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GENETIC BEHAVIOR OF WHEAT CROSSES UNDER IRRIGATED AND WATER STRESS CONDITIONS

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ABSTRACT

Six bread wheat genotypes; Sakha 94, Gemmiza 9, Giza 168, Line 1, Haama 11 and Angi 3 were crossed in a half-diallel mating design and were planted under irrigated as well as water stress conditions to determine their genetic behavior under these conditions. Data were recorded on days to heading, days to physiological maturity, plant height, number of spikes per plant, number of kernels per spike, 100-kernel weight, grain yield per plant and the drought susceptibility index. Data for all traits revealed significant differences among genotypes under both sowing conditions. The additive and dominance gene actions were significant for most of studied characters under the two conditions. Mean degree of dominance $(H_1/D)^{1/2}$ *indicated over dominance for kernels per spike, and grain yield per plant under the two conditions and for plant height under non stress condition. Partial dominance gene effects were found to control the other studied traits, except 100-kernel weight under non stress condition, which is controlled by complete dominance gene effects. Moderate to high heritability estimates in narrow sense were detected for all studied characters under the two conditions except for grain yield per plant under irrigated condition. General and specific combining ability were found to be highly significant for all traits under investigation at the two conditions indicating the importance of additive and non-additive gene actions in controlling the performance of these traits in all genotypes. Two superior crosses* $P_1\times P_2$ *for grain yield and* $P_3\times P_4$ *for kernels per spike under water stress were considered as promising hybrids for improvement purpose. Moreover, they involved good combiner parents which can be used to improve any of these features.*

Key words: *Genetic behavior, Wheat, Water stress, Yield components, Heritability, Gene action.*

INTRODUCTION

Wheat (*Triticum aestivum* L.) is one of the four main cereals cultivated worldwide, viz. wheat, rice, maize and barley. Water scarcity is a real threat to agricultural production in arid and semi-arid areas. As the world population continues to grow, the arable land area per capita will further decrease. Therefore, research on the enhancement of wheat productivity is still an important task for wheat breeders. The Food and Agriculture Organization (FAO 1988) estimated that almost two-thirds of the increase in crop production needed in the next decades must come from higher yields per unit land area. Hence, deficit irrigation requires more control over the amount and timing of water application than full irrigation practice.

Wheat is affected by drought stress, either in the plant development stages, or through yield development. Furthermore, there is also a difference in the intensity of the stress that plays a role in both cases. For example, water stress during seed development affects the yield more than when the stress is experienced in the vegetative stage (Agenbag and De Villiers 1995).

Water stress is recognized as an important factor that affects wheat growth and yield (Ashraf and Naqvi 1995 and Ashraf 1998). However, wheat species and cultivars within species show substantial differences in their response to soil moisture (Rascio *et al* 1992 and Iqbal *et al* 1999). Moreover, reduction in yield and yield components due to water stress have been reported in both durum and bread wheat (Sinha *et al* 1986).

Substantial losses in grain yield are caused by water deficiency depending on the developmental stage at which water stress occurs (Ozturk and Aydin 2004). Water stress at various stages before anthesis can reduce days to heading as reported by Nabipour *et al* (2002) and plant height as indicated by El-Banna *et al* (2002). Moreover, plant traits of the main tiller may play an important role in determining grain yield under water stress condition (Okuyama *et al* 2005).

Understanding the genetic behaviour of attributes under water stress is very important for any breeding program because the progress was less under water-limiting environments in many regions (Richards *et al* 2001 and Trethowan *et al* 2002). In addition, selection for high grain yield and improved performance under drought is not always successful (Cooper *et al* 1997). Therefore, genetic improvement of grain yield under water stress limitation is still a key objective for wheat breeders (van Ginkel *et al* 1998 and Richards *et al* 2002).

On the other hand, yield has low heritability, slow and difficult to be measured especially in early segregations of a breeding program (Rebetzke *et al* 2002). Meanwhile, Arshad and Chowdhry (2003) reported over dominance and additive gene action for kernels per spike under drought conditions. In certain cases, over dominance has also been reported by Kashif and Khaliq (2003) for plant height and grain yield per plant under normal irrigated conditions.

The aims of this study were to determine the nature of genetic mechanisms of some economic traits in wheat crosses exposed to water stress after tillering stage; and, to identify superior genotypes, which have good performance for earliness, plant height and grain yield and its components under water stress.

MATERIALS AND METHODS

A field experiment was conducted at Sakha Agricultural Research Station, Egypt in 2004/2005 and 2005/2006 growing seasons. Six wheat parental genotypes were crossed in a half diallel cross mating design during

2004/2005 season. In the second season, 2005/2006, two adjacent experiments were conducted. The first one was irrigated four times after planting irrigation (control experiment), while, the second experiment was given one irrigation at tellering stage beside the planting irrigation; i.e., two irrigations were given through the whole season (stress experiment). The commercial names, source, cross name and pedigree of the parents used in this study are presented in Table (1).

Table 1. Name, source, cross name and pedigree, and drought tolerance of six parental wheat genotypes.

