

A Genetic Analysis of Yield and its Components of Egyptian Cotton (*Gossypium barbadense* L.) Under Divergent Environments

¹Gamal I.A. Mohamed, ²S.H.M. Abd-El-Halem and ¹E.M.A. Ibrahim

¹Faculty of Agriculture, Assiut University, Egypt

²Faculty of Agriculture, Al-Azhar University at Assiut, Egypt

Abstract: A half-diallel set of crosses was established among six local cotton varieties: Giza-88, Giza 90, Giza 87, Giza 89, Giza 91 and Giza 83 in order to estimate the genetic parameters of seed-cotton yield and its components under two divergent environments of clay-fertile and a sandy-calcareous infertile soils. The average reduction in seed-cotton yield/plant under drought stress were 42 and 37.4% and in lint yield/plant were 46.2 and 40.5% for the parent and it is F₁ hybrids, respectively. The results revealed that the additive and non-additive gene effects were involved in the control of the studied traits in both environments. Most of the variation was attributed to the non-additive gene effects. For seed-cotton yield per plant and boll weight the additive gene effects were more important under favorable conditions but under stress, the non-additive effects of the genes were more important. The W_r/V_r analysis revealed that over-dominance was operating for the F₁ generation and partial dominance was detected for the F₂ generation under the two environments. The order of the dominance of the cultivars was reversed under drought. The genetic parameters indicated unequal distribution of dominant and recessive alleles among the six parents analyzed. Narrow-sense heritability values were much smaller relative to broad-sense heritability in the two environments indicating that the additive component was smaller than the other components of variance.

Key words: Egyptian cotton % Diallel analysis % Drought % Yield and its components

INTRODUCTION

Improving yield of cotton is the ultimate objective of many cotton breeding programs especially under adverse environmental conditions which prevail in the new land. Most of the newly reclaimed soils in Egypt are located in the desert where the availability of irrigation water is the most limiting factor. Drought stress is among the most important environmental factors influencing the yield components of cotton. Reduction in cotton yield is mainly due to moisture deficiency of the soils. Thus, breeding cotton for stress environments depends on their ability to resist drought [1]. Estimating the genetic parameters is an important step for identifying the best progenies to be used in the breeding program. Using information on the genetic structure of yield and its components as a quantification and selection criterion should be superior to use of yield under both normal and moisture deficiency [2,3,4]. The present investigation was conducted to study the effects of drought stress on the performance and

genetic behaviour of some local cotton genotypes crossed in a half diallel and grown in stressed and non-stressed environments. Moreover, the genetic parameters and heritability were estimated for seed-cotton yield and yield components under both environments in order to determine the appropriate breeding strategy for yield improvement.

MATERIALS AND METHODS

Plant Materials: Six Egyptian cotton varieties: namely Giza-88 (P1), Giza-90 (P2), Giza-87 (P3), Giza-89 (P4), Giza-91 (P5) and Giza-83 (P6) were used in this study. The seeds were grown in fertile clay-loam soil in Al-Azhar University Experimental Farm.

Field Experiment Conditions: In 2005 season, the six cotton varieties were sown into the field of Al-Azhar University Experimental Farm and crossed in all possible combinations, excluding reciprocals, in order to obtain a

total of 15 F₁ crosses. In 2006 growing season, seeds of the six parental varieties and the 15 F₁ hybrids were sown into the field and of Al-Azhar University Farm in order to produce the F₂ seeds. Crosses were also made to produce more F₁ seeds.

In 2007 season, seeds of the six parents, the 15 F₁ s and the 15 F₂ s of the six-parent half diallel cross were sown into the field at two experimental sites. The first experiment was conducted under the favourable conditions of the fertile clay-loam soil of Al-Azhar University Farm and was irrigated each three weeks after the planting irrigation.

Meanwhile, the second experiment was carried out under the stressed conditions of the infertile sandy-calcareous soil of the El-Ghoraieb Experimental Station which is located in the eastern desert 15 km south of Assiut and was irrigated each two weeks after the planting irrigation. The experimental layout in each site was a complete randomized block design with three replications. The parents and the F₁ hybrids were represented by one row of plants per block, while four rows per block were used for each of the 15 F₂ populations. Each row was 4.0 meter long, spaced 60 cm apart with plants spaced 25 cm within rows, on one side of the ridge with one seed per hill using the dry planting method. The agricultural practices recommended for cotton production were applied throughout the growing season. Measurements were recorded on a random sample of seven guarded plants for parents and the F₁ hybrids and 20 guarded plants for each F₂ populations in each replicate in the two experiments. The following characters were recorded for each plant: seed-cotton yield/plant, Lint yield/plant, Lint percentage and boll weight (gm).

