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Improving Egyptian Cotton (*Gossypium barbadense*) Using Double Crosses

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GENETIC materials used in the present investigation included five cotton varieties belong to (*Gossypium barbadense,* L.). Three of these varieties were long staple, BBB (big black boll) (P_1), Australian (P_2) and G97 (P_3) while the other two varieties were extra-long staple, Giza 92 (P4) and G96 (P5). Hybrids produced from these parents and the parents were evaluated in Sakha Agricultural Research Station, Kafr Al Sheikh Governorate, Egypt. Studied traits were; boll weight, number of bolls/plant, lint percentage, seed cotton yield, lint cotton yield, first fruiting node, days to first flower appearance, duration of the boll maturation, upper half mean (U.H.M), fiber strength and Micronaire value. Difference between single crosses and double crosses (DC) was highly significant for most studied traits. GCA mean squares in all studied traits were significant for F_1 except for days to first flower and fiber fineness (micronaire reading). GCA mean squares were significant for DC except for lint%, fiber length and days to first flower. A very important issue of double-cross hybrids is the arrangement of parents, i.e., order effect, in the hybrids.

Keywords: Combing ability, Double crosses, Heritability, *Gossypium barbadense*, Order effect, Single crosses.

Introduction

Cotton (*Gossypium* spp.) commonly called ‘White Gold’ that plays a vital role in economic growth by providing substantial employment and making significant contributions to export earnings.

Selection of the appropriate parents provides successes for cotton breeding program. Moreover, for hybridization program, there is a need of the information about combining ability, which helps for selection superior parents. Combining ability analysis is considered a tool to differentiate good and poor combiners, followed by selection of appropriate crosses. One of the techniques widely used for this purpose in different crops, including cotton, is diallel analysis (Hayman, 1954; Griffing, 1956; Dabholkar, 1992; Giri et al., 2020). Diallel mating design is a way to identify superior genotypes and promising recombinants produced through partitioning the entire genetic variability of each trait into general combining ability (GCA) and specific combining ability (SCA) as defined by Sprague & Tatum (1942). Choosing appropriate parents and hybrids based on their combining ability estimates has been widely used by plant breeders (Hamed & Said, 2021; Manonmani et al., 2020).

Heritability plays an important role in informing us how much a phenotypic attribute is contributed by genes in a population. Similarly, association of heritability with selection response helps in understanding the mode of inheritance of various quantitative traits Kumbhar et al. (2020). Heritability values provide information about extent of transmission of traits to subsequent generation and response to selection (Yar et al., 2020). It was obvious from many researches that high heritability represents greater selection response; therefore, traits selected on the base of high heritability makes the improvement easier. If environmental influence is small as compare to genetic differences, the selection will be more effective.

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Quadriallel analysis has some advantage over other designs in providing the information on the order effects of parents in double-cross hybrids. Order in which the parents go into a double cross hybrid is a deciding factor for its high or low performance (Singh & Chaudhary, 1977; Chaudhary, 1984).

The main objectives of this study were to evaluate the general combining ability of parents, specific combining ability of hybrids and importance of order effects for yield in double crosses of cotton in order to select the superior cross combination for yield, yield components and fiber quality traits.

Materials and Methods

Present study was carried out during the three growing seasons 2016, 2017 and 2018. The experiments were conducted in the Agriculture Research Station faculty of Agriculture, Cairo University at first and second seasons and at sakha research station, Kafr Al Sheikh Governorate, Egypt in the third season. Names, pedigree, origin and Characteristics of the parental cotton genotypes are presented in Table 1.

First season

In the first season 2016, the five parents were planted and mated in a diallel mating design excluding reciprocals to obtain 10 single crosses. Seeds from each parental genotype were sown in two rows at three replicates. The row was 7 meters long, 60cm apart and distance between hills 70cm, the hills were thinned to one plant. Crossing process was made between the parents at flowering stage.

Second season

In the second season 2017, F_1 single crosses were grown to mate in a diallel mating design to produce double cross seeds with the restriction that no parent should appear twice in the same double cross combination to obtain 15 double crosse (number of double crosses = P (P-1) (P-2) (P-3)/8 where, P: is equal to number of parental genotypes).

Third season

In the third season 2018, the genetic material were used in these experiments consisted of 30 genotypes (the five parental genotypes, 10 F_1`s single crosses and 15 double crosses). The experimental design used was a randomized complete blocks design in first and second season with three replicates while alpha lattice design (5 x 6) was used in third season. Each plot consisted of two rows. The rows were 4 meters long and 65cm apart. Hills were spaced at 20cm within rows and seedlings were thinned at two plants/hill. All cultural practices were followed throughout the growing season as usually done with ordinary recommendations for cotton culture.

The studied traits

Earliness traits

a. First fruiting node of first sympodium (F.F.N)
b. Days to first flower appearance (D.F.F)
c. Duration of the boll maturation (day).

Yield and yield component traits

a. Seed cotton yield/feddan
b. Lint cotton yield/feddan.
c. Boll weight (g).
d. Number of open bolls/plant.
e. Lint percentage (%).

TABLE 1. Names, pedigree, origins and characteristics of the parental cotton genotypes

Genotypes	Pedigree	Origin	Characteristics *
Australian(p_1)	Not available	Australian	It characterized by high yielding earliness and good fiber traits
BBB (p_2)	BBB	Australian	The long staple characterized by big boll and black
G97 (p_3)	((G89 x G86 x Karshenky) xG94)	Egyptian	It characterized by high early maturity and leaves drop at the end of season.
G92 (p_4)	G84 x (G74 xG68)	Egyptian	An extra long staple characterized by lint length (35.2 m) and Pressley (11.3)
G96 (p_5)	G84×PimaS6	Egyptian	Long staple germplasm. It is characterized by earliness, high yield and outstanding component traits.

* Source: Cotton Res. Dept., Agric. Res. Center (ARC), Egypt, G: Giza.

Fiber properties

Fiber properties were measured using HVI according to (ASTM D-4605-86)

a. Upper half mean (U.H.M): Measured by HVI in (mm).
b. Fiber strength (F.S): Measured by HVI in gram/ tex units
c. Micronaire value (Mic): Fineness was expressed as micronaire instrument reading. The character were measured with micromat instrument. ASTM D-3818-98.

Double crosses (quadriallel)

Statistical model

A double cross or a quadriallel is a product of four parent, for instance (A x B) (C x D). Taking 'P' as the number of parents, all possible double crosses would be P (P – 1) (P – 2) (P – 3) /8. The theoretical aspect of quadriallel analysis has been dealt.

Various components of variance, viz., additive, dominance and interaction between them are worked out. This technique also gives information on the order in which parents should be crossed for obtaining superior recombinants.

Analysis of double cross data is carried out according to the procedure outlined by Singh and Chaudhary (1985) as shown in Table 2. Considering Y(ij)(kl)m as the measurement recorded on a double cross G(ij)(kl)m the statistical model takes the following form:

Y(ij)(kl)m = μ + rm + G (ij) (kl) + e (ij) (kl) m

Combining ability analysis

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 I (fixed model) as outlined by Singh & Chaudhary (1985).

The form of the analysis of GCA and SCA and the expectations of mean squares are presented in Table 3. In general, GCA of a line is the average value of the line in its all hybrid combinations and it is a measure of additive genetic variance.

Estimates of heritability and degree of dominance

Estimates of heritability were determined according to the following equations of Mather & Jinks (1982).