Parent	Source	Cross Name & Pedigree	Drought tolerance
Sakha 94	Egypt	Opata / Rayon // Kauz CMBW 90Y3180 -0TOPM-3Y-010M-10M-010Y-6M-0S	Susceptible
Gemmiza 9	Egypt	Ald "S" / Huac // Cmh 74A. 630 / Sx CGM 4583-5GM-1GM-0GM	Susceptible
Giza 168	Egypt	Mrl / Buc // Seri CM93046-8M-0Y-0M-2Y-0B	Susceptible
Line 1	Egypt	Giza 164 / Sakha 61 S.9242-1BR-2BR-5BR-2BR-0BR	Tolerant
Haama 11	ICARDA	CHAM-4 / TEVEE-2 ICW93-0014-1AP-0BR-5AP-2AP-7AP-0APS-0AP-0S	Tolerant
Angi 3	ICARDA	BLOYKA-2/KAUZ ICW92-0326-12AP-0L-3AP-0L-1AP-0AP-0S	Tolerant

Each experiment was designed in a randomized complete block design using three replicates. Each replicate consisted of 21 rows, 3.8 m long and 30 cm apart with 20 cm between plants. Twenty seeds were planted in each row. The six parental genotypes and their 15 F_1's were planted in both experiments. The data collected on six guarded plants from each genotype and they were; days to heading (DH), days to physiological maturity (DM), plant height (PH), number of spikes per plant (SP^{-1}), number of kernels per spike (KS^{-1}), 100-kernel weight (KW) and grain yield per plant (GYP^{-1}). Drought susceptibility index (SI) was calculated to characterize the relative drought tolerance of all genotypes. It must be emphasized that SI provides a measure of drought tolerance based on minimization of yield loss under dry condition compared to moist one rather than on yield level under dry conditions *per se*. The index was calculated from genotype means for grain yield (SI) using a generalized formula (Fisher and Maurer 1978) in which:

$$SI = (1 - y_d / y_p) / D$$

Where: y_d = mean yield in drought environment,

Y_p= mean yield in normal condition = potential yield,

D = drought stress intensity = 1 - (mean y_d of all genotypes / mean y_p of all genotypes).

Data obtained from the 15 F_1-progenies and six parents were subjected to the basic analysis of variance technique (Steel and Torrie 1980). Gene action and determination of genetic components of variation were also estimated according to Hayman (1954) and Jinks (1955). The combining ability analysis was estimated following model 1, method 2 of Griffing technique (1956).

RESULTS AND DISCUSSION

Combined analysis of variance

The combined analysis of variance for studied characters is shown in Table (2). Statistical analysis revealed high significant effects of irrigation treatments on all studied traits, except kernels per spike, indicating that the two irrigation regimes had different effects on these characters. In addition, mean squares due to genotypes were highly significant for all characters, reflecting the presence of sufficient genetic variability among these genotypes. Similar results were found by El-Gamal (2002).

Analysis of variance

The differences among the genotypes were highly significant for most of the characters under the two conditions (Table 3). This proved the presence of sufficient genetic variability among these genotypes, which enhance the chance of selecting for drought-tolerant bread wheat genotypes.

Table 2. Mean squares of combined analysis of variances for studied characters in wheat genotypes.

Source of Variation	D.F	DH	DM	PH	SP^{-1}	KS^{-1}	KW	GYP^{-1}
		MS						
Irrigation (I)	1	40.35**	2314.29**	1983.33**	276.94**	221.87	1.83**	2627.66**
Error	4	1.06	7.12	3.32	12.74	84.95	0.08	22.72
Genotypes (G)	20	160.26**	38.07**	69.99**	26.36**	152.53**	1.05**	137.94**
I X G	20	1.62*	8.52**	9.20**	4.69	19.39	0.16**	39.61**
Error	80	0.95	1.24	2.93	3.95	25.11	0.06	10.87

*** and ** indicate significant at $p \leq 0.05$ and $p \leq 0.01$, respectively.**
N = Non-stress, S = Stress, DH = Days to heading, DM = Days to physiological maturity,
PH = Plant height and SP^{-1} = Number of spikes per plant, KS^{-1} = Number of kernels per spike,
KW = 100-kernel weight and GYP^{-1} = Grain yield per plant.

Table 3. Mean squares of seven agronomic characters for different genotypes under two different environments (non-stress and stress conditions).

Source of Variation	D.F	KS^{-1}		KW		GYP^{-1}	
		MS					
		N	S	N	S	N	S
Blocks	2	0.51	1.61	3.27*	10.97**	1.47	5.22
Genotypes	20	88.62**	73.28**	39.02**	7.56**	44.22**	34.92**
Error	40	0.96	0.93	0.95	1.518	2.25	3.60

*** and ** indicate significant at $p \leq 0.05$ and $p \leq 0.01$, respectively.**
N = Non-stress, S = Stress, DH = Days to heading, DM = Days to physiological maturity,
PH = Plant height and SP^{-1} = Number of spikes per plant,

Table 3. continued

Source of Variation	D.F	KS^{-1}		KW		GYP^{-1}	
		MS					
		N	S	N	S	N	S
Blocks	**2**	3.10	167.32**	0.16	0.01	38.27	7.37
Genotypes	**20**	77.18*	94.63**	0.54**	0.65**	84.47**	93.26**
Error	**40**	37.47	12.75	0.08	0.05	13.53	8.22

*** and ** indicate significant at $p \leq 0.05$ and $p \leq 0.01$, respectively.**
N = Non-stress, S = Stress, KS^{-1} = Number of kernels per spike, KW = 100-kernel weight and GYP^{-1} = Grain yield per plant.

Mean performance of wheat parents and F_1 crosses under stress and non-stress conditions

Mean performance of the parents and their hybrids of all studied characters under stress and non-stress conditions are presented in Table (4).

Means of genotypes under water stress condition were, insignificantly, earlier in days to heading than those at non-stress one. This result could be due to the rainfall during the vegetative stage. Meanwhile, water stress condition decreased the mean of most studied characters for all genotypes. Similar results were obtained by Abd El-Rahman (2004) for days to heading and days to maturity and Moursi (2003) for plant height, Hefnawy and Wahba (2003) and Moursi (2003) for number of kernels per spike and Gupta *et al* (2001) and Abd El-Wahab (2002) for grain yield per plant.

Among the parental genotypes, Line 1 (P_4) was the earliest in days to heading (86.7 and 86.3 days) and days to maturity (146.0 and 143.3 days) under non-stress and stress conditions, respectively. Moreover, crosses $P_4 \times P_5$ and $P_4 \times P_6$ were the earliest in days to heading (93.0 and 92.7, respectively) assuming partial dominance toward P_4 under non-stress condition, while the same crosses were the earliest (91.7 and 92.2 days, respectively) under stress condition. In addition, under non-stress and stress conditions, cross $P_1 \times P_4$ had the earliest values in days to maturity (150.0 and 144.0 days, respectively) assuming additive to partial dominance effects under the normal condition and partial dominance towards P_1 under water stress.

