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Evaluation of Combining Ability and Heterosis for some Yield and Fiber Quality Properties in Cotton (*G. barbadense* L.) Obtained by Half Diallel Mating Design

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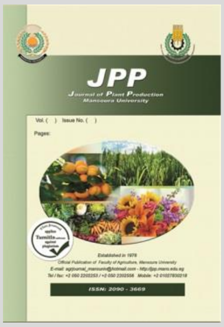

ABSTRACT

At Sakha Agricultural Research Station, Cotton Research Institute, Agricultural Research Center, Egypt, six cotton varieties belong to (*Gossypium barbadense* L.) growing seasons 2020 and 2021. The F_1 hybrids and six cotton varieties Giza 96, Giza94, Giza 92(Egyptian cotton) and Australy13, Karshenky and Pima S_7 (another varieties) were growing in 2021 season in a randomized complete blocks design (RCBD) with three replications. Obtained results showed that the mean squares of parents and crosses were highly significant for all traits under study. The mean squares due to general combining ability (GCA) and specific combining ability(SCA) were highly significant for all traits under study except lint percentage at specific combining ability. The crosses Giza 96 × Karshenky, Giza94 × Australy13 and Australy13 × Karshenky were significant desirable heterosis relative to mid and better-parent for most yield traits under study, while, the crosses Giza 96 x Pima S7 and Giza 92 × Karshenky were significant desirable heterosis relative to mid and better-parent for most fiber traits under study. Highest broad-sense heritability estimates was observed in case of seed cotton yield plant^{-1} with value of 96.81% and the lowest value was for lint percentage with value of 54.26%, while, narrow-sense heritability (h^2_n) was ranged from 5.62% for micronare reading to 58.17% for lint cotton yield/plant, respectively.In general, Australy 13 and Karshenky can be used in breeding programs for improving high yielding varieties, while Giza 92 and Giza 96 can be considered as excellent parents for the production of new varieties characterized with best fiber properties.

Keywords: Cotton, combining ability, Heterosis, Heritability.

INTRODUCTION

Improving cotton is of great significance for plant breeders who need more information about the genetic attitude of the economic traits of cotton. The main objective of cotton breeding programs in Egypt is to increase the yielding capacity and improve fiber properties of commercial cotton varieties. The selection of parents and crosses either for heterosis production or for pedigree breeding is based on knowledge of the nature and magnitude of the genotypic variances and their interactions with environments.

Diallel analysis is an effective biometric approach to identifying suitable parents and crosses through estimating general combining ability (GCA) and specific combining ability (SCA). GCA and SCA allow comparing the performance of investigated parents in different cross combinations. The genotypes that display high GCA reveal great capability to combine with other various genotypes and produce high-yielding progenies. By contrast, the genotypes that exhibit high SCA combine well only in certain crosses. Furthermore, high GCA reveals additive gene effects for the studied characters, and high SCA reveals nonadditive, dominant, and epistatic effects (Başal and Turgut, 2003; Qu *et al*., 2012; Mansour and Moustafa, 2016; Vasconcelos *et al*., 2018). Additionally, diallel analysis enables breeders to detect the most efficient selection method through estimating the genetic nature of evaluated qualitative and quantitative characters (Başal and Turgut, 2003; Salgotra *et al*., 2009). Chaudhary *et al*., (2019) found that the genotype NIAB-KIRN had additive gene action for seed index and seed cotton yield and proved to be a good combiner. While the cross PB-896 × PB-76 showed good SCA for seed cotton yield and cotton seed yield, revealing the importance of non-additive gene effects for such traits. The combination of PB-896 × FH-942 had significantly high heterosis for fiber and seed cotton yield. Abro *et al*., (2021) defined the line CRIS-342 and the tester variety NIA-Noori as the better general combiners. SCA with dominant gene effects in the cross CRIS-342 × NIA-Noori showed the potential for increasing the number of bolls plant^{-1}, boll weight and seed cotton yield plant^{-1}. Gnanasekaran and Thiyagu (2021) found that all traits had greater SCA variance than GCA variance, indicating the predominance of dominant gene action. Two parents were detected with high GCA for seed cotton yield and should be exploited in developing hybrids or recombinants. Three hybrids were identified as the best hybrids for seed cotton yield and one hybrid for fiber properties and recommended for heterosis breeding. AL-Hibbiny *et al*., (2020) and Mokadem *et al*., (2020) found highly significant and desirable heterosis relative to mid- and better-parents for most studied traits. High estimates of heritability in broad-sense (>50%) were detected for most of the studied traits. Chapara *et al*., (2020) noticed that the ratio of σ^2 GCA/σ^2 SCA was smaller than zero for all the

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characters indicating predominance of non-additive gene action (dominant or epistasis) in the inheritance of investigated traits except lint index. Said *et al.*, (2021) and Mabrouk *et al.*, (2018) found that broad-sense heritability showed high values for all the studied traits, while narrow-sense heritability had low values for most of traits.

This study was conducted for evaluating the genetic estimates:- heterosis, combining ability, gene action and heritability for yield, yield components and fiber properties among six parents and their fifteen cotton crosses resulted from half diallel mating design. This study is an attempt to provide useful information for cotton breeding programs and to product cotton crosses with diverse genetic backgrounds to enhance cotton yield and fiber traits.

MATERIALS AND METHODS

The genetic materials used in this research included six cotton varieties belong to *Gossypium barbadense* L. Three of them were Egyptian cotton varieties; Giza 96, Giza 94 and Giza 92, while other three foreign varieties were Australy 13 (Australian variety), Karshenky (Russian variety) and Pima S_7 (American Egyptian variety).

