DOI: 10.34101/ACTAAGRAR/2/4145

Heterobeltiosis and combining ability among Egyptian cotton genotypes under well irrigated and water deficit conditions

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SUMMARY

Two field experiments were carried out during the 2014 and 2015 seasons to evaluate certain genotypes of Egyptian cotton under well irrigated and water stress conditions. The cross combination Giza 69 x Australy recorded the best values for better parent heterosis for all physiological measurements and earliness index under well irrigated and deficit conditions. Of the female parents, Giza 86 was found to be a good general combiner for most yield characters under both normal and stress conditions, followed by Giza 94. Data illustrated that Giza 45 was the best general combiner for most fiber quality traits under both conditions. The cross combinations Giza 86 x Dandra and Giza 69 x Pima S6 showed significant positive SCA values for seed cotton and lint yield/plant under well irrigated and water deficit conditions. However, the combinations Giza 77 x PimaS_6 and Giza 94 x 10229 recorded significant positive SCA effects for seed cotton yield/plant under stress. Whilst, the cross Giza 68 x 10229 recorded significant desirable SCA effects for most fiber quality properties. In this context, the estimates significant positive general and specific combining ability effects indicated that the epistasis and/or dominance effects for F_1 hybrid in cotton could be important to a certain extent.

Keywords: *cotton, heterobeltiosis, general combining ability, specific combining ability*

INTRODUCTION

It is a known fact that the phenomena of heterosis is of common occurrence in both cross and self-pollinated crops. Cotton which is highly self-pollinated crop show heterosis when hybridization takes place among homozygous varieties.

Heterosis is a complex genetical phenomenon, which depends on the balance of different combinations of gene effect as well as distribution of plus and minus alleles in the parent of a mating. Useful heterosis expressed as the percentage deviation of F_1 mean performance from better parent for all traits Donghui et al. (2014).

The ultimate choice of parents in a breeding program is generally based on performance of parents and their F_1 hybrids. However, general and specific combining abilities are more informative than performance, since it also reveals the type of gene effects which help plant breeders to devise breeding and selection strategies. The concept of combining ability plays an important role in the identification and selection of desirable parents for exploiting and development of superior hybrids Khan et al. (2009).

The information of combining ability will help the breeder in developing the future breeding program to be adopted for exploiting additive or/and non-additive gene effects in the existing material. Therefore, the objective of this study was to estimate heterobeltiosis and combining ability among Egyptian cotton genotypes under well irrigated and water deficit conditions.

MATERIALS AND METHODS

The present study was done in the Agronomy Department, Faculty of Agriculture, Mansoura University. The investigation was carried out at Sakha Agric. Res. Stat. Kafr EL-Sheikh, Agric. Res. Center (ARC), Egypt, during 2014 and 2015 growing seasons.

Genetic materials and experimental procedure

The genetic materials used in this study included Thirteen cotton genotypes belonging to *Gossypium barbadense* L., from the Cotton Research Institute (CRI), which devoted to establish the experimental materials for this investigation.

Experimental design and laboratory procedures

The thirteen parents were crossed, in such away Line x Tester (9x4) mating design by using four parents as a Tester parents i.e. Dandra, Pima S_6, Australy and 10229 and nine cotton genotypes as a Line parents i.e. Giza 45, Minufi, Giza 67, Giza 68, Giza 86, Giza 77, Giza 94, Giza 96 and Giza 69, in 2014 crop season to produce 36 F_1 hybrid seeds, and the original parents were also selfed.

In 2015 season, the 36 F_1 hybrids and their parents were grown in a randomized complete block design (RCBD) with three replicates under two separated experiments of irrigated conditions. The first one is the normal irrigated 7 irrigations during the growing season, and the second is the stress condition, three irrigations only during the growing season. Each experimental plot consisted of one row, measuring five meters in length and 0.70 m in width, with plants spaced 30 cm within row. Two plants were left per hill at thinning time. Recommended cultural practices were

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applied for all the entries. Ten guarded plants of each replicate were gained and used to determine yield and fiber characters.

Statistical and genetic analysis

Estimates of heterosis

The values of heterosis were determined as the percentage deviation from the F_1s hybrids over the better parents (B.P.) as follow:

$$H\ (B.P.) = \frac{\overline{F1} - \overline{B.P}}{\overline{B.P}} X100$$

The significance of heterosis was tested using the least significant differences value (L.S.D) at 0.05 and 0.01% levels of probability, according to the formula of Steel and Torrie (1960).

$$L.S.D\ at\ \begin{matrix}0.05\\0.01\end{matrix} = t\ \begin{matrix}0.05\\0.01\end{matrix} x\ s\bar{d}\ ,\ s\bar{d} = \sqrt{\frac{2Ms_e}{r}}$$

General and specific combining ability effects:

Estimation of general combining ability

$$Lines\ g_1 = \frac{x_{1..}}{tr} - \frac{x_{..}}{ltr}$$

$$Testers\ g_j = \frac{x_{j...}}{lr} - \frac{x_{...}}{ltr}$$

Where, g_1 = is the general combining ability effect.
$X_{i...}$ = is the total value of crosses in which the line involved over replications.
$X_{j...}$ = is the total value of crosses in which the tester involved over replications.
$X_{...}$ = is the general total for crosses.
R, l, t = are the number of replications, line and testers respectively.

Estimation of specific combining ability

$$S_{ij} = \frac{x_{ij..}}{r} - \frac{x_{i..}}{tr} - \frac{x_{j..}}{lr} - \frac{x_{..}}{ltr}$$

Where, S_{ij} = is the specific combining ability effects.
X_{ij} = is the total value of crosses between lines and testers over replications.

RESULTS AND DISCUSSION

Heterosis estimates of hybrid combinations are presented in *Table 1*, the data regarding to yield and its contributed characters revealed that, no cross combination recorded useful heterosis for all yield characters under both normal and stress conditions.

The cross combinations which expressed significant heterosis over better parent for seed cotton yield also expressed high heterotic effects for some yield attributes such as boll weight or/and fruiting branches/plant. The results suggested that high yield does not necessarily depend on high heterotic expression of all yield characters, and high heterosis for some or few component traits, which are ultimately associated with yield, can generate significant heterosis in yield. Similar results were discussed by Preetha and Raveendran (2008). The cross combinations Giza 86 x Dandra, Giza 86 x Australy, Giza 86 x PimaS$_6$ and Giza 68 X Australy showed the best heterobeltiosis values for most yield characters under both environments. Improvement of yield capacity under stress conditions is one of the important objectives, thus the superiority of hybrid combinations over better parent or best cultivated varieties, thus utilization of such combination on breeding programs for increasing the commercial values. For fiber quality characters, most combinations showed negative (desirable) values for fiber fineness under both stress and non-stress conditions (*Table 2*). On the other side, the cross combination Giza 77 x Dandra recorded the best values for fiber characters under both conditions. No combinations surpassed better parent for all fiber quality characters.

Regarding earliness and physiological measurements, (*Tables 3 and 4*) most crosses recorded negative values (undesired values) for earliness index. The cross combination Giza 68 x Australy recorded the best heterosis values for earliness index over two environments followed by Giza 69 x Australy. The cross combination Giza 69 x Australy recorded the best values for better parent heterosis for all physiological measurements and earliness index under well irrigated and deficit conditions. In the same time, the cross Giza 86 x Pima S6 showed useful heterosis under water deficit conditions for leaf area index, number of fruiting branches and plant height.

