46			
Yulduz	39,5±1,45			
Niso	40,1±1,60			
Guliston	38,9±1,71			
SS-BK	38,7±1,43			
T-1336	38,6±1,32			
T-1391	40,3±1,78			
T-1391x T-1336	38,5±1,88	-0,9	-2,0	-4,2
T-1391 x Yulduz	39,5±1,91	-1	-1,0	-2,0
T-1391 x Niso	38,7±1,78	-15	-3,7	-4,0
T-1391 x SSB K-1	37,7±1,47	-1,6	-4,1	-6,5
T-1391 x Guliston	39,9±2,02	0,4	0,8	-1,0
T-1336 x T-1391	38,3±1,61	-0,7	-1,5	-3,7
T-1336 x Yulduz	39,7±2,03	1,4	1,7	0,5
T-1336 x Niso	38,4±2,04	-1,1	-2,3	-4,2

T-1336 x SSB K-1	35,6±1,59	-30	-7,8	-8,0
T-1336 x Guliston	39,1±2,22	2	1,0	0,5
Yulduz x T-1391	38,3±1,39	-4	-1,5	-5,0
Yulduz x T-1336	40,1±1,91	2,3	2,7	1,5
Yulduz x Niso	39,9±2,12	0,3	0,3	-0,5
Yulduz x SSB K-1	37,5±2,25	-4	-4,1	-5,1
Yulduz x Guliston	39,5±2,39	1	0,8	0,0
Niso x T-1391	38,8±2,07	-14	-3,5	-3,7
Niso x T-1336	38,4±1,63	-1,1	-2,3	-4,2
Niso x Yulduz	41,3±1,93	5	3,8	3,0
Niso x SSB K-1	38,1±2,23	-1,9	-3,3	-5,0
Niso x Guliston	40,2±1,87	1,5	2,3	0,7
SSB K-1 x T-1391	38,7±2,38	-0,6	-1,5	-4,0
SSB K-1 x T-1336	37,6±1,27	2,6	-4,6	-2,8
SSB K-1 x Yulduz	39,4±1,85	0,7	0,8	-0,3
SSB K-1 x Niso	36,6±1,96	-4	-7,1	-8,7
SSB K-1 x Guliston	37,5±1,84	-13	-3,4	-3,6
Guliston x T-1391	35,6±2,28	-5,7	-10,1	-11,7
Guliston x T-1336	38,2±2,04	-2,5	-1,3	-1,8
Guliston x Yulduz	37,5±1,94	6	-6,0	-5,1
Guliston x Niso	39,7±1,85	0,3	0,5	-1,0
Guliston x SSB K-1	35,6±2,32	-32	-8,2	-8,5

Discussion

The F1 population of the cross Guliston x SSB K-1 displayed the highest boll weight (6.50 g). Boll weight is assumed to increase yield if the bolls plant−1 remains constant. The present results are also supported by previous findings indicating that the significant heterotic effects for boll weight may be due to additive and nonadditive gene effects (Khan & Qasim, 2012). The results suggested that the parental cultivars Yulduz and ‘Gulistan and the tester ‘SSB K-1’ were the best general combiners and, hence, may be used in hybridization and selection programs.

As the number of bolls plant−1 increases in cotton plants, the yield also increases. Thus, a significant positive association exists between bolls plant−1 and seed cotton yield. Regarding heterotic performance, the hybrids of Yulduz x T-1336, Niso x Yulduz, and Niso x Gulistan displayed higher relative heterosis and heterobeltiosis than other genotypes (Table 1). Thus, These hybrids expressed more hybrid vigor for the number of bolls plant−1 than other genotypes and may be exploited for hybrid crop development. Past studies have also reported high heterosis over better parent and standard check cultivars in boll formation, and the said trait is positively associated with seed cotton yield (Patel & Kumar, 2012). In general, the heterotic effects for bolls plant−1 were moderate to high. Dong et al. (2007) noted significant heterosis in boll size and boll numbers over check cultivar. Basal and Turgut (2003) also found considerable heterosis for boll weight. Yuan et al. (2002) noted that the population means heterosis for boll weight over the mid-parental was 13.3%. However, boll weights were not different when compared to the better parent. Khan et al. (2007,2009) confirmed maximum heterosis over better parents for boll weight, which may be translated to improved seed cotton yield since it is one of the major yield contributors and can have a positive association with seed cotton yield if boll number remains constant.

The present results conformed with the findings of Kumar et al. (2014) and Patel and Kumar (2014), who also reported significant heterosis in F1 and F2 populations for seed cotton yield plant−1. For seed cotton yield plant−1, the hybrid of Niso x Yulduz is the maximum relative heterosis and heterobeltiosis, followed by the hybrid of 'Niso x Guliston'. However, the 'Yulduz x T-1336 hybrid also showed a fair amount of heterosis and heterobeltiosis for fiber lint (Table 4). Previous studies also reported significant heterosis over the mid and better parent for fiber yield characteristics (Komal et al., 2014; Baloch et al., 2015).

Conclusions

The importance of heterotic effects was evident from the significant mean squares of parents vs. hybrids. The mean performance revealed that F1 hybrids performed better over the parents for the traits due to the manifestation of heterotic effects. The crosses Niso x Yulduz among the hybrids formed more bolls per plant. Niso x Yulduz maximum lint %, and longer fiber were measured in Yulduz x Guliston and Guliston x Yulduz. T-1391 x Niso va SSB K-1 x Niso o formed a higher boll weight. The heterotic effects of the hybrids revealed that at least three hybrids viz. Niso x Yulduz va Niso x Guliston were identified which exhibited relative heterosis above 50% and heterobeltiosis over 45% for bolls per plant. Overall, the cross Niso x Yulduz va Niso x Guliston performed best in F1 generations.

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