In the growing season of 2020, the six parents were planted and mated in half diallel to obtain 15 F_1 single crosses. The parental varieties were also self-pollinated to obtain enough seeds for further investigations.

In 2021 season, a randomized complete blocks design with three replications was carried out at Sakha Agricultural Research Station at Kafr El-Shiekh Governorate to evaluate 21 genotypes (six parents and their 15 half diallel crosses). Each plot was one row 4.0 m long, 0.6 m between the rows and plant to plant spacing of 0.4 m to insure 10 plants per row. Hills were thinned to keep a constant stand of one plant per hill at seedlings stage.

Agricultural practices were applied as normally recommended for ordinary cotton fields.

- The studied traits were Number of bolls plant^{-1} (NB/P), boll weight (BW. g), seed cotton yield plant^{-1} (SCY/P. g), lint cotton yieldplant^{-1} (LCY/P. g), lint percentage (L %), Seed index (SI. g), Lint index (LI. g), upper half means (UHM), micronaire reading (Mic), fiber strength (FS), uniformity index (UI) . All fiber properties tests were measured in the laboratories of the Cotton Technology Research Division, Cotton Research Institute.

Statistical analysis

Data of plot means were subjected to a regular statistical analysis of RCBD as outlined by Steel and Torrie (1980) to test the null hypothesis of no differences between various F_1 hybrids and their parental means. Least significant difference at 5 % level of probability (LSD at 5 %) was also used for means separation and comparison after significance.

The GCA effects of parents and SCA effects of F_1 crosses were calculated according to the method described by Griffing (1956) based on method 2, model 1 (fixed model) as also outlined by Singh and Chaudhary (1985).

Average heterosis for each F_1 cross was estimated as the deviation of F_1 mean from the mid-parents, and heterobeltosis was calculated as the deviation of F_1 mean from the better parent and expressed in percentages.

Significance of heterosis was determined using the least significant difference value (LSD) at 0.05 and 0.01 levels of probability according to the following equation suggested by Steel and Torrie (1980). Heritability was estimated in both broad (h^2_b%) and narrow (h^2_n%) senses from two formulas given by Allard (1960) and Mather (1949).

RESULTS AND DISCUSSION

- **Mean squares**

Results of the analysis of variance and the mean squares of all studied traits of the six parents and their 15 F_1 crosses are presented in Table 1. Results showed that the mean squares of the genotypes, parents and crosses were highly significant for all traits under study. The mean squares due to parents versus crosses were significant for No. of bolls plant^{-1}, seed cotton yield, lint cotton yield plant^{-1}, boll weight, seed index, fiber strength and uniformity index traits.

- **Combining ability analysis**

The analysis of variance for combining ability (Table 2) shows the mean squares of general combining ability (GCA) and specific combining ability (SCA) were highly significant for all traits under study except lint percentage at specific combining ability (SCA) revealed that significance of both additive and non-additive gene action for these traits. These results are in harmony with those reported by Abd El-Hadi *et al.* (2005), Khan *et al.* (2011), Imran *et al.* (2012) Ekinci and Basbag (2015), Mahrous (2018) and Gnanasekaran and Thiyagu (2021).

Table 1. Mean squares of analysis of variances of genotypes for yield components and fiber quality traits in cotton.

SOV	df	NB/P	SCY/P	LCY/P	L%	BW	SI	UHM	FS	MIC	UI
Replications	2	68.05	824.08**	137.84**	2.89	0.001	0.12	0.77	0.05	0.21	0.07
Genotypes	20	968.58**	9577.32**	1504.47**	4.51**	0.11**	0.63**	5.46**	0.91**	0.29**	3.23**
Parents (P)	5	1046.11**	9321.40**	1628.24**	6.12**	0.06**	0.87**	10.99**	0.49**	0.38**	7.77**
Crosses (C)	14	938.02**	9280.26**	1431.71**	4.21**	0.13**	0.42**	3.82**	0.98**	0.27**	1.57**
P *VS.* C	1	1008.72**	15015.76**	1904.18**	0.73	0.10**	2.37**	0.69	2.18**	0.09**	3.75**
Error	40	14.42	104.18	17.91	0.99	0.02	0.08	0.54	0.10	0.06	0.49

***, ** denote Significant and highly significant at 0.05 and 0.01 levels of probability, respectively.**

Table 2. Mean squares of analysis of variances of combining abilities for yield components and fiber quality traits in cotton.

SOV	df	NB/P	SCY/P	LCY/P	L%	BW	SI	UHM	FS	MIC	UI
GCA	5	865.48**	8210.09**	1397.43**	2.50**	0.05**	0.29**	4.80**	0.60**	0.12**	2.27**
SCA	15	141.98**	1519.89**	202.84**	1.17	0.03**	0.18**	0.83**	0.21**	0.09**	0.68**
GCA/ SCA	--	6.10	5.40	6.89	2.14	1.67	1.61	5.78	2.86	1.33	3.34
Error	40	4.81	34.73	5.97	0.33	0.01	0.03	0.18	0.03	0.02	0.16

***, ** denote Significant and highly significant at 0.05 and 0.01 levels of probability, respectively**

• **The mean performance of genotypes**

The mean performances of the six parents and their 15 F_1 crosses of all studied traits are presented in Table 3. The best mean performances were found for the parent Australy 13 for No. of bolls plant^{-1}, seed cotton yield, lint cotton yield plant^{-1} and lint percentage followed by the parents Giza 94 for boll weight and seed index, Giza 96 for upper half mean and uniformity index and Giza 92 for fiber strength and microniare reading.