Table 4. Mean performance of wheat characters for parents and their F_1 's under non-stress, and stress conditions.

Genotype	DH		DM		PH		SP^{-1}	
	N	S	N	S	N	S	N	S
Sakha 94 (P_1)	104.0	103.7	155.5	146.7	117.2	111.5	22.7	22.4
Gemmiza 9 (P_2)	101.5	101.3	156.3	146.3	115.0	105.3	16.7	16.6
Giza 168 (P_3)	96.7	94.8	157.0	146.7	108.3	98.9	20.9	17.5
Line 1 (P_4)	86.7	86.3	146.0	143.3	114.2	107.5	21.7	19.8
Haama 11 (P_5)	105.3	102.3	159.0	148.7	110.6	108.6	24.4	24.2
Angi 3 (P_6)	104.0	103.3	159.5	149.7	103.3	98.9	25.0	20.9
$P_1 \times P_2$	104.5	103.3	155.3	145.7	119.7	111.9	18.9	18.8
$P_1 \times P_3$	98.0	96.7	158.0	146.3	112.8	106.1	21.1	16.8
$P_1 \times P_4$	95.0	95.0	150.0	144.0	118.6	110.8	22.1	17.4
$P_1 \times P_5$	101.5	99.7	156.3	147.3	115.6	108.6	23.3	19.0
$P_1 \times P_6$	100.5	99.7	151.5	146.0	112.5	105.8	23.3	20.9
$P_2 \times P_3$	100.5	99.3	157.3	146.0	115.8	106.7	18.1	15.2
$P_2 \times P_4$	95.0	95.0	151.0	144.3	119.4	107.8	18.1	15.4
$P_2 \times P_5$	103.5	100.7	156.3	145.7	117.2	109.4	20.9	17.6
$P_2 \times P_6$	103.0	102.0	157.3	146.7	115.6	108.9	21.9	16.2
$P_3 \times P_4$	90.0	89.7	151.3	145.0	117.8	105.8	18.9	17.5
$P_3 \times P_5$	96.3	95.3	158.3	147.7	114.2	102.8	22.8	18.4
$P_3 \times P_6$	96.3	96.0	156.3	147.3	113.6	106.6	22.7	17.2
$P_4 \times P_5$	93.0	91.7	152.3	145.0	116.1	105.6	22.2	18.6
$P_4 \times P_6$	92.7	92.2	150.0	144.7	117.5	107.8	22.4	17.7
$P_5 \times P_6$	106.5	102.7	156.5	148.3	113.9	107.5	23.7	21.4
Mean	98.8	97.7	154.8	146.3	114.7	106.8	21.5	18.5
New LSD 0.05	1.4	1.4	1.4	2.1	2.2	2.9	2.7	4.1
New LSD 0.01	1.9	1.8	1.8	2.8	2.9	3.8	3.5	5.6
C.V. %	1.0	0.9	0.6	0.8	1.3	1.7	7.7	12.1

N = Non-stress, S = Stress, DH = Days to heading, DM = Days to physiological maturity, PH = Plant height and SP^{-1} = Number of spikes per plant.

Table 4. continued

Genotype	KS^{-1}		KW		GYP^{-1}		SI
	N	S	N	S	N	S	
Sakha 94 (P_1)	85.0	81.2	4.4	4.7	53.5	49.6	0.6
Gemmiza 9 (P_2)	83.3	82.4	4.8	4.8	42.1	34.9	1.4
Giza 168 (P_3)	82.6	81.4	4.2	4.3	46.1	31.7	2.6
Line 1 (P_4)	68.1	67.1	5.1	[illegible]	40.8	34.4	1.3
Haama 11 (P_5)	74.8	77.2	4.3	4.5	36.8	35.6	0.3
Angi 3 (P_6)	83.3	83.1	3.6	4.0	42.5	35.2	1.4
$P_1 \times P_2$	82.4	77.3	4.9	5.3	48.6	44.5	0.7
$P_1 \times P_3$	82.3	73.3	4.4	4.6	43.0	32.0	2.1
$P_1 \times P_4$	72.8	71.1	5.0	5.7	44.8	34.4	1.9
$P_1 \times P_5$	81.4	77.1	4.8	4.8	59.3	38.6	2.9
$P_1 \times P_6$	72.8	71.5	4.2	4.5	48.8	44.2	0.7
$P_2 \times P_3$	74.3	72.9	4.7	4.9	45.3	29.6	2.9
$P_2 \times P_4$	69.3	64.7	5.7	5.7	44.1	33.9	1.9
$P_2 \times P_5$	78.4	75.2	5.0	4.9	53.0	39.1	2.2
$P_2 \times P_6$	78.0	77.3	4.6	4.8	47.2	31.7	2.7
$P_3 \times P_4$	77.0	75.3	5.0	5.0	42.0	37.7	0.8
$P_3 \times P_5$	74.8	72.7	4.6	4.7	52.8	41.0	1.8
$P_3 \times P_6$	82.2	82.0	4.8	4.3	51.9	40.7	1.8
$P_4 \times P_5$	77.8	64.8	4.4	5.5	46.8	40.5	1.1
$P_4 \times P_6$	77.8	72.1	4.7	5.3	50.8	40.5	1.7
$P_5 \times P_6$	83.0	81.5	4.4	4.8	50.5	49.1	0.1
Mean	78.2	75.3	4.6	4.9	47.2	38.0	1.6
New LSD 0.05	13.4	5.7	0.4	0.3	5.9	4.4	1.2
New LSD 0.01	18.3	7.5	0.6	0.5	7.7	5.8	1.6
C.V. %	7.9	4.7	5.9	4.6	7.8	7.5	-

N = Non-stress, S = Stress, KS^{-1} = Number of kernels per spike, KW = 100-kernel weight and GYP^{-1} = Grain yield per plant.

