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DIALLEL CROSS ANALYSIS FOR BREAD WHEAT UNDER STRESS AND NORMAL IRRIGATION TREATMENTS

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ABSTRACT: The present study was carried out at the Experimental Farm, Fac. of Agric., Suez Canal University, Ismailia, Egypt during 2000/2001 and 2001/2002 seasons. The nature of combining ability and heterosis in wheat (*Triticum aestivum* L.) were studied throughout a set of diallel crosses, without reciprocals, of six parents. Heading date, plant height, spike length, number of grains/spike, number of spikes/plant, 1000-kernel weight, grain yield/plant, drought susceptibility index, chlorophyll content, and proline content were investigated under stress and normal irrigation treatments. Both additive and non additive gene action were important in controlling all traits under study. Additive gene action seemed to be mainly responsible for the expressions of heading date, 1000-kernel weight, chlorophyll content, drought susceptibility index and proline content, while non additive genes were responsible much more for the remaining traits.

Superior parents P4 (Sakha 8 from Egypt), P5 (Mrbll from Syria) and P6 (Omtel-1 from Mexico) were identified for the most traits and appeared to be good general combiners under both water regimes. There was significant heterosis for all the studied traits. The cross combinations P4 (Sakha 8) x P5 (Mrbll), P4 (Sakha 8)x P6 (Omtel-1) and P5 (Mrbll) x P6 (Omtel-1) showed desirable significant specific combining ability under non stress and stress environment and they appeared significant heterosis over the mid and better parent. Such crosses can be used for improving wheat grain yield under drought conditions.

Key Words: Diallel analysis, wheat, drought, combining ability

INTRODUCTION

Drought is a major limiting production of wheat (*Triticum aestivum* L.) in many areas of the world and there is considerable interest in trying to increase drought tolerance in wheat. Approximately 32% of wheat-growing regions in developing countries experience some type of drought stress during the growing season (Van Ginkel *et al*., 1998).

A feasible strategy to achieve a quantum jump in yield of wheat under drought stress is the commercial production on hybrid varieties. Information on the prepotency of the parents helps in making suitable choice for initiating a hybridization programme. To evolve an effective hybridization programme, combining ability analysis is used to test the performance of parents in different cross combinations and characterize the nature and magnitude of gene effects in the expression of various drought tolerant parameters. General combining ability is recognized as primary measure of additive gene action. While specific combining ability is regarded as an estimate of the effects on non additive gene action.

The information on heterosis and inheritance of developmental and physiological characters like heading date, yield and yield attributes, chlorophyll content and proline content are available under favourable conditions, but they are less available under water stress (Kathiria and Sharma, 1996). Nayeem and Veer (2000) observed significant GCA and SCA effects for chlorophyll content and proline content in 21 cross combinations under favourable and unfavourable conditions. Several investigators studied general and specific combining abilities and their role in the inheritance of earliness, grain yield and yield components traits under normal irrigation. For instance, Martin *et al.* (1995); Awaad (1996); Hassan and Saad (1996) and Saad (1999) reported that both general (GCA) and specific (SCA) combining ability variances were highly significant for most of these traits. Darwish (2003) and El-Seidy (2003) indicated that mean squares due to general and specific combining abilities were significant for heading date, yield and yield attributes under both favourable and water stress conditions. High GCA/SCA ratios that exceed unity were detected for all the studied traits, indicating that the largest part of the total genetic variability for these traits was due to additive and additive by additive type of gene action. Salgotra *et al.* (2002) reported that the crosses exhibiting heterosis for grain yield in wheat also show high heterosis for other desirable yield characters. The main objectives of the present study were 1) to estimate the relative importance of general and specific combining abilities for yield and its attributes. 2) to genetically evaluate parents and helps wheat breeders for producing new genotypes of high yielding ability under drought stress and normal irrigation.

MATERIAL AND METHODS

The field work of this study was carried out at the Experimental Farm, Fac., of Agric., Suez Canal Univ., Ismailia, Egypt in two successive seasons 2000/2001 and 2001/2002. Six genotypes of bread wheat were used in this investigation. They were; two local cultivars (Sakha 8 and Sakha 69) and four introduced genotypes from ICARDA were chosen from the previous screening experiments for drought tolerance (Bayoumi, 1999). The parents were selected on the basis of the presence of wide differences between them with respect to certain economic and drought tolerance traits.

Table (1): The origin and pedigree of the studied parental wheat genotypes

No.	Name	Pedigree	Origin
1	Sakha 69	(Inia/P1 4220//7c/Yr"S",cn15430-25-05,1980)	Egypt
2	Rufom-2	Glennson. 81/3/Fury/51m/Aldan's	Syria/Lebanon
3	Korifla	ICW85-0398-010AP-300L-4AP-OTR	Portugal
4	Sakha 8	Indus 66x Norteno "S" IK 348	Egypt
5	Mrbll/snipe/Magh	ICD 85 – 0538 – ABL – TR – 9 AP – OTR	Syria
6	Omtel -1	ICD 85 – 0988 – 6 – AP – TR – 4AROTR	Mexico/Syria

In 2000/2001 season, the six parents were crossed in all possible combinations excluding reciprocal to obtain a total of 15 F_1's grains.

In 2001/2002 season, the six parents along with 15 F_1, hybrids (21 entries) were sown under two water regimes (stress and non stress). The stressed experiment was irrigated one time after sowing (i.e., two irrigations were given through the whole season). Meanwhile, the non stressed experiment was irrigated five times after sowing irrigation. Each experiment was designed in a randomized complete block design with four replications. The experimental plot consisted of three rows 1.5 m long. The plants were individually spaced 10 cm within and 30 cm between rows. The ordinary cultural practices for wheat production were followed during the growing season.

