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EXPLOITATION OF HETEROTIC EFFECTS IN F_1 HYBRIDS FOR PROMOTING EARLINESS, YIELD COMPONENTS, AND FIBER QUALITY OF UPLAND COTTON (*GOSSYPIUM HIRSUTUM* L.) GENOTYPES

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Abstract

Cotton is an often-pollinated crop and can be manipulated by exploiting heterosis achieved from different crosses among cotton genotypes for boosting lint yield and quality traits. The development of a new short-duration varieties having high yield and superior fiber quality are direly needed for sustainable supplies of lint to local textile industry. For this purpose, 12 parents and their half-diallel hybrids were sown at Hama Center for Scientific Agricultural Research, Syria during the summer of 2019 and 2020 to study the heterotic effects for the traits (earliness, yield, and fiber quality). The analysis of variance (mean squares) showed highly significant differences of the genetic variability among genotypes for all characteristics under investigation. Likewise, estimation of relative heterosis (MP), heterobeltiosis (HP), and standard heterosis (SC) showed significant superiority of some hybrids for all characteristics. The highest number of hybrids with significant heterosis was observed for earliness index (E %) and fiber elongation (FE), while the lowest was observed for fiber fineness (FF). Hybrids, Fantum × Coker 139, NIAB 414 × Deir ELzour 22, Coker 139 × NIAB 414, and Coker 139 × Raqqa 5 exhibited desirable heterosis for most of the traits under study. Thus, these cross combinations may become potent candidates for future hybridization programs in order to exploit heterosis for boosting the seed cotton yield (SCY), earliness and fiber quality traits by developing new varieties.

Key words: Heterosis; Half-diallel; Earliness; Seed cotton yield; Fiber quality.

Introduction

Cotton (*Gossypium hirsutum* L.) is a strategic crop which contributes significantly in the economy of many countries in the world (Alharbi *et al*., 2023; Su *et al*., 2023; Wang *et al*., 2023; Zhang *et al*., 2023). It is one of the most vital industrial crops due to its multiple-uses, especially in textile industry and cotton seed utilization for oil extraction (Khalid *et al*., 2021; Dirbas *et al*., 2023; Kumar *et al*., 2023). In Syria, the cotton yield has not been increased significantly, which has led to a decline in cultivated area owing to lesser profits, and ultimately foreign exchange earnings have been reduced to a great extent (Al-Mohammad & Naser, 2015). Cotton productivity has declined significantly in recent years primarily owing to the loss of the strategic stock of primary seeds. For this reason, it has become necessary to develop cotton genotypes with high lint potential and excellent fiber qualities to meet the quality needs of textile industry. Therefore, selection of the genetic resources by using the half diallel mating and exploiting the phenomenon of hybrid vigor, for developing new genotypes having higher yield and quality hold bright perspectives. Several studies have reported the significant effectiveness of exploiting genetic variation and heterosis for promoting earliness, yield components, and fiber quality traits of cotton (Karademir & Gencer, 2010; Ashokkumar *et al*., 2013; Dirbas, 2020; El Sabagh *et al*., 2021).

The phenomenon of heterosis is a multigenic and complicated trait inferred from several phenotypic features of crops including cotton. It has been pursued to identify the elevated performance of offspring than their progenitors leading toa significant boost in the production of food crops. Interestingly, it assisted during the green revolution and played a central role in hybrid seed production of cereal crops, oil seed crops, and vegetables. It has been established that in heterosis, more diverse parents tend to impart higher vigor in offspring that can be used to identify the hybrid vigor among the genotypes of different crops (Birchler *et al*., 2010). Using this technique, hybrid vigor has been achieved in commercial cops like maize (Wang *et al*., 2023), tomato (Torgeman & Zami, 2023), basil Basil (Lal *et al*., 2023), cabbage (Li *et al*., 2023), wheat (Gogna *et al*., 2023), rice (Sun *et al*., 2023; Abd-El-Aty *et al*., 2023). Cotton is a sexually propagated crop and possesses diverse germplasm which indicates that heterosis may be manipulated by crossing among different cultivars and identification of general combining ability (GCA)/specific combining ability (SCA) to produce superior combination in next generations. Moreover, most of the breeding efforts were intraspecific, and limited information is available on interspecific crosses (Shang *et al*., 2016; Li *et al*., 2023). Unfortunately, interspecific hybrids in cotton are facing the limitations of genetic incompatibility, high vegetative biomass, and inferior lint percentage (Basbag and Gencer, 2007). So, most of the breeding efforts in cotton are formed based on the intraspecific crosses, and the identification of inbred lines exhibit superior characteristics in their offspring populations (Swarkar *et al.*, 2015; Yehia & Abdelbary, 2023). A big breakthrough in hybrid seed production has been previously obtained when male sterility resulted from a duplicate mutation in GHCYP450 making it possible for large-scale production of hybrid seed (Li *et al.*, 2023; Mao *et al.*, 2023). It has been evaluated F1, F2, BC1, and BC2 of MNH886 X FH114 and MNH-988 X FH-Kehkshan for drought tolerance using K-means cluster analysis and biplot analysis (Imtiaz *et al.*, 2023).

Keeping the above in view, it was hypothesized that the exploitation of heterosis in cotton might be used to improve lint yield and quality. In addition, looking into the scope of heterosis in cotton improvement, the objective of the current study was to determine the heterosis over the mid-parent, superior parent, and the check (Aleppo 124) for earliness, yield, and fiber quality to identify the heterotic potential for developing hybrids of cotton with improved fiber quality traits.

Material and Methods

The trial was perfromed at the Hama Center for Scientific Agricultural Research, Syria during the summer seasons of 2019 and 2020. The geographical coordinates of the experiment site are 35° 8' 27.1968" N 36° 45' 18.7164" E, while its altitude is 287 m). In the first season of 2019, 12 parents of cotton including Fantom, Millenium, Lider, Cherpan 432, Coker 139, Aleppo 90, Aleppo 124, Raqqa 5, Aleppo 118, NIAB Kiran, NIAB 414 and Deir ELzour 22, were planted and crossed using the half-diallel method to obtain 65 hybrids.

These parents and their hybrids were tested in a regular arrangement of Randomized Complete Block Design (RCBD) with three replications. There were three rows for each genotype having P×P and R×R spacing of 25 cm and 75 cm, respectively. The agronomic practices were done uniformly for all experimental units according to recommendations of the National Cotton Conference, (2019). Ten plants were randomly selected from each replication for data recording of response variables such as plant height (PH, cm), earliness index (E%), monopodial branches plant-1(MB), sympodial branches plant^{-1}(SB), bolls number plant^{-1}(BN), boll weight (BW, g), seed cotton yield plant-1 (SCY, g) and lint percentage (LP%). Lint samples were analyzed at the Fiber Testing Laboratory of the Department of Plant Breeding at the Cotton Research Administration at 21°C ± 1°C temperature and 65% ± 2% relative humidity. Fiber length at 2.5% (FL, mm) was estimated as the space in mm spanned by 2.5% of the fibers as recorded on a digital fibro graph. Fiber strength (FS) along with fiber elongation (FE) were measured with the help of stelometer (g tex^{-1}). Additionally, to express fiber fineness (FF), the Micronaire reading was used.

The recorded data were subjected to statistical analyses by performing one-way analysis of variance (ANOVA) technique by the Gene State 12 program. Heterosis over mid-parent (relative heterosis), better parent (heterobeltiosis), and standard check (standard heterosis) were estimated as per the formula given by Mather and Jinks (1971). Moreover, significance of heterosis was also determined using (SE) method (Steel & Torrie, 1980).

