COMBINING ABILITY AND DROUGHT TOLERANCE IN BREAD WHEAT UNDER WATER REGIMES

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ABSTRACT

Twenty eight genotypes (seven parents and their 21 F_1 crosses) were evaluated for days to heading, spike length, 1000-grain weight, number of grains/spike and grain yield/plant under three water regimes (35, 65 and 100 % from the field capacity of the soil) over two years. Variance analysis revealed that all studied traits were significantly affected by soil moisture content. Moreover, genotypes x water regimes interaction was significant for all traits. The parents P3, P5 and P7 were moderately tolerant for drought stress. The crosses (P1 x P7), (P3 x P4), (P3 x P7) showed drought susceptibility index less than 0.5 and they were high tolerant to drought stress. Variance of general combining ability (GCA) and specific combining ability (SCA) were significant for all studied traits. The ratio GCA/SCA was more than one for all studied traits at each level of soil available water over two seasons and over all environments, indicating that additive gene effect was the most important in the inheritance of studied traits. The parents P3 and P5 were considered as good combiners for number of spikes/plant, 1000-grain weight and grain yield/plant, while parents P4 and P7 were considered as the best combiners for days to heading. The crosses (P1 x P4) and (P3 x P4) are considered as the best combinations for all studied traits under different levels of soil available water. Moreover, the crosses; (P1 x P4), (P2 x P6), (P3 x P4), (P4 x P5) and (P4 x P6) could be considered as the best combinations for number of spikes/plant, 1000-grain weight and grain yield/plant

Key words: Wheat, Combining ability, Gene action, Water regimes, Drought tolerance.

INTRODUCTION

Several indices have been utilized to evaluate genotypes for drought resistance based on grain yield such as stress susceptibility index (Fischer and Maurer, 1978), stress tolerance index (Fernandez, 1992) and tolerance (Rosielle and Hamblin, 1984). Under semi-arid conditions wheat lines with a longer grain filling duration produced lower yields if high water and temperature deficiency occurred during grain filling (Przulj and Mladenov, 1999). The diallel technique developed by Griffing (1956) lends itself to detailed genetic analysis after only one generation. It can provide valuable knowledge about the nature of combining ability as a measure of additive gene action and specific combining ability as a measure of non-additive gene action. The amount of heterosis as well as the GCA and SCA effects are important consideration for hybrid breeding. Breeding wheat for such specific needs requires the evaluation of genotypes for their combining behavior so that potential genotypes with good general and specific combining abilities may be identified (Arshad and Aslam, 2002). Combining ability analysis provides a guideline to the breeder in evaluating and selecting the elite parents and desirable cross combinations to be used the formulation of systematic breeding programs for improving quantitative traits such as yield and yield attributes (Singh *et al*., 1980). Tolerance implies relative stability of economic yield of wheat in the presence of varying levels of water (Guttieri *et al*., 2001). Rab *et al*., (1984) reported that water deficit at tillering stage caused reduction in grain yield. Kobata *et al*. (1992) summarized that grain yield and 1000-grain weight were reduced under drought stress. Grain yield increased with the increase in soil moisture content (Dawood *et al*., 1988). Grain yield exhibited overdominance type the of gene action under normal irrigated conditions (Kheiralla *et al*., 1993 and Choudhry *et al*., 1999). Ahmed (2003) reported that general and specific combining ability effects were dominant and played a major role in the inheritance of days to heading, plant height 1000-kernel weight and grain yield / plant and he indicated that exposing wheat plant to drought reduced grain yield and 1000- kernel weight. Hegde *et al*. (2007) indicated that a superior performance of the hybrids for some traits depends on the GCA of the parents involved, that progress in improving the desired trait will be slow if the parental selection is based on per se performance alone. For continued improvement, the selection of parents should be based on per se performance as well as combining ability and heterosis. This study aimed to determine general and specific combining ability for 7 wheat parental genotypes and their F_1 crosses under normal and drought stress conditions.

MATERIALS AND METHODS

Seven wheat genotypes (*Triticum aestivum* L.) were chosen on the basis of their diversity in origin namely; CROC-1/AE.SQUARROSA(224)//OPATA (P1), PREW (P2) from ICARDA; Giza 168 (P3), Sedes1 (P4) from Egypt; TRI 5641(P5) , TRI 5643 (P6) from Iran and TRI 12736 (P7) from Russian. In 2005/2006 season the grains were sown in drills spaced 30 cm apart and in hills spaced 5 cm. Hybridization in all possible combinations among the seven parents took place to obtain a total of 21 F_1 hybrids without reciprocals. The parents were crossed again in 2005/2006 season to produce sufficient hybrid seeds from each cross. In 2006/2007 and 2007/2008 seasons, the parents and the F_1 hybrids produced from the half diallel cross were grown in three replicates. The parents and F_1 hybrids were sown in three experiments under three irrigation treatments, i.e. irrigation at 35, 65 and 100 % from the field capacity of the soil (FC), which 35% and 65% FC are considered as drought stressed treatments and 100 % FC as control treatment. Some chemical and hydro-physical properties of experiment soil are presented in Table (1 and 2). The data presented in Table (2) indicated that, the surface layer of experiment soil is clay compared with subsurface layer which transported layer as results of reclamations. Each genotype was grown in three rows, 3 m long, 40 cm apart and 15 cm between plants within rows. F_1 seeds (without reciprocals) were obtained by hand emasculation and pollination. The 7 parents and their 21 F_1 crosses were evaluated for four traits in six environments, i.e. three FC, i.e. 35, 65 and 100% during the two successive seasons 2006/2007 and 2007/2008. The experiments were conducted at the Experimental Farm of Faculty of Agriculture, Sohag University, Egypt. The experimental design was a split-plot with three replications. Moisture levels were assigned in main plots and genotypes (7 parents + 21 F_1 crosses) assigned in sub-plots. Three soil samples were taken from each plot by soil tube at depth of 30 cm from the soil surface. The

samples were oven dried at 105 C° to constant weight and the soil moisture was determined. The three soil moisture used were kept constant at 35, 65 and 100% of available water until harvest. Each 3 days the soil moisture was tested throughout the growing season by dry oven soil samples. At maturity data were recorded on 10 plants of each parent and F_1 hybrid from each replicate to measure the following traits: - (1) Days to heading: Number of days from sowing to 50% of the heads emergence from the flag leaf sheath, (2) Number of spikes / plant: Tillers with fertile spikes, (3) 1000-grain weight (g): It was obtained as the weight of 1000-grains, which were chosen randomly per plant and (4) Grain yield per plant (g): It was recorded as grains weight of individual plant.
Drought tolerance index (DTI) was calculated according to the following equation (Fernandez, 1992).