Observations and measurements were recorded for parents and F_1 hybrids on ten guarded plants taken at random from each plot for each water regime for the following characters:

1- Days to 50% heading
2- Plant height (cm)
3- Spike length (cm)
4- Number of grains/spike
5- Number of spikes/plant
6- 1000-kernel weight (g)
7- Grain yield/plant (g)
8- Drought susceptibility index (S)

The drought susceptibility index (S) was used to characterize the relative stress tolerance of all genotypes according to (Fischer and Maurer, 1978) as follow:

$$S = (1 - Y_d / Y_P)/D$$

Where:

Y_d = mean grain yield in stress environment

Y_P = mean grain yield in non stress environment

D = Drought intensity

=1- (mean Y_d of all genotypes/mean Y_p of all genotypes).

9- Chlorophyll content: The Chlorophyll a,b contents were measured spectrophotometerically at 662 nm and 644 nm according to Faddeel (1962).

10- Free proline content: Free proline was determined spectrophotometrically at 520 nm. to investigate the relationship between proline accumulation and drought tolerance according to Bates *et al.* (1973)

The ordinary complete randomized block analysis was first carried out according to Steel and Torrie (1980) to test the significance of genotypic differences. Moreover, Barttelet test was used to test the homogeneity of error for combined. Heterosis was calculated as the deviation of F_1 mean from the mid parent and better parent values and expressed as percentage. Estimates of combining ability effects were calculated using Griffing's method 2, model 1 (1956). Moreover, the ratio of GCA variance to SCA variance was calculated according to Singh and Chaudhary (1985).

RESULTS AND DISCUSSION

Mean performance:

The result showed significant differences among the studied genotypes for all studied characters. The mean performance of the parents and single crosses for all traits are presented in Table (2). The cross P_5 (Mrbll) x P_6 (Omtel-1) was the earliest hybrid for heading date. Whereas, the cross P_3 (Korifla) x P_4 (Sakha 8) was the shortest hybrid. The crosses P_4 x P_5, P_4 x P_6 and P_5 x P_6 were the best hybrids for grain yield and its attributes under both water regime.

Genetic variability estimated as mean squares for the investigated characters of parents and their F_1 hybrids are presented in Table (3). The mean squares due to genotypes, parents and crosses were highly significant for all traits, indicating the presence of wide diversity among the parental materials and the 15 F_1's crosses under non stress and stress conditions. This indicates that variability existed among the population increases the chances for isolating new recombinations in the advanced generations characterized by drought tolerance in wheat. The significance of the parents *vs* crosses indicated the presence of heterosis and non additive genetic effects in the crosses and justified the use of diallel analysis (Salgotra *et al.*, 2002).

Heterosis effects

Estimates of mid and better parent heterosis for the studied traits are shown in Table (4). Since earliness is an important objective in wheat breeding for drought tolerance, the negative values of heterosis for number of days to 50% heading are desirable. Nine out of 21 crosses showed negative heterosis for days to heading over the mid parent under non stress (-0.52 to -8.8 %) and stress conditions (-0.32 to -12.05%). While, over the better parent 14

Table (2): Mean performance for parents and F_1 generation for yield and its attributes

Genotypes	Heading date		Plant height (cm)		Spike length (cm)		No. of grains/spike		No. of spikes/plant		1000-kernel weight (g)		Grain yield / plant (g)		Chl. A + b (mg/g)		Proline content (mg/g)		DSI
	Non stress	Stress	Non stress	Stress	Non stress	Stress	Non stress	Stress	Non stress	Stress	Non stress	Stress	Non stress	Stress	Non stress	Stress	Non stress	Stress	
P1	97.5	91.5	90.5	85.0	7.5	6.4	56.8	46.6	2.9	2.3	32.7	29.5	8.7	7.2	17.6	10.6	1.9	5.5	0.51
P1	97.5	91.5	90.5	85.0	7.5	6.4	56.8	46.6	2.9	2.3	32.7	29.5	8.7	7.2	17.6	10.6	1.9	5.5	0.51
P_2	97.7	90.0	100.7	94.3	8.6	7.5	57.4	47.4	3.3	2.6	36.3	28.6	9.0	7.4	18.8	12.2	1.7	5.7	0.54
P_3	93.5	88.5	85.5	75.8	8.3	6.9	58.3	48.3	4.1	2.9	39.8	30.1	9.3	6.7	16.4	9.6	2.4	6.3	0.74
P_4	101.5	96.5	80.7	71.5	8.8	7.9	57.2	48.9	4.4	2.7	43.4	30.6	9.6	7.7	32.8	18.9	1.9	6.0	0.57
P_5	99.5	88.7	98.0	92.3	9.3	8.1	60.7	51.1	4.8	2.9	46.4	33.8	9.9	8.3	35.2	23.3	2.5	6.6	0.46
P_6	89.3	82.0	103.2	97.3	9.5	8.4	59.7	55.0	4.4	3.1	48.1	34.1	11.5	8.6	38.8	24.7	2.9	6.7	0.71
$P_1 x P_2$	97.0	89.2	100.0	92.8	8.7	7.7	50.3	40.5	2.7	3.4	38.2	32.4	10.6	9.2	21.4	13.6	2.1	6.5	0.39
$P_1 x P_3$	92.7	87.5	95.0	89.0	9.3	8.4	55.6	45.7	2.4	3.2	36.2	32.3	11.4	9.2	20.9	13.9	2.3	6.6	1.17
$P_1 x P_4$	101.5	94.5	110.0	102.3	9.5	8.5	56.5	46.7	4.1	3.2	35.6	31.5	11.4	8.4	25.6	18.3	1.9	6.0	0.75
$P_1 x P_5$	96.0	88.0	98.3	91.5	8.9	7.8	58.3	48.4	4.4	3.8	37.9	32.7	12.4	8.7	28.8	20.1	1.5	5.9	0.85
$P_1 x P_6$	93.5	87.5	76.2	71.0	9.6	8.7	62.6	54.0	4.6	3.4	39.9	31.6	13.6	8.6	27.9	18.7	2.2	6.3	1.01
$P_2 x P_3$	94.5	89.5	88.5	86.3	8.9	8.1	61.8	52.2	3.3	3.7	33.6	32.7	12.6	8.8	23.9	14.6	1.8	5.9	1.17
$P_2 x P_4$	97.0	90.7	94.2	84.3	8.9	8.9	63.1	54.6	3.8	3.2	43.6	33.4	13.7	8.7	29.5	19.6	1.7	6.0	1.05
$P_2 x P_5$	98.3	89.0	120.0	108.0	9.8	8.8	68.7	57.7	4.9	3.8	45.3	35.3	13.8	8.7	34.2	24.2	2.3	7.4	1.07
$P_2 x P_6$	90.3	81.3	105.0	95.5	9.0	8.7	64.9	56.4	4.3	3.6	43.5	34.5	12.7	10.0	30.8	20.9	2.2	7.1	0.61
$P_3 x P_4$	90.2	90.5	90.2	81.5	9.2	8.2	69.9	58.4	2.9	3.5	46.3	33.8	14.6	8.9	35.9	26.1	1.7	7.0	1.08
$P_3 x P_5$	96.3	92.3	104.2	104.5	10.7	8.7	60.7	54.9	3.4	4.3	41.3	32.5	11.8	8.2	28.7	20.0	2.3	7.7	1.14
$P_3 x P_6$	90.7	91.8	90.6	85.3	9.9	8.9	69.0	60.2	4.7	4.3	46.6	34.4	14.2	8.8	31.6	23.9	2.5	8.0	1.13
$P_4 x P_5$	98.2	87.3	120.0	107.0	10.2	7.9	72.0	61.8	6.1	4.8	48.2	35.6	14.7	9.9	39.7	29.9	3.2	8.7	0.89
$P_4 x P_6$	94.5	84.2	100.0	95.3	9.4	8.7	70.6	61.2	4.6	4.2	47.4	36.6	14.6	10.1	40.8	31.3	3.1	9.0	0.96
$P_5 x P_6$	88.0	83.0	109.2	102.7	10.0	8.8	72.7	65.3	5.7	4.8	49.2	37.8	15.3	10.4	48.1	37.9	3.5	9.7	0.89
LSD 5%	2.39	4.23	4.93	3.54	0.28	0.21	7.71	2.59	0.34	0.17	0.86	0.37	0.18	0.13	1.30	1.05	0.09	0.49	0.067