Results and Discussion

Recently, cotton breeding has been credited for improved production of high-yielding hybrids via the exploitation of heterosis. Previously, the use of heterosis has been well documented in numerous commercial crops like rice, rape, sorghum etc. leading to large-scale hybrid seed production and adoption (Chen *et al.*, 2018; Zhang *et al.*, 2023). Interestingly, interspecific and intraspecific crosses have been worked out to identify and exploit optimum genome combinations for boosting fiber production, accelerating reproductive growth through synthesis of photosynthates (Gupta & Singh, 1987). In conventional breeding, the desired traits have been identified by gleaning genotypes exhibiting heterosis. Upon recognition of heterotic loci, genotypes are scrutinized for agronomic performance (Sarfraz *et al.*, 2021). The ANOVA (mean squares) showed highly significant differences ($p<0.01$) for all the studied characteristics (Table 1) that indicated the presence of significant variability among the genotypes. The genetic variance was expressed as decreasing or increasing the value of the trait i.e., the phenomenon of heterosis.

Table 1. Analysis of variance (ANOVA) for response variables in cotton hybrids (*Gossypium hirsutum* L.)

Source of variance	Replications	Genotypes	Error
df	2	76	152
PH	61.46	216.71**	34.81
E%	380.62	326.1**	66.23
MB	0.0115	0.6527**	0.3572
SB	3.139	2.734**	1.1
B.N	12.14	145.43**	37.92
BW	3.402	1.349**	0.604
SCY	1397	5566**	1381
LP%	1.391	5.016**	1.72
FL	822	2543**	1187
FS	2.9409	3.2823**	0.7278
FE	0.468	3.101**	0.442
FF	0.803	0.2728**	0.1216

*, and ** represent significant at the $p\leq0.05$ and $p\leq0.01$ probability levels, respectively

The relative heterosis (MP), heterobeltiosis (HP), and standard heterosis (SC) were estimated for 12 characteristics (Tables 2, 3, 4, and 5). The results showed heterosis was observed for all the studied traits, and their values varied according to the trait. The MP, HP, and SC for the plant height ranged from -26.14 (Aleppo 118 × NIAB 414) to 35.43 (Millinium × Raqqa 5), -26.66 (Aleppo 118 × NIAB 414) to 29.30 (Coker139 × NIAB 414), and -38.87 (Aleppo 118 × NIAB 414) to 6.91 (Coker139 × NIAB 414), respectively. From 65 cross combinations, 18 and 9 crosses recorded positive and significant or highly significant (desirable) heterosis and heteroclites, respectively whereas no cross showed positive and significant SC for the investigated trait under study (Table 2). These results are as per the findings of Jayshankar (2017) and Al jouma and Dirbas (2020). For the earliness index, MP, HP, and SC ranged from -33.54 (Coker139 × Aleppo 90) to 58.87 (Millinium × Lider), -43.69 (Millinium × Aleppo 118) to 35.82 (Millinium × Lider), and 11.11 (Millinium × Aleppo 118) to 168.01 (Millinium × Lider), respectively. Among hybrids, a total of 22, 4, and 60 hybrids displayed positive and significant or highly significant (desirable) MP, HP, and SC, respectively (Table 2). Özkan and Çopur (2022) found heterosis for the earliness index. The MP, HP and SC for the number of MB plant-1 ranged from -50.68 (NIAB 414 × Deir ELzour 22) to 105.69 (Millinium × Aleppo 90 and Coker139 × Aleppo 90), -45.44 (NIAB 414 × Deir ELzour 22) to 150.04 (Fantum × Lider), and -60.88 (NIAB 414 × Deir ELzour 22) to 30.4 (Coker139 × Lider), respectively. Out of 65 cross combinations, a total of two, one, and six crosses recorded negative and significant or highly significant (desirable) MP, HP, and SC, respectively (Table 2). These results are in concurrence with previously reported findings of Khokhar *et al*., (2018) and Dirbas (2020).

For the number of SB plant^{-1}, MP, HP, and SC ranged from -30.31 (Aleppo 118 × NIAB 414) to 25.12 (Lider × NIAB Kiran), -37.2 (Aleppo 118 × NIAB 414) to 23.51 (Lider × NIAB Kiran), and -29.84 (Lider × NIAB 414) to 8.65 (Coker139 × NIAB 414), respectively. Seven and three crosses recorded positive and significant or highly significant (desirable) MP and HP out of 65 cross combinations, respectively (Table 3). Previous studies have found positive and significant heterosis for the number of SB plant^{-1} (Madhuri *et al*., 2015; Arbad *et al*., 2017), which are as per the results recorded in our study.

The MP, HP, and SC for boll number ranged from -48.9 (Aleppo 124 × Deir ELzour 22) to 179.78 (Cherpan 432 × Aleppo 90), -56.2 (Cherpan 432 × Aleppo 90) to 100.05 (Cherpan 432 × Aleppo 90), and -60 (NIAB 414 × Deir ELzour 22) to 22.54 (Aleppo 90 × Deir ELzour 22), respectively. The results revealed that a total of 11 and 4 hybrids displayed positive and highly significant (desirable) MP and HP, respectively whereas no hybrid exhibited positive and significant SC for the investigated trait under study (Table 3). Similar findings were reported by Chavikant *et al*., (2017) and Surya Naik *et al*., (2021).

For the boll weight, MP, HP, and SC ranged from -32.73 (Aleppo 124 × Deir ELzour 22) to 30.12 (Fantum × NIAB Kiran), -38.56 (Aleppo 124 × Deir ELzour 22) to 23.04 (Fantum × NIAB Kiran), and -38.56 (Aleppo 124 × Deir ELzour 22) to 8.78 (Cherpan 432 × Raqqa 5), respectively. A total of 13 and two hybrids displayed highly significant (desirable) MP and HP, whereas no hybrid showed positive and significant SC (Table 3). These findings corroborate those reported by Reecha *et al*., (2016) and Solongi *et al*., (2019) who inferred that heterosis existed among genotypes and F1 hybrids in terms of BW and other yield attributes. The MP, HP, and SC for the SCY (g plant-1) ranged from -62.76 (Aleppo 124 × Deir ELzour 22) to 136.22 (Raqqa 5× NIAB 414), -72.02 (Aleppo 124 × Deir ELzour 22) to 132.61 (Raqqa 5 × NIAB 414), and -72.13 (NIAB Kiran × Deir ELzour 22) to -7.84 (Coker139 × Raqqa 5), respectively. Out of 65 crosses, 11 and five crosses recorded positive and significant or highly significant (desirable) MP and HP, respectively, whereas none of the crosses was found to be significant over the standard check for the investigated trait under study (Table 4). Similar findings were reported by Sawarkar *et al*., (2015) and Giri *et al*., (2021).