Statistical Analysis: The collected data were analyzed using diallel analysis as developed by Hayman [2,5,6,7], Mather and Jinks [8] and Gomez and Gomez [9].

RESULTS AND DISCUSSION

The Means of the seed-cotton yield/plant, lint yield/plant, lint percentage and boll weight of the six parental cultivars, the 15 F₁ hybrids and 15 F₂ populations in the favourable (Al-Azhar) and stressed (El-Ghoraieb) environments are presented in Table 1. The parental means of seed cotton yield/plant under favourable conditions ranged from 27.64 (P1) to 54.27 (P2) grams with an average of 44.88 g. Under drought stress, the means were rather reduced to range from 14.02 (P1) to 46.72 (P6) with an average of 26.02 g indicating a 42% average

reduction in seed-cotton yield/plant. The means of the F₁ hybrids ranged from 48.45 to 63.21 g with an average of 54.64 g in the non-stress condition but in the stressed environment ranged from 14.53 to 49.11 g with an average of 34.21 g indicating 37.4% average reduction in seed-cotton yield/plant. Averaged over parents and F₁'s, seed-cotton yield/plant were reduced by 39.5% under stress conditions. For lint yield/plant, the parental average reached 19.46 g in the favourable environment but was reduced to 10.53 g under the stressed sandy soil conditions indicating 46.2% reduction in lint yield/plant. The average of the F₁ hybrids decreased from 23.21 g in the non-stress environment to 13.81 g under stress conditions indicating 40.5% reduction in lint yield/plant. In the two environments, the cultivar Giza 88 (P1) was the best in lint percentage trait (50.67 and 47.06) under favourable and stress conditions, respectively. Whereas, Giza 87 (P3) showed the lowest lint percentage (35.86 and 30.87, respectively). The average lint percentage of the F₁ hybrids decreased from 44.67 in the favourable environment to 38.26 in the stress environment. Giza 83 (P6) was the best for boll weight under favourable and stressed environments (2.89 and 2.44 g, respectively). The average boll weight of the F₁ hybrids decreased from 2.98 g in the favourable environment down to 2.43 g in the stressed environment. Such reductions under stress are agreement with Hendawy [10], Kiani *et al.*[11], Mohamed *et al.* [12], Zerihun *et al.* [13] and Rokaya *et al.* [14].

The analysis of variance (Table 2) revealed highly significant differences among the genotypes for all characters studied in both the favourable and the stressed environments.

The Diallel Analysis of Variance: For seed-cotton yield/plant and its components, both "a" and "b" items measuring additive and non-additive gene effects, respectively were highly significant for both F₁ and F₂ generations in the two contrasting environments (Table 2). Directional dominance towards greater expression was operating for seed-cotton yield/plant, lint-yield/plant and boll weight in the two contrasting environments as indicated by the significance of the "b₁" item. However, dominance was ambidirectional for lint percentage in the favourable environment but was directional towards lower lint percentage under stress. The "b₂" item was significant for all characters in the two contrasting environments indicating unequal distribution of dominant and recessive alleles among the parents. The significance of the "b₃" item for all studied traits in the

Table 1: Average performance of the parental varieties and their F₁ crosses (upper values) and F₂ populations (lower values) grown at two contrasted environments