Combining ability effects

General combining ability

The estimates of general combining ability for yield and its components characters are presented in *Table 5*. Among the female parents Giza 86 was found to be a good general combiner for most yield characters under both normal and stress conditions, followed by Giza 94. The female parent Giza 69 was found poor general combiner for all important yield characters, followed by the male parent 10229 under both conditions. For fiber characters, data illustrated in *Table 6* revealed that Giza 45 was the best general combiner for fiber fineness and fiber strength under both conditions. For plant height, the highest GCA estimates were recorded by Giza 67 and this parent was a good general combiner for leaf area index under both conditions, followed by the parents 10229 and Giza 94. However, Giza 69 was the poor general combiner for leaf area index, followed by Dandra. Giza 77 recorded significant negative GCA value for plant height under deficit conditions (*Table 7*). Since, general combining ability reflects parental performance and it is the results of additive gene effects and additive x additive interaction gene effects. In few of this, significance of GCA for the studied characters shows the importance of additive gene effect for these characters. Thus, breeder may utilize the good general combiner genotypes in specific breeding programs for

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improvement the performance of Egyptian cotton especially under water deficit conditions. Similar results were obtained by Ashokkumar (2010), Karademir and Gencer (2010). However, Azhar and Naeem (2008) and EL-Mansy et al. (2014) who suggested that parents having good GCA for the yield and its components characters are expected to yield good hybrids and this suggestion appeared to be true in the present study. GCA effects of seed cotton yield/plant were negatively associated with the GCA effects of growth period duration, boll maturation period, number of fruiting branches, plant height and tolerance index. But, it was positively associated with other tolerance indices (*Table 8*). Thus, under water deficit condition taller plant type was undesirable characters which lead to more shedding in boll. These correlations among the characters should provide cotton breeders with insights on possible impacts of selection for one character on other Lu and Myers (2011) and Natera et al. (2012) detected significant GCA association between yield components and fiber characters.

Specific combining ability

Most combinations which had good specific combining ability effects were having one or two parents of their good x good or good x poor general combiner.

Regarding to yield characters (*Table 9*), no cross combinations gave desirable SCA effects for all yield characters under both water stressed and non-stressed conditions. The cross combinations Giza 86 x Dandra and Giza 69 x Pima S6 showed significant positive SCA values for seed cotton and lint yield/plant under well irrigated and water deficit conditions. However, the combinations Giza 77 x $PimaS_6$ and Giza 94 x 10229 recorded significant positive SCA effects for seed cotton yield/plant under stress. The combination Giza 86 x Australy showed desirable SCA effects for most yield attributed characters under stress conditions. The results of SCA effects showed that the best specific combinations were not always obtained from parents with good and positive general combining ability effects. This finding is inconsistent with reported by Shakeel et al. (2001), Basal et al. (2009) and Shaker et al. (2016).

No cross combinations were surpassed for all fiber quality characters (*Table 10*). The cross Giza 68 x 10229 recorded significant desirable SCA effects for fiber fineness and fiber strength as well as fiber length under both environments.

The cross combinations Giza 94 x Dandra, Giza 86 x 10229, Giza 77 x $PimaS_6$, Giza 96 x Australy, Giza 96 x 10229 and Giza 69 x Australy showed significant positive SCA effects for leaf area index. However, the cross combination Giza 86 x $PimaS_6$ recorded the best SCA values for plant height and number of fruiting branches (*Table 11*). No cross combinations were surpassed for many growth habit and earliness characters under both environments.

In the present investigation estimates of significant positive general and specific combining ability effects for most characters under study, indicated that the epistasis and/or dominance effects for F_1 hybrid in cotton could be important to a certain extent. The presence of significant GCA and SCA in F_1 generation is a consequence of fluctuations in additive and dominance relationships, respectively, among the parents (Basbag et al., 2007 and EL-Mansy et al., 2014).

CONCLUSIONS

In the present investigation improvement of yield capacity under stress conditions is one of the most important objectives, thus the superiority of hybrid combinations over better parent or best cultivated, thus utilization of such combination on breeding programs for increasing the commercial values. On the other side, estimates significant positive general and specific combining ability effects for most characters under study, indicated that the epistasis and/or dominance effects for F_1 hybrid in cotton could be important to a certain extent. The presence of significant GCA and SCA in F_1 generation is a consequence of fluctuations in additive and dominance relationships, respectively, among the parents.

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DOI: 10.34101/ACTAAGRAR/2/4145

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DOI: 10.34101/ACTAAGRAR/2/4145

Table 1

Heterosis over better parent (heterobeltiosis) for yield and yield components traits under normal and water stress conditions