Therefore, F1 transgressive and heterotic hybrids can be exploited to create genetic variability followed by the selection of high-yielding genotypes in cotton. Additionally, it assisted to develop genotypes with superior and improved characteristics through segregating filial generations to bring forth seed cotton yield; however, the degree of heterosis is a key factor for its utilization (Abro *et al*., 2014). For the lint percentage, the MP, HP, and SC ranged from -9.29 (Raqqa 5 × NIAB 414) to 9.71 (Fantum × Lider), -10.27 (Cherpan 432 × Deir ELzour 22) to 8.45 (Fantum × Cherpan 432), and -10.13 (Raqqa 5 × NIAB 414) to 6.67 (Millinium × Aleppo 118), respectively. Overall, nine, four, and three crosses were either significant or highly significant (desirable) MP, HP, and SC, respectively for the investigated trait under study out of 65 cross combinations (Table 4). The results are in agreement with the findings of Srinivas & Bhadru (2015) and Taha *et al*. (2018) who found positive and significant heterosis for the LP. The MP, HP and SC for the FL (mm) ranged from -7.52 (Aleppo 118 × Deir ELzour 22) to 7.59 (Fantum × Coker 139), -9.28 (Aleppo 118 × Deir ELzour 22) to 6.31 (Aleppo 90 × Raqqa 5), and -3.95 (Aleppo 118 × Deir ELzour 22) to 8.16 (Fantum × Coker 139), respectively. Likewise, from 65 cross combinations, overall 8, 5, and 13 crosses were negative, significant and highly significant (desirable) in this trait for the MP, HP, and SC, respectively (Table 4). These results are as per the findings of Gnanasekaran *et al*., (2021) who opined that MP, HP, and SC were observed for the FL. For the FS (g tex-1), the MP, HP, and SC ranged from -12.22 (Lider × Aleppo 118) to 10.39 (Aleppo 124 × Raqqa 5), -13.95 (Lider × Aleppo 118) to 8.53 (Aleppo 124 × Raqqa 5), and -10.33 (Coker 139 × Aleppo 124) to 12 (Aleppo 124 × Raqqa 5), respectively. Among the studied hybrids, overall four, three, and seven hybrids remained significant or highly significant (desirable) MP, HP, and SC, respectively for the investigated trait under study (Table 5). These results are supported by a previous study Monicashree *et al*., (2017) whereby significant heterosis existed among genotypes for the FS of cotton.

The MP, HP, and SC for the FE (g tex-1) ranged from -33.85 (Cherpan 432 × Aleppo 90) to 40.94 (NIAB 414 × Deir ELzour 22), -38.78 (Millinium × Aleppo 90) to 35.19 (NIAB 414 × Deir ELzour 22), and -24.64 (Coker139 × Aleppo 124) to 52.17 (NIAB 414 × Deir ELzour 22), respectively. Out of 65 cross combinations, 18, 9, and 34 crosses were recorded to be positive and highly significant (desirable) MP, HP, and SC for the FE, respectively (Table 5). These findings are in agreement with those of Karademir *et al*., (2011) and Ashokkumar *et al*., (2013), who inferred that there existed a positive and significant heterosis for the FE among different genotypes.

For the fiber fineness, the MP, HP, and SC ranged from -17.09 (NIAB 414 × Deir ELzour 22) to 26.19 (Fantum × Aleppo 90), -15.87 (NIAB 414 × Deir ELzour 22) to 32.05 (Fantum × Aleppo 90), and -16.17 (NIAB 414 × Deir ELzour 22) to 16.92 (Fantum × Aleppo 90), respectively. Among the studied hybrids, a total of four, two, and one hybrids exhibited negative, significant and highly significant (desirable) for the MP, HP, and SC, respectively (Table 5). These results endorse the observations of Lingaraja *et al*., (2017) and Al-Hibbiny *et al*., (2020).

Table 2. Estimates relative heterosis (MP), heterobeltiosis (BP), and standard heterosis (SC) for response variables in cotton hybrids.