$$DTI = \frac{Grain.yield.under.stress.conditions * 100}{Grain.yield.under.normal.conditions}$$

Table (1): Some physical and chemical properties of experiment soil

Soil depth	pH	Ec	CEC#	$CaCO_3$	OM	Sand	Silt	Clay
Cm		dSm^{-1}	Cmole Kg^{-1}##					%
0 – 25	7.75	0.2	34.1	11.43	2.26	49.3	21.9	28.8
25 – 45	8	0.17	11.44	55.65	0.22	93.4	4.6	2
45 – 60	8.1	0.2	10.59	56.4	0.14	91.6	6.3	2.1

Soil depth	N	P	K	Fe	Zn	Mn	Cu
Cm							mg kg^{-1}
0 – 25	44	19	418	11.8	1.3	17	2.3
25 – 45	12	4.3	68	2.8	0.6	3.7	0.5
45 – 60	8	6.4	102	3	0.5	3.2	o.4

#, CEC = cation exchange capacity

##, Cmole Kg^{-1} = meq/100g soil

Table (2): Hydraulic properties of experiment soil

Soil depth Cm)	Property	Value
0-25	Wilting point (cm^3 water /cm^3 soil)	0.165
	Field capacity (cm^3 water /cm^3 soil)	0.276
	Saturation (cm^3 water /cm^3 soil)	0.482
	Saturation hydraulic conductivity (cm hr.)	0.329
	Available water (cm^3 water /cm^3 soil)	0.111
	Available water (in water /foot soil)	1.331
25-45	Wilting point (cm^3 water /cm^3 soil)	0.038
	Field capacity (cm^3 water /cm^3 soil)	0.106
	Saturation (cm^3 water /cm^3 soil)	0.303
	Saturation hydraulic conductivity (cm hr.)	14.918
	Available water (cm^3 water /cm^3 soil)	0.067
	Available water (in water /foot soil)	0.807
45-60	Wilting point (cm^3 water /cm^3 soil)	0401
	Field capacity (cm^3 water /cm^3 soil)	0.110
	Saturation (cm^3 water /cm^3 soil)	0.307
	Saturation hydraulic conductivity (cm hr.)	13.705
	Available water (cm^3 water /cm^3 soil)	0.070
	Available water (in water /foot soil)	0.842

Drought susceptibility index (DSI) was also estimated for grain yield character over two years under favorable and stressed environments using formula of Fischer and Maurer (1978).

$$DSI = 1-\left(Y_S / Y_P\right)/1-\left(\overline{Y}_S / \overline{Y}_P\right)$$

Where Y_S is the yield of the genotype under drought stress, Y_P the yield of the genotype under non stress condition, $\overline{Y}_S$ and $\overline{Y}_P$ are the mean yield of all genotypes under drought stress and non-stress conditions, respectively, and $1-\left(\overline{Y}_S / \overline{Y}_P\right)$ is the stress intensity. The 'DSI' was used to characterize the relative drought stress tolerance of genotypes (DSI≤0.50 highly stress tolerant, DSI>0.50≤1.00 moderately stress tolerant and DSI>1.00 susceptible).

Statistical analysis: The combined analysis of variance over two years for each soil moisture level and combined over all environments were performed according to Gomez and Gomez (1984). The diallel analysis was conducted according to Griffing (1956) method II model 1 (excluding F_1's reciprocal). The analyses of variance were computed using MSTATC and SAS microcomputer program (MSTATC, 1990 and SAS Institute 1999).

RESULTS AND DISCUSSIONS

Mean performance

Both combined analysis of variance for each water level over two seasons and over all environments (Table 3 and 4) revealed significant differences between years, genotypes and their interaction for all studied traits. However, parents and F_1 crosses were significant for days to heading, no. of spikes/plant, 1000-grains weight and grain yield under different FC treatments. Parents vs. crosses were significant for all studied traits. Moreover, genotypes x FC treatments were significant for all studied traits, indicating the differential response of genotypes under different soil moisture

Table (3): Means squares for days to heading, no. of spikes/plant, 1000-grain weight and grain yield/plant traits at each level of field capacity (FC%) of the soil over two seasons