Crosses	Seed cotton yield / plant (g)		Lint percentage (%)		Boll weight (g)		Lint yield / plant (g)		Seed index (g)		Lint index (g)	
	N	S	N	S	N	S	N	S	N	S	N	S
Giza 45 x Dandra	15.81 *	14.00 **	-2.75 **	-14.81 **	2.02 **	-3.49 **	20.85 **	5.02 **	-4.26 **	-3.04 **	-8.42 **	-21.62 **
Giza 45 x Pima S6	10.86	10.21 *	1.67 *	-5.80 **	-9.43 **	-7.53 **	12.88 **	3.75 *	-9.01 **	-16.50 **	-6.45 **	-23.87 **
Giza 45 x Australy	0.15	15.98 **	-3.34 **	-4.55 **	-11.93 **	-2.20 **	5.90 *	11.82**	-6.85 **	-11.15 **	-11.82 **	-12.81 **
Giza 45 x 10229	-4.62	-10.86 *	-0.26	-0.54	8.74 **	5.15 **	3.97	-5.33 **	7.27 **	-5.16 **	6.96 **	-5.94 **
Minufy x Dandra	4.21	-2.79	-1.33	-10.36 **	-9.00 **	-17.98 **	6.44 *	-12.28 **	1.72 **	4.39 **	5.35 **	-10.86 **
Minufy x Pima S6	6.07	6.46	5.81 **	-9.39 **	-10.38 **	-9.68 **	13.23 **	-3.68 *	-9.46 **	-7.52 **	1.61 **	-20.50 **
Minufy x Australy	36.87 **	-14.87 **	-1.24	-9.72 **	-9.17 **	-7.69 **	43.01 **	-23.30 **	-6.02 **	-3.76 **	0.10	-17.85 **
Minufy x 10229	11.11	4.96	-4.16 **	-7.67 **	-2.91 **	-4.12 **	12.21 **	-3.05	0.57	-15.05 **	-4.49 **	-25.11 **
Giza 67 x Dandra	-23.55 **	21.79 **	1.40	-7.46 **	-4.04 **	-3.33 **	-22.51 **	15.26 **	-1.16 **	2.79 **	1.11 **	-5.71 **
Giza 67 x Pima S6	13.10	6.66	-4.96 **	-6.22 **	-13.21 **	-10.75 **	7.44 **	5.59 **	-8.70 **	-11.22 **	-15.74 **	-12.69 **
Giza 67 x Australy	-15.54 *	9.67 *	1.10	-4.88 **	1.83 **	-14.29 **	-14.36 **	10.08 **	-4.06 **	3.91 **	-1.98 **	0.90 **
Giza 67 x 10229	-9.87	12.84 **	-2.31 **	-10.08 **	11.65 **	4.12 **	-12.04 **	1.44	-1.74 **	-8.39 **	-4.93 **	-17.89 **
Giza 68 x Dandra	13.85	17.58 **	-1.22	-4.60 **	3.03 **	10.47 **	12.17 **	12.14 **	10.33 **	-2.09 **	8.18 **	-1.52 **
Giza 68 x Pima S6	-4.88	-17.70 **	8.24 **	-13.51 **	6.60 **	-9.68 **	2.71	-22.83 **	-11.11 **	-11.88 **	2.43 **	-20.10 **
Giza 68 x Australy	6.78	-8.87	3.15 **	-2.08 *	-4.59 **	9.89 **	11.79 **	-7.54 **	14.59 **	7.83 **	23.59 **	15.90 **
Giza 68 x 10229	8.70	30.81 **	-1.30	-6.51 **	-1.94 **	-3.09 **	8.55 **	22.05 **	-3.20 **	-11.94 **	-5.17 **	-12.55 **
Giza 86 x Dandra	59.76 **	72.63 **	8.43 **	-3.79 **	10.10 **	8.99 **	74.93 **	66.02 **	1.51 **	-2.09 **	17.06 **	1.52 **
Giza 86 x Pima S6	4.46	-14.57 **	5.25 **	-9.96 **	0.00	3.23 **	10.97 **	-15.76 **	-5.41 **	-11.88 **	3.01 **	-13.62 **
Giza 86 x Australy	24.43 **	14.22 **	-0.46	3.81 **	-0.92 **	3.30 **	27.96 **	19.25 **	3.92 **	18.51 **	6.61 **	47.27 **
Giza 86 x 10229	8.82	9.91 *	1.93 *	-3.77 **	8.74 **	7.22 **	14.50 **	5.86 **	3.20 **	-6.13 **	6.38 **	-0.50
Giza 77 x Dandra	15.77 *	34.79 **	-1.99 *	-2.39 **	-2.86 **	-3.13 **	13.49 **	31.30 **	-9.37 **	-6.97 **	-12.37 **	-9.15 **
Giza 77 x Pima S6	15.29 *	25.50 **	-8.15 **	-8.30 **	-5.66 **	-9.38 **	15.23 **	21.88 **	-11.57 **	-15.18 **	-22.92 **	-20.95 **
Giza 77 x Australy	19.27 **	11.15 *	-3.69 **	-12.09 **	2.75 **	6.25 **	14.88 **	3.85 *	3.31 **	0.00	-2.89 **	-18.46 **
Giza 77 x 10229	-8.43	-10.15 *	-8.86 **	2.61 **	-0.95 **	-9.28 **	-16.63 **	-7.94 **	-4.41 **	-13.23 **	-17.69 **	-3.52 **
Giza 94 x Dandra	0.95	0.82	2.16 **	-5.11 **	-23.02 **	-5.05 **	3.05	-4.30 *	8.21 **	5.39 **	15.35 **	-3.41 **
Giza 94 x Pima S6	-6.48	-11.12 *	3.64 **	-5.07 **	-9.52 **	5.05 **	-3.06	-15.66 **	-7.21 **	-10.56 **	2.33 **	-16.20 **
Giza 94 x Australy	4.62	-13.52 **	-0.99	-3.87 **	-11.11 **	1.01 **	3.65	-16.69 **	6.23 **	-9.43 **	4.65 **	-14.81 **
Giza 94 x 10229	3.57	1.61	-3.69 **	-7.31 **	-25.40 **	-11.11 **	-0.47	-5.89 **	-1.45 **	-2.90 **	-6.86 **	-10.52 **
Giza 96 x Dandra	26.94 **	-11.33 *	-4.66 **	3.91 **	-4.63 **	-7.29 **	21.18 **	-7.34 **	-3.04 **	-4.88 **	-7.62 **	5.41 **
Giza 96 x Pima S6	-12.42	-34.35 **	-0.34	-2.25 **	-4.63 **	-15.62 **	-12.50 **	-35.45 **	-4.80 **	-7.92 **	-1.60 **	-3.13 **
Giza 96 x Australy	-1.73	-32.79 **	-4.66 **	-2.55 **	-3.67 **	-0.00	-6.17 *	-34.17 **	-3.74 **	-4.27 **	-10.52 **	-6.86 **
Giza 96 x 10229	-0.58	-36.37 **	-1.84 *	-0.29	-5.56 **	-7.22 **	-2.14	-36.16 **	-11.92 **	-15.16 **	-11.41 **	-10.13 **
Giza 69 x Dandra	-4.92	8.17	-5.58 **	-9.03 **	-14.04 **	6.17 **	-10.29 **	-1.70	-12.98 **	-4.18 **	-20.52 **	-13.93 **
Giza 69 x Pima S6	17.97 **	28.45 **	-0.54	-15.44 **	-9.65 **	-2.15 **	22.87 **	14.90 **	-4.72 **	-13.20 **	-5.46 **	-26.83 **
Giza 69 x Australy	5.66	8.27	-7.34 **	-3.20 **	-4.39 **	3.30 **	-2.21	8.50 **	0.00	-7.83 **	-11.35 **	-9.99 **
Giza 69 x 10229	-1.28	1.01	-0.87	-5.12 **	-12.28 **	-5.15 **	-2.07	-4.04 *	-7.85 **	-17.74 **	-8.41 **	-19.54 **
LSD (0.05)	13.28	9.47	1.59	1.79	0.37	0.34	5.16	3.61	0.78	0.84	0.68	0.66

DOI: 10.34101/ACTAAGRAR/2/4145

Table 2

Heterosis over better parent (heterobeltiosis) for fiber quality properties under normal and water stress conditions

Crosses	Fiber fineness micronaire		Fiber strength Pressley		Fiber length		Uniformity ratio (%)	
	N	S	N	S	N	S	N	S
Giza 45 x Dandra	-10.57 **	-10.53 **	-0.92 **	-4.73 **	-4.72 **	-5.61 **	-0.70	-1.03
Giza 45 x Pima S6	-16.03 **	-5.36 **	0.61 **	-3.47 **	-1.93 **	-0.41	-0.27	0.43
Giza 45 x Australy	-4.65 **	-0.00	-3.67 **	-4.73 **	-6.65 **	-4.49 **	-1.36 **	-0.24
Giza 45 x 10229	-4.10 **	-8.77 **	0.00	-6.31 **	-0.29	-2.85 **	0.62	0.20
Minufy x Dandra	-8.66 **	-7.63 **	3.88 **	2.34 **	1.26 **	-6.94 **	0.23	-2.35 **
Minufy x Pima S6	-0.00	-3.39 **	2.94 **	-2.76 **	-2.33 **	0.83	-0.04	0.12
Minufy x Australy	-2.33 **	0.85 **	-1.89 **	-0.00	-0.78 **	-1.35 *	-1.52 **	-2.87 **
Minufy x 10229	-3.94 **	-2.54 **	-1.88 **	-2.01 **	-3.69 **	-3.73 **	-0.00	0.36
Giza 67 x Dandra	6.45 **	-11.02 **	3.86 **	-4.01 **	-0.00	-9.03 **	-0.28	-2.27 **
Giza 67 x Pima S6	-8.40 **	-1.69 **	1.29 **	1.37 **	-0.39	-4.10 **	-0.04	0.44
Giza 67 x Australy	-4.65 **	-6.78 **	-2.20 **	2.39 **	0.29	0.51	0.39	-0.20
Giza 67 x 10229	1.61 **	-0.00	-3.75 *	-4.68 **	0.60	-6.36 **	0.20	-0.64
Giza 68 x Dandra	5.69 **	11.40 **	-7.41 **	-1.67 **	2.96 **	-3.06 **	2.72 **	-1.44 **
Giza 68 x Pima S6	-2.29 **	4.46 **	-6.48 **	-1.70 **	-5.01 **	-9.01 **	-0.63	-1.24 *
Giza 68 x Australy	2.33 **	5.17 **	-9.26 **	-3.06 **	0.59	0.62	0.94 *	-0.12
Giza 68 x 10229	-1.64 **	-5.26 **	-2.47 **	-0.00	1.28 **	3.79 **	0.39	0.16
Giza 86 x Dandra	-2.24 **	0.00	1.59 **	-7.69 **	1.22 *	1.77 **	-0.16	0.04
Giza 86 x Pima S6	-2.99 **	6.25 **	0.32	2.15 **	0.29	-1.35 *	0.99 *	0.36
Giza 86 x Australy	-5.97 **	0.86 **	-4.09 *	4.27 **	1.37 **	-0.31	0.67	0.20
Giza 86 x 10229	-2.99 **	3.51 **	-3.44 **	-4.68 **	0.30	-0.94	-1.02 *	-1.47 **
Giza 77 x Dandra	-10.37 **	-7.44 **	5.83 **	-1.67 **	3.54 **	5.52 **	0.40	-0.28
Giza 77 x Pima S6	-2.96 **	1.65 **	-2.94 **	3.58 **	-1.18 *	-2.59 **	1.34	0.96
Giza 77 x Australy	-8.89 **	-3.31 **	-2.83 **	6.76 **	-1.47 **	1.86 **	-0.79	0.00
Giza 77 x 10229	-5.93 **	-3.31 **	-5.94 **	-3.01 **	0.20	1.46 *	0.39	0.56
Giza 94 x Dandra	2.34 **	2.63 **	2.59 **	-4.68 **	3.88 **	-6.59 **	1.45 **	-2.38 **
Giza 94 x Pima S6	-6.87 *	4.39 **	1.31 **	5.28 **	-0.10	-2.10 **	-0.90 *	-0.79
Giza 94 x Australy	-10.08 **	-7.76 **	0.63 **	7.39 **	-0.29	-1.90 **	0.47	-1.67 **
Giza 94 x 10229	-3.91 **	1.75 **	-1.88 **	-3.01 **	-3.59 **	-3.79 **	1.80 **	-0.40
Giza 96 x Dandra	3.20 **	1.71 **	0.64 **	-5.02 **	-7.38 **	-1.52 **	-2.88 **	-3.79 **
Giza 96 x Pima S6	-3.05 **	2.56 **	-1.28 **	0.69 **	-4.20 **	-3.76 **	-0.85 *	-1.07 *
Giza 96 x Australy	-5.43 **	-1.71 **	-1.89 **	3.09 **	-4.20 **	0.61	-1.27 **	-0.12
Giza 96 x 10229	0.00	-1.71 **	-2.81 **	-3.68 **	-5.60 **	-2.54 **	-1.73 **	-0.36
Giza 69 x Dandra	-12.88 **	-6.67 **	5.50 **	0.33	3.88 **	3.09 **	2.24 **	1.00
Giza 69 x Pima S6	-3.79 **	0.83 **	0.33	5.34 **	-0.59	-1.95 **	0.00	0.24
Giza 69 x Australy	-9.09 **	-4.17 **	-0.63 **	4.98 **	-2.64 **	-1.85 **	-0.86 *	0.40
Giza 69 x 10229	-9.09 **	-6.67 **	-2.50 **	-0.00	1.69 **	-1.95 **	1.30 **	0.91
LSD (0.05)	0.24	0.23	0.39	0.40	0.94	1.14	0.85	1.06