Genotypes	Seed-Cotton yield/plant (g.)		Lint yield/plant (g.)		Lint percentage		Boll weight (g.)	
	Favorable	Stress	Favorable	Stress	Favorable	Stress	Favorable	Stress
P1(Giza-88)	27.64	14.02	14.28	6.62	50.67	47.06	2.67	1.52
P2(Giza-90)	54.72	19.15	21.37	8.01	43.92	41.86	2.43	2.14
P3(Giza-87)	36.51	30.41	12.49	9.89	35.86	30.87	2.86	1.27
P4(Giza-89)	50.74	20.01	23.26	9.04	48.7	45.21	2.72	1.88
P5(Giza-91)	51.91	25.83	22.41	12.08	46.21	45.69	2.65	1.78
P6(Giza-83)	35.01	46.72	22.96	17.53	49.41	38.52	2.89	2.44
Parent means	44.88	26.02	19.50	10.50	45.80	41.50	2.70	1.80
Red. P %	42.02%		46.2%		9.4%		33.3%	
Crosses								
P1 X P2	52.54	36.42	22.51	14.92	43.22	40.93	3.29	2.20
	44.87	13.41	19.52	4.66	43.73	34.73	2.65	2.23
P1 X P3	51.77	46.02	20.01	16.59	38.68	35.93	3.16	1.95
	48.00	14.05	19.27	6.78	41.10	35.30	2.87	1.73
P1 X P4	63.21	49.11	27.03	19.12	42.80	33.10	2.88	2.58
	55.53	17.07	25.82	8.52	46.53	40.19	2.64	2.13
P1x P5	52.24	47.03	23.39	21.70	47.87	43.48	2.91	2.47
	50.81	9.84	23.18	3.90	45.88	39.59	2.82	2.04
P1 X P6	48.45	29.77	22.32	14.85	46.3	45.44	2.68	2.61
	35.29	14.60	14.40	5.14	43.53	35.08	2.45	2.30
P2 X P3	49.96	34.85	22.62	13.26	46.17	38.28	3.15	2.28
	32.79	9.53	13.48	4.45	44.53	33.89	2.79	1.89
P2 X P4	52.24	43.78	21.92	17.66	42.06	40.48	2.87	2.70
	25.43	13.20	9.41	4.43	37.86	33.57	2.37	2.00
P2 X P5	54.57	28.22	18.33	11.88	42.93	40.76	2.92	2.47
	31.74	13.66	19.22	5.66	60.84	41.35	2.44	1.86
P2 X P6	58.13	37.83	25.72	14.43	47.72	38.13	2.84	2.53
	42.52	32.81	15.64	7.98	37.08	24.17	2.63	1.91
P3 X P4	52.65	25.74	24.97	14.60	54.54	51.41	3.00	2.43
	27.12	15.66	18.09	5.72	62.56	36.65	2.51	2.02
P3 X P5	59.91	22.93	29.05	5.25	48.82	22.55	2.64	2.48
	28.78	13.93	19.68	4.84	68.39	34.75	2.16	2.16
P3 X P6	50.48	14.53	18.58	5.68	41.28	39.09	2.85	2.60
	33.77	12.81	15.98	5.50	47.57	42.94	2.27	1.65
P4 X P5	56.84	38.87	26.03	13.72	45.76	27.85	3.18	2.22
	30.76	26.08	13.47	10.96	43.87	38.29	2.25	1.96
P4 X P6	55.06	25.89	21.40	11.02	42.36	39.56	3.21	2.53
	30.75	24.79	14.71	10.86	47.90	43.95	2.41	1.90
P5 X P6	61.48	32.11	24.26	12.49	39.47	36.85	3.08	2.35
	31.97	25.60	13.83	10.43	43.25	39.31	2.39	1.85
Cross means	54.64	34.21	23.2	13.8	44.7	38.3	2.98	2.4
Red. C %	37.4%		40.5%		14.3%		19.5%	
Red. P+C	39.5%		43.1%		11.8%		26.1%	