On the other hand, cross $P_1 \times P_2$ maintained its superiority for plant height (119.7 cm and 111.9 cm) under non-stress and stress conditions, respectively, while, Sakha 94 was the tallest parent under the two conditions (117.2 cm and 111.5 cm).

Under non-stress condition, Haama 11 and Angi 3 had the highest mean values; 24.4 and 25.0, respectively for number of spikes per plant, while, Maama 11 had the highest value; 24.2 only under stress condition. Meanwhile, cross $P_5 \times P_6$ recorded the highest values; 23.7 and 21.4 under non-stress and stress conditions, respectively.

Under non-stress and stress conditions, data in Table (4) showed that cross $P_3 \times P_6$ had the highest mean values (82.2 and 82.0, respectively) for number of kernels per spike. Furthermore, line 1 and cross $P_2 \times P_4$ recorded the highest mean values under the two conditions. In addition, they were the best genotypes for 100-kernel weight (5.1 g and 5.7 g under non-stress condition and 5.5 g and 5.7 g under stress condition, respectively).

The highest yield was recorded by Sakha 94, (53.5 g) under non-stress condition and 49.6g under stressed one. Also, cross $P_1 \times P_5$ had the highest yield; 59.3 g under non-stress condition, while cross $P_5 \times P_6$ estimated 49.1g under stress one. Thus, under the normal condition, the cross $P_1 \times P_5$ surpassed the higher assuming an overdominance behavior.

From these results, it is clearly that most of genotypes differed in the magnitude of reduction in all characters in response to water stress. These results are similar to those obtained by Abd El-Rahman (2004) for days to heading and days to maturity and Farahat (2005) for plant height, kernels per spike, 1000-kernel weight and grain yield.

Low stress susceptibility index (SI<1) is synonymous with the higher stress tolerance. The results indicated that the two parents Sakha 94 (P1), and Haama 11 (P5), as well as the hybrids P1 × P2, P1 × P6, P3 × P4 and P5 × P6 had the lowest SI, reflecting the tolerance of these genotypes to drought. Except for P3 × P4, the tolerant hybrids had one tolerant parent in the cross. In this respect, Bayoumi et al (2002) reported that drought susceptibility index ranged from 0.71 to 1.43.

Estimation of genetic components and heritability

The validity of Hayman 's assumptions was tested using t^2 test. The t^2 values (Table 5 were not significant under the two conditions for all studied characters. Accordingly, the major assumptions postulated for diallel analysis by Hayman (1954) appeared to be valid.

The regression coefficients are expected to be significantly different from zero, but not from unity if all assumptions are correct. This was true for days to heading under the two conditions and days to maturity under stress condition, confirming further validity of diallel assumptions. The other characters, which insignificantly differed from unity and from zero, showed partial *failure* of the assumptions.

Table 5. Values of r^2, regression coefficient of covariance (Wr) on variance (Vr) and *t*-values for b = 0 and b = 1 under non stress and stress conditions.

Character	Cond.	t^2	Regression coefficient	t value for b=0	t value for b=1
Days to heading	N	0.36	0.68 ± 0.25	2.77*	1.30
	S	0.003	0.80 ± 0.29	2.78*	0.70
Days to maturity	N	1.01	0.36 ± 0.28	1.29	2.30
	S	0.06	0.77 ± [illegible]	2.88*	0.88
Plant height	N	0.35	0.58 ± 0.29	2.03	1.47
	S	0.33	0.35 ± 0.35	1.02	1.88
Spikes per plant	N	0.13	0.73 ± 0.26	2.76	1.03
	S	0.12	0.67 ± 0.29	2.28	1.12
Kernels per spike	N	1.96	1.03 ± 0.68	1.52	-0.05
	S	0.86	1.06 ± 0.39	2.72	0.15
100-kernel weight	N	0.04	0.76 ± 0.38	1.98	0.64
	S	0.05	0.75 ± 0.28	2.64	0.90
Grain yield per plant	N	0.01	0.68 ± 0.39	1.77	0.83
	S	1.11	0.95 ± 0.57	1.68	0.08

*** Significant at 0.05.**
N = Non-stress, S = Stress
b = 0 and b = 1 indicate difference of regression coefficient value from 0 and 1 (unit), respectively.

Estimates of the genetic components of variation for all studied characters are presented in Table (6). The additive component "D" was highly significant for all characters under the two conditions. The dominance components (H_1 and H_2) were significant to highly significant for most of the studied characters under the two conditions. These significant values suggest that additive and dominance gene effects play an important role in the inheritance of these characters. The dominance variance "H_1" was larger than that of "H_2" indicating that positive beneficial and negative deleterious alleles do not have the same ratios to the parents. This result indicates that improving these characters through selection might be more effective in early generations for improving such characters. Similar results were obtained by El-Borhamy (2004) for days to heading, days to maturity, plant height and number of kernels per spike under stress conditions.

The "F" values were significant to highly significant and positive for each of grain yield under non-stress condition, days to heading under stress and plant height under the two conditions indicating that the dominant alleles are more frequent than the recessive ones among the parental genotypes. Significant or highly significant and negative F-value was recorded for number of spikes per plant under non-stress condition and 100-kernel weight under stress conditions. Meanwhile, the insignificant "F"

Table 6. Estimates of genetic components of variation for the studied characters of bread wheat genotypes under non-stress and stress conditions.