Heritability in narrow sense (H^2n.s%):$\sigma^2A/(\sigma^2A+\sigma^2D+\sigma^2e)$ .100

Heritability in broad sense (H^2b.s^2%):$(\sigma^2A+\sigma^2D)/(\sigma^2A+\sigma^2D+\sigma^2e)$.100

TABLE 2. Form of the analysis of variance of the double crosses and expectation of mean squares

S.O.V.	d.F	S.S	M.S
Replications	r-1	(8Y2 ….. m) /(r p p1 p2 p3) - C.	R
Total	3r6 C4- 1	∑Y2 (i j) (kl) m – C	
Hybrids	36 C4- 1	(∑Y2 (i j) (kl) /r) – C	H
Error	(r-1) (36 C4- 1)	M - R - H	E
1-line general	P1	(2∑Y2 i…. / r p2 p3 p4) – (4p1 / p4) C	G
2- line specific	P P3 / 2	(2Y2 ij... /3r p4 p5) – (6pp2 / p4p4) C –(3p3 / p5) G	S2
2- line arrangement	P P3 / 2	(2∑Y2 (i j) (. .). /r p1 p2) +(∑Y2 (i .) (j .). /r p1 p2) - (2Y2 ij... /3r p1 p2)	T2
3- line arrangement	P P2 P4/ 3	(Y2 (i j) (k .) . /r p3) - (∑Y2 ijk .. /3r p3 – (2p2/ p3) T2	T3

s.o.v: source of variace, d.F: degees of freedom, S.S:sum of squares, MS: mean squares

TABLE 3. Form of the analysis of variance of the diallel mating design and expectations of mean squares

S.V.	d.f	M.S	E.M.S
GCA	p-1	M_g	$\sigma^2 + (p+2)\left(\frac{1}{P-1}\right)\sum g_i^{\,2}$
SCA	p (p-1)/2	M_s	$\sigma^2 + \frac{2}{P(P-1)}\sum\sum S_{ij}^{\,2}$
Error	(g-1)(r-1)	$M_{\acute{e}}$	$\sigma^2 e$

GCA (general combining ability), SCA (specific combing ability), p (parents), g (genotypes), r (replicates)

The estimated parameters were used in calculating several ratio which added more information about character studied in the used materials these ratio are:

Mean degree of dominance in F_1 = $[1/4(H1/D)^{1/2}$
Mean degree of dominance in DCH = $[1/4(D/A)^{1/2}$

Results and Discussion

Earliness traits

Analysis of variance

Table 4 revealed that differences among hybrids were highly significant (P≤ 0.01) for all earliness traits. Results also showed that line general was highly significant (P≤ 0.01) for all traits suggesting the presence of the additive variance in the inheritance of these traits subsequently selection would be efficient in improvement these traits. Also result in Table 4 showed that 2- line arrangement was highly significant (P≤ 0.01) for all traits, except days to opening 1st boll which was significant only (P≤ 0.05) suggesting the presence of the non-additive variance in the inheritance of these traits. Also, 3- Line arrangement was highly significant (P≤ 0.01) for all traits except for days to opening first boll which was significant only (P≤ 0.05) indicating the contribution of the additive by dominance interaction including all three factors or higher order interaction except all dominance types.

Similar trend of results were detected by El-Feki et al. (2012) whom found highly significant 2- line arrangement and 3- Line arrangement for earliness traits and indicated that the order in which the parents were involved in double crosses was important.

General and specific combining ability

Results in Table 5 showed that GCA mean squares were significant for both F_1 and DC in all earliness traits except for days to first flower. SCA mean squares were highly significant only for F1 in two traits first fruiting node and days to first flower. GCA/SCA ratio revealed that GCA was higher than SCA in F1 for duration of the boll maturation while in DC, it was higher than SCA for first fruiting node and days to opening 1st boll

Results in Table 6 showed that P1 and P2 had highly negative significant general combining ability effects for first fruiting node and days to first flower in F1while P2 had highly negative significant general combining ability effects for first fruiting node in DC indicating that these parents are good combiners for these traits. With respect to duration of the boll maturation, P_1 and P_5 had highly negative significant general combining ability effects in F1 while in DC hybrids, P_3 and P_5 had highly negative significant general combining ability effects. Yehia & El-Hashash (2019) studied GCA effects for parents and found that GCA effects revealed that lines Pima S6, Suvin, G.90, Aust. 12 and tester C.B.58 proved to be a good general combiners for earliness traits.

TABLE 4. Analysis of variance of double cross hybrids for earliness traits

S.V.	d.f.	Position of 1st fruiting node	Days to 1st flower	Days to opening 1st boll
Hybrid	14	1.53**	54.19**	1.80**
1- line general	4	1.60**	14.52**	2.31**
2- Line arrangement	5	0.74**	62.23**	1.58*
3- Line arrangement	5	2.27**	77.92**	1.62*
Error	28	0.26	0.37	.37

*, ** Significant at 5 and 1% level of probability, respectively.

TABLE 5. Analysis of SCA and GCA for F_1 hybrids and double crosses (DC) for earliness traits

S.V	Position of 1st Fruiting node		Days to 1st flower		Days to opening 1st boll	
	F1	DC	F1	DC	F1	DC
GCA	0.41*	0.56*	3.66	2.62	0.75*	1.92*
SCA	0.59**	0.23	14.58**	6.13	0.20	0.46
Error	0.14	0.52	2.39	9.04	0.19	0.58
GCA/SCA	0.69	2.45	0.25	0.43	3.73	4.16

GCA (general combining ability), SCA (specific combing ability)
*, ** Significant at 5 and 1% level of probability, respectively.

TABLE 6. General combining ability effects for and double crosses (DC) hybrids for earliness traits

Parents	Position of 1st fruiting node		Days to 1st flower		Days to opening 1st boll	
	F1	DC	F1	DC	F1	DC
P1	-0.190*	0.111*	-0.47**	0.780**	-0.29**	0.040**
P2	-0.190*	-0.153**	-0.56**	-0.090	-0.100	0.090**
P3	0.238**	0.028	0.200	-0.040	0.52**	-0.070**
P4	-0.143	-0.056	0.50**	-0.170	0.100	0.120**
P5	0.286**	0.069	0.33*	0.120	-0.24*	-0.180**
SE(gi)	0.093	0.050	0.180	0.260	0.110	0.001
L.S.D 0.05	0.1581	0.0851	0.3062	0.4423	0.1871	0.0017
L.S.D 0.01	0.2292	0.1234	0.4441	0.6414	0.2714	0.0025

* and ** Denote significant differences at 0.05 and 0.01 levels, respectively.

Genetic components

The results in Table 7 indicated that the additive gene variance (σ^2A) were negative for all earliness traits except for duration of boll maturation, this results revealed that the additive gene variance equivalent to zero for all earliness traits. Results in Table (7) revealed that broad sense heritability was high for all traits in both F_1 and DC except for DC in first fruiting node. Soliman (2014) revealed that the magnitudes of dominance genetic variance (σ^2D) were positive and larger than those of additive genetic variance ($\sigma2A$), for most studied traits. Estimates values of broad sense heritability for earliness traits were larger than their corresponding of narrow sense heritability.

Two line arrangement

Results in Table 8 cleared two line arrangements in earliness traits. With regard to first fruiting node, p2 * p4 followed by p2 * p3 were the best combinations in 2-line general effects type while p1 * p5 was the worst not only for its positivity but also it was the highest value. For 2-line specific effect of (ij) (--) type, p1 * p3 followed by p2 * p5 had the highest values while p1 * p2 was positive and high value. Two combinations p1 * p2 followed by p1 * p5 recorded negative and highest values in 2-line of (i-) (j-) type.

Regarding days to first flower, two combinations p1 * p5 followed by p1 * p4 had the highest values in 2-line general effects type while p2 * p3 had positive and highest value. In 2-line specific effect of (ij) (--) type, p3 * p5 followed by p1 * p2 recorded the highest values while p2 * p5 was high and positive value. In 2-line of (i-) (j-) type, p2 * p5 followed by p3 * p4 recorded negative and the highest values.

Regarding days to opening 1st boll p3 * p5 followed by p1 * p5 had the highest values in 2-line general effects type while p2 * p4 had positive and highest value. p1 * p3 followed by p2 *p4 recorded the highest value in 2-line specific effect of (ij) (--) type while p1 * p2 was the worst. While the two combinations p1 * p2 followed by p3 * p4 recorded negative and highest values in 2-line of (i-) (j-) type, on the other hand p1 * p3 was the worst compination. El-Feki *et al*. (2012) studied double crosses hybrid and showed that the parents {Australian (P1), BBB (P2)},{Karshenky (P3) and Suvin (P5)} and {BBB (P2) and Giza 70 (P4)} had highest negative of 2-lines general effect.