Character	PH			E%			MB		
	MP	BP	SC	MP	BP	SC	MP	BP	SC
Fantum × Millinium	4.71	-6.05	-13.48**	-8.26	-9.50	83.53**	66.67*	87.55*	-2.19
Fantum × Lider	-1.99	-7.98	-15.25**	16.35	-1.65	99.46**	66.65**	150.04**	30.40
Fantum × Cherpan 432	-2.95	-6.29	-13.70**	1.59	-9.67	83.20**	40.37	66.69*	-13.07
Fantum × Coker 139	-1.12	-6.17	-13.59**	19.13*	16.68	136.65**	70.40*	91.75*	0.00
Fantum × Aleppo 90	-3.53	-7.50	-14.81**	4.76	0.50	121.89**	29.07	33.36	-34.78*
Fantum × Aleppo 124	-11.08*	-14.59**	-14.59**	20.29	-10.20	82.13**	2.85	50.04	-21.75
Fantum × Raqqa 5	-2.76	-16.81**	-23.39**	22.97*	11.78	126.71**	19.33	41.71	-26.10
Fantum × Aleppo 118	4.73	-0.24	-8.13*	9.40	-12.57	77.31**	27.52	83.35*	-4.38
Fantum × NIAB Kiran	-7.72	-15.48**	-22.16**	17.22*	6.70	116.40**	19.40	54.24	-19.56
Fantum × NIAB 414	1.21	-4.23	-11.81*	17.10*	12.51	128.18**	75.49**	108.40**	8.69
Fantum × Deir ELzour 22	4.05	-3.62	-11.24*	-11.82	-15.31	86.55**	46.89*	95.87**	2.15
Millinium × Lider	8.02	2.89	-16.82**	58.87**	35.82**	168.01**	33.32*	73.31*	13.03
Millinium × Cherpan 432	6.80	-1.04	-15.14**	19.33	7.39	111.91**	26.97	33.29	-13.07
Millinium × Coker 139	6.75	0.61	-16.82**	-19.35*	-19.93*	58.00**	59.99*	59.99*	4.34
Millinium × Aleppo 90	0.43	-6.32	-20.83**	-9.49	-14.29	89.22**	105.69**	140.00**	17.37
Millinium × Aleppo 124	7.14	-7.24	-7.24	23.32*	-7.09	83.33**	-2.63	23.34	-19.56
Millinium × Raqqa 5	35.43**	28.32**	-6.12	-2.57	-10.33	76.94**	33.31	39.95	-8.72
Millinium × Aleppo 118	25.65**	17.96**	-1.67	-30.27*	-43.69**	11.11	-1.32	23.34	-19.56
Millinium × NIAB Kiran	-9.10	-11.15*	-31.93**	-2.83	-10.45	76.71**	23.50	39.95	-8.72
Millinium × NIAB 414	17.85**	11.38*	-8.47*	-31.23**	-33.04**	32.13	33.31	39.95	-8.72
Millinium × Deir ELzour 22	13.80*	9.93	-13.70**	-17.12*	-21.44*	73.06**	42.86*	66.65*	8.69
Lider × Cherpan 432	-6.25	-8.93	-21.91**	-2.25	-7.76	45.62*	13.60	39.44*	0.00
Lider × Coker 139	-3.03	-4.11	-20.72**	-33.53**	-42.83**	11.18	-2.58	26.63	-17.41
Lider × Aleppo 90	-4.11	-6.19	-20.72**	-20.74	-35.23**	43.01*	2.12	60.00	-21.75
Lider × Aleppo 124	-13.55**	-21.83**	-21.83**	19.09	2.05	42.94*	-19.17	-17.41	-17.41
Lider × Raqqa 5	12.18*	1.51	-17.93**	11.49	2.80	70.55**	6.18	30.33	-6.53
Lider × Aleppo 118	3.76	2.20	-14.81**	27.85*	19.31	67.10**	-16.12	-13.32	-15.22
Lider × NIAB Kiran	0.43	-2.21	-20.94**	-2.15	-9.90	49.93*	20.93	36.85	13.03
Lider × NIAB 414	-12.57*	-13.28*	-28.73**	-20.86*	-30.78*	29.38	-1.24	21.22	-13.07
Lider × Deir ELzour 22	-8.31	-9.64	-26.95**	-13.83	-29.52**	55.25*	-6.81	2.52	-10.88
Cherpan 432 × Coker 139	-3.87	-5.59	-19.04**	-6.08	-14.92	65.46**	71.43**	79.96**	17.37
Cherpan 432 × Aleppo 90	-7.92	-8.58	-21.61**	-12.39	-24.87*	65.86**	73.01**	113.36**	4.34
Cherpan 432 × Aleppo 124	1.51	-5.72	-5.72	24.59*	1.76	60.64**	-8.86	9.11	-21.75
Cherpan 432 × Raqqa 5	8.11	-4.68	-18.26**	4.07	1.55	68.47**	48.50*	48.50*	6.49
Cherpan 432 × Aleppo 118	1.68	0.26	-14.03**	15.59	2.23	61.38**	7.69	27.28	-8.72
Cherpan 432 × NIAB Kiran	-4.67	-9.75*	-22.61**	35.62**	32.14*	119.88**	38.03*	48.50*	6.49
Cherpan 432 × NIAB 414	0.47	-1.62	-15.64**	-19.22*	-25.50*	39.26*	39.44*	39.44*	0.00
Cherpan 432 × Deir ELzour 22	3.73	-0.65	-14.81**	10.89	-4.82	109.67**	23.30	36.39	-2.19
Coker139 × Aleppo 90	8.89*	7.71	-8.97*	-33.54**	-37.50**	37.99*	105.69**	140.00**	17.37
Coker139 × Aleppo 124	6.79	-2.46	-2.46	51.22**	14.49	122.66**	-5.28	19.98	-21.75
Coker139 × Raqqa 5	24.32**	11.38*	-7.91	-9.08	-15.76	63.82**	33.31	39.95*	-8.72
Coker139 × Aleppo 118	9.59*	7.65	-9.02*	34.45**	9.17	112.32**	25.32	56.63*	2.15
Coker139 × NIAB Kiran	5.70	1.82	-15.81**	-27.76**	-32.97**	30.35	47.06*	66.65*	8.69
Coker139 × NIAB 414	29.69**	29.30**	6.91	32.40**	29.82**	152.48**	26.97	33.29	-13.07
Coker139 × Deir ELzour 22	13.30*	10.44*	-8.69*	-5.91	-11.43	95.11**	-0.03	16.62	-23.94
Aleppo 90 × Aleppo 124	-13.33**	-20.04**	-20.04**	41.76**	2.99	127.38**	40.15*	113.36**	4.34
Aleppo 90 × Raqqa 5	11.96*	-0.65	-16.04**	21.46*	6.37	134.84**	22.54	51.12	-26.10
Aleppo 90 × Aleppo 118	-4.35	-5.00	-19.71**	23.62*	-4.21	111.48**	42.24*	113.36**	4.34
Aleppo 90 × NIAB Kiran	12.66*	7.39	-9.24*	-0.01	-12.32	93.57**	22.34	64.48*	-19.56
Aleppo 90 × NIAB 414	9.82*	8.30	-8.47*	23.38*	13.92	151.51**	40.58	73.36*	-15.22
Aleppo 90 × Deir ELzour 22	10.84*	6.90	-9.65*	-11.34	-11.44	95.52**	11.98	55.52	-23.94
Aleppo 124 × Raqqa 5	-2.02	-18.93**	-18.93**	53.66**	23.14*	104.28**	40.49*	68.19*	20.62
Aleppo 124 × NIAB Kiran	-11.85*	-22.16**	-22.16**	28.99*	3.26	71.82**	-42.88*	-36.85	-47.85*
Aleppo 124 × NIAB 414	-13.82**	-21.50**	-21.50**	36.38**	4.67	95.65**	-12.65	4.58	-25.00
Aleppo 124 × Deir ELzour 22	-15.78**	-24.83**	-24.83**	15.21	-16.24	84.50**	-6.99	0.00	-13.07
Raqqa 5× Aleppo 118	18.96**	6.20	-11.48*	42.51**	23.38*	104.69**	-2.56	15.17	-17.41
Raqqa 5 × NIAB Kiran	5.02	-2.62	-25.40**	-0.49	-0.64	65.33**	-18.31	-12.11	-36.97*
Raqqa 5× NIAB 414	6.94	-3.93	-21.05**	9.33	3.19	92.87**	63.67**	63.67*	17.37
Raqqa 5× Deir ELzour 22	-19.37**	-26.06**	-41.95**	-11.01	-22.00*	71.82**	-20.54	-12.11	-36.97*
Aleppo 118 × NIAB Kiran	5.26	1.00	-15.81**	32.08*	14.20	90.03**	1.19	10.52	-8.72
Aleppo 118 × NIAB 414	-26.14**	-26.66**	-38.87**	-10.13	-25.89*	38.52*	30.76	54.56*	10.84
Aleppo 118 × Deir ELzour 22	-8.98*	-11.63*	-26.34**	19.85*	-7.06	104.72**	-15.29	-9.99	-21.75
NIAB Kiran × NIAB 414	14.02**	10.16*	-9.47*	-8.38	-13.41	61.85**	35.24	45.50*	4.34
NIAB Kiran × Deir ELzour 22	25.13**	23.62**	-2.96	0.74	-11.58	94.78**	-23.06	-21.03	-34.78*
NIAB 414 × Deir ELzour 22	20.79**	18.09**	-2.96	-20.93*	-26.92**	60.98**	-50.68*	-45.44*	-60.88**
SE	**4.17**	**4.82**	**4.82**	**5.754**	**6.644**	**6.644**	**0.42**	**0.48**	**0.48**

*, and ** represent significant at the $p \leq 0.05$ and $p \leq 0.01$ probability levels, respectively

Table 3. Estimation of relative heterosis (MP), heterobeltiosis (BP) and standard heterosis (SC) for studied traits in cotton hybrids.