Character	Cond.	D	H_1	H_2	F	h^2	E
Days to heading	N	49.89** ±1.66	15.43** ±4.21	12.28** ±3.76	-2.05 ±4.05	4.32 ±2.53	0.31 ±0.63
	S	46.51** ±0.81	9.70** ±2.04	7.50** ±1.83	3.81* ±1.97	5.11** ±1.23	0.32 ±0.30
Days to maturity	N	23.93** ±1.89	9.42* ±4.81	6.87 ±4.29	4.04 ±4.63	2.71 ±2.89	0.35 ±0.72
	S	4.13** ±0.14	0.09 ±0.35	0.20 ±0.31	0.05 ±0.14	1.83** ±0.21	0.66** ±0.05
Plant height	N	25.20** ±3.10	28.64** ±7.87	23.17** ±7.03	17.66* ±7.58	58.89** ±4.73	0.74 ±1.17
	S	25.95** ±2.19	23.52** ±5.56	16.16** ±4.97	22.36** ±5.35	14.77** ±3.34	1.23 ±0.83
Spikes per plant	N	7.91** ±0.22	-0.39 ±0.55	-0.03 ±0.49	-1.36* ±0.53	0.26 ±0.33	0.96** ±0.08
	S	6.42** ±0.67	2.41 ±1.69	3.25* ±1.51	-0.44 ±1.63	14.20** ±1.02	1.94** ±0.25
Kernels per spike	N	32.23** ±6.02	40.09** ±15.28	35.00* ±13.65	18.01 ±14.71	6.81 ±9.19	11.94** ±2.28
	S	29.91** ±2.65	48.73** ±6.72	49.35** ±6.00	-3.45 ±6.46	61.11** ±4.04	6.70** ±1.00
100-kernel weight	N	0.25** ±0.02	0.25** ±0.06	0.25** ±0.05	0.04 ±0.05	0.31** ±0.03	0.03** ±0.01
	S	0.24** ±0.01	0.13** ±0.03	0.12** ±0.03	-0.12** ±0.03	0.32** ±0.02	0.02* ±0.01
Grain yield per plant	N	27.43** ±8.89	112.54** ±22.56	76.81** ±20.16	49.64* ±21.71	65.41** ±13.57	4.90 ±3.36
	S	37.96** ±9.24	108.95** ±23.45	81.46** ±20.95	41.08 ±22.57	5.51 ±14.10	2.73 ±3.49

*** and ** indicate significant at $p \leq 0.05$ and $p \leq 0.01$, respectively.**
N = Non-*stress*, S = Stress.

values for the other characters may be a sign of equality in the relative frequencies of dominant and recessive genes in the parent.

The dominance effect "h^2" estimates, which are the measure of heterozygous loci, were highly significant and positive for each of plant height, 100-kernel weight under both conditions, and grain yield under the non-stress condition. Moreover, similar effects were observed for all traits under stress except for grain yield per plant. The observed positive and significant "h^2" values indicated that the dominant genes of these characters were due to heterozygosity and dominance seemed to be acting in a positive direction (unidirectional). Contrarily, the remaining h^2 values were not significant indicating that it could be due to the presence of considerable amount of canceling the dominant effects in the parents.

Estimation of the ratios between the parameters of genetic variance for the studied characters is provided in Table (7). The mean degree of dominance $(H_1/D)^{1/2}$ is more than unity for plant height under non-stress condition and for number of kernels per spike and grain yield per plant under both conditions. These results back up the presence of overdominance, suggesting early selection might improve of these traits. Meanwhile, the same parameter for days to heading under non-stress condition and each of days to heading, days to maturity, plant height, number of spikes per plant, and 100-kernel weight under stress condition is less than unity. These results confirm the role of partial dominance gene effects in controlling these traits. Contrary wise, the mean degree of dominance indicated the presence of complete dominance for 100-kernel weight under non- stress condition.

Table 7. Proportions of genetic components for the studied characters.

Character	Cond.	$(H1/D)^{1/2}$	$H_2/4H_1$	KD/KR	h^2/H_2 (K)	r	h^2_n
Days to heading	N	0.56	0.20	0.93	0.35	0.63	0.89
	S	0.46	0.19	1.20	0.68	0.44	0.91
Days to maturity	N	0.63	0.18	1.31	0.39	0.52	0.84
	S	0.15	0.25	0.74	9.35	0.92	0.74
Plant height	N	1.07	0.20	1.98	2.54	-0.66	0.50
	S	0.95	0.17	2.65	0.91	-0.37	0.51
Spikes per plant	N	-	0.02	-	-7.50	-0.81	0.82
	S	0.61	0.25	0.89	4.38	0.82	0.52
Kernels per spike	N	1.12	0.22	1.67	0.19	0.50	0.32
	S	1.28	0.25	0.91	1.24	0.24	0.46
100-kernel weight	N	1.00	0.25	1.18	1.28	-0.04	0.54
	S	0.74	0.22	0.49	2.69	-0.63	0.80
Grain yield per plant	N	2.03	0.17	2.61	0.85	-0.41	0.22
	S	1.69	0.19	1.94	0.07	0.70	0.35

N = Non-stress, S = Stress

These results are in accordance with those obtained by El-Borhamy (2004) for kernels per spike and grain yield per plant under stress condition, Abd El-Rahman (2004) for days to heading and days to maturity under stress condition, Hassani *et al* (2005) for days to heading and grain yield per plant under non-stress condition and Dere and Yildirim (2006) for grain yield per plant under non-stress condition.

The proportion of genes with negative and positive effects in the parent ($H_2/4H_1$) was equal or near to one quarter for most of the studied characters under the two conditions, indicating that the negative and positive alleles were equally distributed among the parents. The proportion of dominant and recessive alleles in the parents (KD/KR) were found to be unequal with more dominant than recessive alleles for most characters. The recessive alleles were more than dominant alleles for days to heading in non-stress condition and each of days to maturity, number of spikes per plant, number of kernels per spike and 100-kernel weight under stress condition (Table 7).

Concerning number of effective factors (K) that controls the trait and exhibit dominance to certain degree, the data showed that the gene blocks governing the traits under non-stress condition ranged between one gene block for number of kernels per spike to eight genes for number of spikes per plant under non stress condition. Under stress condition, the gene blocks ranged from one gene for grain yield per plant to ten genes for days to maturity.