Results revealed that the best F_1 crosses performances were Giza 94 x Australy 13 for No. of bolls plant^{-1}, seed cotton yield, lint cotton yield plant^{-1} and microniare reading, Giza 94 x Pima S_7 for boll weight and seed index and Australy 13 x Karshenky for lint percentage, while, the crosses Giza 96 x Giza 92 for upper half mean and fiber strength and Giza 96 x Australy 13 for uniformity index. Results showed that the parents Giza 96 and Giza 92 were the better mean performances for most fiber traits, while, Austrealy 13 gave high value for most yield traits under study.

• **Combining ability effects:**

Estimates of GCA effects are shown in Table 4. The parental genotype Giza 96 gave significant and positive (desirable) GCA effects for upper half mean and uniformity index while significant negative (desirable) GCA effects for microniare reading. The parent Giza 94 exhibited significant and positive (desirable) GCA effects for boll weight, seed index and uniformity index, The parent Giza 92 exhibited significant and positive (desirable) GCA effects for boll weight and fiber strength, while significant and negative (desirable) GCA effect for microniare reading were determined for this parent. The parents Australy 13 and Karshenky showed significant and positive (desirable) GCA effects for No. of bolls plant^{-1}, seed cotton yield, lint cotton yield plant^{-1} and lint percentage. The parent Pima S_7 recorded significant and positive (desirable) GCA effects for seed index.

Table 3. Mean performances of 6 parents and 15 F_1's crosses for yield components and fiber quality traits in cotton.

Genotypes		No.B/P	SCY/P, g	LCY/P, g	L%	BW, g	SI, g	UHM	FS	MIC	UI
Giza 96		32.08	105.93	38.47	36.31	3.30	10.23	37.00	9.75	3.98	87.70
Giza 94		42.09	144.07	56.68	39.37	3.43	11.57	34.63	9.45	4.18	86.03
Giza 92		48.47	160.43	59.34	37.01	3.31	10.20	33.37	10.32	3.68	84.47
Australy 13		78.98	255.03	101.11	39.66	3.23	10.23	31.93	9.18	4.75	83.83
Karshenky		73.44	221.73	86.39	38.97	3.02	10.33	31.90	9.32	4.28	83.53
Pima S_7		44.40	142.17	52.73	37.10	3.21	10.77	33.40	9.58	4.08	84.10
Giza 96 x Giza 94		42.13	148.93	56.57	38.00	3.54	11.10	34.33	9.62	3.82	86.17
Giza 96 x Giza 92		39.66	136.37	51.60	37.85	3.44	10.87	36.17	11.05	4.05	86.53
Giza 96 x Australy 13		61.90	198.70	73.74	37.17	3.21	11.17	34.13	9.55	4.05	86.90
Giza 96 x Karshenky		88.26	281.90	106.30	37.70	3.20	10.93	34.77	9.35	4.12	85.60
Giza 96 x Pima s7		41.02	142.30	53.91	37.89	3.47	10.80	34.30	10.62	4.02	84.37
Giza 94 x Giza 92		42.06	148.20	58.11	39.19	3.53	11.23	32.90	10.02	4.45	85.13
Giza 94 x Australy 13		95.39	314.60	117.17	37.25	3.30	10.90	33.70	9.88	3.52	85.57
Giza 94 x Karshenky		65.35	185.87	71.15	38.27	2.85	10.47	32.43	9.32	4.22	85.23
Giza 94 x Pima s7		50.40	179.07	66.36	37.02	3.57	11.60	34.40	10.48	4.18	85.57
Giza 92 x Australy 13		63.92	227.17	85.16	37.49	3.55	10.10	32.20	10.85	4.22	84.20
Giza 92 x Karshenky		57.08	181.57	65.49	36.09	3.18	11.20	35.00	9.42	3.88	85.63
Giza 92 x Pima S7		55.96	183.07	66.27	36.21	3.28	11.20	35.23	10.62	3.72	85.20
Australy 13 x Karshenky		78.62	277.13	113.59	40.98	3.53	10.83	32.53	9.68	4.78	85.03
Australy 13 x pima S7		71.47	235.93	89.52	37.95	3.30	11.47	33.33	9.82	4.08	85.17
Karshenky x pima S7		78.29	245.23	94.40	38.45	3.13	10.90	33.63	9.92	4.05	85.97
LSD at	0.05	1.43	3.84	1.59	0.37	0.05	0.11	0.28	0.12	0.09	0.26
	0.01	1.91	5.14	2.13	0.50	0.06	0.15	0.37	0.16	0.12	0.35

Table 4. General combining ability effects of parental genotypes for yield components and fiber quality traits in cotton.

Genotypes	No. of bolls plant^{-1}	Seed cotton yield plant^{-1}	Lint cotton yield plant^{-1}	Lint percentage	Boll weight
Giza 96	-9.98**	-31.47**	-12.79**	-0.51**	0.03
Giza 94	-4.68**	-13.37**	-4.83**	0.40*	0.06**
Giza 92	-7.67**	-21.82**	-9.51**	-0.56**	0.05*
Australy 13	14.03**	48.98**	20.01**	0.61**	0.02
Karshenky	12.18**	30.42**	12.80**	0.52**	-0.16**
Pima S_7	-3.88**	-12.73**	-5.68**	-0.45*	-0.004
LSD at 0.05	1.43	3.84	1.59	0.37	0.05
LSD at 0.01	1.91	5.14	2.13	0.50	0.06

***, ** denote Significant and highly significant at 0.05 and 0.01 levels of probability, respectively.**

Table 4. cont.