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Table 3

Heterosis over better parent (heterobeltiosis) for growth habit and earliness characters under normal and water stress conditions

Crosses	Position of first fruiting node		Boll maturation period (day)		Relative growth rate 1 (mg / g /day)		Relative growth rate 2 (mg / g /day)		Earliness (%)	
	N	S	N	S	N	S	N	S	N	S
Giza 45 x Dandra	-0.00	-0.00	-3.29 **	-2.11 **	78.73 **	53.11 **	17.10 **	-3.90 **	-4.80	-12.45 *
Giza 45 x Pima S6	4.55 **	5.26 **	-4.61 **	-2.11 **	17.59 **	5.39 **	-22.12 **	-10.11 **	26.94 **	-0.61
Giza 45 x Australy	-19.23 **	-16.67 **	-4.61 **	-2.82 **	-55.28 **	-14.11 **	-14.74 **	-32.26 **	5.41	-3.51
Giza 45 x 10229	9.09 **	4.76 **	-3.92 **	2.82 **	-16.75 **	-6.22 **	-13.32 **	-6.26 **	26.51 **	1.66
Minufy x Dandra	-13.04 **	-5.26 **	-2.00 *	-3.50 **	35.11 **	88.52 **	29.02 **	1.12 **	-18.63 **	-5.67
Minufy x Pima S6	-4.35 **	-0.00	0.67	-2.80 **	53.70 **	3.98 **	-25.86 **	-27.74 **	-6.58 *	-12.86 **
Minufy x Australy	-19.23 **	-25.00 **	-1.33	-2.10 **	-6.54 **	-6.09 **	0.24 **	-23.12 **	23.17 **	-7.06
Minufy x 10229	-17.39 **	-23.81 **	-3.92 **	-4.20 **	-6.71 **	-4.92 **	-9.24 **	-6.13 **	-0.86	-8.07
Giza 67 x Dandra	-20.00 **	-10.00 **	0.68	0.00	8.81 **	56.60 **	43.24 **	8.92 **	-10.69 **	2.48
Giza 67 x Pima S6	-12.00 **	0.00	-0.68	1.42	22.84 **	-3.81 **	-17.06 **	-12.77 **	-19.56 **	-36.95 **
Giza 67 x Australy	-15.38 **	-16.67 **	0.00	-0.71	-41.19 **	-8.63 **	19.08 **	-24.32 **	-40.91 **	-2.35
Giza 67 x 10229	-16.00 **	-14.29 **	-4.58 **	-2.84 **	-8.21 **	-2.37 **	-13.40 **	-19.65 **	-2.28	8.64
Giza 68 x Dandra	-8.70 **	0.00	0.67	-1.39	-4.43 **	-41.40 **	33.76 **	10.19 **	-12.35 **	-8.22
Giza 68 x Pima S6	4.35 **	0.00	-2.01 *	-2.78 **	-26.35 **	12.90 **	-15.26 **	-25.38 **	-22.32 **	-7.39
Giza 68 x Australy	-11.54 **	-16.67 **	-0.00	-0.69	0.49 **	-0.81 **	-13.92 **	-26.06 **	26.28 **	29.34 **
Giza 68 x 10229	-13.04 **	-14.29 *	-2.61 **	-2.08 **	-30.91 **	-16.59 **	-11.58 **	-21.25 **	33.27 **	-7.64
Giza 86 x Dandra	-9.09 **	-5.00 **	-6.54 **	-1.43 *	13.18 **	-19.30 **	12.49 **	-14.01 **	0.92	-16.34 **
Giza 86 x Pima S6	-9.09 **	-5.00 **	-2.61 **	-0.71	-29.03 **	-5.98 **	-9.74 **	-28.15 **	17.06 **	-19.96 **
Giza 86 x Australy	-15.38 **	-20.83 **	-2.61 **	-2.14 **	4.77 **	4.32 **	-19.66 **	-13.55 **	-12.43 **	-8.16
Giza 86 x 10229	-4.55 **	-9.52 **	-0.65	-0.00	7.85 **	-5.45 **	-33.46 **	-34.65 **	31.96 **	-10.00 *
Giza 77 x Dandra	-8.70 **	-5.00 **	-1.29	-1.42	104.76 **	8.65 **	7.15 **	8.71 **	7.99 *	2.94
Giza 77 x Pima S6	-8.70 **	-15.00 **	-3.23 **	-0.71	-5.80 **	-4.89 **	-19.16 **	-22.29 **	10.01 **	-14.03 **
Giza 77 x Australy	-19.23 **	-20.83 **	-2.58 **	0.71	50.72 **	24.21 **	-11.47 **	-17.25 **	-21.57 **	-6.12
Giza 77 x 10229	-8.70 **	-14.29 **	-3.87 **	-2.13 **	-1.45 **	-14.69 **	-14.61 **	-21.46 **	1.63	-1.66
Giza 94 x Dandra	4.55 **	10.53 **	-9.49 **	-1.46 *	21.87 **	26.47 **	-11.89 **	-4.27 **	-45.42 **	10.87 *
Giza 94 x Pima S6	-4.55 **	-0.00	-7.59 **	0.72	-5.33 **	7.34 **	-22.04 **	9.25 **	-9.55 **	-18.79 **
Giza 94 x Australy	-19.23 **	-20.83 **	-4.43 **	3.62 **	18.38 **	38.33 **	-16.54 **	-24.70 **	9.71 **	4.65
Giza 94 x 10229	-9.09 **	-9.52 **	-6.96 **	2.88 **	37.13 **	-6.87 **	-27.48 **	-23.32 **	1.58	-0.74
Giza 96 x Dandra	-4.35 **	-0.00	-0.66	1.44 *	69.97 **	109.54 **	-7.10 **	-14.32 **	-18.15 **	-9.85 *
Giza 96 x Pima S6	-4.35 **	-0.00	-1.99 *	0.72	22.05 **	-4.64 **	-0.70 **	-11.36 **	33.89 **	-9.03
Giza 96 x Australy	-15.38 **	-25.00 **	-3.31 **	-0.72	90.87 **	42.53 *	-16.87 **	-42.87 **	25.33 **	-15.47 **
Giza 96 x 10229	4.35 **	-4.76 **	-3.27 **	2.88 **	53.92 **	-5.21 **	-7.27 **	-18.79 **	-7.40 *	-19.57 **
Giza 69 x Dandra	-4.55 **	0.00	-2.65 **	-1.43 *	2.64 **	87.59 **	-12.74 **	-34.62 **	-40.98 **	10.32 *
Giza 69 x Pima S6	-4.55 **	-10.53 **	-3.31 **	-0.71	-9.76 **	-4.05 **	-8.57 **	-27.85 **	-2.74	-7.58
Giza 69 x Australy	-15.38 **	-16.67 **	-2.65 **	0.71	18.09 **	26.84 **	-11.14 **	-29.38 **	20.73 **	13.19 **
Giza 69 x 10229	4.55 **	-4.76 **	1.96 *	2.86 **	-32.72 **	10.90 **	-2.27 **	-6.71 **	-9.40 **	12.00 *
LSD (0.05)	1.10	0.87	1.86	1.43	0.008	0.005	0.008	0.010	6.25	9.60