DSI = Drought susceptibility index

Table (3): Mean squares for parents, crosses, parents vs. crosses, irrigations and their interactions for the studied traits in bread wheat

S.O.V	d.f	Heading date		Plant height		Spike length		No. of grains / spike		No. of spikes / plant		1000-kernel weight		Grain yield/plant		DSI	Chlorophyll a+b	
		Non stress	Stress	Non stress	Stress	Non stress	Stress	Non stress	Stress	Non stress	Stress	Non stress	Stress	Non stress	Stress		Non stress	Stress
Reps.	3	1.47	9.79	75.70	28.95	0.43	0.004	2.62	4.11	0.205	0.047	8.27	0.193	0.354	0.12	0.018	12.09	3.97
Genotypes	20	58.89**	81.65**	505.57**	480.56**	2.63**	1.79**	161.64**	150.98**	6.32**	1.88**	107.66**	21.46**	18.30**	3.80**	0.258**	282.4**	202.4**
parents	5	78.50**	88.84**	321.45**	460.7**	2.23**	2.36**	7.75**	38.02**	12.89**	0.327**	141.69**	21.44	3.93**	1.99**	0.056**	402.48**	175.7**
Crosses	14	51.98**	83.67**	545.7**	446.21**	1.89**	0.706**	180.37**	175.5**	2.56**	1.165**	101.84**	14.13**	9.46**	2.05**	0.198**	233.01**	186.9
Parents vs. crosses	1	57.62**	17.42**	864.3**	1060.8**	15.03**	14.30**	668.73**	372.59**	26.11**	19.78**	18.91**	124.09**	213.8**	37.33**	2.109**	373.4**	551.7**
Error	60	2.87	1.33	9.46	26.29	0.035	0.024	0.163	6.24	0.487	0.014	0.375	0.171	0.320	0.017	0.002	10.76	9.56

DSI = Drought susceptibility index

and 10 out of 15 crosses showed negative heterosis for both conditions and ranged from (-0.77 to –11.55 %) for non stress and (-0.38 to -12.5%) for stress condition.

The cross combination P2 x P6 and P5 x P6 were the earliest in heading among all crosses. Thus it may be possible to use these hybrids as promising genotypes for drought tolerance or as source genes for earliness along with yield components. Kheiralla *et al.*, (2001) reported that four hybrids were significantly earlier than the better parent. While El-Hennawy (1996) found 10 out of 28 crosses showed negative heterosis over the mid parent. For plant height, ten hybrids exhibited significant positive values over the mid parent and ranged from (1.18 to 28.7%) under non stress and (0.01 to 26.68%) under stress conditions. While over the better parent seven hybrids were significantly taller than others for both conditions.

Regarding spike length, 14 out of 15 crosses showed highly significant positive heterosis relative to mid parent for both conditions and P5 x P6, P4 x P6 and P3 x P5 hybrids were the longest spike for both conditions over mid and better parent. Number of grains/spike showed highly significant increase for eleven crosses in their respective to the mid parent and the values ranged from (5.48 to 26.30%) under non stress and (4.51 to 26.60%) under stress conditions. Nine and ten crosses for the number of grains/spike were positively and significantly heterotic effect over the better parent for non stress and stress condition, respectively. Concerning number of spikes/plant, 11 and 15 out of 15 F_1 crosses showed highly significant positive heterosis relative to mid parent values under non stress and stress conditions, respectively. Compared to better parent values, highly significant positive heterotic effects were obtained in seven and fifteen crosses for this trait under both non stress and stress conditions, respectively. The highest values of heterosis were observed for the crosses P5 x P6 and P4 x P6 over mid and better parent for both conditions. 1000-kernel weight was highly and significantly heavier than the mid parent in 13 crosses for both non stress (3.8 to 18.6%) and for stress (3.85 to 21.52%) conditions. Whereas, four and nine out of 15 F_1 crosses showed highly and