Genotypes	Seed index	Upper half mean	Fiber strength	Microniare reading	Uniformity index
Giza 96	-0.09	1.33**	0.05	-0.09*	0.96**
Giza 94	0.30**	-0.01	-0.13*	-0.02	0.30*
Giza 92	-0.13*	0.14	0.42**	-0.13**	-0.21
Australy 13	-0.14*	-0.92**	-0.14*	0.18**	-0.35**
Karshenky	-0.13*	-0.62**	-0.37**	0.11	-0.35**
Pima S_7	0.18**	0.08	0.17**	-0.06	-0.36**
LSD at 0.05	0.11	0.28	0.12	0.09	0.26
LSD at 0.01	0.15	0.37	0.16	0.12	0.35

***, ** denote Significant and highly significant at 0.05 and 0.01 levels of probability, respectively.**

Significant and favorable specific combining ability (SCA) effects were shown by some crosses for yield and fiber quality traits (Table 5). The results indicated that specific combining ability (SCA) effects of No. of bolls plant^{-1} were significant and positive (desirable) for crosses Giza 96 × Karshenky, Giza 94 × Australy 13, Giza 92 × Australy 13, Giza 92 x Pima S_7.and Karshenky ×Pima S_7. SCA effects of crosses Giza 96 × Karshenky, Giza 94 × Australy 13, Giza 94 x Pima S_7 Giza 92 × Australy 13, Giza 92 × Pima S_7 and Karshenky × Pima S_7 were significant and positive (desirable) for seed cotton yield plant^{-1}. SCA effects of crosses Giza 96 × Karshenky, Giza 94 × Australy 13, Giza 94 × Pima S_7, Giza 92 × Australy 13, Giza 92 × Pima S_7, Australy 13 × Karshenky and Karshenky × Pima S_7 were significant and positive (desirable) for lint cotton yield plant^{-1}. SCA effects for four crosses *i.e*. Giza 96 × Giza 92, Giza 96 × Pima S_7, Giza 94 x Giza 92 and Australy 13 x Karshenky were significant and positive (desirable) for lint percentage %. SCA effects of crosses Giza 96 x Giza 94, Giza 96 × Pima S_7, Giza 94 × Giza 92, Giza 94 ×Pima S_7 and Australy 13 × Karshenky were significant and positive (desirable) for boll weight. SCA effects of crosses Giza 96 x Giza 92, Giza 96 x Australy 13, Giza 96 × Karshenky, Giza 94 x Giza 92 , Giza 94 × Pima S_7, Giza 92 x Karshenky, Giza 92 x Pima S_7, Australy 13 x Karshenky and Australy 13 x Pima S_7 were significant and positive (desirable) for seed index. SCA effects of Giza 96 x Giza 92, Giza 94 x Australy 13, Giza 94 × Pima S_7, Giza 92 × Australy 13, Giza 92 × Karshenky and Giza 92 x Pima S_7 were significant and positive (desirable) for upper half mean. SCA effects of crosses Giza 96 x Giza 92, Giza 96 x Pima S_7, Giza 94 × Australy 13, Giza 94 × Pima S_7 , Giza 92 × Australy 13 and Australy 13 × Karshenky were significant and positive (desirable) for fiber strength, respectively. SCA effects of crosses *i.e.* Giza 96 x Giza 94 , Giza 96 × Australy 13, Giza 94 x Australy 13, Giza 92 × Australy 13, Giza 92 x Karshenky, Giza 92 × Pima S_7 and Australy 13 × Pima S_7 were significant and negative (desirable) for micronaire reading character. SCA effects of crosses *i.e*. Giza 96 × Giza 92, Giza 96 x Australy 13, Giza 92 × Karshenky, Giza 92 × Pima S_7, Australy 13 ×Pima S_7 and Karshenky x Pima S_7 were significant and positive (desirable) for uniformity index character.

Table 5. Specific combining ability effects of each cross for yield components and fiber quality traits in cotton.

Genotypes	No. of bolls plant^{-1}	Seed cotton yield plant^{-1}	Lint cotton yield plant^{-1}	Lint percentage	Boll weight
Giza 96 x Giza 94	-2.77*	-2.20	-0.30	0.21	0.14**
Giza 96 x Giza 92	-2.25*	-6.32	-0.59	1.02**	0.04
Giza 96 x Australy 13	-1.72	-14.78**	-7.96**	-0.83	-0.16**
Giza 96 x Karshenky	26.49**	86.97**	31.81**	-0.21	0.01
Giza 96 x Pima s7	-4.69**	-9.47**	-2.10	0.95**	0.13**
Giza 94 x Giza 92	-5.16**	-12.58**	-2.04	1.45**	0.11**
Giza 94 x Australy 13	26.47**	83.03**	27.52**	-1.66**	-0.09*
Giza 94 x Karshenky	-1.73	-27.15**	-11.29**	-0.54	-0.36**
Giza 94 x Pima s7	-0.60	9.20**	2.39*	-0.83**	0.20**
Giza 92 x Australy 13	26.47**	83.03**	27.52**	-1.66**	-0.09*
Giza 92 x Karshenky	-7.01**	-23.00**	-12.27**	-1.77**	-0.02
Giza 92 x Pima S7	7.94**	21.65**	6.97**	-0.69*	-0.08*
Australy 13 x Karshenky	-7.16**	1.77	6.31**	1.95**	0.36**
Australy 13 x pima S7	1.75	3.72	0.72	-0.11	-0.03
Karshenky x pima S7	10.42**	31.57**	12.81**	0.49	-0.02
LSD at 0.05	2.22	5.95	2.47	0.58	0.07
LSD at 0.01	2.96	7.97	3.30	0.78	0.10

***, ** denote Significant and highly significant at 0.05 and 0.01 levels of probability, respectively**

Table 5. cont.