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Table 4

Heterosis over better parent (heterobeltiosis) for Physiological measurements under normal and water stress conditions

Crosses	Leaf area index (cm^2)		Number of fruiting branches		Plant height (cm)	
	N	S	N	S	N	S
Giza 45 x Dandra	6.95	2.48	-4.00 **	2.50 **	-1.62	5.71
Giza 45 x Pima S6	0.61	-3.59	6.12 **	17.50 **	16.23 **	12.14 **
Giza 45 x Australy	8.15 *	-1.30	-8.33 **	0.00	-4.42	-1.67
Giza 45 x 10229	12.94 **	6.77 *	2.04 **	7.50 **	2.62	0.46
Minufy x Dandra	13.58 **	9.56 **	-4.00 **	5.13 **	-5.58	4.38
Minufy x Pima S6	8.72 *	5.16	-0.00	10.26 **	4.58	6.51 *
Minufy x Australy	13.55 **	9.81 **	-6.25 **	10.26 **	-5.78	9.80 **
Minufy x 10229	9.49 *	6.87 *	-6.12 **	7.50 **	-3.78	4.41
Giza 67 x Dandra	11.06 **	8.47 **	-6.00 **	-7.14 **	-3.01	4.59
Giza 67 x Pima S6	11.52 **	7.13 *	-0.00	2.38 **	6.21	0.92
Giza 67 x Australy	12.05 **	6.51 *	-2.08 **	4.76 **	-4.81	1.38
Giza 67 x 10229	13.74 **	6.10 *	2.04 **	2.38 **	5.01	0.23
Giza 68 x Dandra	4.50	1.11	0.00	5.13 **	4.70	3.80
Giza 68 x Pima S6	11.58 **	6.27 *	-4.08 **	2.56 **	2.15	-1.66
Giza 68 x Australy	13.26 **	11.03 **	-4.08 **	7.69 **	-1.76	1.19
Giza 68 x 10229	9.98 *	5.94	-0.00	2.50 **	-3.72	-0.46
Giza 86 x Dandra	6.45	2.95	-2.00 **	-2.63 **	0.98	-5.11
Giza 86 x Pima S6	10.44 **	6.91 *	-8.16 **	10.26 **	-3.14	7.23 *
Giza 86 x Australy	8.94 *	6.03 *	-8.33 **	5.26 **	-6.86	3.19
Giza 86 x 10229	15.09 **	9.34 **	-0.00	7.50 **	-0.59	1.86
Giza 77 x Dandra	3.46	0.61	0.00	2.50 **	10.10	0.48
Giza 77 x Pima S6	13.60 **	10.27 **	-6.12 **	-2.50 **	-2.81	-2.17
Giza 77 x Australy	8.14 *	5.37	2.08 **	0.00	-0.60	1.45
Giza 77 x 10229	14.54 **	7.69 *	2.04 **	7.50 **	5.03	0.46
Giza 94 x Dandra	12.09 **	10.44 **	0.00	2.50 **	10.10	-3.95
Giza 94 x Pima S6	11.16 **	5.56	-4.08 **	0.00	-2.81	-5.35
Giza 94 x Australy	8.01 *	6.13 *	2.04 **	10.00 **	-1.20	2.56
Giza 94 x 10229	9.21 *	5.87	6.12 **	12.50 **	10.06	5.57
Giza 96 x Dandra	4.43	-1.63	-15.38 **	2.44 **	-7.96	3.93
Giza 96 x Pima S6	7.94 *	0.82	-5.77 **	4.88 **	-2.91	1.62
Giza 96 x Australy	16.93 **	11.09 **	-1.92 **	4.88 **	1.75	2.31
Giza 96 x 10229	15.95 **	9.03 **	-5.77 **	4.88 **	2.72	1.15
Giza 69 x Dandra	6.75	1.03	2.00 **	13.16 **	10.00	4.09
Giza 69 x Pima S6	7.02	-1.12	4.08 **	7.69 **	-0.80	2.16
Giza 69 x Australy	16.02 **	9.35 **	4.17 **	13.16 **	0.40	6.73 *
Giza 69 x 10229	11.35 **	7.18 *	-6.12 **	2.50 **	1.40	-0.46
LSD (0.05)	7.70	5.95	1.30	1.00	10.66	6.53

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Table 5

Predicted general combining ability (GCA) effects for yield and yield components under normal and water stress conditions