Table (4): Heterosis as percentage of mid-parent (upper values) and better parent (lower values) for all characters studied in the F_1 generation

Crosses	Heading date		Plant height		Spike length		No. of grains/spike		No. of spikes/plant	
	Non stress	Stress	Non stress	Stress	Non stress	Stress	Non stress	Stress	Non stress	Stress
P1 x P2	0.52	2.18	7.35**	8.79**	0.66	2.00	-12.69	-18.18**	24.30**	25.60**
	-0.77	0.00	-0.74	-1.59	0.86	2.00	-12.48	-14.40**	22.28**	34.31**
P1 x P3	5.18**	-6.18**	1.98	4.39**	7.57**	12.00**	-3.26	-7.69**	-0.67	16.25**
	-6.15**	-7.65**	4.79**	10.55**	11.64**	22.62**	-4.60	-5.32*	20.49**	10.42**
P1 x P4	5.18**	8.05**	18.00**	19.94**	9.29**	12.10**	-1.71	-5.80*	-31.00**	18.09**
	0.00	0.26	21.34**	27.01**	8.26**	7.64**	-1.17	-4.64*	-33.76**	19.44**
P1 x P5	-0.52	-1.44	5.50**	7.33**	2.68*	3.30**	1.14	-2.44	-12.16**	39.36**
	-3.51	-3.55	0.25	-0.81	-4.28	-4.32	2.46**	-5.38*	-21.68**	31.03**
P1 x P6	-3.10	-3.11	-17.60**	-16.71	11.00**	15.66**	8.87**	10.70**	20.20**	22.86**
	-4.10**	-5.19**	-25.66**	-26.99**	1.04	3.89**	4.76**	-0.27	-4.30	8.94**
P2 x P3	-2.00	-0.32	-2.57	1.17	3.25**	7.30**	7.36**	4.51*	18.20**	33.86**
	-3.32	-0.83	-9.92	-8.48**	3.45**	7.33**	6.00**	7.19**	43.44**	26.95**
P2 x P4	0.52	-1.34	1.18	-1.17	3.25**	18.33**	9.74**	7.27**	8.78**	18.09**
	-4.43**	-5.95**	-6.45	-10.61**	2.27	13.05**	9.96**	8.63**	4.54**	19.44**
P2 x P5	1.80	2.18	28.70**	26.68**	12.75**	17.33**	19.38**	18.47**	4.72**	37.53**
	-1.25	1.66	19.10**	14.58**	5.09**	8.64**	19.62**	14.92**	-15.06**	29.31**
P2 x P6	-6.47**	-12.05**	12.70**	12.02**	4.11**	15.30**	12.87**	11.00**	18.20**	32.02**
	-7.67**	-12.50	1.69	-1.79	-5.23	3.59**	8.60**	0.00	-5.91**	17.07**
P3 x P4	-3.88	1.07	-3.11	-4.39	5.84**	8.66**	21.43**	20.85**	25.60**	30.19**
	-8.62**	-6.21**	5.55**	7.59**	4.84**	3.82**	19.89**	22.36**	20.77**	23.47**
P3 x P5	-0.25	2.18	11.37**	22.58**	21.09**	14.33**	5.48**	8.24**	2.00	55.86**
	-3.26	3.09	6.37**	13.27**	12.86**	5.86**	4.15**	4.99**	-12.77**	46.55**
P3 x P6	-5.95**	3.30	3.75**	0.01	14.18**	18.00**	19.87**	20.00**	10.80**	58.43**
	-2.94	4.51*	-12.83**	-12.33**	3.92**	5.98**	15.41**	8.13**	-29.03**	40.65**
P4 x P5	1.80	-1.16	28.70**	25.51**	18.20**	4.66**	25.00**	25.24**	8.78**	74.20**
	-3.20	-8.29**	22.44**	15.98**	10.18**	-3.08	25.76**	21.47**	-3.01	63.79**
P4 x P6	-2.00	-4.51*	7.35**	11.73**	23.59**	15.33**	22.60**	22.31**	47.29**	52.20**
	-6.89**	-11.39**	-3.14	-2.05	12.56**	3.59**	18.01**	10.17**	17.20**	34.95**
P5 x P6	-8.80**	-8.98**	17.20**	20.52**	23.97**	17.60**	26.30**	26.60**	47.30**	76.77**
	-11.55**	-8.16**	5.81**	5.65**	12.82**	5.68**	21.60**	14.03**	27.26**	56.91**

*, ** significant at 0.05 and 0.01 levels of probability, respectively

Table (4): Conti.