S.O.V	d.f	Means squares							
		Days to heading				No. of spikes/plant			
		35%	65%	100%	Over all	35%	65%	100%	Over All
Years (Y)	1	352.1**	373.55**	409.1**	377.94**	2.617	3.12**	5.561*	3.689**
R/Y	4	18.63	5.611	10.01	1.003	5.71	0.2805	0.6287	0.15
Genotypes (G)	27	158.10**	166.14**	189.33**	167.25**	25.19**	24.52**	21.21**	21.67**
Parents (P)	6	331.65**	370.78**	382.587**	359.71**	66.43**	49.11**	59.652**	56.42**
P *vs.* C	1	100.27**	2080.11**	208.15**	123.91**	2.64**	3.21**	0.66*	0.81*
Crosses (C)	20	108.931**	09.05**	130.41**	111.68**	13.943**	18.21**	10.704**	12.29**
Error	80	0.423	0.001	0.001	0.047	0.178	0.001	0.001	0.02
GCA	6	315.54**	320.37**	359.19**	329.84**	32.05**	33.99**	31.38**	30.98**
SCA	20	15.67**	19.68**	24.10**	17.71**	7.53**	6.53**	5.09**	5.49**
Y x G	27	0.079	0.069	0.066	0.070	0.005	0.006	0.006	0.005
Y x GCA	6	0.256**	0.028	0.446	0.108	0.320**	0.002	0.311	0.002
Y x SCA	20	2.85**	0.011*	3.048**	4.974**	1.142**	0.003 *	1.080**	0.002*
Error (a)	108	0.577	0.0007	0.0001	0.603	0.186	0.002	0.0001	0.021
GCA/SCA #	-	20.14	16.28	14.90	18.62	4.26	5.20	6.17	5.64
S.O.V	d.f	100-grain weight				Grain yield/plant			
Years (Y)	1	84.035*	120.58**	181.94	125.66	52.02	83.9**	163.52	94.449
R/Y	4	6.7825	3.4255	4.4902	0.7369	12.6698	4.3479	5.4944	0.8093
Genotypes (G)	27	142.28**	98.53**	148.93**	117.45**	150.59**	91.30**	81.08**	84.26**
Parents (P)	6	221.61**	117.41**	137.908**	145.21**	151.14**	98.46**	68.032**	95.35**
P *vs.* C	1	12.31**	13.26**	21.88**	0.68*	622.45**	135.01**	423.33**	316.54**
Crosses (C)	20	124.98**	97.13**	158.59**	114.954**	126.83**	86.97**	67.886**	69.323**
Error	80	0.628	0.001	0.001	0.07	1.133	0.001	0.001	0.126
GCA	6	171.36**	94.11**	152.0**	130.83**	188.01**	70.78**	49.83**	64.59**
SCA	20	47.26**	39.75**	57.3**	42.05**	51.65**	41.89**	37.41**	38.89
Y x G	27	0.099	0.065	0.094	0.077	2.193n.s	0.076	0.125n.s	0.070
Y x GCA	6	1.531**	0.013	1.423	0.018	4.000**	0.013	3.945	0.011
Y x SCA	20	7.861**	0.036*	8.422**	0.038*	5.512**	6.641**	24.469**	0.041*
Error (a)	108	0.77	0.0002	0.0004	0.301	1.50	0.0004	2.04	0.164
GCA/SCA #	-	3.63	2.37	2.65	3.11	3.64	1.69	1.33	1.66

the ratio was estimated according to Griffing 1996, Method II, Method I.
*,** Significant at 0.05 and 0.01 probability levels, respectively.

treatments. Years x genotypes x FC treatments interaction was significant for all traits.

The results showed that the averages of days to heading of all parents were 87.48, 84.45 and 81.72 days at 100%, 65% and 35% FC respectively, reflecting reduction of 3.6 and 6.6% in days to heading under 65% and 35% FC relative to 100% FC, respectively (Table 5). Days to heading for parental genotypes ranged

Table (4): Means squares for years, drought treatments, parents, crosses and genotypes for studied traits over all environments.

		Means squares			
S.O.V	d.f	Days to heading	No. of spikes/plant	1000-grain weight	Grain yield/plant
Years (Y)	1	360.41**	3.758**	126.64**	75.6**
Drought treatments (D)	2	334.93**	174.94**	1945.72**	3671.21**
Y x D	2	0.137	0.04	1.279	3.044*
Error (a)	4	1.592	0.187	0.265	2.207
Parents(P)	6	1079.1**	169.27**	435.43**	286.13**
Y x P	6	0.449	0.039	0.29	0.239
D x P	12	2.957**	2.961**	20.748**	15.754**
Y x D x P	12	0.001	0.001	0.014	0.013
Error (b)	80	0.56	0.166	0.579	0.707
S.O.V	d.f	Days to heading	No. of spikes/plant	1000-grain weight	Grain yield/plant
Years (Y)	1	1133.67**	10.992 **	377.14**	283.44**
Drought treatments (D)	2	1325.33**	661.482**	7204.77**	9620.14**
Y x D	2	0.544	0.153	4.71**	8.006**
Error (a)	4	1.474	0.276	1.912	3.598
Crosses (C)	20	335.020**	36.877**	344.82**	207.93**
Y x C	20	0.139	0.009	0.228	0.173
D x C	40	6.680**	2.99**	17.95**	36.878**
Y x D x C	40	0.003	0.001	0.012	0.031
Error (b)	248	0.544	0.123	0.34	1.231
S.O.V	d.f	Days to heading	No. of spikes/plant	1000-grain weight	Grain yield/plant
Years (Y)	1	1493.93**	14.75**	503.78**	327.73**
Drought treatments (D)	2	1651.82**	834.31**	9127.88**	13070.89**
Y x D	2	0.677	0.19	5.97**	6.62*
Error (a)	4	2.799	0.439	2.12	2.28
Genotypes(G)	27	501.74**	65.02**	352.26**	257.43**
Y x G	27	0.209	0.015	0.23	1
D x G	54	5.92**	2.95**	18.74**	32.77**
Y x D x G	54	0.002	0.001	0.01	0.7
Error (b)	332	0.544	0.132	0.4	1.82

*,** Significant at 0.05 and 0.01 probability levels, respectively.

from 72.38 for P4 to 94.45 days for P3 at 100% FC, but it decreased to 65.70 and 87.40 days for the same two parental genotypes at 35% FC. The data also showed that the averages of all F_1 crosses were 90.10, 86.08 and 83.54 days at 100%, 65% and 35% FC, indicating reduction of 4.46 and 7.29% in days to heading at 65% and 35% FC comparing with 100% FC, respectively. The F_1 crosses ranged from 79.67 for (P3 x P4) to 95.67 days for (P2 x P6) at 100% FC, but it reduced to 76.36 and 89.93 days for (P3 x P4) and (P1 x P2) at 35% FC, respectively. The results showed that decreasing field capacity of the soil reduced days to heading. Turner (1979) reported that the increase in adaptation to dry environments in many crops has been linked to earlier flowering. The obtained results are in line with those obtained by Attia (1998), Kheiralla *et al*. (2001), Ahmed (2003) and Mohamed (2006).

Average number of spikes/plant for parental genotypes ranged from 7.93 to 17.60 spikes for P4 and P5, respectively at 100% FC, while it reduced to 3.57 and 13.46 spikes for P4 and P7, respectively at 35% FC. The data in Table (5) showed that the averages of all parents were 13.86, 10.83 and 9.90 spikes at 100%, 65% and 35% FC, respectively indicating reduction of 21.91% and 28.57% for number of spikes per plant under 65% and 35% relative to 100% FC, respectively. The averages of spikes/plant for F_1 hybrids ranged from 10.42 for (P2 x P4) to 16.37 spikes for (P5 x P7) at 100% FC, but it decreased to 5.49 and 13.11 spikes for (P2 x P4) and (P1 x P7) at 35% FC, respectively. These results are in agreement with those obtained by Ismail (2001) and Kheiralla *et al*. (2001).