Parents	Seed cotton yield / plant (g)		Lint percentage (%)		Boll weight (g)		Lint yield / plant (g)		Seed index (g)		Lint index (g)	
	N	S	N	S	N	S	N	S	N	S	N	S
L1- Giza 45	-5.44	0.53	-0.71	-2.00 **	-0.07	-0.04	-2.65 *	-1.26	-0.32	-0.21	-0.38 *	-0.57 **
L2- Minufy	8.63 *	1.11	-0.38	-2.57 **	-0.23 *	-0.26 **	2.83 *	-1.34	0.21	0.69 **	0.01	-0.25
L3- Giza 67	1.12	-3.54	-0.19	-0.82 *	0	-0.13	0.12	-1.75	0.01	0.14	-0.04	-0.13
L4- Giza 68	-0.69	-2.98	0.83 *	0.37	0.06	0.07	0.4	-0.8	0.37	0.01	0.44 *	0.1
L5- Giza 86	8.15 *	7.47 **	1.20 **	2.09 **	0.18	0.22 *	4.27 **	4.37 **	0.23	0.41	0.48 **	0.79 **
L6- Giza 77	-4.41	2.19	-0.23	0.15	0.04	0.04	-1.78	0.77	0.39 *	-0.39	0.17	-0.2
L7- Giza 94	-3.52	1.83	0.44	2.04 **	0.03	0.18 *	-0.98	2.10 *	0.17	0.26	0.22	0.62 **
L8- Giza 96	4.22	-8.31 **	-0.01	1.88 **	0	-0.07	1.49	-1.79	-0.64 **	-0.32	-0.39 *	0.23
L9- Giza 69	-8.05 *	1.71	-0.95 *	-1.14 **	-0.02	-0.01	-3.70 **	-0.3	-0.42 *	-0.59 **	-0.51 **	-0.59 **
LSD (0.05)	6.52	4.78	0.82	0.86	0.19	0.18	2.52	1.85	0.39	0.45	0.35	0.34
LSD (0.01)	8.66	6.35	1.08	1.14	0.26	0.24	3.35	2.45	0.52	0.59	0.46	0.46
T1- Dandra	3.51	6.64 **	0.04	0.03	-0.11	-0.09	1.41	2.58 **	0.11	0.29	0.08	0.16
T2- Pima S6	0.48	1.76	0.43	-1.10 **	-0.03	-0.09	0.45	-0.21	-0.61 **	-0.39 *	-0.25 *	-0.47 **
T3- Australy	1.11	-3.23 *	-0.13	0.50	0.10	0.06	0.33	-0.85	0.24	0.19	0.11	0.25 *
T4- 10229	-5.10 *	-5.16 **	-0.33	0.57 *	0.04	0.12 *	-2.19 *	-1.52 *	0.27 *	-0.09	0.06	0.06
LSD (0.05)	4.35	3.19	0.54	0.57	0.13	0.12	1.68	1.23	0.26	0.30	0.23	0.23

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Table 6

Predicted general combining ability (GCA) effects for fiber quality properties under normal and water stress conditions

Parents	Fiber fineness micronaire		Fiber strength Pressley		Fiber length		Uniformity ratio (%)	
	N	S	N	S	N	S	N	S
L1- Giza 45	-0.30 **	-0.26 **	0.35 **	0.28 **	-0.38	-0.21	0.18	0.93 **
L2- Minufy	-0.01	-0.02	0.07	-0.02	0.08	-0.52	-0.11	-0.56 *
L3- Giza 67	0.04	-0.09	0.03	-0.04	-0.18	-0.86 **	-0.40	-0.12
L4- Giza 68	0.12 *	0.12 *	-0.33 **	-0.05	0.06	-0.51	0.22	-0.54
L5- Giza 86	0.18 **	0.07	-0.03	-0.29 **	-0.03	0.21	-0.46 *	0.2
L6- Giza 77	0.05	0.08	-0.16	0	-0.18	0.78 *	-0.38	0.13
L7- Giza 94	-0.03	0	0.07	0.05	0.55 **	0.38	0.64 **	-0.44
L8- Giza 96	0.06	0.08	-0.07	-0.07	-0.02	0.39	0.12	0
L9- Giza 69	-0.11 *	0.01	0.07	0.14 *	0.12	0.36	0.19	0.40
LSD (0.05)	0.10	0.12	0.19	0.20	0.50	0.60	0.45	0.57
T1- Dandra	0	-0.06	0.19 **	-0.04	0.26	-0.23	0.13	-0.80 **
T2- Pima S6	0.04	0.08 *	-0.07	-0.01	-0.12	-0.19	-0.08	0.31
T3- Australy	-0.02	0.02	-0.09	0.11	0.05	0.46 *	-0.2	-0.07
T4- 10229	-0.02	-0.04	-0.03	-0.05	-0.19	-0.03	0.15	0.56 **
LSD (0.05)	0.07	0.08	0.13	0.13	0.33	0.40	0.30	0.38

Table 7

Predicted general combining ability (GCA) effects for physiological measurements under normal and water stress conditions

Parents	Leaf area index (cm^2)		Number of fruiting branches		Plant height (cm)	
	N	S	N	S	N	S
L1- Giza 45	11.60 **	-5.69 **	0.06	0.27	2	2.33
L2- Minufy	4.30	4.33 **	-0.44	0.19	-6.17 **	3.00
L3- Giza 67	8.57 **	5.01 **	-0.03	0.1	-1.33	3.50 *
L4- Giza 68	1.16	0.14	-0.03	-0.31	1.83	-2.25
L5- Giza 86	0.78	0.83	-0.53	-0.40	-3.17	-3.17
L6- Giza 77	0.66	1.1	0.14	-0.40	1.5	-5.00 **
L7- Giza 94	4.75 *	2.54 *	0.47	0.19	3.33	-1.42
L8- Giza 96	-2.76	-3.24 *	-0.03	0.27	-0.17	3.17
L9- Giza 69	-5.86 **	-5.02 **	0.39	0.1	2.17	-0.17
LSD (0.05)	4.41	3.11	0.64	0.53	5.45	3.43
T1- Dandra	-8.90 **	-3.63 **	0.07	-0.43 *	1.62	-1.19
T2- Pima S6	-2.65	-2.07 **	0	0.09	1.92	-0.34
T3- Australy	3.73 *	2.11 *	-0.3	0.06	-5.60 **	-0.08
T4- 10229	7.82 **	3.60 **	0.22	0.28	2.06	1.62
LSD (0.05)	2.94	2.07	0.43	0.35	3.63	2.28

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Table 8

Simple correlation among GCA effects of various characters

	SCY/P	LP	BW	LY	SI	LI	FFN	BMP	RGR1	RGR2	Earliness	LAI	N.of fruitin branches	Plant height	FF	FS	FL
LP	-0.08																
BW	0.14	0.75*															
LY	0.83*	0.49	0.53														
SI	0.28	0.06	-0.05	0.31													
LI	0.10	0.87*	0.63*	0.59*	0.55*												
FFN	-0.11	0.21	0.4	0.02	-0.17	0.12											
BMP	-0.70*	0.10	0.24	-0.57*	-0.58*	-0.21	0.52										
RGR1	-0.004	-0.38	-0.58*	-0.21	-0.08	-0.37	-0.02	-0.16									
RGR2	0.22	0.12	0.21	0.26	0.2	0.19	-0.23	-0.19	-0.04								
Earliness	-0.12	-0.40	-0.38	-0.34	-0.27	-0.49	-0.28	0.14	0.56*	0.52							
LAI	-0.20	0.13	0.09	-0.08	0.58*	0.38	-0.41	-0.14	-0.51	0.27	-0.10						
N.O.F.b	-0.60*	-0.25	-0.26	-0.67*	-0.16	-0.31	0.14	0.35*	0.35*	-0.49*	0.11	0.05					
Plant height	0.57*	-0.40	-0.60*	-0.71*	0.09	-0.32	0.05	0.14	0.55*	-0.45	0.12	0.06	0.80*				
FF	-0.05	0.49	0.27	0.22	-0.10	0.36	-0.42	-0.01	-0.56*	-0.06	-0.29	0.17	-0.40	-0.52			
FS	-0.17	-0.5	-0.24	-0.46	-0.39	-0.63*	0.39	0.41	0.44	0.02	0.56*	-0.40	0.48	0.27	-0.59*		
FL	0.08	0.51	0.52	0.32	-0.38	0.25	-0.07	-0.002	-0.05	0.36	0.16	-0.22	-0.10	-0.51	0.36	0.07	
UR	-0.14	-0.17	0.20	-0.24	-0.61*	-0.42	0.30	0.29	0.02	-0.21	-0.06	-0.33	0.39	0.15	-0.35	0.35	0.24

* Significant at 0.05 level of probability.