Crosses	1000-lernel weight		Grain yield/plant		Drought	Chl. (a + b)		Proline content	
	Non stress	Stress	Non stress	Stress	Susceptibility index	Non stress	Stress	Non stress	Stress
$P_1 \times P_2$	-7.10*	4.17**	9.19**	20.0**	-34.2**	13.4**	19.2**	3.5**	1.4
	5.08**	10.0**	17.3**	23.5**	-28.3**	12.4**	11.6**	24.9**	9.8**
$P_1 \times P_3$	12.60**	3.85**	17.7**	19.7**	96.1**	31.7**	38.3**	9.7**	10.3**
	-9.03**	7.48**	22.3**	27.1**	51.9**	18.4**	31.2**	-3.0**	4.8*
$P_1 \times P_4$	14.10**	1.12	17.4**	9.4**	25.7**	-3.7	26.0**	9.9**	-4.0
	-18.00**	2.85	17.7**	8.2**	31.0**	-22.0**	-3.3	-0.51	-4.2
$P_1 \times P_5$	8.67**	4.91**	28.0**	13.7**	42.5**	8.2**	36.7**	30.8**	-8.4**
	-18.36	-3.40	25.6**	5.2**	65.0**	-18.1**	-13.5	-39.6**	-12.9
$P_1 \times P_6$	3.80**	1.44	40.8**	14.5**	67.6**	4.9**	5.6**	4.29**	6.6**
	-17.09**	-7.60**	18.4**	2.0**	42.6**	-27.8**	-24.4**	-23.2**	-4.9*
$P_2 \times P_3$	19.00**	5.07**	29.5**	15.2**	96.1**	-10.0	36.1**	13.9**	5.5**
	-15.63**	8.72**	34.6**	18.6**	51.9**	25.7**	20.4**	-23.9**	-10.2**
$P_2 \times P_4$	5.18**	7.39**	41.7**	13.9**	76.0**	10.5**	17.8**	21.8**	-7.1**
	0.46	9.23**	42.0**	12.7**	83.8**	-10.3**	3.5**	-13.6**	-3.3
$P_2 \times P_5$	9.27**	13.33**	42.5**	13.0**	79.4**	28.2**	46.3**	9.1**	18.5**
	-2.31	4.36**	39.6**	4.6**	96.3**	-2.9	4.1**	-4.7	12.7**
$P_2 \times P_6$	4.01**	10.92**	31.6**	30.3**	-3.6	15.7**	26.2**	5.4**	17.9**
	-9.61**	1.02	10.7**	16.2**	-13.0**	-20.4**	-15.4**	-22.3	5.1**
$P_3 \times P_4$	11.50**	8.77**	45.5**	15.6**	81.1**	35.6**	58.3**	-20.0	8.5**
	6.55**	10.62**	39.8**	14.3**	40.9**	9.9**	38.6**	-29.4	3.1**
$P_3 \times P_5$	0.40	4.59**	21.4**	6.9**	91.1**	8.6**	20.8**	6.7**	23.1**
	-10.98**	-3.69	19.1**	-0.99	48.3**	-17.8**	-13.9**	-6.8**	17.0**
$P_3 \times P_6$	12.00**	10.37**	45.1**	14.6**	89.4**	19.7**	45.0**	15.7**	28.1**
	-3.06	0.512	22.0**	2.2**	47.0**	-17.6**	-2.9	-14.7**	14.2**
$P_4 \times P_5$	16.10**	14.23**	52.4**	29.2**	49.2**	50.0**	37.1**	47.1**	38.1**
	3.87**	5.17**	49.1**	19.6**	56.7**	13.4**	28.9**	28.7**	31.3**
$P_4 \times P_6$	14.20**	17.99**	61.4**	31.6**	60.9**	56.0**	43.1**	44.4**	41.0**
	-1.50	7.46**	36.0**	17.2**	35.9**	7.3**	26.3**	6.3**	25.7**
$P_5 \times P_6$	18.60**	21.52**	59.9**	40.1**	49.2**	80.6**	58.1**	66.8**	55.2**
	2.28**	10.68**	34.5**	24.8**	25.7**	24.1**	53.1**	22.7**	38.5**

significant positive heterosis over the better parent under non stress (3.87 to 6.55%) and stress (5.17 to 16.68%) conditions.

The heterosis over the mid parent for grain yield/plant ranged from (9.19 to 61.4%) for non stress and (6.9 to 40.1%) for stress conditions. For better parent positive and significant heterosis was observed in all crosses for non stress and stress conditions. The range of better parent heterosis was (10.7 to 49.1%) for non stress and (2.0 to 24.8%) for stress conditions. Several studies have also demonstrated significant levels of heterosis in wheat of them El-Hennawy (1996), Saad (1999), Afaf Tolba (2000) and Salgotra *et al.* (2002) they stated that genetic diversity is important for heterotic expression therefore, the level of heterosis expressed in this study may reflects a high degree genetic diversity among these parents.

Application of the drought susceptibility index over both irrigation treatments (non stress and stress) indicated that, 13 hybrids exhibited highly significant heterosis over the mid parent and the better parent. Only two hybrids had negative heterosis (P1 x P2 and P2 x P6) for the drought susceptibility index over the mid and better parent.

Chlorophyll content (a+b) was estimated from ten random plants of the parents and F_1 for the two water regimes. Heterosis over the mid parent showed a vast wide range for this trait, where, it was (4.9 to 80.6%) under non stress and (5.6 to 58.1%) under stress conditions. While, over the better parent it ranged from (9.9 to 25.7%) under non stress and (3.5 to 53.1%) under stress conditions. These results may be indicate that the expression of the trait is developmentally programmed according to the state of water regimes and kind of cross. Concerning proline content attempts have been made to relate the increase in free proline to drought tolerance or to use it as an indicator of the level of stress (Aspinall *et al.* (1983), Narayan and Misra (1989)). 14 and 12 out of 15 F_1 crosses showed positive and highly significant heterosis relative to mid parent values for both water regimes. Compared to better parent values, positive and highly significant heterotic effects were obtained only in four crosses under non stress and ten crosses under stress conditions. Some accumulation of free proline under irrigated (non stress) condition was apparently a response to atmospheric drought (Narayan and Misra, 1989).

Combining ability

The analysis of variance for combining ability (Table 5) showed highly significant mean squares for both general and specific combining abilities of all the studied traits under non stress and stress conditions. This result revealed the importance role of both additive and non additive effects in the expression of these traits. The magnitude of GCA was larger than SCA one for all the studied characters except plant height and grain yield/plant, resulting in GCA/SCA ratio was more than unity. To reveal the nature of genetic variance controlling the studied characters, additive variance (σ^2_A)), dominance variance (σ^2_D) GCA/SCA ratio and heritability in narrow sense were computed. The high ratio of GCA/SCA and high additive variance (σ^2_A) than dominance were detected for heading date, 1000-kernel weight, chlorophyll (a+b), drought susceptibility index and proline content. This result reveal that the inheritance of these traits were mainly controlled by additive effects of genes, while, the remaining traits were controlled by non additive gene. In this respect, El-Marakby *et al.* (1993), Awaad (1996) and Nayeem and Veer (2000) reached the same conclusion concerning the inheritance of the above traits in wheat.