Averages of 1000-grain weight of parental genotypes ranged form 38.28 for P1 to 52.71 g for P5 at 100% FC, while it was from 23.37 for P1 and 38.48 g for P3 at 35% FC. Average of all parents were 47.23, 39.74 and 33.28 g at 100%, 65% and 35% FC respectively, reflecting reduction amounted 15.85% and 29.54% in 1000-grain weight under the two drought treatments, respectively. However average of the F_1 hybrids ranged from 36.77 for (P1 x P7) to 56.37 g for (P4 x P6) at 100% FC, but it decreased to 25.36 and 42.26 g for (P6 x P7) and (P3 x P4) at 35% FC, respectively. The averages all crosses were 48.08, 39.08 and 32.64 g at 100%, 65% and 35% FC respectively, reflecting reduction amounted 18.72% and 32.11% for 1000-grain weight under 65% and 35% FC relative to 100% FC, respectively. These results are in harmony with those found by Kherialla et al. (2001), Ahmed (2003) and Mohamed (2006). Bruckner and Frohberg (1987) reported a reduction of about 30% in kernel weight due to water stress conditions.

Data in Table (6) showed that the averages grain yield/plant for parental genotypes ranged from 33.40 for P2 to 42.43 g for P5 at 100% FC, while it was from 12.08 and 24.51 g at 35% FC for P2 and P3, respectively. The data indicated that the averages of all parents were 37.56, 27.00 and 18.36 g at 100%, 65% and 35% FC, respectively, inducting reduction of 28.12% and 51.13% in grain yield under 65% and 35% relative to 100% FC, respectively. The F_1 hybrids performance ranged from 34.27 for (P6 x P7) to 48.30 g for (P4 x P5) at 100% FC, while it ranged from 17.54 for (P2 x P4) to 35.38 g for (P3 x P4) at 35% FC. The results revealed that the averages of all F_1 hybrids were 40.64, 29.13 and 22.93 g at 100%, 65% and 35% FC respectively, indicating reduction of 28.33% and 45.58% for grain yield at 65% and 35% relative to 100% FC, respectively. The F_1 hybrids; (P1 x P4), (P1 x P6), (P2 x P5), (P3 x P4), (P3 x P5), (P4 x P5), (P4 x P6), (P4 x P7) and (P5 x P7) exhibited high grain yield/plant as compared to the average over all F_1 hybrids under 100% FC. While (P1 x P4), (P1 x P6), (P1 x P7), (P2 x P5), (P3 x P4), (P3 x P7), (P4 x P5), (P4 x P6), (P4 x P7 and (P5 x P7) gave high grain yield/plant as compared to the average over all F_1 hybrids under 65% FC. Moreover, F_1 hybrids (P1 x P7), (P2 x P5), (P3 x P4), (P3 x P7), (P4 x P5) and (P5 x P7) exhibited high grain yield/plant as compared to the average over all F_1 hybrids under 35% FC. These results are in agreement with those obtained by Attia (1998), Kherialla *et al*. (2001), Ahmed (2003) and Mohamed (2006). Kobata et al. (1992) reported that grain yield at low soil moisture was reduced by 33% relative to high moisture; the reduction was mainly due to the decrease in 1000-grain weight.

Drought tolerance index (DTI) at 65% and 35% FC shown in Table (6). High tolerance was found for the parents P3, P5, P6 and P7 at 35% FC, while P1, P3, P5 and P7 parents gave intermediate tolerance for grain yield/plant at 65% FC comparing with yield at 100% FC. On the other hand, these hybrids exhibited high drought tolerance were (P1 x P6), (P1 x P7), (P2 x P5), (P3 x P4), (P3 x P7), (P4 x P5), (P5 x P6), (P5 x P7) and (P6 x P7) under both 35% and 65% FC.

Drought susceptibility index (DSI) revealed that the hybrids; (P1 x P7), (P3 x P4), (P3 x P7) were highly tolerant to drought stress where their 'DSI' values were ≤ 0.50 under 35% and 65% FC, while the hybrids; (P2 x P5), (P5 x P6) and (P6 x P7) expressed as moderate tolerance to drought stress under 35% FC. Moreover, the hybrids; (P1 x P6), (P2 x P5) and (P5 x P6) expressed as moderate tolerance to drought stress under 65% FC, because (DSI>0.50≤1.00). In addition the parents; P3, P5 and P7 had moderate tolerance to drought stress under 35% and 65% % FC because (DSI>0.50≤1.00). Furthermore, all the other parents and hybrids were susceptible to drought stress (DSI>1.00). Khanna-Chopra and Viswanathan (1999) reported that high stability grain yield under drought stress was associated with moderate grain yield potential in wheat. In the present study also, all the tolerant parents and hybrids produced moderate grain yield under drought stress, while certain high yielding parents and hybrids were highly drought tolerant (Table 6).

Combining ability:

Mean squares of general combining ability (GCA) and specific combining ability (SCA) were highly significant for all studied traits under the three treatments of FC over two years (Table 3 and 4), suggesting, the importance of additive and non-additive gene effects in the inheritance of these traits. The ratio GCA/SCA was more than one for all studied traits at each FC over two seasons and over all environments, reflecting that additive gene action was the most important in the inheritance of the studied traits. These results agree with those reported by Attia (1998), Kherialla *et al*. (2001), Ahmed (2003) and Mohamed (2006). The interaction among GCA x year and SCA x year were significant for all studied traits (Table 4). The ratio GCA/SCA mean squares (Table 3) was greatly more than one, showing the relative importance of the additive gene effects in the inheritance of 1000-grain weight. Jumbo and Carena (2008) found that general combining ability (GCA) mean squares were on average larger than specific combining ability (SCA). Khan and Bajwa (1990) observed great GCA variance for grains yield per spike and 1000-grains weight. On the other hand, Arshad and Aslam (2002) reported low GCA/SCA ratio depicted importance of non-additive effects for the trait under study. Both general and specific combining ability variances were significant for some agronomic traits of wheat (Ahmed, 1999; Salem *et al*., 2000; Hamada 2003, Abd EL-Majeed *et al*., 2004; Koumber and Esmail, 2005). The inheritance of days to heading and grain yield per plant controlled by the additive gene action (Yadav and Singh, 1988).