{Red. P %=(P_{Fav.}-P_{Str.}/P_{Fav.})100 , Reduction C %=(C_{Fav.}-C_{Str.}/C_{Fav.})100, Reduction P+C %=(P_{Fav.+C_{Fav.}})-(P_{Str.+C_{Str.}})/(P_{Fav.+C_{Fav.}}) 100 }

Table 2: The diallel analysis of variance of the F₁ (upper values) and F₂ (lower values) generations of the diallel cross grown in two contrasted environments

Items	d.f.	Seed-Cotton yield/plant (g.)		Lint yield/plant (g.)		Lint percentage		Boll weight (g.)	
		Favorable	Stress	Favorable	Stress	Favorable	Stress	Favorable	Stress
		MS	MS	MS	MS	MS	MS	MS	MS
Blocks	2	83.55	72.05	1.97	12.76	8.42	3.70	1.39**	0.04
Genotypes	35	165.33**	12.58	3.49	1.90	57.48	64.40*	0.58**	0.092
		283.19**	204.1**	53.97**	27.64**	212.45**	81.39**	0.14**	0.16**
a #	5	264.2**	261.78**	50.36**	91.44**	16.96	147.40**	0.026	0.57**
		342.4**	655.36**	64.07**	84.04**	302.60**	150.66**	0.25**	0.26**
B	15	225.26**	663.90**	71.87**	103.14**	119.30**	263.24**	0.31**	0.55**
		546.63**	257.79**	104.58**	36.48**	394.90**	139.68**	0.24**	0.29**
B1	1	1420.74**	1004.86**	210.84**	161.68**	19.12	161.45**	1.15**	5.24**
		1015.34**	1184.27**	82.68**	225.10**	51.14	320.12**	0.55**	0.29**
B2	5	161.32**	1142.79**	46.3**	164.84**	106.99**	137.63**	0.11	0.15**
		941.24**	179.90**	158.12**	19.42**	419.47**	88.20**	0.26**	0.45**
B3	9	127.96**	359.97**	70.64**	62.36**	137.27**	344.30**	0.33**	0.25**
		275.32**	198.11**	77.27**	24.99**	419.36**	148.24**	0.20**	0.2**
a X B	10	78.26	27.28	11.70	5.32	54.71	32.44	0.12	0.039
		44.61	29.43	4.14	1.93	60.10	25.76	0.19	0.073
b X B	30	80.24	58.64	8.00	8.45	28.88	31.25	0.098	0.042
		30.19	14.67	4.97	2.63	41.81	26.75	0.071	0.069
b1 X B	2	180.04	7.49	0.36	4.50	50.42	62.98	0.11	0.051
		134.4	32.76	1.16	1.81	16.45	109.28	0.096	0.009
b2 X B	10	72.44	54.53	6.75	3.22	44.29	22.90	0.057	0.037
		12.2	28.88	6.74	3.65	32.76	14.55	0.064	0.054
b3 X B	18	73.49	66.61	9.55	11.79	17.92	32.37	0.12	0.043
		28.61	4.76	4.41	2.15	49.66	24.36	0.072	0.008
Block interaction	70	45.57	29.03	5.10	4.38	20.19	18.03	0.059	0.023
		19.3	10.49	2.72	1.40	26.51	15.14	0.058	0.04
Wr+Vr	5	21961.3**	18615.04*	1314.2**	407.5*	4445.20	6579.40*	0.006	0.08**
		11479.4**	23975.90**	304.64	549.21**	11091.80**	842.30	0.003	0.033*
Wr-Vr	5	1303.7	16190.98	271.80**	351.10*	975.30*	4786.60*	0.003	0.002
		15560.01*	2352.90*	897.95**	22.91	13216.20*	2019.50*	0.007	0.006**