TABLE 7. Genetic components for F_1 and double crosses (DC) hybrids for earliness traits

S.V	Position of 1st fruiting node		Days to 1st flower		Days to opening 1st boll	
	F1	DC	F1	DC	F1	DC
σ^2_A	0	0	0	0	0.16	0.36
σ^2_D	0.45	0.05	14.05	6.01	0.01	0.00
H_n^2%	-	10.21	-	-	29.03	48.58
H_b^2%	51.11	21.25	82.03	54.74	45.88	99.8

σ^2_A (Additive), σ^2_D (Dominance), H_n^2% (Hertability in narrow sense), H_b^2% (Hertability in broad sense)

TABLE 8. Two line interaction effects of i and j due to particular arrangement and its specific arrangement effects irrespective of arrangement for earliness traits

Combinations	Position of 1st fruiting node			Days to 1st flower			Days to opening 1st boll		
	Ij	(ij) (..)	(i.) (j.)	Ij	(ij) (..)	(i.) (j.)	Ij	(ij) (..)	(i.) (j.)
p1 * p2	-0.01	0.28	-0.14	0.11	-3.1	1.55	0.04	0.44	-0.22
p1 * p3	0.05	-0.46	0.23	-0.09	1.56	-0.78	-0.01	-0.67	0.33
p1 * p4	0.02	-0.07	0.04	-0.12	0.81	-0.4	0.05	0.3	-0.15
p1 * p5	0.06	0.26	-0.13	-0.13	0.73	-0.36	-0.05	-0.07	0.04
p2 * p3	-0.04	0.11	-0.06	0.17	-0.09	0.05	0.01	0.04	-0.02
p2 *p4	-0.07	-0.11	0.06	0.14	-0.88	0.44	0.07	-0.44	0.22
p2 * p5	-0.03	-0.28	0.14	0.13	4.07	-2.03	-0.03	-0.04	0.02
p3 * p4	-0.01	0.26	-0.13	-0.06	1.7	-0.85	0.02	0.33	-0.17
p3 * p5	0.03	0.09	-0.05	-0.07	-3.17	1.58	-0.09	0.3	-0.15
p4 * p5	0.00	-0.07	0.04	-0.09	-1.63	0.81	-0.02	-0.19	0.09

Ij, (ij) (..), (i.) (j.) 2-line interaction effect of lines i and j

Three line arrangement

Table 9 showed the three line arrangement in earliness traits. Regarding first fruiting node, results showed that (P3xP4) (P1) followed by (P1xP2) (P3) and (P3xP4) (P2) were the best combinations in specific order of three lines type (ij) (k.), while (P1xP4) (P3.) was the highly positive combination so it was the worst. The combinations (P2xP3) (P4) followed by (P2xP4) (P5) were the best without respect to arrangement (ijk type).

With respect to days to first flower, (P2xP5) (P3) followed by (P3xP4) (P2) and (P1xP3) (P5) were the best combinations according to specific order of three lines type. Without respect to arrangement (ijk type), the combinations (P1xP4) (P5) followed by (P1xP3) (P5) and (P1xP3) (P4) were the best combinations for arrangement (ijk type).

Considering duration to boll maturation, the best combinations according to specific order of three lines type were (P1xP2) (P5) and (P3xP5) (P1) followed by (P1xP4) (P3) and (P4xP5) (P2). While the combinations (P1xP3) (P5.) followed by (P2xP3) (P5.) and (P3xP4) (P5.) were the best without respect to arrangement. El-Feki et al. (2012) revealed that in all possible combinations without respect to arrangement (ijk) the best triple was ($P_3P_5P_6$) followed $P_1P_2P_4$, $P_1P_2P_5$ and $P_1P_2P_3$ and $P_2P_4P_5$.

Four line arrangement

The 4-line interactions with respect to particular arrangement of the parents in double crosses are shown in Table 10. Considering the general effect of set of any four parents in first fruiting node, it is clear that parents (P_1xP_3) (P_4xP_5) followed by (P_2xP_3) (P_4xP_5) formed the best combination followed by the combination (P_1xP_2) (P_3xP_4). Respecting days to first flower, the best combination was (P_1xP_3) (P_4xP_5) which had highest specific with value. Regarding days to opening 1st boll, the combinations (P1xP2) (P3xP5) and (P1xP3) (P4xP5) were the highest and negative specific effect followed by the combination (P_2xP_3) (P_4xP_5). As regarded from the results the combination (P_1xP_3) (P_4xP_5) was the best combination in all earliness traits. These results a given confirm that the order in which the parents go into a double hybrids is deciding factor of high or low performance. El-Feki et al. (2012) mentioned that parents (Australian, BBB,), (Australian, BBB, G70, suvin), (Australian, Karshenky, suvin and G93), (Australian, G70, suvin and G93) exhibited the best effected to forming the double crosses for position of first node, for days to first flower, days to first boll

Yield and yield components

Analysis of variance

Results in Table 11 show that line general was highly significant ($P \leq 0.01$) only for boll weight and No. of bolls/plant suggesting the presence of the additive variance in the inheritance of these traits subsequently selection would be efficient in improvement these traits, whereas it was significant ($P \leq 0.05$) only for seed cotton yield/ kentar. Meanwhile, line general was insignificant for lint cotton yield/kentar and lint%. Also result in Table 11 showed that 2-line arrangement was highly significant (P≤0.01) for all traits except for lint percentage (L%) suggesting the presence of the non-additive variance in the inheritance of these traits. Table 11 also revealed that 3-line arrangement was highly significant (P≤0.01) for all traits except for lint percentage (L %) indicating the contribution of the additive by dominance interaction including all three factors or higher order interaction except all dominance types. Similar results reported with El.Feki et al. (2012) and El-Fesheikawy et al. (2018).

TABLE 9. Three line interaction effects of i , j and k due to particular arrangement and its specific arrangement effects irrespective of arrangement for earliness traits

Combinations	Position of 1st fruiting node		Days to 1st flower		Days to opening 1st boll	
	(ij)(k-)	i,j and k	(ij)(k-)	i,j and k	(ij)(k-)	i,j and k
$(P_1xP_2)(P_3.)$.	-0.241	0.002	-0.237	0.094	0.130	0.020
$(P_1xP_2)(P_4.)$.	-0.093	-0.007	1.417	0.068	-0.185	0.085
$(P_1xP_2)(P_5.)$.	0.037	0.002	1.917	0.060	-0.389	-0.017
$(P_1xP_3)(P_2.)$.	0.037		-0.154		-0.037	
$(P_1xP_3)(P_4.)$.	0.000	0.011	0.617	-0.134	0.148	0.030
$(P_1xP_3)(P_5.)$.	0.074	0.020	-2.022	-0.143	0.556	-0.072
$(P_1xP_4)(P_2.)$.	0.130		0.544		0.204	
$(P_1xP_4)(P_3.)$.	0.278		-1.822		-0.296	
$(P_1xP_4)(P_5.)$.	0.000	0.011	0.470	-0.169	-0.204	-0.007
$(P_1xP_5)(P_2.)$.	-0.019		-1.939		0.056	
$(P_1xP_5)(P_3.)$.	-0.093		2.839		-0.167	
$(P_1xP_5)(P_4.)$.	-0.111		-1.630		0.185	
$(P_2xP_3)(P_1.)$.	0.204		0.391		-0.093	
$(P_2xP_3)(P_4.)$.	0.111	-0.017	-1.219	0.126	0.130	0.048
$(P_2xP_3)(P_5.)$.	-0.093	-0.007	0.920	0.117	-0.074	-0.054
$(P_2xP_4)(P_1.)$.	-0.037		-1.961		-0.019	
$(P_2xP_4)(P_3.)$.	0.056		3.643		0.019	
$(P_2xP_4)(P_5.)$.	0.056	-0.017	-0.804	0.091	0.444	0.011
$(P_2xP_5)(P_1.)$.	-0.019		0.022		0.333	
$(P_2xP_5)(P_3.)$.	0.074		-3.452		-0.130	
$(P_2xP_5)(P_4.)$.	-0.056		-0.637		-0.167	
$(P_3xP_4)(P_1.)$.	-0.278		1.206		0.148	
$(P_3xP_4)(P_2.)$.	-0.167		-2.424		-0.148	
$(P_3xP_4)(P_5.)$.	-0.074	0.002	-0.481	-0.111	-0.333	-0.044
$(P_3xP_5)(P_1.)$.	0.019		-0.817		-0.389	
$(P_3xP_5)(P_2.)$.	0.019		2.531		0.204	
$(P_3xP_5)(P_4.)$.	0.148		1.452		-0.111	
$(P_4xP_5)(P_1.)$.	0.111		1.159		0.019	
$(P_4xP_5)(P_2.)$.	0.000		1.441		-0.278	
$(P_4xP_5)(P_3.)$.	-0.074		-0.970		0.444	