Table (5): Mean days to heading, no. of spikes/plant and 1000-grain weight for parents and F_1 crosses under each field capacity (FC%) of the soil over two years and over all environments.

Genotypes	Days to heading				Number of spikes per plant				1000-grains weight			
	35%	65%	100%	mean	35%	65%	100%	mean	35%	65%	100%	mean
P1	86.91	90.75	93.69	90.45	10.88	11.56	14.48	12.31	23.37	32.68	38.28	31.44
P2	80.04	81.69	84.02	81.92	9.00	9.01	14.26	10.76	25.37	35.21	43.47	34.68
P3	87.40	90.15	94.45	90.67	11.64	11.90	15.04	12.86	38.48	40.93	47.22	42.21
P4	65.70	68.09	71.38	68.39	3.57	6.01	7.93	5.84	35.84	40.53	48.20	41.52
P5	83.02	86.09	89.33	86.15	12.67	13.56	17.60	14.61	37.54	42.06	52.71	44.10
P6	86.69	90.43	93.37	90.16	8.11	9.35	11.59	9.68	34.81	40.34	49.94	41.69
P7	82.27	83.98	86.11	84.12	13.47	14.40	16.15	14.67	37.55	46.48	50.78	44.94
Crosses												
P1 x P2	89.53	91.86	95.38	92.26	8.28	8.68	13.15	10.04	30.33	36.16	44.64	37.04
P1 x P3	85.40	86.75	94.21	88.79	9.61	10.24	15.15	11.67	31.91	38.42	47.25	39.19
P1 x P4	76.52	79.86	83.33	79.90	9.72	9.23	15.48	11.48	36.49	43.18	52.62	44.09
P1 x P5	83.36	85.02	91.22	86.53	8.92	9.96	13.48	10.79	29.37	35.95	42.09	35.80
P1 x P6	87.63	91.76	93.44	90.94	8.75	9.40	13.37	10.51	35.25	41.42	51.01	42.56
P1 x P7	86.51	88.15	89.43	88.03	13.11	13.79	15.71	14.20	29.44	34.93	36.77	33.71
P2 x P3	87.08	89.16	93.67	89.97	9.32	10.01	14.04	11.12	31.21	36.69	49.54	39.15
P2 x P4	77.45	80.10	85.02	80.86	5.49	5.78	10.48	7.25	32.47	37.20	49.89	39.85
P2 x P5	83.62	84.88	92.68	87.06	10.00	13.12	16.26	13.13	32.03	39.87	46.45	39.45
P2 x P6	88.87	92.22	95.67	92.25	8.72	9.23	13.48	10.48	31.70	38.24	48.42	39.45
P2 x P7	85.23	87.55	91.10	87.96	9.66	11.39	13.15	11.40	25.66	35.60	43.86	35.04
P3 x P4	76.36	78.21	79.67	78.08	11.94	12.57	13.59	12.70	42.26	49.63	53.54	48.48
P3 x P5	84.05	86.79	91.33	87.39	9.88	11.23	15.15	12.09	31.37	40.01	49.28	40.22
P3 x P6	87.35	90.67	94.23	90.75	9.25	10.23	13.04	10.84	31.70	37.81	48.91	39.47
P3 x P7	83.03	85.20	89.35	85.86	9.16	10.90	14.04	11.37	30.86	38.21	46.02	38.36
P4 x P5	76.50	80.18	82.32	79.67	9.61	11.23	14.26	11.70	40.34	46.40	55.80	47.51
P4 x P6	84.33	87.20	91.23	87.59	9.30	10.23	12.93	10.82	37.18	41.61	56.37	45.05
P4 x P7	76.44	80.20	82.00	79.55	10.12	10.90	13.48	11.50	40.81	42.55	55.33	46.23
P5 x P6	87.49	91.13	93.41	90.68	9.61	10.01	14.48	11.37	26.37	33.97	40.88	33.74
P5 x P7	83.55	84.98	92.12	86.88	12.44	13.01	16.37	13.94	33.34	40.47	50.12	41.31
P6 x P7	84.03	85.87	91.34	87.08	8.96	9.45	13.15	10.52	25.36	32.37	40.89	32.87
Parents mean	81.72	84.45	87.48	84.55	9.90	10.83	13.86	11.53	33.28	39.74	47.23	40.08
F_1 mean	83.54	86.08	90.10	86.57	9.61	10.50	14.01	11.38	32.64	39.08	48.08	39.93
General mean	83.08	85.68	89.45	86.07	9.68	10.59	13.97	11.41	32.80	39.24	47.87	39.97
LSD 0.05	0.77	0.13	0.14	0.29	0.44	0.04	0.04	0.15	0.91	0.13	0.16	0.33
LSD 0.01	1.02	0.18	0.19	0.38	0.58	0.05	0.05	0.20	1.20	0.17	0.21	0.44

General (GCA) and specific (SCA) combining ability effects:

Days to heading

The parental genotypes P4 and P7 exhibited significant negative GCA effects under all FC over two seasons (Table 7). These parents could be considered as good combiners for reducing days to heading which involve favorable genes for earliness. Specific combining ability effects in Table (8) showed that the best crosses had negative and significant SCA effects for days to heading were (P1 x P4), (P1 x P5), (P3 x P4), (P3 x P5), (P3 x P6), (P3 x P7) and (P6 x P7) under all treatments of FC over two seasons. These results indicated that selecting crosses on basis of its mean performance for earliness in heading may be effective in wheat breeding programmers. The results agree with those obtained by Gamil (1984), Attia (1998) Kherialla *et al*. (2001), Ahmed (2003) and Mohamed (2006).