Genotypes	Seed index	Upper half mean	Fiber strength	Microniare reading	Uniformity index
Giza 96 x Giza 94	0.03	-0.85**	-0.20*	-0.18**	-0.42*
Giza 96 x Giza 92	0.22*	0.83**	0.69**	0.16*	0.46*
Giza 96 x Australy 13	0.53**	-0.15	-0.26**	-0.15*	0.96**
Giza 96 x Karshenky	0.29**	0.19	-0.23*	-0.01	-0.34
Giza 96 x Pima s7	-0.16	-0.97**	0.50**	0.06	-1.56**
Giza 94 x Giza 92	0.20*	-1.10**	-0.16	0.50**	-0.29
Giza 94 x Australy 13	-0.12	0.75**	0.26**	-0.75**	0.28
Giza 94 x Karshenky	-0.57**	-0.81**	-0.08	0.02	-0.05
Giza 94 x Pima s7	0.25**	0.46*	0.55**	0.16**	0.29
Giza 92 x Australy 13	-0.12	0.75**	0.26**	-0.75**	0.28
Giza 92 x Karshenky	0.60**	1.60**	-0.52**	-0.20**	0.86**
Giza 92 x Pima S7	0.28**	1.15**	0.14	-0.20**	0.44*
Australy 13 x Karshenky	0.24**	0.20	0.30**	0.39**	0.40
Australy 13 x pima S7	0.56**	0.30	-0.11	-0.14*	0.54*
Karshenky x pima S7	-0.02	0.30	0.22	-0.10	1.34**
LSD at 0.05	0.17	0.43	0.18	0.14	0.41
LSD at 0.01	0.23	0.57	0.24	0.18	0.55

***, ** denote Significant and highly significant at 0.05 and 0.01 levels of probability, respectively**

Results indicated that the parents Giza 96 and Giza 92 were the better combiner for most fiber characters, while, Austrealy 13 and Karshenky gave the better combiner for most yield traits under study. The crosses Giza 96 ×Karshenky, Giza 94 × Pima S_7, Giza 92 × Pima S_7 and Australy 13 × Karshenky were significant and positive (desirable) for most yield traits under study, while, the crosses Giza 96 x Giza 92, Giza 94 x Australy 13, Giza 92 × Australy 13, Giza 92 x Karshenky and Giza 92 x Pima S_7 were significant (desirable) for most fiber traits. These results are in common agreement with the results obtained by many authors among them Abd El- Hadi *et al.* (2005), Imran *et al.* (2012), Simon *et al.* (2013), Sultan *et al* (2018), AL-Hibbiny *et al.* (2020) and Mokadem *et al*. (2020).

- **Heterosis**

The amounts of heterosis for all studied traits over the mid-parent (MP) and better-parent (BP) are presented in Tables 6 and 7. For the No. of bolls plant^{-1} character, 7 out of 15 studied crosses were found to be detect significant and positive desirable heterosis relative to mid-parent which ranged from 7.57% of Giza 94 × Karshenky to 68.80% of Giza 94 × Australy 13, four crosses showed significant and positive desirable heterosis relative to better-parent *i.e.* Giza 96 × Karshenky, Giza 94 × Australy 13, Giza 94 x Pima S_7 and Giza 92 × Pima S_7 with value of 20.18%, 20.78%, 13.52% and 15.45%, respectively. With respect to seed cotton yield plant^{-1}, six crosses out of 15 crosses showed significant and positive desirable heterosis relative to mid-parent which were ranged from 16.26% of Australy 13 x Karshenky to 68.68% of Giza 94 x Australy 13, three crosses showed significant and positive desirable heterosis relative to better-parent *i.e*. Giza 96 x Karshenky, Giza 94 × Australy 13 and Giza 94 x Pima S_7 with value of 27.13%, 23.36% and 24.29%, respectively. For lint cotton yield plant^{-1}, the results showed that eight crosses out of 15 crosses were significant and positive desirable heterosis relative to mid-parent which ranged from 6.14% of Giza 92 × Australy 13 to 61.89% of Giza 94 x Australy 13, six crosses showed significant and positive desirable heterosis relative to better-parent which ranged from 9.27% of Karshenky x Pima S_7 to 23.05% of Giza 96 x Karshenky. For lint percentage the results showed that two crosses out of 15 crosses were significant and positive desirable heterosis relative to mid-parent *i.e.* Giza 94 × Giza 92 and Australy 13 × Karshenky with value of 2.62% and 4.22%, respectively, three crosses out of 15 crosses were significant and positive desirable heterosis relative to better-parent *i.e.* Giza 96 × Giza 92, Giza 96 x Pima S7 and Australy 13 × Karshenky with value of 2.27%, 2.14% and 3.31%, respectively, Regarding to boll weight 10 crosses out of 15 crosses were found to be significant and positive desirable heterosis relative to mid-parent which ranged from 0.64% of Karshenky × Pima S7 to 13.01% of Australy 13 × Karshenky, eight crosses indicated significant and positive desirable heterosis relative to better-parent, which ranged from 2.06% of Australy 13 × Pima S7 to 9.28% of Australy 13 × Karshenky.