TABLE 10. Specific four line interaction with respect to arrangement for earliness traits

Combinations	Position of 1st fruiting node	Days to 1st flower	Days to opening 1st boll
(P_1xP_2) (P_3xP_4)	-0.07	0.15	0.18
(P_1xP_2) (P_3xP_5)	0.06	0.13	-0.12
(P_1xP_2) (P_4xP_5)	-0.03	0.05	0.07
(P_1xP_3) (P_4xP_5)	-0.15	-0.56	-0.09
(P_2xP_3) $(P_4xP_{5)}$	-0.11	0.22	-0.04

TABLE 11. Analysis of variance of double cross hybrids for yield and its component traits

S.V.	Df	SCY/k	LCY/k	L%	BW	No. B/P
Hybrid	14	12.50**	13.49**	6.41	0.45**	86.990**
1-line general	4	2.70*	3.00	7.88	0.54**	32.522**
2- line arrangements	5	25.38**	26.37**	9.00	0.24**	100.756**
3- line arrangements	5	7.47**	8.99**	2.65	0.58**	116.800**
Error	44	0.81	1.87	3.96	0.02	0.562

* and ** Significant at P< 0.05 and P< 0.01 levels of significant, respectively

General and specific combining ability

Table 12 showed partitioning of genetic variance into GCA and SCA for both F1 and DC. Results revealed that, GCA mean squares were highly significant (P≤0.01) for F1 and DC in all yield traits except for Lint% which was insignificant with DC. Specific combining ability (SCA) mean squares were highly significant (P≤0.01) for F1 and DC in all yield traits except for Lint% with F1 and No. of bolls/plant with DC. GCA/SCA ratio revealed that GCA was higher than SCA in F1 for seed cotton yield, lint cotton yield, Lint % and boll weight while in DC; it was higher than SCA for seed cotton yield and No.of bolls/plant.

Results in Table 13 showed the general combining ability effects for yield and yield components traits. The data indicated that P1 and P3 had positive significant general combining ability effects for seed cotton yield per feddan in F1 while in DC, P4 had positive significant general combining ability effects indicating that these parents are good combiner for this trait. For lint cotton yield per feddan, P3 had positive significant general combining ability effects in F1 while P2 had positive significant general combining ability effects in DC. In lint percentage and boll weight , P3 and P4 had positive significant general combining ability effects in F1 while P1 and P3 had positive significant general combining ability effects in DC only for lint percentage. With respect to no. bolls / plant P1 and P4 had positive significant general combining ability effects in F1 while P3 and P4 had positive significant general combining ability effects in DC. Hamed & Said (2021) mentioned that the lines Giza 86 and Giza 94 were significant and positive desirable GCA effects for most yield traits.

Genetic components

Table 14 showed genetic parameters; additive (σ^2A) and dominance (σ^2D)variances. Also heritability in narrow (Hn^2%) and broad (Hb^2%) sense. The results revealed that dominance genetic variance (σ^2D) were larger than additive genetic variance (σ^2A) except for number of bolls /plant in double crosses and lint percentage in F1. Also results in Table (14) revealed that hertability in broad sense recorged high values were 91.13, 89.87, 88.88, 90.92, 93.97, 96.51, 99.11, 76.52, 67.08 and 76.49 for seed cotton yield/feddan, lint yield/feddan, boll weight, number of open bolls/ plant and lint percentage, respectively. Hamed and Said (2021) mentioned that the non-additive of genetic parameters was larger than additive genetic variance with respect to all studied traits (seed cotton yield , lint yield, boll weight and number of bolls per plant) except lint percentage.

Two line arrangement

Results in Table 15 showed that 2-line effects with and without respect to their particular arrangement. With respect the boll weight, p4 * p5 had the highest 2-line general effects followed by p2 *p4 and p2 * p5. The combination p3 * p4 had the highest 2-line specific effect of (ij) (--) type followed by p2 *p4 and p1 * p5 while p2 * p3 and p4 * p5 were the worst combinations because their 2-line specific effects are not only negative but also high. With respect to 2-line of (i-) (j-) type, p2 * p3 and p4 * p5 recorded the highest value followed by p1 * p4.

TABLE 12. Analysis of SCA and GCA for F1 hybrids and double crosses for yield and its components traits

S.V	SCY/k		LY/k		Lint %		BW		NO. bolls/P	
	F1	DC	F1	DC	F1	DC	F1	DC	F1	DC
GCA	2.99**	16.19**	4.81**	9.26**	6.33**	8.43	0.18**	0.38**	17.87**	9.26**
SCA	2.57**	5.87**	3.90**	21.10**	1.99	11.97**	0.11**	0.57**	26.06**	0.73
Error	0.24	0.81	0.46	1.87	1.06	3.19	0.01	0.02	0.21	0.56
GCA/SCA	1.17	2.76	1.23	0.44	-	0.70	1.60	0.66	0.69	12.65

Scy: seed cotton yield, Ly: lint yield, lint %: lint percentage, BW: boll weight
* and ** Denote significant differences at 0.05 and 0.01 levels, respectively.
GCA (general combining ability), SCA (specific combing ability)

TABLE 13. General combining ability effects for F1 and double crosses hybrids for yield and its component traits

Parents	SCY/kentar		LY/kentar		LINT %		BW		NO . B /P	
	F1	DC	F1	DC	F1	DC	F1	DC	F1	DC
P_1	0.45**	0.07	0.21	0.19	-0.61*	0.26*	-0.13**	-0.01	1.26**	0.02
P2	0.01	0.14	0.16	0.3**	0.37	-0.26	-0.17**	0.02	-0.98**	-0.2
P3	0.79**	-0.13	1.20**	-0.03	0.83**	0.23*	0.22**	-0.10*	-0.60**	0.72*
P4	-0.87**	.72*	-0.69**	0.02	0.77**	-0.18	0.10**	0.04	2.07**	.6*
P_5	-0.37**	-0.17	-0.88**	-0.21*	-1.35**	-0.04	-0.01**	0.05	-1.74**	0.05
SE(gi)	0.12	0.38	0.17	0.12	0.26	0.75**	0.02	0.06	0.12	0.31
L.S.D 0.05	0.2	0.65	0.29	0.2	0.44	0.23	0.03	0.1	0.2	0.53
L.S.D 0.01	0.3	0.94	0.42	0.3	0.64	0.32	0.05	0.15	0.3	0.76

Scy: seed cotton yield, Ly: lint yield, lint %: lint percentage, BW: boll weight
* and ** Denote significant differences at 0.05 and 0.01 levels, respectively.