Heritability estimates in narrow sense were relatively high to moderate in F_1 hybrids for the most traits. For chlorophyll a+b they were (79.5 and 63.2%), drought susceptibility index (76%), 1000-kernel weight (75.7 and 58.6%) and heading date (96.7 and 53.2%) under non stress and stress conditions, respectively, as well as for proline content (56.1%) under non stress conditions. On the other hand, grain yield/plant and the other traits showed low narrow sense heritabilities under both conditions. Hamada *et al.* (2002) and El-Seidy (2003) found that heritability estimates in narrow sense were high moderately to high for 1000-kernel weight, No. of kernel/spike and heading date. Whereas, Saad (1999) and Darwish (2003) showed that hertabilities in narrow sense were low for grain yield/plant, number of grains/spike and spike length.

Table (5): Mean squares for general (G.C.A) and specific (S.C.A) combining ability as well as variance components for additive (σ^2_A), dominance (σ^2_D) and heritability in narrow sense (h^2) for the studied characters in bread wheat

S.O.V	d.f	Heading date		Plant height		Spike length		No. of grains / spike		No. of spikes / plant		1000-kernel weight		Grain yield/plant		DSI	Chlorophyll a+b		Proline content	
		Non stress	Stress	Non stress	Stress	Non stress	Stress	Non stress	Stress	Non stress	Stress	Non stress	Stress	Non stress	Stress		Non stress	Stress	Non stress	Stress
GCA	5	43.88**	42.88**	179.1**	177.18**	1.34	0.64**	59.67**	58.16**	2.78**	0.969**	87.87**	11.30**	5.07**	1.11**	0.664**	238.4**	146.2**	0.76**	2.485**
S.C.A	15	5.00**	12.92**	188.8**	181.12**	0.43	0.38**	33.98**	21.94**	1.18**	0.439**	6.59**	2.38**	5.40**	1.89**	0.165**	14.64**	18.72**	0.176**	0.851**
Error	60	0.719	6.33	2.36	6.57	0.099	0.086	0.041	0.061	0.122	0.064	0.094	0.818	0.005	0.062	0.001	0.192	0.141	0.061	0.195
GCA/ S.C.A		8.77	3.31**	0.95	0.97	3.08	1.66	1.75	3.90	2.35	2.20	13.32	3.33	0.94	0.59	4.02	16.28	7.79	4.34	2.92
σ^2_A		9.72	7.48	17.56	19.01	0.112	0.064	6.42	15.8	0.40	0.133	20.31	2.22	0.166	0.054	0.124	55.9	31.88	0.146	0.41
σ^2_D		4.28	6.58	106.4	94.55	0.335	0.30	33.94	21.88	1.059	0.375	6.5	1.57	4.404	0.834	0.164	14.45	18.57	0.114	0.656
h^2		69.4	53.2	14.1	16.74	25.0	17.58	15.9	41.8	27.4	26.18	75.7	58.59	3.63	6.13	76.0	79.45	63.19	56.1	38.5

DSI = Drought susceptibility index

1- General combining ability

Estimates of general combining ability effect for each parent are given in Table (6). Since negative and significant values of GCA would be of interest for earliness, the parents P6, P3 and P5 are considered to be the most desirable among the parental set for improving earliness. The parents P3, P1 and P4 had more genes for dwarfness, and P5 and P2 for tallness than others. The parental genotypes P6 and P5 were considered to be the best among the parental set (good combiners) for all the studied traits for both water regimes. These results indicated that the parents P6 and P5 were promising parents and showing high GCA effects for important yield traits. So, it can be claimed that GCA effects represent the fixable component of genetic variance. Thus the previous parents may be useful in hybrid breeding programmes for improving the grain yield under both stress and non stress conditions (Mann and Sharma, 1995).

2- Specific combining ability

Specific combining ability effects for different crosses are given in Table (7). Results revealed that the crosses (P1 x P3, P1 x P5, P2 x P5, P2 x P6, P3 x P4, P4 x P5, and P5 x P6) exhibited negative and significant SCA effects for heading (towards earliness) under both water regimes. While, the crosses (P1 x P4, P1 x P6, and P2 x P5) attained positive and significant SCA effects towards lateness in days to heading. For plant height, nine hybrids showed positive and significant SCA effects toward tallness under non stress and stress conditions. Moreover, six crosses exhibited negative SCA effects towards dwarfness. Regarding spike length, ten crosses under non stress and eight crosses under stress conditions showed positive and significant SCA effects and the best hybrid in spike length was P1 x P3 followed by P1 x P4 and P3 x P5 under both water regimes.

Specific combining ability effects were consistent with the two water regimes for number of grains/spike. Out of 15 crosses, only five crosses P1 x P2, P1 x P3, P1 x P4, P1 x P5, and P3 x P5 showed negative SCA effects for number of grains/spike under non stress and stress conditions. While, number of spikes/plant were inconsistent for SCA effects over the two water regimes for crosses

Table (6): General combining ability effects for the studied characters in bread wheat under non stress and stress conditions