All items were tested among the pooled block interaction

*,** Significance at 0.05 and 0.01, respectively

two environments in the F₁ and F₂ generations indicated further dominance due to specific cross combinations and/or epistasis.

The Interpretation of the Wr/Vr Graph: The Wr, Vr, (Wr+Vr) and (Wr-Vr) values were calculated for each array in each block separately from the F₁ and F₂ diallel tables in both environments. The results of the analysis of the variance of the (Wr+Vr) and (Wr-Vr) values (Table 2) revealed significant array differences in the (Wr+Vr) value for F₁ generations in most cases confirming the presence of non-additive genetic variation for most characters

studied, except boll weight under favourable environment. The differences in the magnitude of the (Wr-Vr) values over arrays were significant in most cases indicating the presence of either non-allelic gene interaction or epistatic effects. The Wr/Vr relationship is graphically illustrated in Fig. 1. The slope of the Wr/Vr regression line was significantly different from zero but not from unity ($b = 0.76 \pm 0.23$) for the F₁'s of seed cotton yield/plant under favourable conditions indicating the adequacy of additive-dominance model. The regression line intercepted the Wr axis near the origin point indicating almost complete dominance. However, for the F₂

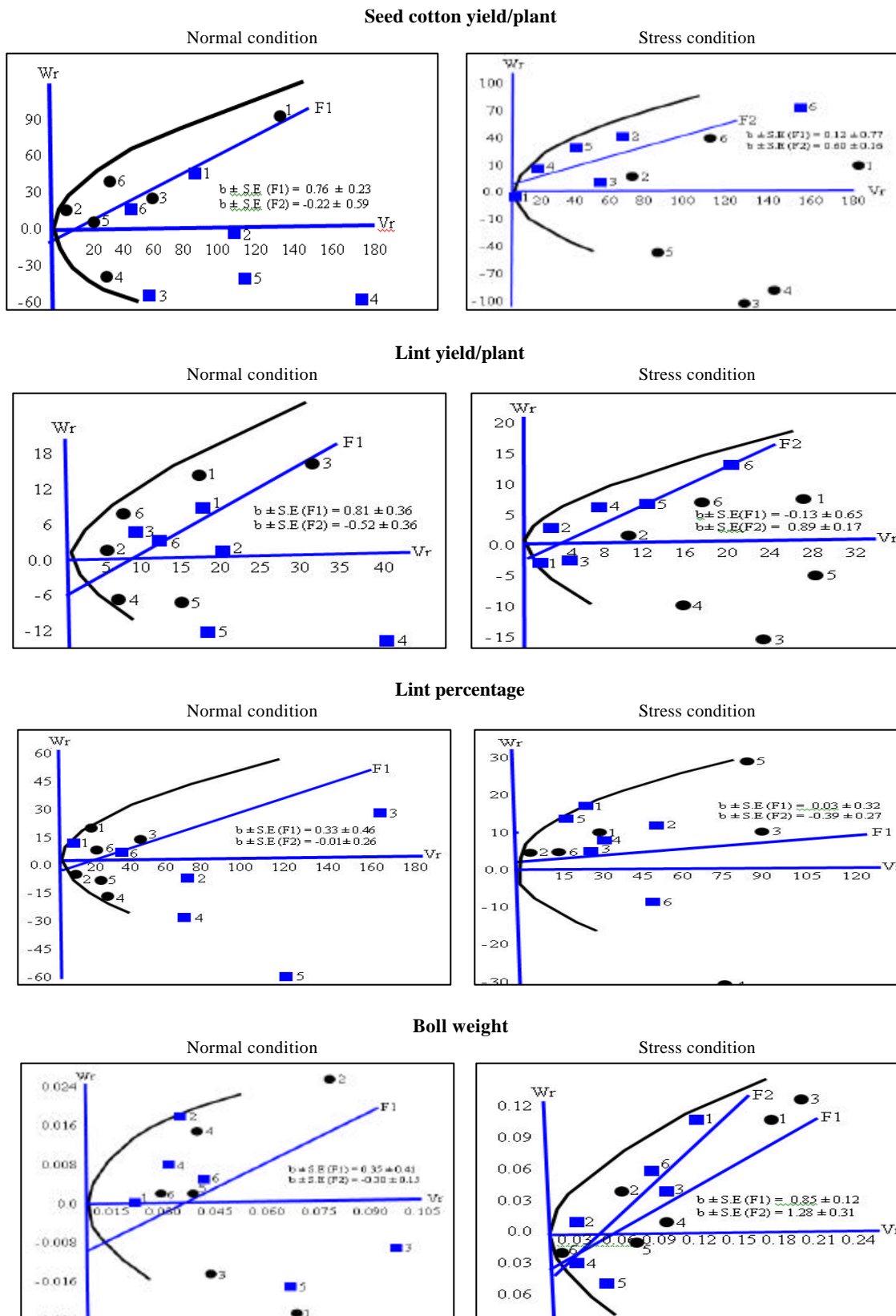


Fig. 1: W_r, V_r graphs of the F_1 (●) and F_2 (■) for seed cotton yield/plant, lint yield/ plant, lint percentage and boll weight in both normal and stress conditions

generation, the regression line was not significantly deviating from zero indicating non-allelic interaction. Under stress conditions, the slope of F_1 regression line was not significantly deviating from zero ($b = 0.12 \pm 0.77$). However, the F_2 regression line was significantly deviating from both zero and unity ($b = 0.596 \pm 0.156$) indicating that non-allelic interaction was operating. For lint yield per plant, the slope of the W_r/V_r regression line was significantly different from zero but not from unity ($b = 0.81 \pm 0.36$) for the F_1 under favourable conditions indicating the adequacy of additive-dominance model. The regression line intercepted the W_r axis below the origin point indicating over-dominance. However, for F_2 generation, the regression line was not significantly deviating from zero indicating non-allelic interaction. Under stress conditions, the slope of the F_1 regression line was not significantly deviating from zero ($b = 0.13 \pm 0.65$). However, the F_2 regression line was significantly deviating from zero ($b = 0.89 \pm 0.17$) indicating the adequacy of additive-dominance model. For lint percentage, the slope of the regression lines were not significantly deviating from zero for the F_1 ($b = 0.33 \pm 0.46$) and the F_2 ($b = 0.13 \pm 0.26$) under favourable conditions, as well as the F_1 ($b = 0.29 \pm 0.32$) and the F_2 ($b = 0.39 \pm 0.27$) under stress conditions indicating non-allelic interaction was operating. The regression line of the F_1 generation under favourable condition intercepted the W_r axis near the origin point indicating almost complete dominance. For boll weight, the slope of the regression line were not significantly deviating from zero for the F_1 ($b = 0.35 \pm 0.41$) and the F_2 ($b = 0.297 \pm 0.15$) under favourable conditions indicating non-allelic interaction. However, under stress conditions the slope of the regression lines were significantly different from zero but not from unity for both the F_1 ($b = 0.85 \pm 0.12$) and the F_2 ($b = 1.28 \pm 0.31$) indicating the adequacy of additive-dominance model. The regression line intercepted the W_r axis below the origin point indicating over-dominance for both the F_1 and F_2 generations under stress conditions.

Genetic Parameters: The estimates of various components of genetic variation are given in Table 3. For seed-cotton yield/plant, the "D" parameter estimating the additive effect was much smaller than the dominance parameter " H_1 " for both the F_1 and the F_2 in the two environments except that of the F_1 in the favourable environment where the "D" parameter was quite larger. These results confirmed those revealed by the W_r/V_r graph regarding the non-allelic interaction operating. The average degree of dominance as measured by the $(H_1/D)^{1/2}$