SCY = Seed cotton yield / plant

LP = Lint percentage ,

BW = Boll weight ,

LY = Lint yield / plant ,

SI = Seed index ,

LI = Lint index ,

FFN = Position of first fruiting node ,

BMP = Boll maturation period ,

RGR = Relative growth rate ,

LAI = Leaf area index ,

N.O.F.b = Number of fruiting branches ,

FF = Fiber fineness ,

FS = Fiber strength ,

FL = Fiber length ,

UR = Uniformity ratio ,

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Table 9

Predicted specific combining ability (SCA) effects for yield and yield components under normal and water stress conditions

Parents	Seed cotton yield / plant (g)		Lint percentage (%)		Boll weight (g)		Lint yield / plant (g)		Seed index (g)		Lint index (g)	
	N	S	N	S	N	S	N	S	N	S	N	S
Giza 45 x Dandra	3.60	-3.93	-0.75	-2.49 **	0.11	-0.15	0.57	-3.29	-0.33	0.13	-0.41	-0.47
Giza 45 x Pima S6	6.19	4.33	-0.40	0.93	-0.15	-0.04	2.08	2.27	-0.00	-0.32	-0.10	0.05
Giza 45 x Australy	-6.15	7.18	-0.08	-0.29	-0.27	-0.09	-2.33	2.42	-0.99 *	-0.57	-0.61	-0.41
Giza 45 x 10229	-3.64	-7.58	1.23	1.85 *	0.32	0.28	-0.32	-1.40	1.31 **	0.75	1.12 **	0.83 *
Minufy x Dandra	-12.26	-7.50	-0.56	-0.26	-0.06	-0.26	-5.11 *	-3.03	0.47	0.76	0.10	0.33
Minufy x Pima S6	-7.66	3.85	0.76	1.00	-0.02	0.11	-2.10	2.00	-0.10	0.17	0.19	0.35
Minufy x Australy	17.74 **	-6.06	0.38	-0.72	-0.01	-0.04	6.98 **	-2.46	-0.55	-0.01	-0.23	-0.20
Minufy x 10229	2.18	9.72 *	-0.58	-0.02	0.08	0.20	0.23	3.48	0.18	-0.92 *	-0.06	-0.48
Giza 67 x Dandra	-17.82 **	-4.25	0.89	-0.15	-0.16	0.08	-5.88 *	-1.85	0.21	0.04	0.36	-0.01
Giza 67 x Pima S6	21.16 **	6.01	-1.88 *	1.46	-0.35	-0.05	6.11 *	3.20	0.06	-0.14	-0.46	0.25
Giza 67 x Australy	-7.55	6.56	1.06	0.37	0.16	-0.37 *	-1.80	2.52	-0.25	0.04	0.13	0.09
Giza 67 x 10229	4.22	-8.31	-0.07	-1.68	0.35	0.34	1.58	-3.88 *	-0.02	0.06	-0.03	-0.33
Giza 68 x Dandra	2.87	-1.64	-1.61	0.79	0.01	0.15	-0.38	-0.19	0.58	-0.29	-0.14	0.01
Giza 68 x Pima S6	-9.55	-10.97 *	1.50	-1.59	0.29	-0.22	-2.32	-4.69 *	-0.93 *	-0.08	-0.17	-0.40
Giza 68 x Australy	-0.56	-5.40	0.82	1.31	-0.13	0.16	0.58	-1.35	0.92 *	0.54	0.85 *	0.63
Giza 68 x 10229	7.24	18.01 **	-0.71	-0.50	-0.17	-0.09	2.12	6.23 **	-0.58	-0.17	-0.54	-0.24
Giza 86 x Dandra	22.54 **	23.75 **	1.46	-0.17	0.12	0.06	10.22 **	8.87 **	-0.14	-0.69	0.36	-0.51
Giza 86 x Pima S6	-12.56 **	-19.32 **	-0.68	-1.50	-0.07	0.03	-5.38 *	-8.13 **	-0.15	-0.48	-0.30	-0.71 *
Giza 86 x Australy	-2.11	-1.66	-0.91	2.38 **	-0.13	-0.19	-1.80	0.92	-0.00	1.14 *	-0.28	1.42 **
Giza 86 x 10229	-7.87	-2.78	0.13	-0.70	0.07	0.09	-3.03	-1.66	0.30	0.03	0.22	-0.19
Giza 77 x Dandra	-1.47	-0.60	1.41	0.99	0.03	0.10	0.56	0.56	-0.58	-0.36	0.04	0.03
Giza 77 x Pima S6	8.74	12.97 **	-1.40	-0.16	-0.12	-0.09	2.02	4.67 *	-0.12	-0.01	-0.45	-0.03
Giza 77 x Australy	3.53	1.73	0.91	-3.21 **	0.15	0.26	2.04	-1.38	0.83 *	0.28	0.76 *	-0.61
Giza 77 x 10229	-10.79	-14.10 **	-0.92	2.38 **	-0.06	-0.27	-4.62	-3.85 *	-0.14	0.09	-0.35	0.61
Giza 94 x Dandra	-3.27	-1.95	0.67	0.06	-0.13	0.00	-0.69	-0.69	0.55	0.53	0.54	0.37
Giza 94 x Pima S6	-6.49	-5.85	0.84	1.21	0.35	0.34	-1.67	-1.29	-0.30	-0.19	0.04	0.14
Giza 94 x Australy	2.22	-2.63	-0.34	0.10	0.16	0.06	0.57	-0.96	-0.08	-0.84	-0.15	-0.49
Giza 94 x 10229	7.55	10.43 *	-1.16	-1.37	-0.38	-0.40 *	1.79	2.94	-0.18	0.51	-0.43	-0.02
Giza 96 x Dandra	17.91 **	7.83	-0.72	1.58	0.11	0.09	5.83 *	4.07 *	0.12	-0.22	-0.13	0.28
Giza 96 x Pima S6	-14.36 *	-6.45	0.55	0.35	0.02	-0.18	-4.78	-2.07	0.78 *	0.66	0.61	0.45
Giza 96 x Australy	-5.39	-0.16	-0.55	-1.36	-0.04	0.17	-2.48	-1.02	-0.34	-0.26	-0.35	-0.51
Giza 96 x 10229	1.84	-1.22	0.73	-0.56	-0.08	-0.08	1.43	-0.98	-0.57	-0.17	-0.14	-0.22
Giza 69 x Dandra	-12.09	-11.72 *	-0.79	-0.35	-0.04	-0.07	-5.12 *	-4.46 *	-0.89 *	0.11	-0.72 *	-0.01
Giza 69 x Pima S6	14.54 *	15.44 **	0.72	-1.68	0.04	0.10	6.04 *	4.04 *	0.76	0.39	0.65	-0.10
Giza 69 x Australy	-1.72	0.45	-1.28	1.42	0.12	0.05	-1.74	1.30	0.45	-0.32	-0.12	0.08
Giza 69 x 10229	-0.73	-4.17	1.36	0.61	-0.12	-0.07	0.82	-0.88	-0.32	-0.17	-0.41	0.03
LSD (0.05)	13.04	9.57	1.63	1.72	0.39	0.36	5.04	3.69	0.78	0.89	0.70	0.69

DOI: 10.34101/ACTAAGRAR/2/4145

Table 10

Predicted specific combining ability (SCA) effects for fiber quality properties under normal and water stress conditions