TABLE 14. Genetic components for F1 and double crosses hybrids for yield and its components traits

S.V	SCY/k		LY/k		BW		NO. bolls/P		Lint %	
	F1	DC	F1	DC	F1	DC	F1	DC	F1	DC
σ^2_A	0.12	1.55	0.26	0.00	0.02	0.00	0.00	1.28	1.24	0.00
σ^2_D	2.33	5.60	3.44	20.48	0.10	0.57	25.85	0.55	0.93	10.91
H_n^2%	4.52	19.44	6.25	-	14.66	-	-	53.62	38.37	-
H_b^2%	91.13	89.87	88.88	90.92	93.97	96.51	99.11	76.52	67.08	76.49

σ^2_A (Additive), σ^2_D (Dominance), H_n^2% (Hertability in narrow sense), H_b^2% (Hertability in broad sense)

TABLE 15. Two line interaction effects of i and j due to particular arrangement and its specific arrangement effects irrespective of arrangement for yield and yield traits

Hybrids	BW			NO. BOLLS /P			Lint %			SCY /K			LY / K		
	Ij	(ij) (..)	(i.) (j.)	Ij	(ij) (..)	(i.) (j.)	Ij	(ij) (..)	(i.) (j.)	Ij	(ij) (..)	(i.) (j.)	Ij	(ij) (..)	(i.) (j.)
p1 * p2	0.01	0.06	-0.03	-0.06	3.93	-1.96	0.00	-1.29	0.65	0.070	0.12	-0.06	0.07	-0.36	0.18
p1 * p3	-0.04	-0.06	0.03	0.25	0.81	-0.41	0.16	0.11	-0.06	-0.019	-0.26	0.13	0.05	-0.30	0.15
p1 * p4	0.01	-0.10	0.05	-0.19	-3.78	1.89	0.02	0.31	-0.15	0.052	1.99	-1.00	0.07	2.41	-1.20
p1 * p5	0.01	0.10	-0.05	0.02	-0.96	0.48	0.07	0.87	-0.44	-0.032	-1.85	0.93	-0.01	-1.75	0.87
p2 * p3	-0.03	-0.21	0.11	0.17	0.67	-0.33	-0.01	0.60	-0.30	0.004	-0.67	0.34	0.00	-0.49	0.24
p2 *p4	0.02	0.11	-0.05	-0.26	-1.70	0.85	-0.15	1.33	-0.67	0.070	-1.90	0.95	0.02	-1.61	0.80
p2 * p5	0.02	0.04	-0.02	-0.05	-2.89	1.44	-0.10	-0.64	0.32	-0.010	2.45	-1.23	-0.06	2.46	-1.23
p3 * p4	-0.02	0.21	-0.10	0.04	0.07	-0.04	0.02	-1.06	0.53	-0.014	0.72	-0.36	0.00	0.35	-0.17
p3 * p5	-0.02	0.07	-0.03	0.26	-1.56	0.78	0.06	0.35	-0.17	-0.098	0.21	-0.11	-0.08	0.43	-0.22
p4 * p5	0.03	-0.21	0.11	-0.18	5.41	-2.70	-0.07	-0.58	0.29	-0.027	-0.81	0.41	-0.06	-1.14	0.57

Ij, (ij) (..), (i.) (j.) 2-line interaction effect of lines i and j

Regarding No. of bolls / plant, p3 * p5 recorded the highest 2-line general effects followed by p1* p3. The combination (p4 * p5) had the highest 2-line specific effect of (ij) (--) type followed by p1 * p2. Regarding 2-line of (i-) (j-) type, p1 * p4 had the highest value followed by p2 * p5. With respect to lint percentage, p1 * p3 had the highest 2-line general effects followed by p2 * p4 and p2 * p5. For 2-line specific effect of (ij) (--), p1 * p2 had the highest desirable value followed by p3 * p4 and p2 * p5. Regarding 2-line of (i-) (j-) type, p2 * p4 had the highest value followed by p1 * p2 and p3 * p4. With respect to seed cotton yield/kentar, p1 * p2 and p2 * p4 the highest 2-line general effects followed by p1 * p4. The combination P2 * p5 followed by p1 * p4 recorded the highest 2-line specific effect of (ij) (--) type. The two combinations p2 * p4 and p1 * p5 recorded the highest 2-line of (i-) (j-) type. For lint cotton yield/plant, p1 * p2 and p1 * p4 followed by p1 * p3 recorded the highest values in 2-line general effects type. The hybrid P2 * p5 followed by p1 * p4 were the best combinations in 2-line specific effect of (ij) (--) type. Three combinations p1 * p5 followed by p2 * p4 and p4 * p5 had high value in 2-line of (i-) (j-) type. El-Fesheikawy *et al*. (2018) studied six Egyptian cotton varieties and their 45 double crosses and found that two line arrangements was significant for yield traits and revealed that concerning two line interaction effect, S2 (12), S2 (13), S2 (14), S2 (24) and S2 (45) showed desirable effects for most traits.

Three line arrangement

Three-line effects with and without respect to their particular arrangement are shown in Table 16. Considering specific order of three lines type, (P_1xP_2) (P_5.) was the best combinations followed by (P_2xP_3) (P_4.) and (P_3xP_4) (P_5.) in boll weight while (P2xP4) (P5.) was the worst because it was highly negative without respect to arrangement, the best combinations were (P_2xP_4) (P_5.) followed by (P_1xP_4) (P_5.) while (P_1xP_2) (P_3.) was the highly negative combination. With respect to number of bolls / plant , three combinations were the best in specific order of three lines type (P_1xP_4) (P_2.) followed by (P_2xP_5) (P_1.) and (P_2xP_4) (P_5.). The combination (P_1xP_3) (P_5.) was the best combination without respect to arrangement followed by (P_2xP_3) (P_5.). Regarding lint %, the combination (P1xP2) (P4.) followed by (P_3xP_4) (P_1.) were the best combination with respect to arrangement. Without respect to arrangement, (P1xP3) (P5.) was the best combination. For seed cotton yield, (P1xP5) (P2.) was the best combination followed by (P4xP5) (P1.). Without respect to arrangement, the best combination was (P1xP2) (P4.) followed by (P2xP3) (P4.) for lint cotton yield, the combination (P1xP5) (P2.) was the best combination followed by (P1xP2) (P4.) with respect to arrangement while the combination (P1xP2) (P4.) was the best combination without respect to arrangement followed by (P1xP2) (P3.). El-Fesheikawy *et al*. (2018) studied 6 Egyptian cotton varieties G85 (P_1), ashmoni (P_2), G75 (P_3), G80 (P_4), G86 (P_5) and G90 (P_6) and revealed that 3-line effects cleared the S^3 (124), S^3 (125), S^3 (126), S^3 (134), S^3 (136), S^3 (145), S^3 (245) were the best combinations.

Four line arrangement

The 4-line interaction with respect to particular arrangements of the parents in double crosses is shown in Table 17. Considering the general effect of set of any four parents in boll weight, it is clear that (P1xP2) (P4xP5) formed the best combination. Respecting number of bolls/plant, the best combination was (P1xP2) (P3xP5) which had highest specific with value followed by (P1xP3) (P4xP5). With respect to lint% (P1xP3) (P4xP5) followed by (P1xP2) (P3xP5) were the best combinations according to arrangement. Regarding seed and lint cotton yield, (P1xP2) (P3xP4) followed by (P1xP2) (P4xP5) were the best combinations. El-Fesheikawy et al. (2018) studied 6 Egyptian cotton varieties G85 (P_1), ashmoni (P_2), G75 (P_3), G80 (P_4), G86 (P_5) and G90 (P_6) and mentioned that 4-line interaction mean squares were significant for all yield traits. The best combinations for most yield traits were S^4 (2345), S^4 (2346) and S^4 (1456).

Fiber quality traits

Analysis of variance

Results in Table 18 showed highly significant differences (P≤0.001) among hybrids for fiber strength and micronaire value . Morover, mean square of hybrids were partitioned into line general, 2-line arrangement and 3- line arregement, all the parts exhibited highly significant differences (P≤0.001) except upper half mean length. El-Fesheikawy et al. (2018) found that the mean squares of genotypes were highly significant for all studied traits (fiber fineness, fiber strength and upper half mean), the partition of crosses mean square to its components showed that the mean square due to 1-line general, 2-line specific, 2-line arrangement, 3-line arrangement and 4-line arrangement were either significant or highly significant for all studied characters.This result suggesting the presence of the additive and non-additive genetic variance in the inheritance of these traits.