ratio reached (0.999) for the F_1 in the favourable environment indicating complete dominance. Meanwhile, the $(H_1/D)^{1/2}$ were (2.396) for the F_2 in the favourable environment and for F_1 and F_2 were 2.417 and 1.215, respectively in the stressed condition indicating over-dominance. Similar results were obtained by Talaat [15] and Iqbal *et al.* [16], however the results are on the contrary with those obtained by Ahmed [17]. The "F" parameter is positive for both the F_1 and the F_2 in the two soil types indicating that there were more dominant than recessive alleles. Similar results were obtained by Abdel-Hafez *et al.* [18] and Afiah and Ghoneim [19]. The $H_2/4H_1$ value indicated that the UV value was not equal to 0.25 indicating non-equal distribution of the dominant and recessive alleles among the six parents analyzed, which was indicated before from the significance of the " b_2 " item. Broad-sense heritability values were 0.32 and 0.83 for the F_1 and F_2 in the favourable environment, whereas under stress, the values were 0.78 and 0.87, respectively. The narrow-sense heritability values were 0.09 and 0.13 under favourable conditions and 0.07 and 0.42 under stressed for F_1 and F_2 , respectively. These results indicated that the additive component was much smaller than the other components of variance. Such moderate estimates were also reported by Basal and Turgut [20] and Costa *et al.* [21].

For lint yield/plant, the "D" parameter was much smaller than the dominance parameter " H_1 " for both the F_1 and the F_2 in the two environments. Thus, over-dominance was operating which confirm the results revealed by the W_r/V_r graph. The "F" parameter is positive for both the F_1 and F_2 in the two environments indicating that there were more dominant alleles than recessive ones. Similar results were obtained by El-Ameen [22]; Esmail and Abdel-Hamid [23] and El-Zahab *et al.* [24]. The $(H_1/D)^{1/2}$ ratio were 1.58 and 2.19 for the F_1 and the F_2 , respectively, in the favourable environment and were 2.95 and 1.35 for the F_1 and the F_2 , respectively, in the stressed environment indicating over dominance. Similar results were obtained by Kar *et al.* [25]. The value of UV was not equal to 0.25 indicating non-equal distribution of the dominant and recessive alleles among the six parents analyzed, which has been indicated before from the " b_2 " item. Broad-sense heritability values were 0.69 and 0.88 in the favourable environment, but were 0.82 and 0.88 under stress for both F_1 and F_2 , respectively. Meanwhile, narrow-sense heritability values were 0.11 and 0.14 in the favourable environment and were 0.18 and 0.39 under stress for F_1 and F_2 , respectively. These results indicated that the additive component was much smaller

Table 3: Genetic parameters of the F₁ and F₂ generations in the two contrasting environments

Genotypes	Seed-Cotton yield/plant (g.)				Lint yield/plant (g.)			
	Favorable		Stress		Favorable		Stress	
	F ₁	F ₂	F ₁	F ₂	F ₁	F ₂	F ₁	F ₂
D	64.69±18.4	90.9±36.9	105.9±44.9	124.5±14.4	17.79±3.8	20.17±3.2	10.74±5.1	13.72±1.7
H1	64.5±46.6	522.1±93.9	619.1±114.2	183.9±36.4	44.6±9.7	97.6±8.1	93.71±12.9	24.9±4.2
H2	61.6±41.6	326.9±83.9	386.2±101.9	151.5±32.6	37.99±8.7	64.4±7.2	60.24±11.6	21.6±3.8
F	55.9±44.9	255.6±90.3	321.2±109.9	88.2±35.1	20.78±9.4	47.3±7.8	35.75±12.5	8.24±4.1
UV	0.24	0.16	0.16	0.21	0.21	0.17	0.16	0.22
Broad	0.32	0.83	0.78	0.87	0.69	0.88	0.82	0.88
Heritability								
Narrow	0.09	0.13	0.07	0.42	0.11	0.14	0.18	0.39
Heritability								
E	45.57±6.9	19.3±13.9	29.03±16.9	10.49±5.4	5.1±1.5	2.72±1.2	4.38±1.9	1.4±0.6
(H1/D) ^{1/2}	0.999	2.396	2.417	1.215	1.583	2.199	2.95	1.347

Table 3: Continued

Genotypes	Lint percentage				Boll weight (g.)			
	Favorable		Stress		Favorable		Stress	
	F ₁	F ₂	F ₁	F ₂	F ₁	F ₂	F ₁	F ₂
D	9.36±10.4	3.04±33.7	18.8±18.8	21.7±12.3	-0.032±0.04	-0.031±0.03	0.15±0.02	0.14±0.02
H1	49.5±26.5	285.8±85.6	158±47.6	72.3±31.3	0.076±0.11	0.067±0.08	0.34±0.05	0.19±0.04
H2	40.3±23.7	211.7±76.5	140.4±42.5	63.7±28	0.094±0.09	0.05±0.07	0.32±0.05	0.12±0.04
F	24.5±25.5	53.8±82.4	27±45.8	19.5±30.2	-0.03±0.11	-0.019±0.08	0.12±0.05	0.19±0.04
UV	0.20	0.19	0.22	0.22	0.31	0.19	0.24	0.16
Broad	0.26	0.71	0.69	0.59	0.19	0.21	0.82	0.47
Heritability								
Narrow	-0.11	0.13	0.08	0.15	-0.14	0.034	0.21	0.087
Heritability								
E	20.2±3.9	26.5±12.8	18.03±7.1	15.1±4.7	0.06±0.02	0.06±0.01	0.02±0.008	0.04±0.006
(H1/D) ^{1/2}	2.299	9.694	2.896	1.825	1.551	1.481	1.488	1.168

than the other components of variance. Similar results were also reported by Lyanar *et al.* [26].