The correlation coefficient values "r" between the parental order of dominance (Wr+Vr) and the parental measurement (yr) were negative for plant height, number of spikes per plant, 100-kernel weight and grain yield under non stress condition. Moreover, plant height and 100-kernel weight followed the same direction under stress condition. These results suggested that the parents contains most increasing genes have the lowest values of $Wr_i + Vr_i$, and thus contain most dominant genes controlling these characters. However, correlation coefficient was found to be positive for the remaining values indicating that high mean expression is associated with recessive genes. The possession of recessive gene with high expression is an advantage in breeding program as it might facilitate fixation of the traits in the early generations.

Moderate to high heritability estimates in narrow sense (h^2_n) were detected for all studied characters under both conditions except for grain yield per plant under non-stress condition. These results suggest that these characters are governed by more additive than dominance genes suggesting the importance of straight forward phenotypic selection in the early segregating generations. Moderate heritability estimates were obtained under water stress by Subhani and Chowdhry (2000) and Subhani *et al* (2000) for days to heading, El-Borhamy (2000) for days to maturity, plant height and number of spikes per plant and Riaz and Chowdhry (2003) for 1000-kernel weight. The present results are also in agreement with those obtained under normal conditions by Hassani *et al* (2005) for days to heading, plant height, 1000-kernel weight and grain yield per plant.

Combining ability analysis

The variances estimated for general combining ability "GCA" and specific combining ability "SCA" are presented in Table (8). Mean squares of GCA and SCA were highly significant for all the studied traits under the two conditions except for the SCA mean squares for days to maturity under stress, number of kernels per spike under non-stress and number of spikes per plant under both conditions which were insignificant. Both general and specific combining ability variances were found to be highly significant for most traits under investigation at the two conditions indicating the importance of additive and non-additive gene actions in controlling the performance of these characters in all genotypes.

The GCA variance was higher than that of SCA variance for all traits under study in the two environments, indicating that additive gene effects were more important than the non-additive in the expression of these traits. Howevere, higher estimates of non-additive genetic variation were noticed only for grain yield per plant under non-stress condition. These results are in harmony with those obtained by Afiah and Darwish (2002) for number of kernels per spike under rainfed stress; El-Beially and El-Sayed (2002) for days to heading, days to maturity, plant height, number of spikes per plant and under well water, and Arshad and Chowdhry (2002) for plant height, number of kernels per spike and 1000-kernels weight under both sowing conditions.

The estimates of GCA/SCA ratio under the two conditions were more than unity for all traits except for grain yield per plant under well watering. These results suggest that the studied traits are predominantly controlled by additive gene action. Therefore, it could be concluded that improving these traits through selection would be more effective in the early segregating generations. On the other hand, grain yield per plant under stress condition was mainly controlled by non-additive gene action. These results are in agreement with those reported by Hassani *et al* (2005) for days to heading, plant height, kernels per spike and 1000-kernel weight under well water and Darwish (2003) for kernels per spike under stress condition (one irrigation).

Table 8. Mean squares of general (GCA) and specific combining ability (SCA) for the agronomic characters under non-stress and stress conditions.

Source of Variation	D.F	DH		DM		PH		SP^{-1}	
		MS							
		N	S	N	S	N	S	N	S
GCA	5	319.91**	269.99**	134.78**	25.64**	91.76**	82.76**	54.53**	42.22**
SCA	15	11.52**	7.69**	7.10**	1.54	28.33**	19.07**	1.62	7.52
Error	40	0.96	0.93	0.95	1.52	2.28	3.59	2.78	5.12
GCA/ SCA	-	27.77	35.11	18.98	16.65	3.24	4.34	33.66	5.61

* and ** indicate significant at $p \leq 0.05$ and $p \leq 0.01$, respectively.
N = Non-stress, S = Stress, DH = Days to heading, DM = Days to physiological maturity,
PH = Plant height and SP^{-1} = Number of spikes per plant.

Table 8. continued

Source of Variation	D.F	KS^{-1}		KW		GYP^{-1}	
		MS					
		N	S	N	S	N	S
GCA	5	156.36**	208.27**	1.36**	2.16**	72.84**	141.58**
SCA	15	50.78	56.90**	0.27**	0.17**	88.33**	76.93**
Error	40	37.50	12.71	0.08	0.05	13.53	8.22
GCA/ SCA	-	3.08	3.66	5.04	12.71	0.82	1.84

* and ** indicate significant at $p \leq 0.05$ and $p \leq 0.01$, respectively.
N = Non-stress, S = Stress, KS^{-1} = Number of kernels per spike,
KW = 100-kernel weight and GYP^{-1} = Grain yield per plant.

Combining ability effects

Estimates of GCA effects of parents for each trait in both environments are presented in Table (9).

Results indicated that Gemmiza 9 expressed high significant negative effects for days to heading under both conditions. In addition, Giza 168 had high significant negative effects for days to maturity under normal condition. Therefore, these genotypes can be considered as good combiners for developing early genotypes. The cultivar Haama 11 proved to be good

Table 9. **Estimates of general combining ability effects for the studied parents in the F_1 generation for the agronomic characters under non-stress and stress conditions.**

Parent		DH		DM		PH		SP^{-1}	
		N	S	N	S	N	S	N	S
Sakha 94 (P_1)		1.21**	1.49**	1.08**	0.96**	-0.14	0.02	0.29	1.92**
Gemmiza 9 (P_2)		-1.79**	-1.18**	-0.05	0.77**	-3.39**	-3.44**	0.04	1.40**
Giza 168 (P_3)		2.13**	1.41**	-0.71**	-0.06	-3.46**	-2.44**	0.68*	1.37**
Line 1 (P_4)		1.01**	0.52**	0.45*	0.61*	-4.22**	-0.60	1.05**	2.16**
Haama 11 (P_5)		1.55**	1.91**	0.66**	0.52*	-2.92**	0.95**	0.11	2.25**
Angi 3 (P_6)		1.34**	1.77**	2.95**	1.27**	-5.68**	-4.58**	0.14	0.98*
$S_{(gi)}$	0.05	0.37	0.36	0.37	0.46	0.57	0.71	0.63	0.85
	0.01	0.49	0.49	0.49	0.62	0.76	0.95	0.84	1.14
$SE_{(gi-gj)}$		0.08	0.08	0.08	0.13	0.19	0.30	0.23	0.43