Parents	Heading date		Plant height		Spike length		No. of grains / spike		No. of spikes / plant		1000-kernel weight		Grain yield/plant		DSI	Chlorophyll a+b		Proline content	
	Non stress	Stress	Non stress	Stress	Non stress	Stress	Non stress	Stress	Non stress	Stress	Non stress	Stress	Non stress	Stress		Non stress	Stress	Non stress	Stress
P_1	1.02	1.12	-3.28	-3.57	-0.55	-0.43	-4.63	-5.10	-0.95	-0.37	-4.99	-1.49	-1.07	-0.29	-0.09	-6.25	-4.78	-0.34	-0.69
P_2	0.771	0.01	2.99**	2.39**	-0.32	-0.05	-1.29	-2.03	-0.30	-0.22	-2.04	-0.72	-0.49	-0.09	-0.07	-3.99	-3.34	-0.28	-0.50
P_3	-1.69**	0.44	-5.78	-4.7	-0.10	-0.17	-0.05	-0.38	-0.05	0.03	-1.18	-0.67	-0.36	-0.48	0.164**	-4.41	-3.27	-0.03	0.004*
P_4	2.58	2.90	-1.44	-2.85	0.091**	0.08**	1.57**	1.26**	0.28*	-0.02	1.84**	0.11	0.44**	0.06**	-0.004	3.57**	2.35**	-0.04	-0.048
P_5	1.18	-0.37*	7.52**	7.77**	0.43**	0.12**	1.21**	2.18**	0.25*	0.34**	2.69**	1.27**	0.32**	0.22**	0.018**	5.08**	4.30**	0.24**	0.483**
P_6	-3.85**	-4.09**	-0.006	1.02**	0.47**	0.41**	3.19**	4.07**	0.77**	0.24**	3.69**	1.50**	1.16**	0.57**	0.014**	6.00**	4.74**	0.46**	0.761**
SE (gi)	0.27	0.18	0.49	0.24	0.03	0.02	0.06	0.08	0.11	0.01	0.09	0.04	0.02	0.01	0.0007	0.14	0.12	0.0009	0.002
L.S.D at 5%	0.55	0.37	0.99	0.49	0.04	0.13	0.13	0.16	0.22	0.04	0.19	0.08	0.12	0.03	0.0001	0.28	0.24	0.001	0.004
L.S.D at 1%	0.73	0.50	1.32	0.65	0.06	0.17	0.17	0.21	0.29	0.06	0.26	0.11	0.16	0.04	0.0002	0.37	0.32	0.002	0.006

DSI = Drought susceptibility index

Table (7): Specific combining ability effects for the studied traits in bread wheat under non stress and stress conditions

Crosses	Heading date		Plant height		Spike length		No. of grains / spike		No. of spikes / plant		1000-kernel weight		Grain yield/plant		DSI	Chlorophyll a+b		Proline content	
	Non stress	Stress	Non stress	Stress	Non stress	Stress	Non stress	Stress	Non stress	Stress	Non stress	Stress	Non stress	Stress		Non stress	Stress	Non stress	Stress
$P_1 \times P_2$	0.018	1.55	2.06	3.05	0.27	-0.07	-5.82	-5.21	2.11	0.51	3.34	1.59	-0.06	0.86	-0.29	1.68	1.15	0.44	0.63
$P_1 \times P_3$	-3.01	-5.88	5.85	6.46	0.65	0.85	-1.66	-1.67	0.95	0.02	0.52	1.44	0.64	1.22	0.25	1.53	1.43	0.47	0.68
$P_1 \times P_4$	2.70	3.89	16.05	17.80	0.61	0.65	-2.38	-2.37	-0.51	0.12	-3.12	-0.19	-0.20	-0.09	-0.002	-1.70	0.09	0.06	-0.16
$P_1 \times P_5$	-1.38	-1.32	-4.21	-3.56	-0.31	-0.09	-0.37	-1.63	0.21	0.34	-1.70	-0.17	0.95	0.07	0.11	0.01	-0.02	-0.67	-0.96
$P_1 \times P_6$	1.14	0.89	-18.18	-17.31	0.38	0.54	2.1	3.01	0.90	-0.02	-0.70	-1.48	1.35	-0.22	0.24	-1.78	-1.88	-0.13	-0.31
$P_2 \times P_3$	0.24	-0.01	-4.67	-2.25	0.04	0.07	1.12	1.31	0.99	0.34	-5.01	1.04	1.21	0.68	0.22	2.37	0.72	-0.09	-0.50
$P_2 \times P_4$	-1.54	-0.98	-5.52	-6.16	-0.15	0.65	0.87	1.05	0.31	-0.03	1.94	0.98	1.58	0.05	0.27	-0.10	-0.03	-0.25	-0.55
$P_2 \times P_5$	1.11	3.05	11.26	6.96	0.34	0.54	6.78	5.68	-0.16	0.13	2.79	1.68	1.79**	-0.18	0.31	3.10	2.66	0.12	0.51
$P_2 \times P_6$	-1.85	-5.97	3.79	1.21	-0.45	0.09	1.05	0.09	0.17	0.08	-0.06	0.69	-0.11	0.79	-0.18	-1.16	-1.09	-0.16	0.19
$P_3 \times P_4$	-3.33	-1.66	-0.74	-1.75	-0.15	0.09	6.35	6.12	0.69	0.05	3.75	1.37	1.82	0.57	0.08	6.98	6.51	-0.46	-0.08
$P_3 \times P_5$	1.58	2.61	4.29	10.62	0.84	0.47	-2.46	-1.05	-0.31	0.39	-2.07	-1.09	-0.39	-0.26	0.15	-1.70	-1.63	-0.18	0.29
$P_3 \times P_6$	1.11	7.33	-2.42	-1.87	0.20	0.45	3.89	2.91	-1.15	0.56	2.44	0.48	1.06	-0.02	0.11	0.32	1.93	-0.20	0.31
$P_4 \times P_5$	-0.70	-2.80	15.69	11.21	0.40	-0.49	7.19	5.74	-0.25	0.94	1.78	1.13	1.81	0.91	0.07	1.34	2.7	0.70	1.27
$P_4 \times P_6$	0.58	-2.13	3.22	6.21	0.83	0.01	3.81	2.40	0.66	0.44	-0.05	2.06	1.88	0.74	0.11	2.02	3.54	0.42	1.16
$P_5 \times P_6$	-4.51	-2.80	3.51	3.08	0.52	0.15	6.32	3.60	0.69	0.75	0.93	2.01	1.82	1.23	0.05	7.06	8.22	0.61	1.51
SE(Sij)	0.75	0.51	1.36	1.10	0.08	0.11	0.17	0.22	0.31	0.12	0.27	0.11	0.10	0.03	0.02	0.38	0.33	0.02	0.06
L.S.D 5%	1.50	0.37	2.72	1.34	0.16	0.14	0.35	0.16	0.61	0.11	0.54	0.24	0.12	0.07	0.04	0.28	0.66	0.01	0.04
L.S.D 1%	1.99	0.49	3.62	1.78	0.22	0.18	0.47	0.21	0.82	0.14	0.72	0.31	0.17	0.10	0.06	0.37	0.88	0.03	0.06