For lint percentage, the "D" parameter was much smaller than the dominance parameter "H₁" for both the F₁ and the F₂ in the two environments, confirming that over-dominance since the (H₁/D)^{1/2} were 2.29 and 9.69 in the favourable environment and 2.896 and 1.83 under stress for the F₁ and the F₂, respectively. These results confirming the results of the Wr/Vr graph. Similar results were also reported by Zerihun *et al.* [13]. The "F" parameter is positive for both the F₁ and F₂ in the two environments indicating that there were more dominant than recessive alleles. Similar results were obtained by Zerihun *et al.* [13] and Rajeswari [27]. The value (H₂/4H₁)

that measures UV was not equal to 0.25 indicating non-equal distribution of the dominant and recessive alleles among the six parents analyzed, which was indicated before from the "b₂" item. Broad-sense heritability values under favourable conditions were 0.26 and 0.71, whereas under stress, the values were 0.69 and 0.59 for the F₁ and F₂, respectively. The narrow-sense heritability reached -0.11 and 0.13 under favourable conditions and 0.08 and 0.15 under stress for the F₁ and F₂, respectively. Similar results were obtained by El-Ameen [22] and Nadeem *et al.* [28].

For boll weight, the "D" parameter estimating the additive effect was much smaller than the dominance parameter "H₁" for both the F₁ and the F₂ generations in

the two environments, indicating over-dominance since the average degree of dominance as measured by the $(H_i/D)^{1/2}$ were 1.55 and 1.48 in the favourable conditions and were 1.49 and 1.17 for the F_1 and the F_2 , respectively, under stress. The "F" parameter is positive for both the F_1 and the F_2 in the stressed environment indicating that there were more dominant than recessive alleles. However, for the favourable environment the "F" value was negative for both the F_1 and the F_2 indicating an excess of recessive over dominant alleles. The UV value was not equal to 0.25 indicating non-equal distribution of dominant and recessive alleles among the six parents analyzed. Broad-sense heritability values under favourable conditions were 0.19 and 0.21 and under stress, the values were 0.82 and 0.47 for the F_1 and F_2 , respectively. These results indicating that the major proportion of the total phenotypic variation was non-genetic variation, except for the F_1 generation under stress. The narrow-sense heritability values indicated that the additive component was much smaller than the other components of variance. Similar results were obtained by Iqbal *et al.* [16], Esmail and Abdel-Hamid [23] and Gerik *et al.* [29].