* and ** indicate significant at $p \leq 0.05$ and $p \leq 0.01$, respectively.
N = Non-stress, S = Stress, DH = Days to heading, DM = Days to physiological maturity,

Table 9. continued

Parent		KS^{-1}		KW		GYP^{-1}	
		N	S	N	S	N	S
Sakha 94 (P_1)		3.00*	4.52**	-0.14**	-0.22**	1.03	4.94**
Gemmiza 9 (P_2)		4.48**	5.83**	-0.32**	-0.37**	-3.13**	1.29*
Giza 168 (P_3)		3.30	3.10**	-0.25**	-0.04	-0.29	-0.87
Line 1 (P_4)		0.02	3.04**	-0.15**	-0.37**	-1.33	-1.01
Haama 11 (P_5)		-2.98*	2.27**	-0.16**	-0.26**	-11.83**	-5.75**
Angi 3 (P_6)		1.64	1.95**	-0.39**	-0.24**	-5.68**	-5.41**
$S_{(gi)}$	0.05	2.31	1.34	0.10	0.09	1.39	1.08
	0.01	3.09	1.80	0.14	0.11	1.85	1.44
$SE_{(gi-gj)}$		3.13	1.06	0.01	0.004	1.13	0.68

* and ** indicate significant at $p \leq 0.05$ and $p \leq 0.01$, respectively.
N = Non-stress, S = Stress, KS^{-1} = Number of kernels per spike, KW = 100-kernel weight and GYP^{-1}= Grain yield per plant.

combiner for both of plant height and number of spikes per plant under stress condition. As for number of spikes per plant, Line 1 showed high significant positive effects under non-stress condition. Moreover, Sakha 94 and Gemmiza 9 displayed high significant positive effects for number of kernels per spike under both conditions. Meanwhile, each of Giza 168, Line 1, Haama 11 and Angi 3 had high significant positive effects under water stress condition. Sakha 94 and Gemmiza 9 had also high and / or significant and positive effects and were the best combiners for grain yield per plant under the same condition. This may suggest that evaluation of significance of GCA effects for a specific trait can guide the breeder to select parents for improving this trait. Similar results were estimated by Sultan *et al* (2006) for number of spikes per plant, number of kernels per spike and grain yield under stress condition.

Specific combining ability effects of the parental combinations were computed in Table (10). Six crosses; (P_1× P_5), (P_1× P_6), (P_3× P_5), (P_3× P_6), (P_4× P_5) and (P_4× P_6) gave high significant positive estimates of SCA effects for days to heading under the two stress conditions. Only three crosses, viz (P_1× P_6), (P_2× P_5) and (P_4× P_6) exhibited significant or highly significant negative effect under stress condition. Concerning plant height, the best crosses were (P_2× P_6), (P_3× P_6) and (P_4× P_6) at both conditions and each of (P_1× P_2), (P_3× P_4), (P_5× P_6) under non stress condition

The crosses (P_3× P_4) and (P_2× P_6) had high significant positive effects under non-stress and stress conditions, respectively. Only one cross (P_3× P_4) exhibited significant desirable SCA effects for kernels per spike under stress condition. The crosses (P_1× P_5), (P_2× P_4) and (P_3× P_6) expressed significant to highly significant positive SCA effects under non-stress condition, while crosses (P_1× P_2), (P_1× P_4), (P_4× P_6) and (P_5× P_6) showed significantly positive effects under stress condition for 100-kernel weight. On the other hand, the crosses (P_3× P_5) and (P_3× P_6) had significant or highly significant positive SCA effects under the two conditions for grain yield per plant.

Table 10. Estimates of specific combining ability effects for the studied crosses under non-stress and stress conditions.

Cross	DH		DM		PH		SP^{-1}	
	N	S	N	S	N	S	N	S
$P_1 \times P_2$	1.46**	0.99	-0.07	-0.10	1.87*	1.87	-0.62	0.91
$P_1 \times P_3$	-0.66	-1.14*	1.93**	-0.02	-1.80*	-0.30	-0.25	-1.54
$P_1 \times P_4$	0.78	1.00*	0.02	-0.35	0.74	1.04	0.62	-1.67
$P_1 \times P_5$	-1.79**	-1.64**	-0.05	0.27	0.16	-0.98	-0.02	-2.23
$P_1 \times P_6$	-2.22**	-2.21**	-3.99**	-1.19	-0.68	-1.67	-0.30	0.69
$P_2 \times P_3$	1.59**	1.37**	0.29	-0.14	0.74	1.63	-0.36	-0.45
$P_2 \times P_4$	0.53	0.84	0.04	0.19	1.04	-0.64	-0.59	-0.99
$P_2 \times P_5$	-0.04	-0.80	-1.03*	-1.19	1.30	1.24	0.41	-0.98
$P_2 \times P_6$	0.03	-0.04	0.87	-0.31	1.83*	2.79**	1.09	-1.29
$P_3 \times P_4$	-0.10	0.05	-0.30	0.27	2.68**	1.13	-1.52	0.60
$P_3 \times P_5$	-2.83**	-1.59**	0.31	0.23	1.53	-1.73	0.58	-0.59
$P_3 \times P_6$	-2.27**	-1.50**	-0.80	-0.23	3.76**	4.15**	0.19	-0.77
$P_4 \times P_5$	-1.72**	-1.46**	0.39	-0.44	0.20	-2.33*	-0.26	-1.19
$P_4 \times P_6$	-1.49**	-1.46**	-1.05*	-0.89	3.80**	1.99*	-0.34	-1.08
$P_5 \times P_6$	3.28**	1.67**	-0.94	0.07	2.65**	1.90	-0.91	0.50
$S_{(sij)}$ 0.05	1.01	1.00	1.01	1.27	1.56	1.96	1.72	2.34
0.01	1.36	1.34	1.35	1.71	2.09	2.62	2.31	3.13
$SE_{(sij-sik)}$	0.56	0.54	0.56	0.89	1.33	2.09	1.62	2.99

* and ** indicate significant at $p \leq 0.05$ and $p \leq 0.01$, respectively.
N = Non-stress, S = Stress, DH = Days to heading, DM = Days to physiological maturity, PH = Plant height and SP^{-1} = Number of spikes per plant.