General and specific combining ability

Results in Table 19 revealed that, GCA mean squares were significant for fiber length and fiber strength in F1, while GCA mean squares were significant for fiber strength and fiber fineness (Micronaire reading) in DC. Specific combining ability mean squares were only significant for F1 in both traits fiber strength and fiber fineness (Micronaire reading). GCA/SCA ratio revealed that GCA was higher than SCA in F1 for fiber length while in DC, it was higher than SCA for fiber length and fiber fineness (Micronaire reading). Hamed and said (2021) showed that the crosses Giza 90 x Pima S4, Giza 93 x Karshenky and Giza 95 x Pima S4 were significant desirable SCA effects for most fiber traits (fiber length and fiber strength)while Giza 93 had significant desirable GCA effects for all fiber traits.

Results in Table 20 revealed that P3 had positive significant general combining ability effects in F1 for fiber lenth (UHML). P2 and P3 had positive significant general combining ability effects in F1 for fiber strength while P1 had positive significant general combining ability effects in DC for fiber fineness (micronaire reading), P1 and P3 had negative significant general combining ability effects in F1 for fiber strength while only P3 had negative significant general combining ability effects for micronaire value.

Genetic components

Results in Table 21 showed genetic parameters, additive (σ^2A) and dominance (σ^2D) variances and heritability in broad (Hb^2%) and narrow (Hn^2%) sense. Results showed that additive genetic variance (σ^2A) were larger than dominance genetic variance (σ^2D) for all studied traits. High broad sense heritability was recorded for upper half mean in F1, fiber strength in both F1 and double cross and micronaire reading in F1 while double crosses in micronaire reading recorded intermediate heritability. Hassan (2018) showed that the additive effect (d) was recorded significant positive values for fiber length and uniformity ratio traits while the dominance effect showed significant valuefor uniformity ratio trait and it was larger in magnitude than the additive effect in two crosses for all studied traits (fiber length and uniformity ratio) except micronaire in cross I and cross II and Fiber strength in cross II.

TABLE 16. Three line interaction effects of I, j and K due to particular arrangement and its specific arrangement effects irrespective of arrangement for yield and yield traits

Hybrids	BW		NO. bOlls		LINT%		SCY/K		LY/K	
	(ij)(k-)	i,j and k	(ij)(k-)	i,j and k	(ij)(k-)	i,j and k	(ij)(k-)	i,j and k	(ij)(k-)	i,j and k
(P_1xP_2) $(P_3.)$.	-0.069	-0.029	-0.963	0.180	0.550	0.074	-0.829	0.027	-0.719	0.063
(P_1xP_2) $(P_4.)$.	-0.233	0.019	-1.333	-0.256	0.626	-0.062	0.767	0.098	1.125	0.081
(P_1xP_2) $(P_5.)$.	0.243	0.021	-1.630	-0.043	0.118	-0.016	-0.062	0.014	-0.044	0.004
(P_1xP_3) $(P_2.)$.	0.065		-0.130		0.243		0.071		0.216	
(P_1xP_3) $(P_4.)$.	0.156	-0.023	-2.833	0.050	-0.554	0.101	0.220	0.010	0.005	0.060
(P_1xP_3) $(P_5.)$.	-0.157	-0.021	2.148	0.263	0.196	0.147	-0.026	-0.074	0.075	-0.017
(P_1xP_4) $(P_2.)$.	0.139		3.889		-0.370		-1.323		-1.635	
(P_1xP_4) $(P_3.)$.	-0.006		0.889		-0.059		0.168		0.135	
(P_1xP_4) $(P_5.)$.	-0.033	0.027	-1.000	-0.172	0.122	0.010	-0.838	-0.004	-0.905	0.001
(P_1xP_5) $(P_2.)$.	-0.174		-1.796		-0.520		1.314		1.238	
(P_1xP_5) $(P_3.)$.	0.043		0.481		-0.434		0.529		0.437	
(P_1xP_5) $(P_4.)$.	0.028		2.278		0.082		0.009		0.073	
(P_2xP_3) $(P_1.)$.	0.004		1.093		-0.794		0.758		0.504	
(P_2xP_3) $(P_4.)$.	0.185	-0.014	1.463	-0.024	0.219	-0.071	-0.582	0.032	-0.558	0.006
(P_2xP_3) $(P_5.)$.	0.022	-0.012	-3.222	0.189	-0.024	-0.025	0.494	-0.052	0.540	-0.071
(P_2xP_4) $(P_1.)$.	0.094		-2.556		-0.255		0.556		0.510	
(P_2xP_4) $(P_3.)$.	0.041		0.852		-0.665		0.556		0.367	
(P_2xP_4) $(P_5.)$.	-0.243	0.036	3.407	-0.246	-0.413	-0.161	0.794	0.019	0.732	-0.053
(P_2xP_5) $(P_1.)$.	-0.069		3.426		0.402		-1.252		-1.194	
(P_2xP_5) $(P_3.)$.	-0.078		0.444		0.414		-0.062		0.109	
(P_2xP_5) $(P_4.)$.	0.102		-0.981		-0.178		-1.138		-1.371	
(P_3xP_4) $(P_1.)$.	-0.150		1.944		0.613		-0.388		-0.140	
(P_3xP_4) $(P_2.)$.	-0.226		-2.315		0.445		0.026		0.191	
(P_3xP_4) $(P_5.)$.	0.169	-0.005	0.296	0.059	0.001	0.002	-0.362	-.070	-0.398	-0.074
(P_3xP_5) $(P_1.)$.	0.115		-2.630		0.238		-0.503		-0.512	
(P_3xP_5) $(P_2.)$.	0.056		2.778		-0.390		-0.432		-0.649	
(P_3xP_5) $(P_4.)$.	-0.237		1.407		-0.195		0.723		0.727	
(P_4xP_5) $(P_1.)$.	0.006		-1.278		-0.204		0.829		0.832	
(P_4xP_5) $(P_2.)$.	0.141		-2.426		0.591		0.344		0.639	
(P_4xP_5) $(P_3.)$.	0.069		-1.704		0.194		-0.362		-0.329	

I,j and k , (ij) (k.) 3-line interaction effect of lines i , j and k

TABLE 17. Specific four line interaction with respect to arrangement for yield and its component traits

Hybrids	BW	No.bolls/p	Lint%	SCY /K	LY / K
(P_1xP_2) (P_3xP_4)	-0.05	-0.05	0.04	0.17	0.21
(P_1xP_2) (P_3xP_5)	-0.04	0.59	0.18	-0.08	-0.02
(P_1xP_2) (P_4xP_5)	0.10	-0.72	-0.23	0.13	0.03
(P_1xP_3) (P_4xP_5)	-0.02	0.20	0.26	-0.14	-0.03
(P_2xP_3) $(P_4xP_{5)}$	0.01	-0.02	-0.25	-0.07	-0.19

BW: boll weight, No.bolls/p: number of bolls per plant, lint %: lint percentage, SCY:seed cotton yield and LY: lint yield
* and ** Denote significant differences at 0.05 and 0.01 levels, respectively.