Parents	Fiber fineness micronaire		Fiber strength pressley		Fiber length		Uniformity ratio (%)	
	N	S	N	S	N	S	N	S
Giza 45 x Dandra	-0.16	-0.11	-0.19	0.05	-0.72	-0.51	-0.36	0.07
Giza 45 x Pima S6	-0.21 *	-0.11	0.25	0.16	0.63	1.15	0.21	0.19
Giza 45 x Australy	0.28 **	0.28 *	-0.20	-0.10	-1.17 *	-0.83	-0.60	0.00
Giza 45 x 10229	0.09	-0.06	0.14	-0.11	1.27 *	0.19	0.75	-0.26
Minufy x Dandra	-0.26 *	-0.11	-0.01	0.49 *	0.64	-1.10	0.35	-0.18
Minufy x Pima S6	0.20	-0.09	0.06	-0.34	-0.20	1.36 *	0.33	0.77
Minufy x Australy	0.09	0.14	-0.02	-0.20	0.16	0.01	-0.82	-1.35 *
Minufy x 10229	-0.04	0.06	-0.02	0.06	-0.60	-0.27	0.13	0.76
Giza 67 x Dandra	0.23 *	-0.18	0.10	-0.13	-0.72	-1.16	-0.49	-0.55
Giza 67 x Pima S6	-0.21 *	0.04	0.10	0.17	0.26	0.40	-0.08	0.61
Giza 67 x Australy	-0.06	-0.09	-0.01	0.15	0.52	1.25 *	0.67	0.45
Giza 67 x 10229	0.05	0.23 *	-0.18	-0.19	-0.06	-0.49	-0.11	-0.51
Giza 68 x Dandra	0.09	0.34 **	-0.30	0.12	0.64	-0.42	1.33 **	-0.00
Giza 68 x Pima S6	-0.02	-0.13	0.06	-0.08	-1.55 **	-1.82 **	-1.26 **	-0.94
Giza 68 x Australy	0.17	0.10	-0.21	-0.34	0.38	0.63	0.52	0.37
Giza 68 x 10229	-0.23 *	-0.31 **	0.45 *	0.29	0.53	1.61 **	-0.59	0.57
Giza 86 x Dandra	0.06	-0.04	0.06	-0.25	-0.77	0.77	-0.65	0.99
Giza 86 x Pima S6	-0.01	-0.01	0.19	0.02	0.35	-0.07	0.79	0.15
Giza 86 x Australy	-0.09	-0.02	-0.16	0.16	0.74	-0.39	0.97 *	0.39
Giza 86 x 10229	0.05	0.07	-0.09	0.06	-0.31	-0.30	-1.11 *	-1.54 **
Giza 77 x Dandra	-0.15	-0.11	0.42 *	0.07	0.28	1.40 *	-0.67	0.13
Giza 77 x Pima S6	0.14	0.11	-0.31	-0.13	-0.00	-1.04	1.01 *	0.03
Giza 77 x Australy	-0.07	-0.03	0.11	0.11	-0.08	-0.26	-0.34	-0.40
Giza 77 x 10229	0.07	0.03	-0.22	-0.06	-0.20	-0.10	0.01	0.24
Giza 94 x Dandra	0.27 *	0.14	-0.14	-0.28	1.08 *	-0.77	0.50	-0.10
Giza 94 x Pima S6	-0.07	0.06	-0.10	0.16	0.10	0.69	-1.29 **	0.13
Giza 94 x Australy	-0.22 *	-0.28 *	0.25	0.23	-0.14	0.11	-0.00	-0.23
Giza 94 x 10229	0.02	0.08	-0.01	-0.11	-1.03 *	-0.04	0.78	0.21
Giza 96 x Dandra	0.11	0.12	-0.10	-0.20	-0.99 *	0.33	-1.17 *	-1.28 *
Giza 96 x Pima S6	0.00	0.01	-0.04	0.07	0.53	-0.45	0.81	-0.08
Giza 96 x Australy	-0.11	-0.09	0.12	0.18	0.36	0.33	0.56	1.09
Giza 96 x 10229	-0.00	-0.04	0.02	-0.06	0.10	-0.21	-0.19	0.26
Giza 69 x Dandra	-0.18	-0.04	0.16	0.13	0.58	1.45 *	1.16 *	0.92
Giza 69 x Pima S6	0.18	0.12	-0.20	-0.04	-0.10	-0.22	-0.53	-0.85
Giza 69 x Australy	0.00	-0.02	0.12	-0.19	-0.77	-0.84	-0.97 *	-0.34
Giza 69 x 10229	0.00	-0.06	-0.08	0.10	0.30	-0.39	0.34	0.26
LSD (0.05)	0.21	0.23	0.38	0.39	0.99	1.21	0.90	1.14

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Table 11

Predicted specific combining ability (SCA) effects physiological measurements under normal and water stress conditions

Parents	Leaf area index (cm^2)		Number of fruiting branches		Plant height (cm)	
	N	S	N	S	N	S
Giza 45 x Dandra	7.89	7.19 *	-0.24	-0.16	-10.37	2.44
Giza 45 x Pima S6	-17.23 **	-9.89 **	-0.58	0.66	20.33 **	10.59 **
Giza 45 x Australy	-1.19	-8.20 *	-1.20	-0.97	-6.81	-9.00 *
Giza 45 x 10229	6.80	10.91 **	0.28	-0.19	-3.15	-4.04
Minufy x Dandra	15.65 **	8.99 **	0.26	-0.07	-6.54	-3.22
Minufy x Pima S6	-5.22	-2.33	0.67	0.07	10.17	0.26
Minufy x Australy	2.93	-0.13	-0.37	0.11	0.35	2.00
Minufy x 10229	-13.37 **	-6.52 *	-0.56	-0.11	-3.98	0.96
Giza 67 x Dandra	5.77	7.19 *	-0.49	-0.66	-8.04	5.28
Giza 67 x Pima S6	0.92	2.26	0.25	0.16	7.00	-0.91
Giza 67 x Australy	-3.86	-3.46	-0.12	0.53	-3.81	-0.50
Giza 67 x 10229	-2.83	-6.00	0.36	-0.03	4.85	-3.87
Giza 68 x Dandra	-7.19	-7.92 *	0.51	0.43	5.80	4.69
Giza 68 x Pima S6	7.94	4.65	-0.42	-0.43	1.17	-3.82
Giza 68 x Australy	6.62	7.90 *	-0.12	0.28	2.02	-0.08
Giza 68 x 10229	-7.37	-4.64	0.03	-0.28	-8.98	-0.79
Giza 86 x Dandra	-2.45	-4.01	0.68	-0.82	4.13	-10.06 **
Giza 86 x Pima S6	3.27	5.54	1.17	1.32 *	-3.17	7.43 *
Giza 86 x Australy	-7.62	-4.65	-0.62	-0.31	-1.98	-0.83
Giza 86 x 10229	10.53 **	3.12	0.53	0.47	1.02	3.46
Giza 77 x Dandra	-10.60 *	-10.10 **	0.34	0.51	9.46	0.11
Giza 77 x Pima S6	13.68 **	13.72 **	-0.92	-0.68	-10.83	-3.74
Giza 77 x Australy	-9.14 *	-3.96	0.38	-0.31	0.02	0.33
Giza 77 x 10229	6.07	0.33	0.19	0.47	1.35	3.30
Giza 94 x Dandra	14.90 **	12.99 **	0.01	-0.07	7.63	-4.14
Giza 94 x Pima S6	5.81	0.44	-0.92	-0.93	-12.67 *	-6.99 *
Giza 94 x Australy	-10.13 *	-6.22 *	0.38	0.44	-2.81	4.08
Giza 94 x 10229	-10.57 *	-7.21 *	0.53	0.56	7.85	7.05 *
Giza 96 x Dandra	-16.90 **	-11.37 **	-1.49 *	0.18	-12.54 *	3.61
Giza 96 x Pima S6	-4.77	-5.65	0.25	-0.01	-4.17	-0.57
Giza 96 x Australy	10.98 *	10.61 **	1.21	0.03	11.35 *	0.17
Giza 96 x 10229	10.69 *	6.41 *	0.03	-0.19	5.35	-3.20
Giza 69 x Dandra	-7.06	-2.96	0.43	0.68	10.46	1.28
Giza 69 x Pima S6	-4.40	-8.74 **	0.50	-0.18	-7.83	-2.24
Giza 69 x Australy	11.41 *	8.10 *	0.46	0.19	1.69	3.83
Giza 69 x 10229	0.05	3.59	-1.39 *	-0.69	-4.31	-2.87
LSD (0.05)	8.81	6.22	1.29	1.06	10.90	6.85