Character[1]	SB			BN			BW		
	MP	BP	SC	MP	BP	SC	MP	BP	SC
Fantum × Millinium	-0.25	-2.68	-12.11	-10.80	-24.61	-39.69**	-4.48	-4.52	-22.76*
Fantum × Lider	7.67	-1.01	-14.97*	34.63*	32.75*	6.20	-4.82	-10.74	-17.61*
Fantum × Cherpan 432	-7.30	-12.44	-15.40*	20.47	6.36	-14.91	-16.60*	-23.19*	-26.27**
Fantum × Coker 139	17.86*	16.31*	-0.09	-4.97	-8.93	-27.14*	-4.38	-9.72	-17.86*
Fantum × Aleppo 90	-9.42	-12.56	-19.29*	46.27*	-2.79	-22.23	17.42*	14.78	-2.86
Fantum × Aleppo 124	-0.70	-7.70	-7.70	-19.59	-27.63*	-27.63*	-7.55	-16.42*	-16.42*
Fantum × Raqqa 5	-13.20*	-16.21*	-22.66**	-6.98	-11.48	-21.60	-4.50	-8.32	-19.46**
Fantum × Aleppo 118	-12.54*	-23.96**	-11.59	-15.15	-26.32*	-20.00	-0.17	-8.44	-11.31
Fantum × NIAB Kiran	-1.41	-8.26	-21.19**	-35.22*	-36.26*	-47.31**	30.12**	23.04*	-0.56
Fantum × NIAB 414	-1.30	-5.19	-11.59	-4.24	-23.43	-38.74**	23.31*	15.50	-6.65
Fantum × Deir ELzour 22	-2.40	-3.26	-15.40*	16.57	10.32	-11.74	11.99	10.75	-8.46
Millinium × Lider	10.07	-1.05	-10.64	-19.31	-31.01*	-46.34**	19.32*	11.95	3.33
Millinium × Cherpan 432	-13.65*	-16.47*	-19.29**	-11.16	-15.53	-48.26**	-0.83	-8.63	-12.29
Millinium × Coker 139	-1.64	-5.27	-14.45*	5.91	-7.17	-31.91*	22.61*	15.82	5.37
Millinium × Aleppo 90	-15.77*	-16.68*	-23.10**	86.83**	37.97	-23.80*	11.98	9.51	-7.33
Millinium × Aleppo 124	-6.09	-10.64	-10.64	28.03*	-0.63	-0.63	-1.50	-10.91	-10.91
Millinium × Raqqa 5	-1.09	-2.16	-9.69	20.09	-2.52	-13.66	14.17	9.64	-3.67
Millinium × Aleppo 118	-10.64*	-20.61**	-7.70	20.15	-9.37	-1.60	5.01	-3.65	-6.67
Millinium × NIAB Kiran	-1.74	-10.63	-19.29**	-12.97	-27.41	-40.00**	8.18	2.25	-17.28*
Millinium × NIAB 414	-2.64	-4.17	-10.64	80.34**	68.44**	-6.97	11.21	4.12	-15.77*
Millinium × Deir ELzour 22	0.54	-1.05	-10.64	9.27	-3.12	-30.80*	6.63	5.49	-12.80
Lider × Cherpan 432	3.18	-9.94	-12.98*	-0.21	-10.80	-30.63*	-16.48*	-18.08*	-21.37*
Lider × Coker 139	-1.22	-8.07	-23.10**	-1.68	-4.48	-25.71*	14.56*	13.74	4.99
Lider × Aleppo 90	18.11*	5.15	-2.94	20.14	-19.58	-37.46**	12.62	7.94	-0.37
Lider × Aleppo 124	3.87	-10.64	-10.64	1.80	-9.51	-9.51	-6.69	-10.28	-10.28
Lider × Raqqa 5	16.95*	4.12	-3.89	16.80	9.68	-2.86	-5.83	-8.10	-15.17
Lider × Aleppo 118	-14.29*	-30.58**	-19.29**	-10.73	-23.39*	-16.83	9.93	7.34	3.98
Lider × NIAB Kiran	25.12**	23.51*	-8.65	7.64	4.46	-13.66	-6.84	-17.07*	-23.45*
Lider × NIAB 414	-15.12*	-24.77**	-29.84**	8.59	-12.23	-31.74*	19.61*	5.54	-2.58
Lider × Deir ELzour 22	-0.65	-9.40	-20.76**	-35.73*	-38.35*	-52.06**	-0.88	-6.06	-13.29
Cherpan432 × Coker 139	-0.86	-7.52	-10.64	13.22	3.90	-23.80*	-4.41	-6.90	-10.63
Cherpan432 × Aleppo 90	-6.41	-8.50	-11.59	179.78**	100.05**	22.54	3.71	-2.43	-6.34
Cherpan432 × Aleppo 124	-6.12	-7.70	-7.70	7.87	-13.03	-13.03	-9.39	-11.20	-11.20
Cherpan432 × Raqqa 5	-2.84	-5.01	-8.22	4.23	-11.84	-21.91	18.34*	13.32	8.78
Cherpan432 × Aleppo 118	-27.75**	-33.85**	-23.10**	-15.14	-33.63*	-27.94*	-14.47*	-14.86	-17.52*
Cherpan432 × NIAB Kiran	-10.95	-21.40**	-24.05**	4.98	-8.61	-24.46*	6.69	-6.62	-10.37
Cherpan432 × NIAB 414	-14.99*	-16.47*	-19.29**	19.47	6.48	-34.77*	27.54**	10.66	6.23
Cherpan432 × Deir ELzour 22	-10.15	-14.41*	-17.30*	-3.36	-10.24	-35.89*	19.66*	11.35	6.89
Coker139 × Aleppo 90	-4.92	-9.37	-16.35*	47.78*	0.43	-26.34*	13.96	9.97	0.06
Coker139 × Aleppo 124	6.74	-1.99	-1.99	-7.70	-20.00	-20.00	0.37	-4.16	-4.16
Coker139 × Raqqa 5	3.74	-1.12	-8.74	19.99	9.68	-2.86	6.38	4.55	-4.88
Coker139 × Aleppo 118	-17.27**	-28.87**	-17.30*	-31.24*	-42.39**	-37.46**	-15.05*	-17.63*	-20.21*
Coker139 × NIAB Kiran	10.98	4.55	-12.54*	9.89	3.70	-14.29	1.63	-8.96	-17.17*
Coker139 × NIAB 414	22.84**	16.51*	8.65	7.33	-11.26	-34.91*	6.46	-5.47	-13.99
Coker139 × Deir ELzour 22	14.56*	12.07	-1.99	-11.86	-13.01	-36.20*	-5.57	-9.89	-18.02*
Aleppo 90 × Aleppo 124	-10.03	-13.49*	-13.49*	19.58	-24.46*	-24.46*	9.71	1.28	1.28
Aleppo 90 × Raqqa 5	1.03	1.03	-6.75	17.70	-23.65	-32.37*	-2.43	-4.23	-15.86*
Aleppo 90 × Aleppo 118	-13.81*	-22.69**	-10.12	16.22	-27.79*	-21.60	-1.99	-8.19	-11.06
Aleppo 90 × NIAB Kiran	4.06	-6.28	-13.49*	1.91	-32.80*	-44.46**	20.17*	11.23	-5.87
Aleppo 90 × NIAB 414	-4.71	-5.19	-11.59	75.62*	36.05	-34.77*	28.51**	17.86	-0.26
Aleppo 90 × Deir ELzour 22	-10.68	-13.03	-19.72**	146.99**	69.04**	20.74	20.15*	18.76*	0.50
Aleppo 124 × Raqqa 5	-4.00	-7.70	-7.70	-13.64	-18.57	-18.57	-7.98	-13.57	-13.57
Aleppo 124 × NIAB Kiran	7.71	-6.31	-6.31	-1.99	-10.49	-10.49	-0.93	-14.79	-14.79
Aleppo 124 × NIAB 414	-20.41**	-23.10**	-23.10**	51.29**	11.91	11.91	-14.40	-26.99**	-26.99**
Aleppo 124 × Deir ELzour 22	-20.81**	-25.78**	-25.78**	-48.90**	-56.20**	-56.20**	-32.73**	-38.56**	-38.56**
Raqqa 5× Aleppo 118	-26.25**	-33.85**	-23.10**	-23.68*	-30.71*	-24.77*	-17.00*	-20.86*	-23.33*
Raqqa 5 × NIAB Kiran	13.32*	2.06	-5.80	-43.00**	-44.90**	-51.20**	16.29	5.82	-7.03
Raqqa 5× NIAB 414	-20.93**	-21.34*	-26.64**	56.26**	20.42	6.66	17.20*	5.68	-7.15
Raqqa 5× Deir ELzour 22	-10.20	-12.56	-19.29**	-41.68**	-47.32**	-53.34**	-13.50	-16.06	-26.26**
Aleppo 118 × NIAB Kiran	-2.23	-20.01**	-7.01	16.54	2.63	11.43	-10.61	-22.07*	-24.51**
Aleppo 118 × NIAB 414	-30.31**	-37.20**	-26.99**	21.69	-12.29	-4.77	-5.45	-18.28*	-20.84*
Aleppo 118 × Deir ELzour 22	-16.01*	-26.41**	-14.45*	-37.56**	-48.24**	-43.80**	9.57	1.53	-1.64
NIAB Kiran × NIAB 414	-2.33	-12.43	-18.34*	5.49	-16.66	-31.11*	15.07	13.92	-17.94*
NIAB Kiran × Deir ELzour 22	7.18	-1.09	-13.49*	-39.44*	-43.55*	-53.34**	-2.98	-9.22	-24.96**
NIAB 414 × Deir ELzour 22	2.06	-1.11	-7.79	-32.98	-44.00*	-60.00**	14.53	6.16	-12.25
SE	**0.74**	**0.86**	**0.86**	**4.35**	**5.03**	**5.03**	**0.55**	**0.64**	**0.64**