Number of spikes/plant

Three parents; P3, P5 and P7 exhibited highly significant and positive GCA estimates under all FC over two seasons and over all environments (Table 7). Also, the parental genotypes P1, P2, P4 and P6 showed highly significant and negative GCA estimates under the three levels of FC over two seasons and over all environments. Specific combining ability effects in Table (8) showed that the best crosses displayed positive and significant SCA effects for no. of spikes/plant were (P1 x P4), (P1 x P7), (P2 x P5), (P2 x P6), (P3 x P4), (P4 x P5) and (P4 x P7) under all FC over two seasons and over all environments. However, other crosses showed negative and significant SCA effects for no. of spikes/plant under the three levels of FC treatments. These results are in agreement with the finding of Mahdy (1988), Saad et al (1997), Ismail (2001) and Kherialla *et al*. (2001).

1000-grian weight

The parental genotypes P3, P4 and P5 exhibited significant and positive GCA effects under FC treatments over two seasons and over all environments (Table 7). These parents could be considered as good combiners for 1000-grain weight. Six crosses; (P1 x P2), (P1 x P4), (P1 x P6), (P2 x P6), (P3 x P4) and (P4 x P5) exhibited positive and significant SCA effects for 1000-grain weight under all FC treatments over two seasons and over all environments. These results are in line obtained by Mahdy (1988), Attia (1998), Kherialla *et al*. (2001) and Mohamed (2006).

Grain yield/plant

Three parents could be considered as good combiners for grain yield/plant, i.e. P3 and P4 which showed significant and positive GCA estimate under FC treatments over two seasons and over all environments (Table 7). Data in Table (9) showed that the two crosses; (P1 x P2) and (P1 x P6) had significant and positive SCA effects for grain yield/plant under the three levels of FC over two seasons and over all environments. On the other hand, the crosses; (P1 x P2), (P1 x P4), (P1 x P6), (P2 x P6), (P3 x P4), (P4 x P5), (P4 x P6) and (P5 x P7) showed positive and significant SCA effects for this trait under 65% and 100% FC over two seasons and over all environments. These results are similar to those obtained by Attia (1998), Kherialla *et al*. (2001) and Mohamed (2006).

It could be concluded that (P1 x P7), (P3 x P4), (P3 x P7) hybrids were highly tolerant to drought stress where their 'DSI' values were ≤ 0.50 under 35% and 65% % FC. The parents P3 and P5 were considered as good combiners for number of spikes/plant, 1000-grain weight and grain yield/plant, while parents P4 and P7 are considered as the best combiners for days to heading. The crosses (P1 x P4) and (P3 x P4) appeared to be as the best combinations for all studied traits under different levels of FC. Moreover, the crosses; (P1 x P4), (P2 x P6), (P3 x P4), (P4 x P5) and (P4 x P6) could be considered as the best combinations for number of spikes/plant, 1000-grain weight and grain yield/plant.

Table (6): Mean grain yield/plant for parents and F_1 crosses under each field capacity of the soil over two years and over all environments drought tolerance index (DTI) and drought susceptibility index (DSI).

Genotypes	Grain yield/plant (g)							
	35%	65%	100%	mean	DTI1#	DTI2#	DSI1##	DSI2##
P1	14.75	24.85	34.58	24.72	42.64	71.85	1.12	1.00
P2	12.08	22.10	33.40	22.52	36.15	66.15	1.25	1.20
P3	24.51	29.60	38.83	30.98	63.13	76.23	0.72	0.85
P4	12.46	22.94	35.16	23.52	35.42	65.24	1.26	1.24
P5	23.12	31.32	42.43	32.29	54.48	73.80	0.89	0.93
P6	20.49	25.58	37.17	27.74	55.12	68.81	0.88	1.11
P7	21.11	32.63	41.38	31.70	51.03	78.86	0.96	0.75
Crosses								
P1 x P2	19.45	26.09	38.06	27.86	51.09	68.54	1.12	1.11
P1 x P3	20.84	27.54	40.32	29.57	51.69	68.30	1.11	1.12
P1 x P4	22.30	31.30	45.08	32.89	49.47	69.45	1.16	1.08
P1 x P5	19.95	25.90	37.85	27.90	52.71	68.43	1.09	1.11
P1 x P6	22.20	32.12	43.32	32.55	51.26	74.13	1.12	0.91
P1 x P7	30.22	32.41	36.83	33.15	82.05	87.99	0.41	0.42
P2 x P3	18.82	24.95	38.59	27.45	48.78	64.66	1.18	1.25
P2 x P4	17.54	25.37	39.10	27.33	44.86	64.90	1.27	1.24
P2 x P5	24.54	30.71	41.77	32.34	58.75	73.52	0.95	0.93
P2 x P6	20.11	27.00	40.14	29.08	50.11	67.25	1.14	1.16
P2 x P7	19.61	24.23	37.50	27.11	52.30	64.60	1.09	1.25
P3 x P4	35.38	38.41	44.53	39.44	79.44	86.26	0.47	0.49
P3 x P5	21.10	28.02	41.91	30.34	50.35	66.86	1.14	1.17
P3 x P6	19.85	27.34	39.71	28.97	49.98	68.85	1.15	1.10
P3 x P7	33.75	35.85	40.11	36.57	84.16	89.40	0.36	0.37
P4 x P5	25.32	34.29	48.30	35.97	52.42	71.01	1.09	1.02
P4 x P6	21.67	29.82	43.51	31.66	49.80	68.54	1.15	1.11
P4 x P7	22.77	29.98	44.45	32.40	51.23	67.45	1.12	1.15
P5 x P6	22.37	26.19	35.87	28.14	62.36	73.00	0.86	0.95
P5 x P7	23.60	30.06	42.37	32.01	55.71	70.96	1.02	1.03
P6 x P7	20.17	24.18	34.27	26.20	58.85	70.57	0.94	1.04
Parents mean	18.36	27.00	37.56	27.64	-	-	-	-
F_1 mean	22.93	29.13	40.64	30.90	-	-	-	-
General mean	21.79	28.60	39.87	30.09	-	-	-	-
LSD 0.05	1.25	0.14	0.16	0.43	-	-	-	-
LSD 0.01	1.66	0.19	2.17	0.57	-	-	-	-

#, DTI1 and DTI2 = Drought tolerance index at 35 and 65% field capacity of the soil, respectively.

##, DSI1 and DSI2 = Drought susceptibility index at 35 and 65% field capacity of the soil, respectively

Table (7): Estimates of general combining ability (GCA) effects for days to heading, No. of spikes/plant, 1000-grain weight and grain yield/plant under each level of field capacity of the soil over two seasons and over all treatments.