The seed index trait 13 crosses out of 15 crosses were found to be significant and positive desirable heterosis relative to mid-parent which ranged from 1.83% of Giza 96 × Giza 94 to 9.79% of Australy 13 × Pima S7, eight crosses indicated significant and positive desirable heterosis relative to better-parent, which ranged from 1.24% of Karshenky × Pima S7 to 9.12% of Giza 96 × Australy 13. For upper half mean the results showed that 10 cross out of 15 crosses were significant and positive desirable heterosis relative to mid-parent which ranged from 1.17% of Giza 94 × Australy 13 to 8.02% of Giza 92 × Karshenky, three crosses showed significant and positive desirable heterosis relative to better-parent *i.e.* Giza 92 × Karshenky, Giza 92 x Pima S7 and Australy 13 x Karshenky with value of 4.90%, 5.49% and 1.88%, respectively. With respect to fiber strength 10 crosses out of 15 crosses were found to be significant and positive desirable heterosis relative to mid-parent which ranged from 1.35% of Giza 94 × Giza 92 to 12.31% of Giza 96 × Giza 92, nine crosses showed significant and positive desirable heterosis relative to better-parent, which ranged from 2.43% of Karshenky x Pima S7 to 9.39% of Giza 94 × Pima S7. Regarding to micronaire reading 10 crosses out of 15 crosses were found to be significant and negative desirable heterosis relative to mid-parent which ranged from -1.44% of Giza 96 x Karshenky to -16.38% of Giza 96 × Australy 13, eleven crosses showed significant and negative desirable heterosis relative to better-parent, which ranged from -1.63% of Giza 96 x Pima S7 to -25.96% of Giza 96 × Australy 13. The uniformity index trait seven crosses out of 15 crosses were found to be significant and positive desirable heterosis relative to mid-parent which ranged from 1.39% of Giza 94 × Pima S7 to 2.57% of Karshenky x Pima S7, four crosses showed significant and positive desirable heterosis relative to better-parent, which ranged from 1.27% of Australy 13 × Pima S7 to 2.22% of Karshenky x Pima S7.

Results indicated that the crosses Giza 96 × Karshenky, Giza 94 x Australy 13 and Australy 13 × Karshenky were significant desirable heterosis relative to mid and better-parent for yield traits under study, while, the crosses Giza 96 × Pima S7 and Giza 92 x Karshenky were significant desirable heterosis relative to mid and better-parent for fiber traits under study. These results were in harmony with those obtained by Karademir and Gençer (2010), Attia (2014), Al-Hibbiny (2015), El- Fesheikawy *et al.* (2015), Sorour *et al.* (2015), Salem (2016) and Said *et al.* (2021).

Table 6. Heterosis relative to the mid-parent (MP) for yield components and fiber quality traits in the studied cotton hybrids.

Genotypes	No. of bolls plant^{-1}	Seed cotton yield plant^{-1}	Lint cotton yield plant^{-1}	Lint percentage	Boll weight
Giza 96 x Giza 94	13.62**	-119.15*	18.90**	0.40	5.30**
Giza 96 x Giza 92	-2.98	-0.32	0.20	0.76	2.75**
Giza 96 x Australy 13	22.80**	19.43*	15.40**	-2.43**	-3.39**
Giza 96 x Karshenky	60.43**	58.87**	55.41**	-1.49*	-1.92**
Giza 96 x Pima s7	-22.96**	-17.06*	-18.05**	-0.48	6.85**
Giza 94 x Giza 92	-7.12*	-2.66	0.17	2.62**	4.65**
Giza 94 x Australy 13	68.80**	68.68**	61.89**	-3.71**	-0.74**
Giza 94 x Karshenky	7.57**	-4.84	-6.23*	-1.24	-12.37**
Giza 94 x Pima s7	-12.31**	-3.04	-6.86*	-3.66**	10.08**
Giza 92 x Australy 13	0.30	9.35	6.14*	-2.21**	8.55**
Giza 92 x Karshenky	-14.76**	-14.52	-20.40**	-6.38**	-0.17
Giza 92 x Pima S7	-8.74**	-6.04	-11.52**	-5.18**	2.71**
Australy 13 x Karshenky	3.17	16.26*	21.16**	4.22**	13.01**
Australy 13 x pima S7	8.94**	14.36	11.79**	-1.63*	4.65**
Karshenky x pima S7	32.88**	34.78**	35.72**	1.10	0.64**
LSD at 0.05	5.43	14.59	6.05	1.42	0.18
LSD at 0.01	7.26	19.52	8.09	1.90	0.24

***, ** denote Significant and highly significant at 0.05 and 0.01 levels of probability, respectively**

Table 6. cont.

Genotypes	Seed index	Upper half mean	Fiber strength	Microniare reading	Uniformity index
Giza 96 x Giza 94	1.83**	-4.14**	0.17	-6.53**	-0.81
Giza 96 x Giza 92	1.87**	3.33**	12.31**	2.53**	0.54
Giza 96 x Australy 13	5.76**	-0.29	-1.29**	-2.41**	1.63**
Giza 96 x Karshenky	3.99**	2.96**	-2.64**	-1.44**	0.57
Giza 96 x Pima s7	2.32**	1.76**	10.59**	-3.47**	-0.68
Giza 94 x Giza 92	3.22**	-3.24**	1.35**	13.14**	-0.14
Giza 94 x Australy 13	2.19**	1.17*	2.42**	-16.38**	0.93
Giza 94 x Karshenky	-1.10**	-1.59**	-2.61**	-0.20	0.91
Giza 94 x Pima s7	9.23**	4.10**	9.54**	-0.32	1.39**
Giza 92 x Australy 13	-1.14**	-1.38*	11.28**	0.01	0.06
Giza 92 x Karshenky	9.21**	8.02**	-1.97**	-8.39**	2.01**
Giza 92 x Pima S7	7.87**	7.91**	10.59**	-11.51**	1.45**
Australy 13 x Karshenky	5.35**	1.93**	4.68**	5.90**	1.61**
Australy 13 x pima S7	9.79**	2.85**	4.87**	-6.61**	1.60**
Karshenky x pima S7	3.32**	3.01**	4.94**	-3.19**	2.57**
LSD at 0.05	0.41	1.05	0.44	0.34	1.00
LSD at 0.01	0.55	1.40	0.59	0.45	1.34

***, ** denote Significant and highly significant at 0.05 and 0.01 levels of probability, respectively**

Table 7. Heterosis relative to the better-parent (BP) for yield components and fiber quality traits in the studied cotton hybrids.