TABLE 18. Analysis of variance of double cross hybrids for quality traits

S.V.	d.f.	U.H.M.L	F.S.	MIC
Hybrids	14	0.42	1.351**	0.455**
1-line general	4	0.38	1.559**	0.766**
2- line arrangement	5	0.48	0.386**	0.570**
3- line arrangement	5	0.40	2.150**	0.091**
Error	28	0.92	0.008	0.004

** Significant at1% level of probability, U.H.M = upper half mean length
F.S = fiber strength, Mic =micronaire value

TABLE 19. Analysis of general (GCA) and specific (SCA) combining ability**and genetic components for F1 and double crosses (DC) hybrids for quality traits**

S.V	UHM		Fiber strength		Micronaire	
	F1	DC	F1	DC	F1	DC
GCA	0.78*	0.44	0.17**	1.02*	0.02	0.11*
SCA	0.14	0.40	0.45**	-0.17	0.11**	0.03
Error	0.23	0.92	0.03	0.23	0.02	0.07
GCA/SCA	5.57	1.10	0.38	6.0	0.18	3.67

* and ** Denote significant differences at 0.05 and 0.01 levels, respectively.
GCA (general combining ability), SCA (specific combing ability)

TABLE 20. General combining ability effects for F1 and double crosses (DC) hybrids for quality traits

Parents	UHML		Fiber strength		Micronaire	
	F1	DC	F1	DC	F1	DC
P1	-0.17	0.09	-0.03**	0.12**	-0.06**	-0.02
P2	0.02	-0.02	0.18**	-0.12**	0.01	0.10**
P3	0.21*	-0.04	0.11**	0.06	-0.03**	-0.09**
P4	-0.16	-0.02	-0.02*	0.03	0.02*	0.05*
P5	0.12	-0.01	-0.23*	-0.09	0.08**	-0.03
SE(gi)	0.122	0.403	0.01	0.04	0.01	0.03
L.S.D 0.05	0.21	0.69	0.02	0.07	0.02	0.05
L.S.D 0.01	0.30	0.99	0.03	0.10	0.02	0.07

* and ** Denote significant differences at 0.05 and 0.01 levels, respectively.

TABLE 21. Genetic components for F1 and double crosses (DC) hybrids for quality traits

S.V	UHM		Fiber strength		Micronaire	
	F1	DC	F1	DC	F1	DC
σ^2_A	0.01	0.10	0.80	0.06	0.20	0.04
σ^2_D	0.00	0.09	0.45	0.00	0.10	0.03
H_n^2%	8.71	0.60	-20.10	51.08	-24.28	0.86
H_b^2%	54.81	9.56	92.46	91.14	78.07	29.11

(σ^2_A) additive, (σ^2_D) dominance , heritability in broad (H_b^2%) , heritability in narrow (H_n^2%)

Two line arrangement

Results in Table 22 showed two line arrangement for fiber traits. With respect to upper half mean length, the combination p1 * p5 followed by p1 * p2, p1 * p3 and p1 * p4 recorded the highest values in 2-line general effects type while p4 * p5 had the highest value in 2-line specific effect of (ij) (--) type. Two combinations p1 * p4 followed by p2 * p5 recorded the hghest values in 2-line of (i-) (j-) type. Respect to fiber strength, p1 * p3 had the highest value in 2-line general effect type and 2-line specific effect of (ij) (--) type. In 2-line of (i-) (j-) type, p1 * p5 followed by p2 * p3 registered the highest values. Regarding micronaire reading , p3 * p5 and p1 * p3 had the highest negative values in 2-line general effects type while p2 *p4 was the highest positive value. The combination p3 * p5 recorded the highest value in 2-line of (i-) (j-) type followed by p2 *p4 while p2 * p5 had the highest positive value. In 2-line specific effect of (ij) (--) type p2 * p5 had the highest value. El-Fesheikawy et al.(2018) studied six Egyptian cotton varieties and their 45 double crosses and found that two lines arrangement was significant for fiber quality traits and revealed that concerning two lines interaction effect, S2 (12), S2 (13), S2 (14), S2 (24) and S2 (45) showed desirable effects for most traits (fiber length and fiber fineness).

Three line arrangement

Three line arrangement for fiber quality traits are shown in Table 23. With regard to upper half mean length, (P2xP5) (P1.) followed by (P1xP4) (P2.) and (P3xP4) (P1) were the best combinations in specific order of three lines type, while the combinations (P1xP2) (P5) and (P1xP4) (P5) followed by (P1xP2) (P4.) were the best without respect to arrangement. Respecting fiber strength, (P1xP4) (P3.) followed by (P3xP5) (P1.) were the best combinations in specific order of three lines type, while (P1xP3) (P5.) followed by (P1xP4) (P5.) were the best without respect to arrangement. Considering fiber fineness, the combinations (P3xP5) (P2) followed by (P2xP4) (P3.) and (P2xP3) (P4.) were the best combinations in specific order of three lines type while the best combination without respect to arrangement were (P1xP3) (P5.) followed by (P3xP4) (P5.) and (P1xP3) (P4). El-Fesheikawy et al. (2018) mentioned that the combinations S^3 (125), S^3 (145), S^3 (245) and S^3 (346) were the best combinations for fiber quality traits.

Four line arrangement

The 4-line interaction with respect to particular arrangements of the parents in double crosses is shown in Table 24. Considering the general effect of set of any four parents in upper half mean length, it is clear that (P1xP2) (P4xP5) formed the best combination followed by (P1xP2) (P3xP5) and (P1xP3) (P4xP5). Respecting fiber strength, the best combination was (P1xP3) (P4xP5) followed by (P1xP2) (P3xP4). Regarding fiber fineness, (P1xP3) (P4xP5) followed by (P1xP2) (P3xP5) were the best combinations. El-Fesheikawy et al. (2018) mentioned that 4-line interaction mean squares were significant for all fiber quality traits. The best combinations for most fiber traits were S^4 (2345), S^4 (2346) and S^4 (1456).

Conclusion

Results revealed that parents involved in this study were differed genetically having highly combining ability. General and specific combining ability mean squares were significant or highly significant for most traits in F1 and double crosses. It could be concluded that the combination (P1xP2) (P4xP5) formed the best combination among 15 combinations for most studied traits.

TABLE 22. Two line interaction effects of i and j due to particular arrangement and its specific arrangement effects irrespective of arrangement for fiber quality traits

Hybrids	Upper half mean length			Fiber strength			Fiber fineness		
	Ij	(ij) (..)	(i.) (j.)	Ij	(ij) (..)	(i.) (j.)	Ij	(ij) (..)	(i.) (j.)
p1 * p2	0.02	0.17	-0.09	0.00	0.00	0.00	0.03	0.00	0.00
p1 * p3	0.02	0.08	-0.04	0.06	0.34	-0.17	-0.04	-0.15	0.07
p1 * p4	0.02	-0.38	0.19	0.05	-0.13	0.07	0.01	0.09	-0.04
p1 * p5	0.03	0.13	-0.06	0.01	-0.20	0.10	-0.02	0.06	-0.03
p2 * p3	-0.02	-0.02	0.01	-0.02	-0.17	0.09	0.00	0.17	-0.08
p2 *p4	-0.01	0.12	-0.06	-0.03	0.00	0.00	0.05	0.20	-0.10
p2 * p5	-0.01	-0.27	0.14	-0.07	0.18	-0.09	0.02	-0.37	0.19
p3 * p4	-0.02	0.03	-0.01	0.03	-0.03	0.01	-0.02	-0.31	0.16
p3 * p5	-0.02	-0.09	0.04	-0.01	-0.14	0.07	-0.04	0.29	-0.15
p4 * p5	-0.01	0.24	-0.12	-0.02	0.16	-0.08	0.00	0.02	-0.01

TABLE 23. Three line interaction effects of i , j and k due to particular arrangement and its specific arrangement effects irrespective of arrangement for fiber quality traits