*, and ** represent significant at the p≤0.05 and p≤0.01 probability levels, respectively

Table 4. Estimation of relative heterosis (MP), heterobeltiosis (BP), and standard heterosis (SC) for studied traits in cotton hybrids.

Character	SCY			LP			FL		
	MP	BP	SC	MP	BP	SC	MP	BP	SC
Fantum × Millinium	-6.29	-34.16*	-54.81**	6.82**	4.33	3.14	-4.74*	-5.38*	-1.23
Fantum × Lider	19.02	6.24	-27.07*	9.71**	8.45**	2.21	-5.78**	-6.30**	-3.51
Fantum × Cherpan 432	-21.28	-23.96	-47.80**	7.61**	4.50*	4.53*	-1.44	-1.78	1.84
Fantum × Coker 139	-28.43*	-31.37*	-52.89**	1.65	0.00	-2.59	7.59**	5.03*	8.16**
Fantum × Aleppo 90	-6.16	-20.36	-45.33**	-0.76	-4.71*	-2.41	1.25	2.44	3.07
Fantum × Aleppo 124	-41.24**	-50.45**	-50.45**	-1.75	-4.58*	-4.58*	2.94	1.45	4.47*
Fantum × Raqqa 5	-5.39	-28.32*	-50.80**	1.76	-0.35	-2.02	-0.60	-1.36	1.58
Fantum × Aleppo 118	-41.49**	-51.33**	-49.65**	7.13**	4.63*	3.43	-2.10	-2.64	0.26
Fantum × NIAB Kiran	-16.53	-33.10*	-54.08**	0.85	-3.16	-0.85	0.34	-0.77	2.19
Fantum × NIAB 414	-3.59	-27.72*	-50.38**	2.44	-0.42	-0.60	-2.24	-3.15	-0.26
Fantum × Deir ELzour 22	10.64	-4.16	-34.22**	-2.41	-7.07**	-3.16	-1.89	-3.23	2.46
Millinium × Lider	27.68	-3.23	-47.84**	1.90	-1.59	-2.71	0.13	-1.09	3.25
Millinium × Cherpan 432	4.33	-25.16	-52.13**	-4.19*	-4.75*	-4.73*	0.51	0.17	4.56*
Millinium × Coker 139	28.78	-7.19	-41.53**	-1.62	-2.34	-3.46	4.16*	1.01	5.44*
Millinium × Aleppo 90	59.67*	26.20	-39.58**	-6.47**	-8.09**	-5.87*	0.98	-0.84	3.51
Millinium × Aleppo 124	0.22	-35.96**	-35.96**	-2.75	-3.31	-3.31	1.29	-0.84	3.51
Millinium × Raqqa 5	135.08**	109.95**	-25.75*	-0.44	-0.70	-1.84	-0.43	-1.85	2.46
Millinium × Aleppo 118	-9.58	-42.64**	-40.66**	7.90**	7.90**	6.67*	0.04	-1.18	3.16
Millinium × NIAB Kiran	22.86	2.69	-57.49**	-3.39	-5.05*	-2.79	-4.36*	-6.05*	-1.93
Millinium × NIAB 414	93.71**	75.41*	-39.86**	-1.69	-2.17	-2.34	-2.56	-4.12*	0.09
Millinium × Deir ELzour 22	63.86**	27.23	-36.03**	-5.70*	-8.12**	-4.25	-4.80*	-5.47*	0.09
Lider × Cherpan 432	12.74	3.87	-33.55**	2.27	-1.79	-1.77	-3.46*	-4.31*	-0.79
Lider × Coker 139	6.29	-1.38	-37.87**	0.97	-1.79	-4.33	-0.66	-2.50	-0.70
Lider × Aleppo 90	-14.28	-19.07	-56.38**	2.11	-3.04	-0.70	-1.65	-2.24	-0.44
Lider × Aleppo 124	-28.68*	-45.12**	-45.12**	5.62*	1.44	1.44	-0.91	-1.81	0.00
Lider × Raqqa 5	38.25*	14.48	-38.29**	0.43	-2.76	-4.38	1.86	1.64	3.51
Lider × Aleppo 118	-8.77	-30.62**	-28.22**	5.39*	1.79	0.62	2.76	2.76	4.65*
Lider × NIAB Kiran	12.61	-0.45	-46.34**	4.35*	-0.90	1.47	-0.39	-0.95	0.88
Lider × NIAB 414	15.37	-5.62	-49.13**	0.43	-3.46	-3.63	-1.17	-1.55	0.26
Lider × Deir ELzour 22	-30.10*	-32.45*	-63.59**	-0.04	-5.85*	-1.89	-6.59**	-8.37**	-2.98
Cherpan 432 × Coker 139	-6.15	-6.86	-40.42**	-0.72	-2.01	-1.99	-1.30	-3.98*	-0.44
Cherpan 432 × Aleppo 90	43.61*	25.54	-19.69*	-3.91*	-5.03*	-2.74	-4.25*	-5.67*	-2.19
Cherpan 432 × Aleppo 124	-25.58*	-38.99**	-38.99**	-3.62	-3.63	-3.61	-0.34	-2.12	1.49
Cherpan 432 × Raqqa 5	6.63	-17.21	-47.04**	-0.80	-1.64	-1.62	-2.31	-3.38	0.18
Cherpan 432 × Aleppo 118	-26.95*	-40.89**	-38.85**	-0.99	-1.57	-1.54	1.75	0.85	4.56*
Cherpan 432 × NIAB Kiran	7.41	-11.55	-43.41**	-7.85**	-8.92**	-6.74*	0.52	-0.93	2.72
Cherpan 432 × NIAB 414	21.70	-6.54	-40.21**	-5.13*	-5.22*	-5.20*	1.63	0.34	4.04
Cherpan 432 × Deir ELzour 22	0.58	-10.19	-42.54**	-8.43**	-10.27**	-6.49*	-3.98*	-4.97*	0.61
Coker 139 × Aleppo 90	16.22	2.27	-35.57**	-3.60	-5.95*	-3.68	6.31**	4.97*	5.61*
Coker 139 × Aleppo 124	-26.93*	-40.45**	-40.45**	-3.25	-4.50*	-4.50*	3.28	2.28	2.28
Coker 139 × Raqqa 5	87.39**	46.29*	-7.84	-2.71	-3.16	-4.78*	3.87*	2.16	3.60
Coker 139 × Aleppo 118	-43.44**	-54.50**	-52.93**	2.99	2.24	1.07	-0.57	-2.41	-0.61
Coker 139 × NIAB Kiran	6.48	-11.78	-44.43**	-2.52	-4.88*	-2.61	0.71	-0.61	0.09
Coker 139 × NIAB 414	20.49	-6.97	-41.39**	3.52	2.27	2.09	2.73	1.22	2.28
Coker 139 × Deir ELzour 22	-16.15	-24.61	-52.51**	-0.23	-3.49	0.57	3.14	-0.66	5.18*
Aleppo 90 × Aleppo 124	-11.83	-34.81**	-34.81**	-2.50	-3.64	-1.32	2.40	2.09	2.72
Aleppo 90 × Raqqa 5	21.64	5.75	-49.37**	-1.41	-3.38	-1.05	6.73**	6.31**	7.81**
Aleppo 90 × Aleppo 118	-27.65*	-47.09**	-45.26**	-5.58*	-7.22**	-4.98*	2.25	1.64	3.51
Aleppo 90 × NIAB Kiran	6.48	-0.73	-52.47**	-7.40**	-7.41**	-5.18*	4.23*	4.18*	4.91*
Aleppo 90 × NIAB 414	52.16*	30.57	-37.49**	-5.88*	-7.07**	-4.83*	1.87	1.65	2.72
Aleppo 90 × Deir ELzour 22	32.13*	28.97	-35.16**	0.10	-0.76	3.41	-0.08	-2.57	3.16
Aleppo 124 × Raqqa 5	-15.47	-42.79**	-42.79**	-2.65	-3.46	-3.46	2.00	1.30	2.72
Aleppo 124 × NIAB Kiran	-12.96	-38.47**	-38.47**	4.28*	3.06	5.52*	4.72*	4.36*	5.09*
Aleppo 124 × NIAB 414	0.42	-32.58**	-32.58**	-0.56	-0.65	-0.65	1.66	1.13	2.19
Aleppo 124 × Deir ELzour 22	-62.76**	-72.02**	-72.02**	-3.67	-5.61*	-1.64	-5.16*	-7.79**	-2.37
Raqqa 5× Aleppo 118	-30.77*	-53.55**	-51.95**	-1.70	-1.96	-3.09	-1.34	-1.55	0.26
Raqqa 5 × NIAB Kiran	-2.50	-9.60	-62.58**	1.35	-0.66	1.72	3.82*	3.46	4.91*
Raqqa 5× NIAB 414	136.22**	132.61**	-17.74*	-9.29**	-9.97**	-10.13**	3.21	3.03	4.47*
Raqqa 5× Deir ELzour 22	-27.26	-69.89**	-68.85**	-3.07	-5.80*	-1.84	-2.84	-4.89*	0.70
Aleppo 118 × NIAB Kiran	-3.20	-32.23**	-29.90*	1.09	-0.66	1.72	-0.91	-1.46	0.35
Aleppo 118 × NIAB 414	15.36	-23.21*	-20.56*	-0.66	-1.15	-1.32	2.38	1.98	3.86
Aleppo 118 × Deir ELzour 22	-50.82**	-63.46**	-62.20**	-4.35*	-6.81**	-2.89	-7.52**	-9.28**	-3.95
NIAB Kiran × NIAB 414	85.08**	69.19**	-29.97**	-9.04**	-10.18**	-8.04**	-1.74	-1.91	-0.88
NIAB Kiran × Deir ELzour 22	-39.19*	-32.66	-72.13**	-7.19**	-8.00**	-4.13	-5.90**	-8.20**	-2.81
NIAB 414 × Deir ELzour 22	-32.67	-43.38*	-71.53**	-1.20	-3.27	0.80	-2.16	-4.39*	1.23
SE	**26.28**	**30.34**	**30.34**	**0.93**	**1.07**	**1.07**	**24.36**	**28.13**	**28.13**