Genotypes	No. of bolls plant^{-1}	Seed cotton yield plant^{-1}	Lint cotton yield plant^{-1}	Lint percentage	Boll weight
Giza 96 x Giza 94	0.10	3.38	-0.20	-3.50**	3.40**
Giza 96 x Giza 92	-18.17**	-15.00	-13.04**	2.27**	3.82**
Giza 96 x Australy 13	-21.63**	-22.09*	-27.07**	-6.30**	-2.93**
Giza 96 x Karshenky	20.18**	27.13**	23.05**	-3.27**	-3.23**
Giza 96 x Pima s7	-7.62*	0.09	2.25	2.14**	5.15**
Giza 94 x Giza 92	-13.23**	-7.63	-2.08	-0.46	2.92**
Giza 94 x Australy 13	20.78**	23.36**	15.88**	-6.09**	-3.70**
Giza 94 x Karshenky	-11.02**	-16.18	-17.64**	-2.79**	-16.93**
Giza 94 x Pima s7	13.52**	24.29**	17.08**	-5.99**	4.09**
Giza 92 x Australy 13	-19.07**	-10.93	-15.78**	-5.49**	7.24**
Giza 92 x Karshenky	-22.28**	-18.11*	-24.19**	-7.40**	-3.92**
Giza 92 x Pima S7	15.45**	14.11	11.67**	-2.40**	-1.01**
Australy 13 x Karshenky	-0.45	8.67	12.34**	3.31**	9.28**
Australy 13 x pima S7	-9.51	-7.49	-11.46**	-4.33**	2.06**
Karshenky x pima S7	6.61	10.60	9.27*	-1.33**	-2.29**
LSD at 0.05	6.27	16.84	6.98	1.64	0.20
LSD at 0.01	8.38	22.53	9.34	2.20	0.27

***, ** denote Significant and highly significant at 0.05 and 0.01 levels of probability, respectively**

Table 7. cont.

Genotypes	Seed index	Upper half mean	Fiber strength	Microniare reading	Uniformity index
Giza 96 x Giza 94	-4.03**	-7.21**	-1.37**	-8.76	-1.75
Giza 96 x Giza 92	6.19**	-2.25**	7.11**	1.67	-1.33
Giza 96 x Australy 13	9.12**	-7.75**	-2.05**	-14.74	-0.91
Giza 96 x Karshenky	5.81**	-6.04**	-4.10**	-3.89	-2.39
Giza 96 x Pima s7	0.31	-7.30**	8.89**	-1.63	-3.80
Giza 94 x Giza 92	-2.88**	-5.00**	-2.91**	6.37	-1.05
Giza 94 x Australy 13	-5.76**	-2.69**	4.59**	-25.96	-0.54
Giza 94 x Karshenky	-9.51**	-6.35**	-1.41**	-1.56	-0.93
Giza 94 x Pima s7	0.29	-0.67	9.39**	0.00	-0.54
Giza 92 x Australy 13	-1.30**	-3.50**	5.17**	-11.23	-0.32
Giza 92 x Karshenky	8.39**	4.90**	-8.72**	-9.34	1.38
Giza 92 x Pima S7	4.02**	5.49**	2.91**	-8.98	0.87
Australy 13 x Karshenky	4.84**	1.88**	3.94**	0.70	1.43
Australy 13 x pima S7	6.50**	-0.20	2.43**	-14.04	1.27
Karshenky x pima S7	1.24**	0.70	3.48**	-5.45	2.22
LSD at 0.05	0.48	1.21	0.51	0.39	1.15
LSD at 0.01	0.64	1.62	0.68	0.52	1.54

***, ** denote Significant and highly significant at 0.05 and 0.01 levels of probability, respectively**

- **Genetic parameters**

Knowledge of gene action helps in terms of selecting desirable parents to be used in the hybridization and also in selecting suitable breeding programs for genetic improvement of various quantitative characters. Hence, the nature of gene action involved in the expression of the various quantitative characters is essential for a plant breeder to initiate a judicious breeding program. The genetic variance components and dominance degree ratio were calculated for all studied traits and shown in Table 8. The results showed that the non-additive of genetic variances were larger than the additive genetic variance with respect to all studied traits except, No. of bolls plant-1, seed cotton yield, lint cotton yield plant-1 and upper half mean traits. These results indicated that the non-additive effects play a major role in the expression of these traits, while additive effects had a minor role. These results are in harmony with those obtained by Mabrouk *et al.* (2018), Taha *et al.* (2018), AL-Hibbiny *et al.* (2020), Mokadem *et al.* (2020), Rakesh *et al.* (2016), Reddy *et al*. (2017), Chaudhary *et al*. (2019), Abro *et al.* (2021) and Moiana *et al*. (2021).