Parents	Days to heading				No. of spikes/plant			
	35%	65%	100%	Over all	35%	65%	100%	Over all
P1	2.018**	2.17**	2.09**	2.09**	0.30**	-0.03	0.39**	0.22**
P2	0.80**	0.42**	0.67**	0.63**	-0.89**	-0.94**	-0.30**	-0.71**
P3	1.49**	1.30**	1.75**	1.51**	0.55**	0.48**	0.37**	0.47**
P4	-7.30**	-7.05**	-7.69**	-7.35**	-1.57**	-1.41**	-1.75**	-1.58**
P5	-0.01	-0.03	0.69**	0.22**	0.92**	1.22**	1.49**	1.21**
P6	3.16**	3.81**	3.39**	3.45**	-0.74**	-0.83**	-0.91**	-0.82**
P7	-0.15	-0.61**	-0.89**	-0.55**	1.44**	1.51**	0.71**	1.22**
SE(gi)	1.56	1.63	1.67	1.61	0.71	0.60	0.67	0.65
LSD(gi-gj) 0.05	0.18	0.03	0.03	0.05	0.08	0.03	0.03	0.04
LSD(gi-gj) 0.01	0.28	0.05	0.05	0.08	0.13	0.05	0.05	0.06
parents	100-grain weight				Grain yield/plant (g)			
P1	-2.54**	-2.06**	-3.56**	-2.72**	-3.10**	-0.42**	-0.93**	-0.81**
P2	-3.14**	-2.2**	-1.47**	-2.27**	-3.05**	-2.92**	-1.90**	-2.72**
P3	1.54**	0.96**	0.67**	1.06**	1.64**	1.39**	0.42**	1.51**
P4	4.32**	3.07**	4.11**	3.83**	4.41**	0.70**	1.81**	0.67**
P5	0.61**	0.76**	0.79**	0.72**	0.71*	1.00**	1.55**	1.18**
P6	-0.58**	-0.88**	0.38**	-0.36**	-0.49	-1.22**	-0.87**	-0.96**
P7	-0.20	0.35**	-0.93**	-0.26**	-0.11	1.46**	-0.08**	1.13**
SE(gi)	1.27	0.91	1.01	1.03	1.08	0.85	0.70	0.83
LSD(gi-gj) 0.05	0.24	0.03	0.03	0.06	0.52	0.03	0.03	0.08
LSD(gi-gj) 0.01	0.37	0.05	0.05	0.09	0.79	0.05	0.05	0.12

*,** Significant at 0.05 and 0.01 probability levels, respectively.

Table (8): Estimates of specific combining ability (SCA) effects for days to heading and no. of spikes/plant under each level of field capacity of the soil (FC%) over two seasons and over all treatments.

Crosses	Days to heading				No. of spikes/plant			
	35%	65%	100%	Over all	35%	65%	100%	Over all
P1 x P2	3.64**	3.60**	3.18**	3.47**	-0.81**	-0.94**	-0.91**	-0.89**
P1 x P3	-1.18*	-2.39**	0.92**	-0.88**	-0.92**	-0.79**	0.42**	-0.43**
P1 x P4	-1.28*	-0.93**	-0.51**	-0.91**	1.31**	0.09**	2.86**	1.42**
P1 x P5	-1.73**	-2.79**	-1.00**	-1.84**	-1.99**	-1.82**	-2.37**	-2.06**
P1 x P6	-0.62	0.11**	-1.49**	-0.66**	-0.49*	-0.33**	-0.09**	-0.30**
P1 x P7	1.57**	0.92**	-1.22**	0.42**	1.70**	1.73**	0.64**	1.35**
P2 x P3	1.71**	1.77**	1.80**	1.76**	-0.02	-0.11**	0.00	-0.05
P2 x P4	0.87	1.06**	2.60**	1.51**	-1.73**	-2.45**	-1.45**	-1.87**
P2 x P5	-0.26	-1.19**	1.88**	0.15*	0.28	2.25**	1.10**	1.21**
P2 x P6	1.83**	2.32**	2.17**	2.11**	0.67**	0.41**	0.72**	0.60**
P2 x P7	1.49**	2.07**	1.88**	1.81**	-0.57**	0.24**	-1.23**	-0.52**
P3 x P4	-0.91	-1.71**	-3.84**	1.51**	3.28**	2.92**	1.00**	2.40**
P3 x P5	-0.52	-0.16**	-0.56**	0.15*	-1.28**	-1.06**	-0.68**	-1.01**
P3 x P6	-0.38	-0.11**	-0.36**	2.11**	-0.24	0.01	-0.39**	-0.22*
P3 x P7	-1.40**	-1.16**	-0.96**	1.81**	-2.51**	-1.67**	-1.01**	-1.73**
P4 x P5	0.72	1.59**	-0.12**	-0.41**	0.58**	0.84**	0.54**	0.65**
P4 x P6	5.39**	4.77**	6.09**	-0.28**	1.93**	1.88**	1.61**	1.80**
P4 x P7	0.80	2.19**	1.14**	-1.17**	0.57**	0.22**	0.54**	0.45**
P5 x P6	1.26*	1.67**	-0.11**	0.94**	-0.26	-0.97**	-0.08**	-0.44**
P5 x P7	0.63	-0.06**	2.88**	1.15**	0.40*	-0.30**	0.20**	0.10**
P6 x P7	-2.07**	-3.01**	-0.60**	-1.89**	-1.42**	-1.82**	-0.63**	-1.29**
SE(Sij)	0.54	0.53	0.58	0.54	0.20	0.22	0.17	0.18
LSD(Sij-Sik) 0.05	1.04	0.03	0.03	0.14	0.36	0.03	0.03	0.07
LSD(Sij-Sik) 0.01	1.42	0.04	0.04	0.19	0.50	0.04	0.04	0.09
LSD(Sij-Skl) 0.05	0.92	0.03	0.03	0.13	0.32	0.03	0.03	0.06
LSD(Sij-Skl) 0.01	1.25	0.04	0.04	0.17	0.44	0.04	0.04	0.08

*,** Significant at 0.05 and 0.01 probability levels, respectively.