*, and ** represent significant at the $p \leq 0.05$ and $p \leq 0.01$ probability levels, respectively

Table 5. Estimation of relative heterosis (MP), heterobeltiosis (BP), and standard heterosis (SC) for studied traits in cotton hybrids.

Character	FS			FE			FF		
	MP	BP	SC	MP	BP	SC	MP	BP	SC
Fantum × Millinium	2.40	2.32	4.11	-1.79	-16.66**	25.61**	13.62*	15.98*	8.10
Fantum × Lider	-3.84	-5.32*	-0.77	13.07*	10.34	15.94*	4.00	10.80*	7.54
Fantum × Cherpan 432	0.41	-1.78	4.33	-7.98	-17.13**	8.70	3.66	4.55	1.48
Fantum × Coker 139	3.66	3.45	5.53*	14.85*	10.13	26.09**	-1.23	6.07	2.96
Fantum × Aleppo 90	-3.57	-6.12*	0.69	0.00	-9.04	16.67**	26.19**	32.50**	16.92**
Fantum × Aleppo 124	5.00*	4.18	5.83*	8.83	6.21	11.59	-7.82	-6.43	-9.18
Fantum × Raqqa 5	2.37	1.71	4.67	-3.20	-6.80	5.80	10.24*	14.75*	2.96
Fantum × Aleppo 118	-4.05	-4.47	-2.96	14.98*	9.59	27.06**	11.19*	11.41*	7.72
Fantum × NIAB Kiran	1.66	1.38	3.56	-15.94**	-24.73**	0.00	2.73	7.20	4.06
Fantum × NIAB 414	-8.37**	-11.08**	-3.99	15.87*	14.94*	20.77**	6.45	9.48	6.27
Fantum × Deir ELzour 22	-5.14*	-7.08*	-1.59	-3.67	-6.88	4.83	-1.31	0.00	-2.93
Millinium × Lider	-2.93	-4.34	0.26	-5.58	-21.47**	18.36*	-2.54	6.11	-1.10
Millinium × Cherpan 432	-5.94*	-7.91**	-2.19	-33.85**	-38.14**	-6.77	14.55*	17.94**	9.93
Millinium × Coker 139	-0.93	-1.05	0.94	-12.57*	-23.08**	15.94*	6.74	17.16*	9.20
Millinium × Aleppo 90	-6.44*	-8.83**	-2.23	-33.85**	-38.78**	-7.72	16.30**	19.58**	5.52
Millinium × Aleppo 124	-1.38	-2.23	-0.51	-1.35	-17.95**	23.67**	13.04*	17.16*	9.20
Millinium × Raqqa 5	-3.83	-4.37	-1.59	-27.60**	-36.54**	-4.35	24.63**	27.05**	13.99*
Millinium × Aleppo 118	3.28	2.74	4.54	4.35	-7.69	39.13**	9.97*	12.02*	4.41
Millinium × NIAB Kiran	-4.06	-4.24	-2.19	-32.54**	-36.54**	-4.35	2.86	9.66	2.21
Millinium × NIAB 414	-6.11*	-8.81**	-1.54	1.15	-14.74**	28.51**	6.30	11.64*	4.06
Millinium × Deir ELzour 22	-3.98	-5.87*	-0.30	-26.24**	-35.58**	-2.90	12.49*	16.38*	8.47
Lider × Cherpan 432	-10.66**	-11.26**	-5.74*	-10.97*	-21.55**	2.90	-3.01	2.41	1.10
Lider × Coker 139	-8.85**	-10.06**	-5.74*	-14.42*	-19.84**	-8.22	3.40	4.18	14.34*
Lider × Aleppo 90	-9.84**	-10.87**	-4.41	27.40**	13.37*	45.41**	7.34	20.43**	6.27
Lider × Aleppo 124	-10.17**	-12.23**	-8.02**	21.74**	21.74**	21.74**	-3.60	1.10	1.10
Lider × Raqqa 5	-3.71	-4.58	0.00	26.25**	18.73**	34.78**	3.23	14.75*	2.96
Lider × Aleppo 118	-12.22**	-13.95**	-9.82**	18.12**	10.00	27.54**	-7.03	-0.75	-4.04
Lider × NIAB Kiran	-1.70	-2.94	1.71	-4.56	-16.36**	11.12	-14.59**	-12.88*	-8.07
Lider × NIAB 414	-3.95	-5.36*	2.19	17.34*	15.42*	19.32*	2.50	6.09	8.82
Lider × Deir ELzour 22	-10.41**	-10.89**	-5.62*	1.82	-3.86	8.22	2.19	7.37	6.99
Cherpan 432 × Coker 139	-4.86**	-6.74*	-0.94	9.35*	2.40	34.30**	-4.10	2.06	0.75
Cherpan 432 × Aleppo 90	-7.31**	-7.75**	-1.07	-27.74**	-28.54**	-6.28	13.68*	20.43**	6.27
Cherpan 432 × Aleppo 124	3.22	0.20	6.43*	6.17	-6.44	22.71**	-3.04	-2.41	-3.66
Cherpan 432 × Raqqa 5	-0.31	-1.86	4.24	-14.71**	-20.44**	4.35	13.16*	18.83**	6.62
Cherpan 432 × Aleppo 118	-2.96	-5.49*	0.39	-1.47	-7.18	21.74**	3.86	4.95	1.48
Cherpan 432 × NIAB Kiran	-7.34**	-9.12**	-3.47	-25.34**	-25.82**	-1.45	7.30	10.99*	9.57
Cherpan 432 × NIAB 414	-3.50	-4.29	3.34	-12.66*	-21.91**	2.42	1.92	3.91	2.58
Cherpan 432 × Deir ELzour 22	-6.77**	-6.64*	-1.11	-29.83**	-34.81**	-14.49*	16.77**	17.32**	15.82*
Coker 139 × Aleppo 90	-7.33**	-9.59**	-3.04	-11.04*	-15.82**	7.97	5.52	19.38**	5.34
Coker 139 × Aleppo 124	-11.22**	-12.10**	-10.33**	-29.73**	-34.18**	-24.64**	0.18	5.89	5.89