Table 10. continued

Crosses	KS^{-1}		KW		GYP^{-1}	
	N	S	N	S	N	S
$P_1 \times P_2$	2.04	0.63	0.07	0.25*	-0.25	5.30**
$P_1 \times P_3$	1.69	-4.17*	-0.12	-0.01	-6.45**	-6.60**
$P_1 \times P_4$	-2.24	0.68	0.07	0.30*	-2.55	-5.68**
$P_1 \times P_5$	1.53	1.28	0.33*	0.01	8.71**	-4.44**
$P_1 \times P_6$	-9.01	-7.45**	-0.07	-0.11	-1.51	1.53
$P_2 \times P_3$	-4.78	-4.50*	-0.17	0.16	-0.49	-3.50*
$P_2 \times P_4$	-4.14	-5.65**	0.48**	0.18	0.41	-0.63
$P_2 \times P_5$	0.13	-0.58	0.14	0.02	6.07**	1.69
$P_2 \times P_6$	-2.21	-1.57	0.11	0.13	0.51	-5.44**
$P_3 \times P_4$	-1.42	4.15*	0.13	-0.12	-2.33	3.71*
$P_3 \times P_5$	-3.79	-3.95*	0.13	0.09	5.27**	3.99**
$P_3 \times P_6$	1.71	2.261	0.53**	-0.04	4.58*	4.13**
$P_4 \times P_5$	4.82	-4.70*	-0.42**	0.14	1.47	2.14
$P_4 \times P_6$	2.95	-0.56	0.05	0.25*	5.65**	2.48
$P_5 \times P_6$	3.28	3.41	0.14	0.25*	2.14	8.12**
$S_{(sij)}$ **0.05**	**6.33**	**3.69**	**0.29**	**0.23**	**3.80**	**2.96**
0.01	**8.47**	**4.93**	**0.38**	**0.31**	**5.09**	**3.97**
SE $_{(sij\text{-}sik)}$	**21.88**	**7.42**	**0.04**	**0.03**	**7.89**	**4.79**

*** and ** indicate significant at $p \leq 0.05$ and $p \leq 0.01$, respectively.**
N = Non-stress, S = Stress, KS^{-1} = Number of kernels per spike, KW = 100-kernel weight and GYP^{-1}= Grain yield per plant.

Hence, the superior crosses ($P_1\times P_2$) for grain yield and ($P_3\times P_4$) for kernels per spike under water stress are considered promising hybrids, as they involved good combiner parents.

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السلوك الوراثي لهجن قمح تحت ظروف الري والإجهاد المائي

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أجريت هذه الدراسة في مزرعة محطة البحوث الزراعية بسخا خلال موسمي الزراعة 2004-2005 و2005-2006م. وقد استخدمت ستة تراكيب وراثية من قمح الخبز وهي سخا 94، جميزة 9، جيزة 168، السلالة 1، حماه 11 و إنجي 3 . وتم التهجين فيما بينها بنظام الهجن الدائرية (بدون هجن عكسية) بغرض تحديد السلوك الوراثي لتلك التراكيب الوراثية تحت الظروف الطبيعية والقاسية المائية (رية واحدة بخلاف رية الزراعة). وقد تم تسجيل وتحليل البيانات لكل من صفة عدد الأيام حتى طرد السنابل، عدد الأيام حتى النضج الفسيولوجي وطول النبات و عدد السنابل للنبات وعدد حبوب السنبلة ووزن المائة حبة ومحصول الحبوب للنبات ومعامل الحساسية للجفاف. وقد أظهرت النتائج المتحصل عليها اختلافات معنوية إلى عالية المعنوية بين التراكيب الوراثية في كل من البيئتين. كما أشارت النتائج إلى معنوية كل من التأثيرات الجينية السائدة و المضيفة لأغلب الصفات المدروسة تحت كلا البيئتين. كما أشارت قيم متوسط درجة السيادة إلى تحكم السيادة التامة في صفة عدد الأيام حتى النضج وطول النبات وعدد حبوب السنبلة ومحصول حبوب النبات تحت ظروف الري الطبيعية، وكل من عدد حبوب السنبلة ومحصول حبوب النبات تحت ظروف الإجهاد المائي، في حين تحكمت السيادة الجزئية في باقي الصفات ماعدا وزن المائة حبة تحت ظروف الري العادية حيث تحكم فيها تأثير السيادة الكاملة للجينات. وقد أظهرت درجة التوريث بالمعنى الضيق قيم متوسطة لكل الصفات في البيئتين ماعدا محصول النبات تحت ظروف الري العادي. بالإضافة إلى أن الدراسة أوضحت أهمية التأثير الجيني المضيف وغير المضيف في التحكم في الصفات لكل التراكيب الوراثية.

أظهر الهجين $P_1\times P_2$ تفوقاً بالنسبة لصفة محصول النبات ، و الهجين $P_3 \times P_4$ تفوق في عدد حبوب السنبلة تحت ظروف الإجهاد ولذلك يوصى باستخدامها بغرض التحسين خصوصا وآباء هذه الهجن لها قدرة عامة على التآلف يمكن استغلالها لتحسين هذه الصفات.