DSI = Drought susceptibility index

P1 x P4, P1 x P6, P2 x P4, P2 x P5, P3 x P5, P3 x P6, and P4 x P5. Only four crosses showed positive and significant SCA effects under both non stress and stress conditions for number of spikes/plant. Regarding 1000-kernel weight, significant and positive SCA effects were observed in the seven crosses for this trait under both non stress and stress conditions. In contrast, four crosses showed negative and significant SCA effects under both water regimes for 1000-kernel weight.

The results concerning specific combining ability effects proved that desirable specifying combining ability effect for grain yield/plant was obtained from three types of combinations; good x good, good x poor and poor x poor general combiners. In cross (P1 x P3) and (P2 x P3) both the parents were bad combiner for grains yield and had negative GCA effect but gave high SCA effects for this trait. This may be due to the high genetic diversity among the parents. The crosses P4 x P5, P4 x P6, and P5 x P6 showing significant SCA effects and both parents were good general combinors for grain yield/plant for both water regimes. This result may be indicate that these parents are stable under the two environments. The same conclusion was reported by Kathiria and Sharma (1996).

Specific combining ability effects were calculated for each cross for the drought susceptibility index (DSI) trait. Only three crosses showed negative SCA effects, while the remaining crosses (12 crosses) exhibited significantly positive SCA effects for the drought susceptibility index. Crosses which identified as stress tolerant based on DSI should possess tolerance mechanisms, and may need to be incorporated into germplasm with higher yield potential, for development of high yielding and stress tolerant hybrids. Chlorophyll (a+b) showed non fixable components of gene action, where the estimates of SCA effect were not consistent over two environments in same crosses. High SCA effects for chlorophyll content was observed in nine crosses for the two water regimes. Nayeem and Veer (2000) observed significant SCA effects for chlorophyll content and proline content in 11 cross combinations. In respect of proline content seven and nine crosses exhibited significant positive SCA effects under non stress and stress conditions, respectively.

It is interesting to note that the three cross combinations P4 x P5, P4 x P6 and P5 x P6 and P5 x P6 showed desirable significant SCA for non stress and stress environments for the most traits. At the same time, the previous crosses showed significant heterosis over mid and better parent, moreover theses crosses included combination of Egyptian (P4) x Mexico (P6) and Syria (P5) types. This emphasizes the need for combining two diverse germplasms to create maximum genetic variability which is the prime requirement and this alone would help in raising yield levels through selection in any successful breeding programme.

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تحليل الهجن التبادلية في قمح الخبز تحت معاملتي الري الطبيعي والإجهاد المائي

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أجريـت هـذه الدراسة بمزرعة كلية الزراعة ، جامعة قناة السويس بالإسماعيلية حيث تم عمل الهجن فى موسـم ٢٠٠٠/٢٠٠١ وقيمـت الآبـاء والهجن فى موسم ٢٠٠١/٢٠٠٢ وذلك بهدف دراسة طبيعة القدرة على الـتآلف مـن خـلال تحليل البيانات المتحصل عليها من التهجينات المتعددة التي أجريت في اتجاه واحد بين ٦ تراكيـب وراثـية لمحصول القمح في تجربتين: التجربة الأولى رويت خمس ريات (ري طبيعي) بالإضافة لرية الـزراعة والتجربة الثانية رويت رية واحدة (الاجهاد المائي) بالإضافة لرية الزراعة وذلك للصفات الآتية: عدد الأيـام حتى طرد ٥٠% من النباتات ، طول النبات ، طول السنبلة ، عدد الحبوب في السنبلة ، عدد السنابل على النـبات ، وزن ١٠٠٠ حبة ، محصول الحبوب للنبات ، دليل الحساسية للجفاف ، المحتوى الكلوروفيللي للأوراق ومحتوى البرولين.

كـــان لكـــل من التأثيرات الوراثية المضيفة وغير المضيفة دوراً في توريث جميع الصفات المدروسة كما أوضـــحت النـــتائج أن التأثير المضيف كان غالباً في وراثة صفة عدد الأيام حتى طرد ٥٠% من السنابل ووزن ١٠٠٠حـــبة والمحتوى الكلوروفيللي للأوراق ودليل الحساسية للجفاف ومحتوى الأوراق من البرولين ، بينما كان التأثير غير المضيف له الدور الأكبر في وراثة باقي الصفات.

أمكن من خلال هذه الدراسة التعرف على أن الأباء رقـــم ٤ (سخا ٨ من مصر) رقم ٥ (Mrbll مـــن ســـوريا) و رقـــم ٦ (Omtel-1 من المكسيك) هم أفضل الأباء في قدرتهم على التآلف وتوريث معظم الصفات المرغوبة تحت كل من معاملتي الري. أمكن الحصول على قوة هجين عالية في كل الصفات المدروسة ، كما أظهرت الهجن التالية :

P4 (Sakha 8) x P5 (Mrbll), P4 (Sakha 8)x P6 (Omtel-1) and P5 (Mrbll) x P6 (Omtel-1)

قوة هجين عالية وقدرة خاصة على التآلف عالية تحت كل من ظروف الري العادي والإجهاد المائي ، لذلك فإنه يمكن استخدام هذه الهجن في تحسين محصول الحبوب في القمح تحت ظروف الجفاف.