- **Heritability**

The results of heritability in broad- and narrow-sense are illustrated in Table 8. Broad sense heritability (h^2_b) values was high (>50%)for all the studied traits, the highest broad-sense heritability estimates was observed in case of seed cotton yield plant^{-1} with value of 96.81% and the lowest value was for lint percentage with value of 54.26%, these results indicated higher genotypic variance than environmental one and the presence of considerable amount of genetic variance in the studied materials that permit to practice efficient selection for superior progenies to improve the studied traits. On the other hand, narrow-sense heritability (h^2_n) was low to moderate for most of the studied traits, which may be ascribed to the opposite direction of additive and dominance variances, narrow-sense heritabilities were ranged from 5.62% for micronare reading to 58.17% for lint cotton yield plant^{-1}, respectively. The same findings were reported by Amein *et al.* (2013), Sultan *et al.* (2018), Balcha *et al.* (2019), Mokadem *et al*. (2020), Gnanasekaran and Thiyagu (2021) and Moiana *et al*. (2021).

Table 8. Estimates of variance components of combining ability and heritabilities for yield components and fiber quality traits in cotton.

Variance components and heritability	No.B /P	SCY /P	LCY /P	L %	BW	SI	UHM	FS	MIC	UI
σ^2_{GCA}	90.44	836.27	149.32	0.17	0.003	0.01	0.50	0.05	0.004	0.20
σ^2_{SCA}	137.18	1485.16	196.88	0.84	0.026	0.15	0.65	0.17	0.07	0.51
$\sigma^2_{GCA}/\sigma^2_{SCA}$	0.66	0.56	0.76	0.20	0.12	0.07	0.77	0.29	0.06	0.39
σ^2_A	180.87	1672.55	298.65	0.33	0.005	0.03	0.99	0.10	0.01	0.40
σ^2_D	137.18	1485.16	196.88	0.84	0.026	0.15	0.65	0.17	0.07	0.51
h^2_b	95.66	96.81	96.51	54.26	66.96	68.41	75.28	74.05	58.02	65.11
h^2_n	54.40	51.28	58.17	15.33	11.18	10.58	45.63	26.84	5.62	28.40

CONCLUSION

Dominance gene effects play the major role in controlling the genetic variance for all traits studied except, No. of bolls plant^{-1}, seed cotton yield plant^{-1}, lint cotton yield plant^{-1} and upper half mean traits. Heterosis over mid and better parent was significant desirable for most traits studied. Narrow-sense heritability (h^2_n) was low to moderate for most of the studied traits, which may be ascribed to the opposite direction of additive and dominance variances.

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تقدير القدرة علي التآلف وقوة الهجين لبعض صفات المحصول وصفات التيلة في أقطان الباربادنس بواسطة التحليل التبادلي

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الملخص

أجريت هذه الدراسة في محطة البحوث الزراعية بسخا – معهد بحوث القطن – مركز البحوث الزراعية – مصر خلال موسمي الزراعة ٢٠٢٠ و ٢٠٢١. تم استخدام ستة أصناف من القطن تنتمي جميعها إلي أقطان الباربادنس منها ثلاثة أصناف مصرية وهي جيزة ٩٦ و جيزة ٩٤ و جيزة ٩٢ وثلاثة أصناف أجنبية وهي استرالي ١٣ و كارشنكي و بيما س٧. تم التهجين بينهم بطريقة التزاوج التبادلي النصف دائري لانتاج ١٥ هجين للجيل الأول في موسم ٢٠٢٠ وفي موسم ٢٠٢١ تم تقييم الستة أصناف والخمسة عشر هجين في تجربة قطاعات كاملة عشوائية في ثلاث مكررات. وكانت أهم النتائج المتحصل عليها ما يلى: أشارت نتائج تحليل التباين لكل من التراكيب الوراثية والأباء والهجن وجود فروق معنوية لكل الصفات المدروسة. أما بالنسبة لتبايني القدرة العامة والقدرة الخاصة علي التآلف فكانت عالية المعنوية لكل الصفات المدروسة ماعدا صفة معدل الحليج بالنسبة للقدرة الخاصة علي التآلف. أشارت دراسة قوة الهجين إلي وجود قوة هجين مفيدة محسوبة بالنسبة لمتوسطات الأبوين وأفضل الأبوين وذلك لمعظم الصفات المدروسة، وقد أظهرت الهجن جيزة ٩٦ x كارشنكي وجيزة ٩٤ x استرالي١٣ واسترالي١٣x كارشنكي أعلي قيم لقوة الهجين بالنسبة لمتوسط الأبوين وأفضل الأبوين لمعظم الصفات المحصولية المدروسة. بينما أظهرت الهجن جيزة ٩٦ x بيما س٧ وجيزة ٩٢ x كارشنكي أعلي قيم لقوة الهجين بالنسبة لمتوسط الأبوين وأفضل الأبوين لمعظم صفات التيلة. كانت أعلي قيمة لدرجة التوريث بالمعني الواسع لصفة محصول القطن الزهر على النبات (٩٦,٨١%) بينما كانت أقل قيمة لصفة معدل الحليج (٥٤,٢٦%). كانت درجة التوريث بالمعني الضيق تتراوح بين ٥,٦٢% لصفة قراءة الميكرونير و ٥٨,١٧% لصفة محصول القطن الشعر على النبات. عموما فانه يمكن استخدام الصنفين استرالي ١٣ وكارشنكي في برامج التربية لتحسين وزيادة القدرة الانتاجية للأصناف الجديدة بينما يمكننا اعتبار الصنفين جيزة ٩٦ وجيزة ٩٢ كآباء متفوقة في برامج التربية للحصول علي أصناف جديدة عالية الجودة.