Hybrids	Upper half mean		Fiber strength		Fiber fineness	
	(ij)(k-)	i,j and k	(ij)(k-)	i,j and k	(ij)(k-)	i,j and k
(P1xP2) (P3.).	0.019	0.009	0.031	0.020	-0.041	-0.005
(P1xP2) (P4.).	-0.039	0.017	0.052	0.010	0.119	0.041
(P1xP2) (P5.).	-0.154	0.020	-0.080	-0.030	-0.078	0.016
(P1xP3) (P2.).	-0.026		-0.002		0.065	
(P1xP3) (P4.).	-0.198	0.009	-0.254	0.071	-0.030	-0.021
(P1xP3) (P5.).	0.143	0.013	-0.085	0.031	0.113	-0.047
(P1xP4) (P2.).	0.261		-0.404		-0.081	
(P1xP4) (P3.).	0.046		0.474		-0.002	
(P1xP4) (P5.).	0.074	0.020	0.063	0.021	-0.006	-0.001
(P1xP5) (P2.).	-0.148		0.404		0.017	
(P1xP5) (P3.).	-0.024		-0.335		-0.031	
(P1xP5) (P4.).	0.046		0.135		-0.044	
(P2xP3) (P1.).	0.007		-0.030		-0.024	
(P2xP3) (P4.).	0.119	-0.027	0.120	-0.011	-0.098	0.016
(P2xP3) (P5.).	-0.107	-0.023	0.083	-0.052	-0.044	-0.009
(P2xP4) (P1.).	-0.222		0.352		-0.037	
(P2xP4) (P3.).	-0.020		-0.435		-0.104	
(P2xP4) (P5.).	0.124	-0.016	0.087	-0.061	-0.063	0.037
(P2xP5) (P1.).	0.302		-0.324		0.061	
(P2xP5) (P3.).	-0.007		0.317		0.228	
(P2xP5) (P4.).	-0.020		-0.174		0.081	
(P3xP4) (P1.).	0.152		-0.220		0.031	
(P3xP4) (P2.).	-0.098		0.315		0.202	
(P3xP4) (P5.).	-0.080	-.023	-0.069	0.000	0.078	-0.026
(P3xP5) (P1.).	-0.119		0.420		-0.081	
(P3xP5) (P2.).	0.115		-0.400		-0.183	
(P3xP5) (P4.).	0.093		0.120		-0.028	
(P4xP5) (P1.).	-0.120		-0.198		0.050	
(P4xP5) (P2.).	-0.104		0.087		-0.019	
(P4xP5) (P3.).	-0.013		-0.052		-0.050	

TABLE 24. Specific four lineinteraction with respect to arrangement for quality traits

Hybrids	Upper half mean	Fiber strength	Fiber fineness
(P1xP2) (P3xP4)	0.008	0.091	0.032
(P1xP2) (P3xP5)	0.019	-0.032	-0.046
(P1xP2) (P4xP5)	0.042	-0.059	0.093
(P1xP3) (P4xP5)	0.019	0.124	-0.096
(P2xP3) (P4xP5)	-0.089	-0.123	0.018

Refrences

Chaudhary, B.D. (1984) Double-cross hybrid analysis for spikes per plant in barley. *The Andhra Agricultural Journal,* **31**, 201-206.

Dabholkar, A.R. (1992) "*Elements of Biometrical Genetics*". Concept Publishing Company, New Delhi, India, pp: 138-140.

El-Fesheikawy, A.B.A., Baker, Kh.M.A., El, Dahan, M.A.A., Abd El-Rahman, Y.Sh. (2018) Double crosses analysis of some economic characters in Egyptian cotton. *Menoufia Journal of Plant Production*, **3**, 147–164.

El-Feki, T.A., El- Agamy, A.I., Yassien, H.E., El-hoseiny, H.A. (2012) Combining ability and the order effect in double cross hybrids of cotton. *Egyptian Journal of Agricultural Research,* **90**(1), 173–190.

Giri, R.K., Verma, S.K., Yadav, J.P . (2020) Combining ability analysis for yield & it's contributing traits based on multi-environment testing in upland cotton (G. *hirsutum* L.). *Electronic Journal of Plant Breeding*, **11**(02), 416-424.

Griffing, B. (1956) Concept of general and specific combining ability in relation to diallel crossing systems. *Australian Journal of Biological Sciences*, **9**, 463-493

Hamed, H.H.E., Said, S.R.N. (2021) Estimation of heterosis and combinig ability for yield and fiber quality traits by using line x tester analysis in cotton on (*Gossypium barbadense* L.). *Menoufia Journal*, **6**, 35-51.

Hassan, S.S. (2018) Genetic analysis of some quantitative characters in Egyptian cotton. *Journal of Plant Production, Mansoura University*, **9**(5), 469-475.

Hayman, B.I. (1954) The theory and analysis of diallel crosses. *Genetics*, **39**, 789-809.

Kumbhar, Z.M., Jatoi, W.A., Sootaher, J.K., Baloch, M.I., Chang, M.S. (2020) Studies on correlation and heritability estimates in upland cotton (*Gossypium hirsutum* L.) genotypes under the agro- climatic conditions of Tandojam, sindh, Pakistan. *Pure and Applied Biology*, **9**(4), 2272-2278.

Manonmani, K., Mahalingam, L., Malarvizhi, D., Premalatha, N., Sritharan, N. (2020) Combining ability studies for seed cotton yield in intraspecific hybrids of upland cotton (*Gossypium hirsutum* L.). *Electronic Journal of Plant Breeding,* **11**(01), 36-44.

Mather, K., Jinks, J.L. (1982) "*Biometrical Genetics*". 3rd ed. Cambridge Univ. Press, London, N.Y.

Singh, R.K., Chaudhary, B.D. (1977) The order effects in doublecross hybrids. *Crop Improvement,* **4**, 213-220.

Singh, R.K., Chaudhary, B.D. (1985) Double cross hybrid analysis and order effects in barley. In: "*Advances in Cytogenetics and Crop Improv.*" Singh R.B., Singh, R.M., Singh, B.D. (Ed.), pp. 319-325. Kalyani Publishers, New Delhi.

Soliman, Y.A.M. (2014) Improving Egyptian cotton using F2 quadriallel crosses. *Journal of Agricultural Chemistry and Biotechnology, Mansoura University,* **5**(1), 25-41.

Sprague, G.F., Tatum, L.A. (1942) General and specific combining ability in single crosses of corn. *Journal of the American Society of Agronomy*, **34**, 923-932.

Yar, M.M., Iqbal, M., Mehmood, A., Naeem, M. (2020) Estimation of heritability and genetic advance to develop drought tolerance in cotton (*Gossypium* *hirsutum* L.). *Applied Ecology and Environmental Research,* **18**(3), 4309-4323.

Yehia, W.M.B., El-Hashash, E.F. (2019) Combining ability effects and heterosis estimates through Line X Tester analysis for yield, yield components and fiber traits in Egyptian cotton. *Journal of Agronomy, Technology and Engineering Management,* **2**(2), 248-262.

تحسين القطن المصرى بإستخدام الهجن الزوجية

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اشتملت المواد الوراثية المستخدمة في هذا البحث على خمسة أصناف من القطن تنتمي إلى (*Gossypium barbadense,* L.). ثلاثة من هذه الأصناف كانت طويلة التيلة ، BBB (P1) ، أسترالي (P2) ,G97 (P3) بينما الصنفان الآخران من طبقة الاصناف فائقة الطول، جيزة 92 (P4) و G96 (P5. وتم إجراء التهجين بين الاباء بطريقة التهجين نصف الدائرى فى اتجاه واحد للحصول على الهجن الفردية وكذلك الهجن الزوجية ثم تقييم الهجن الناتجة وكذلك الاباء في مزرعة مركز البحوث الزراعية في سخا .وكانت اهم الصفات المدروسة؛ محصول القطن الزهر، محصول القطن الشعر ،متوسط وزن اللوزة، نسبة التصافى، عدد اللوز/ نبات، ارتفاع العقدة الثمرية الأولى، عدد الأيام حتى ظهوراول زهرة، مدة نضج اللوزة، طول التيلة (UHM)، متانة التيلة والنعومة. الهدف من هذه الدراسة هو دراسة تأثير ترتيب الاباء داخل الهجن الزوجية ودراسة القدرة العامة والخاصة على التألف. اثبت الدراسة ان هناك فرق معنوى بين الهجن الفردية والهجن الزوجية لمعظم الصفات. كانت متوسطات المربعات لـ GCA معنوية بالنسبة لـ F1 باستثناء عدد الأيام حتى اول زهرة و نعومة الألياف (قراءة الميكرونير). كانت متوسطات المربعات لـ GCA معنوية للهجن الزوجية (DC) فيما عدا نسبة التصافى وطول الألياف وعدد الايام حتى اول زهرة.