Coker 139 × Raqqa 5	-5.50*	-5.91*	-3.17	11.87*	11.39*	27.54**	-3.85	7.77	-3.31
Coker 139 × Aleppo 118	-5.01*	-5.63*	-3.73	-4.40	-5.00	10.14	1.77	9.51	5.89
Coker 139 × NIAB Kiran	-0.10	-0.17	1.97	-7.04	-13.46*	14.97*	-6.78	-4.18	1.10
Coker 139 × NIAB 414	-9.33**	-11.83**	-4.80	12.65*	7.18	22.71**	-3.44	0.71	3.31
Coker 139 × Deir ELzour 22	-7.57**	-9.27**	-3.90	4.68	3.80	18.84*	-8.71*	-3.32	-3.66
Aleppo 90 × Aleppo 124	0.48	-2.92	4.11	-2.64	-13.37*	11.12	8.59	15.83*	2.21
Aleppo 90 × Raqqa 5	-3.81	-5.76*	1.07	2.70	-3.20	24.16**	11.14*	12.08*	-1.10
Aleppo 90 × Aleppo 118	-0.27	-3.32	3.69	-21.66**	-25.42**	-4.35	8.15	13.33*	0.00
Aleppo 90 × NIAB Kiran	-0.06	-2.44	4.63	-16.00**	-17.45**	9.67	-0.95	8.75	-4.04
Aleppo 90 × NIAB 414	1.21	0.87	8.92**	-3.65	-12.99*	11.59	13.87*	23.13**	8.65
Aleppo 90 × Deir ELzour 22	-3.76	-4.36	2.57	-13.34*	-18.64**	4.35	17.41**	25.00**	10.30
Aleppo 124 × Raqqa 5	10.39**	8.83**	12.00**	5.21	-1.06	12.32	-0.58	5.11	-5.69
Aleppo 124 × NIAB Kiran	-0.81	-1.85	0.26	16.39**	2.00	35.51**	-3.93	-1.28	-1.28
Aleppo 124 × NIAB 414	-5.44*	-8.93**	-1.67	16.15*	14.26*	18.12*	-2.54	-1.28	-1.28
Aleppo 124 × Deir ELzour 22	-7.87**	-10.44**	-5.14*	15.91*	9.44	23.19**	6.08	6.27	5.89
Raqqa 5× Aleppo 118	7.58**	6.41*	9.52**	-0.84	-1.88	13.77*	10.06*	14.33*	2.58
Raqqa 5 × NIAB Kiran	-6.73**	-7.08*	-4.37	7.65	-0.19	32.61**	5.08	14.33*	2.58
Raqqa 5 × NIAB 414	-2.93	-5.20*	2.36	12.25*	7.24	21.74**	18.55**	27.05**	13.99*
Raqqa 5 × Deir ELzour 22	-1.27	-2.67	3.09	17.95**	17.45*	33.33**	6.01	11.88*	0.38
Aleppo 118 × NIAB Kiran	-3.21	-3.90	-1.84	-5.63	-11.64*	17.39*	9.10*	14.08*	10.30
Aleppo 118 × NIAB 414	-4.31*	-7.54**	-0.17	-3.52	-8.75	5.80	5.72	8.94	5.34
Aleppo 118 × Deir ELzour 22	7.47**	4.82*	11.02**	-7.40	-8.75	5.80	7.87	9.51	5.89
NIAB Kiran × NIAB 414	-3.18	-5.80*	1.71	-3.47	-14.18*	14.01*	10.25*	11.83*	14.71*
NIAB Kiran × Deir ELzour 22	-5.77*	-7.45**	-1.97	-14.96**	-21.46**	4.35	-10.75*	-8.12	-8.45
NIAB 414 × Deir ELzour 22	-7.70**	-8.57**	-1.29	40.94**	35.19**	52.17**	-17.09**	-15.87*	-16.17*
SE	**0.60**	**0.7**	**0.7**	**0.47**	**0.54**	**0.54**	**0.25**	**0.28**	**0.28**

*, and ** represent significant at the $p \leq 0.05$ and $p \leq 0.01$ probability levels, respectively

Conclusions

Uniform and superior hybrids seeds of commercial crops especially cotton are the critical textile industry standards. Heterosis exploitation in cotton is empirical and requires immediate efforts to cross-diverse cotton genotypes to identify the superior parents. From the findings of this study, it was concluded that a wide range of genetic variations was exhibited by different parent genotypes of cotton for all response variables under investigation, which was imparted to their hybrids. The highest number of hybrids with significant heterosis was observed for the earliness index and fiber elongation, while the lowest was observed for the fiber fineness. Hybrids, Fantum × Coker 139, NIAB 414 × Deir ELzour 22, Coker 139 × NIAB 414, and Coker 139 × Raqqa 5 exhibited desirable heterosis for different yield components and qualitative traits of cotton. So based on these findings, it might be inferred that these cross combinations could be utilized in future hybridization programs for the exploitation of heterosis followed by selection to boost the cotton seed yield and to develop new varieties having the higher genetic potential to produce high quality lint for textile industry.

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