REFERENCES

1. Fischer, R.A. and A. Maurer, 1978. Drought resistance in spring wheat cultivars. Grain yield responses. Aust. J. Agri. Res., 29: 897-912.
2. Hayman, B.I., 1954b. The theory and analysis of diallel crosses. Genetics, 39: 789-809.
3. Griffing, J.B., 1956. Concept of general and specific combining ability in relation to diallel crossing system Austral. J. Biol. Sci., 9: 463-493.
4. Rosielle, A.A. and I. Hamblin, 1981. Theoretical aspects of selection for yield in stress and nonstress environments. Crop Sci., 21: 943-946.
5. Hayman, B.I., 1954a. The analysis of variance of diallel tables. Biometrics, 10: 235-244.
6. Hayman, B.I., 1957a. The Interaction, heterosis and diallel crosses. Genetics, 42: 336-355.
7. Hayman, B.I., 1957b. The theory and analysis of diallel crosses II. Genetics, 43: 63-85.
8. Mather, K. and J.L. Jinks, 1971. Introduction to Biometrical Genetics. Cornell University Press, New York, pp: 231.
9. Gomez, K.A. and A.A. Gomez, 1984. Statistical procedures for agricultural research. John Wiley and Sons. Inc. New York, USA.
10. Hendawy, F.A., 1994. Effect of plant density on heterosis and combining ability in six parental diallel cross of Egyptian and upland cottons. Menofiya J. Agri. Res., 19 (5): 2339-2361.
11. Kiani, G., G.A. Nematzadeh, S.K. Kazemitabar and O. Alishah, 2007. Combining ability in cotton cultivars for agronomic traits. Intl. J. Agric. Biol., 9 (3): 521-522.
12. Mohamed, S.A.S., I.S.M. Hassan and G.M. Hemaida, 2000. Combining ability and nature of gene action in some inter-specific hybrids of cotton. Annals of Agricultural Science, Moshtohor. Faculty of Agriculture, Zagazig University, 38(2): 701-710.
13. Zerihun, D., N. Ratanadilok, R. Kaveeta, P. Pongtongkam and A. Kuantham, 2004. Heterosis and combining ability for yield and yield components of cotton (*Gossypium hirsutum* L.). Kasetsart Journal, Natural Sciences. Kasetsart University, Bangkok, Thailand, 38 (1): 11-20.
14. Rokaya, M.H., A.M. El-Marakby, M.H. El-Agroudy and M.G. Seif, 2005. Heterosis and combining ability for fiber-to-seed attachment force, earliness, yield and yield components in a half diallel cross of cotton. Arab Universities Journal of Agricultural Sciences. Faculty of Agriculture, Ain Shams University, 13 (3): 741-753.
15. Talaat, A.R., 2006. Genetic analysis of drought tolerance in Egyptian cotton (*Gossypium barbadense* L.). M.Sc. Thesis, Agron. Dept., Assiut University, Egypt.
16. Iqbal, M., R.S.A. Khan, K. Hayat and Noor-ul-Islam Khan, 2005. Genetic variation and combining ability for yield and fiber traits among cotton F_1 hybrid population. J. Biol. Sci., 5 (6): 713-716.
17. Ahmed, M.F., 2007. Cotton diallel cross analysis for some agronomic traits under normal and drought conditions and biochemical genetic markers for heterosis and combining ability. Egyptian J. Plant Breed., Agronomy Department, Giza, Egypt, 11(1): 57-73.
18. Abdel-Hafez, A.G., M.S. El-Keredy, A.F. El-Okkia and B.M.R. Gooda, 2007. Estimates of heterosis and combining ability for yield, yield components and fiber properties in Egyptian cotton (*Gossypium barbadense* L.). Egyptian J. Plant Breed. Agronomy Department, Giza, Egypt, 11(1): 423-435.
19. Afiah, S.A.N. and E.M. Ghoneim, 1999. Evaluation of some Egyptian cotton (*Gossypium barbadense* L.) varieties under desert conditions of south Sinai. Annals Agric. Sci., Ain Shams Univ., Cairo, 44 (1): 201-211.

20. Basal, H. and I. Turgut, 2003. Heterosis and combining ability for yield components and fiber quality parameters in a half diallel cotton (*G. hirsutum* L.) population. Turkish J. Agric. Forest. (TUBITAK). 27(4): 207-212.
21. Costa, J.N., E.C. Freire, M.N. Costa, J.W. Santos and R. de Macedo Vieira, 1998. Heterosis and general and specific combining ability in cotton *Gossypium hirsutum* L. Revista de Oleaginosas e Fibrosas, 2(2): 151-156.
22. El-Ameen, T.M., 1999. Selection under stress conditions for yield and quality attributes in Egyptian cotton. Ph.D. Thesis. Fac. Agric. Assiut Univ., Egypt.
24. El-Zahab, A.A.A., H.Y. Awad and K.M.A. Baker 2007. Prospective for breeding short season cotton. A second look. I. Combining ability for yield and yield related traits. Egyptian Journal of Plant Breeding. Agronomy Department, Egypt, 11(3): 1-22.
23. Esmail, R.M. and A.M. Abdel-Hamid, 1999. Breeding cotton for water stress conditions. Monofiya J. Agric. Res., 24 (6): 1925-1947.
25. Kar, M., B.B. Patro, C.R. Sahoo and S.N. Patel, 2001. Response of hybrid cotton to moisture stress. Indian J. Plant Physiol., 6 (4): 427-430.
26. Iyanar, K., R. Ravikesavan, A. Subramanian, K. Thangaraj and P.V. Varman, 2005. Studies on combining ability status in relation to heterosis in cotton (*Gossypium hirsutum*). Academy of Plant Sciences, Adv. Plant Sci., 18 (1): 317-322.
27. Rajeswari, V.R., 1995. Evaluation of cotton genotypes for drought tolerance under rainfed conditions. Ann. Plant Physiol., 9 (2): 109-112.
28. Nadeem Austin, Munir-ud-Din Khan, M.A. Khan and Mushtaq Ahmad, 1998. Genetic studies of cotton (*Gossypium hirsutum* L). I. Combining ability and heterosis studies in yield and yield components. Pak. J. Sci. Indus. Res., 41 (1): 54-56.
29. Gerik, T.J., K.L. Faver, P.M. Thaxton and K.M. El-Zik, 1996. Late season water stress in cotton. Plant growth, water use and yield. Crop Sci., 36: 914-921.