Table (9): Estimates of specific combining ability (SCA) effects for 1000-grain weight and grain yield/plant traits under each level of field capacity (FC%) of the soil over two seasons and over all treatments.

	1000-grain weight				Grain yield/plant			
Crosses	35%	65%	100%	Over All	35%	65%	100%	Over all
P1 x P2	3.21**	1.17**	1.79**	2.06**	3.78*	0.82**	1.01**	1.31**
P1 x P3	0.11	0.27**	2.27**	0.88**	0.68	-2.04**	0.95**	-1.22**
P1 x P4	1.92*	2.92**	4.20**	3.01**	2.49	2.42**	4.33**	2.95**
P1 x P5	-1.50*	-1.99**	-3.01**	-2.17**	-0.93	-3.29**	-2.64**	-2.55**
P1 x P6	5.57**	5.11**	6.32**	5.67**	6.14**	5.16**	5.25**	4.23**
P1 x P7	-0.61	-2.60**	-6.61**	-3.27**	-0.04	2.76**	-2.03**	2.75**
P2 x P3	0.01	-1.32**	2.47**	0.39*	-0.07	-2.12**	0.18**	-1.43**
P2 x P4	-1.50*	-2.92**	-0.62**	-1.69**	-1.59	-1.01**	-0.69**	-0.71**
P2 x P5	1.76*	2.07**	-0.74**	1.03**	1.67	-2.97**	2.24**	3.80**
P2 x P6	2.62**	2.07**	1.64**	2.11**	2.53	2.54**	3.03**	2.67**
P2 x P7	-3.80**	-1.79**	-1.61**	-2.40**	-3.88*	-2.92**	-0.40**	-1.39**
P3 x P4	3.60**	6.35**	0.89**	3.61**	3.52*	7.73**	2.42**	7.17**
P3 x P5	-3.58**	-0.96**	-0.05**	-1.53**	-3.66*	-2.97**	0.06	-2.44**
P3 x P6	-2.06**	-1.52**	-0.01	-1.20**	-2.14	-1.43**	0.28**	-1.67**
P3 x P7	-3.28**	-2.34**	-1.59**	-2.40**	-3.36	4.40**	-0.11**	3.84**
P4 x P5	2.62**	3.32**	3.26**	2.99**	2.54	3.99**	5.07**	4.04**
P4 x P6	0.65	0.17**	4.01**	1.60**	0.57	1.75**	2.70**	1.86**
P4 x P7	3.90**	-0.12**	4.28**	2.69**	3.82*	-0.78**	2.85**	0.51**
P5 x P6	-6.46**	-5.16**	-8.16**	-6.59**	-6.55**	-2.19**	-4.68**	-2.17**
P5 x P7	0.13	0.12**	2.40**	0.88**	0.05	-1.01**	1.03**	-0.38*
P6 x P7	-6.65**	-6.35**	-6.43**	-6.48**	-6.73**	-4.66**	-4.65**	-4.06**
SE(Sij)	0.57	0.50	0.64	0.54	0.60	0.47	0.42	0.42
LSD(Sij-Sik) 0.05	1.45	0.03	0.03	0.19	3.37	0.03	0.03	0.33
LSD(Sij-Sik) 0.01	1.98	0.04	0.04	0.26	4.59	0.04	0.04	0.45
LSD(Sij-Skl) 0.05	1.27	0.03	0.03	0.17	2.95	0.03	0.03	0.29
LSD(Sij-Skl) 0.01	1.74	0.04	0.04	0.23	4.02	0.04	0.04	0.40

*,** Significant at 0.05 and 0.01 probability levels, respectively.

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دراسة القدرة على الائتلاف وتحمل الجفاف فى قمح الخبز تحت نظم الرى

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تم تقييم ثمانية وعشرون تركيب وراثى وهى عبارة عن (سبعة آبــاء وهجنهــا الفرديــة الاحــدى وعشرون) لصفات طرد السنابل وعدد السنابل لكل نبات ووزن الالف حبة ومحصول الحبوب للنبات الفردى تحت ثلاث مستويات من ماء التربة الميسر (35 ، 65 ، 100%) من السعة الحقلية خــلال ســنتين. ولقــد اوضحت النتائج وجود اختلافات معنوية بين الاباء وهجن الجيل الاول وكذلك الأباء ضد الهجن عبر السنوات لكل الصفات المدروسة تحت مستويات الاجهاد المختلفة. وجدت اختلافات معنوية لتفاعل التركيب الوراثية * مستويات الاجهاد المائى. أيضا كان تفاعل السنوات * التركيب الوراثية * مستويات الاجهاد المائى معنوى لكل الصفات تحت الدراسة. تم حساب معامل تحمل الجفاف ومعامل الحساسية للجفاف لمحصــول الحبــوب للنبات الفردى ووجد ان الاب الثالث والخامس والسابع عالية التحمل للجفاف تحت المستويات المختلفة مــن الاجهــاد المائى. أظهرت النتــائــج ان معامل الحساسية كان اقل من 0.5 للــهجــن حيث اعتبرت عاليــة التحمل للجفاف.(P1 x P7), (P3 x P4) and (P3 x P7)

كان تباين القدرة العامة والخاصة على الائتلاف عالى المعنوية لكــل الصــفات تحــت الدراســة. واوضحت النسبة بين القدرة العامة والقدرة الخاصة على الائتلاف ان فعل الجين الاضافى هو الرئيسى فــى التوريث للصفات المدروسة. من خلال دراسة تاثيرات القدرة العامة للائتلاف وجد ان الاب الثالث والخامس هى احسن الاباء بالنسبة لصفات عدد السنابل لكل نبات ووزن الالف حبة ومحصول الحبوب/نبات. بينما وجد ان الاب الرابع والسابع هى الافضل بالنسبة لصفة طرد السنابل. من خلال دراسة القدرة الخاصة للائــتلاف وجد ان الهجن

كانت الافضل لكل الصفات تحت الدراسة. (P1 x P4) and (P3 x P4)

وبالاضافة لذلك وجد ان افضل الهجن لصفات عدد السنابل لكل نبات ووزن الالف حبة ومحصول الحبوب للنبات الفردى هى (P1 x P4), (P2 x P6), (P3 x P4), (P4 x P5) and (P4 x P6).