Selection Efficiency for Grain Yield Under Normal Irrigation and Water Stress Conditions in Bread Wheat

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Abstract
The objective of the present research was to study the efficiency of pedigree selection for grain yield/plant under normal irrigation and water stress conditions. Two cycles of pedigree selection for grain yield/plant were practiced separately under normal irrigation and water stress conditions. The base population was the F_3 population of Sids 1/Misr 1. In the third year, selections under normal irrigation and water stress were evaluated at both environments. The phenotypic was slightly larger than the genotypic variance, and generally decreased from the F_3 to the F_5 generation. Broad-sense heritability was 87.08 and 85.38% under normal irrigation compared to 84.88 and 82.40% under water stress after cycle1 and 2, respectively. The realized heritability was 40.08 and 67.40% under normal irrigation compared to 40.19 and 78.47% under water deficit after cycle1 and 2, respectively. The average observed gains of normal irrigation selections were 19.58 and 23.66% from bulk sample and 7.93 and 8.73% from the better parent, while the average observed gains of water stress selections were 26.44 and 32.57% from bulk sample and 14.12 and 16.57% from the better parent, when evaluation practiced under normal irrigation and water stress, respectively. The results indicated that the antagonistic selection was better than synergistic selection in changing the mean and decreased the sensitivity. Grain yield/plant revealed positive and high phenotypic correlation with each of biological yield/plant, number of spikes/plant and number of kernels/spike under normal irrigation and water stress, and 100-kernel weight under water stress in the base population and after two cycle of selection for grain yield/plant. The results of path-coefficient analysis revealed that number of spikes/plant had the highest positive direct effect on grain yield/plant followed by number of kernels/spikes and 100-kernel weight after two cycle of pedigree selection for grain yield/plant under normal irrigation and water stress conditions.

Keywords: pedigree selection, selection response, drought susceptibility, synergistic vs. antagonistic, correlation, path-coefficient, wheat.

Introduction

Wheat is one of the most important cereal crops all over the world and the main food crop in Egypt. The cultivated area in Egypt reached 3.4 million feddans in 2014/2015 growing season, with an average yield of 18.00 ardab/feddan, and the total production was about 9.47 million tons (Economic Affairs Annual Report, 2015). Water stress is one of the main abiotic stresses and an important factor for reducing yield of cultivated plants in semi arid agricultural lands (Amin-Alim, 2011). Therefore, breeding programs should aim at developing high yielding cultivars over a wide range of stress and non-stress environments. The efficiency of a breeding program for drought toler-

ance depends largely on the selection criteria and selection method used to achieve genetic improvement through selection, in addition to the complexity of drought itself (Passioura, 2007). Pedigree selection can be used to identify superior genotypes for grain yield in a cultivar development program. Several workers indicated that pedigree selection is effective method in improving grain yield (Kheiralla *et al.* 1993; Ismail, 1995; Tammam *et al.* 2004; Ahmed, 2006; Ali, 2011 and Mahdy *et al.* 2012). Breeding for drought tolerance should focus on increasing genetic variance and choosing a selection environment that is representative of the target environment. Some researchers believe in selection under favorable conditions (Betran *et al.* 2003), other prefer selection in a target stress condition (Rathjen, 1994), while other yet have chosen a mid-point and believe in selection under both favorable and stress conditions (Byrne *et al.* 1995). Jinks and Connolly (1973 and 1975), Jinks and Pooni (1982) and Falconer (1990) indicated that, environmental sensitivity was reduced if selection and environment effects were in opposite direction, while sensitivity was increased if selection and environ-

ment effects were in the same direction. Correlation coefficient is an important statistical tool which can help wheat's breeders to select the genotypes of high yield. Path analysis divides the correlation coefficients into direct and indirect effects. Consequently, correlation studies along with path analysis provide a better understanding of the association of different traits with grain yield.

The objectives of the present research were to study; 1) the efficiency of pedigree selection for grain yield/plant under normal irrigation and water stress conditions, 2) the sensitivity of selected lines to water stress, and 3) the correlation and path coefficient for yield and its components in the base population and cycle two of selection under normal irrigation and water stress.

Materials and Methods

The present research was carried out at Shandaweel Agric. Res. Station, Agricultural Research Center (ARC), Egypt during 2013/2014 to 2015/2016 growing seasons. The breeding materials used were 100 F_3 families traced back to 100 random F_2 plants originated from the cross (Sids 1× Misr 1). The pedigree of the parents is presented in Table 1.

Table 1. The pedigree of the parents of the wheat population.

Parent	pedigree
Sids 1	HD 2172 / PAVON"S" // 1158.57 / MAYA 74"S"
Misr 1	OASIS/KAUZ//4*BCN/3/2*PASTOR.

In 2013/2014 season (F_3-generation); 100 F_3 families, original parents and F_3 bulked random sample (a mixture of equal number of grains from each plant to represent the generation mean) were sown in two field

experiments using a randomized complete block design with three replications. The experiment under normal irrigation was grown in supplemental water applied regularly as recommended, while the experiment

under water stress did not receive any irrigation after the second irrigation (planting irrigation and two irrigations throughout the growing season). Each plot consisted of a single row 3m long, 30 cm apart and 10 cm between grains within row. The recommended cultural practices for wheat production were adopted throughout the growing season in the two experiments. At the end of the season, separate analysis of variance of the two treatments was applied on a plot mean basis. The best 20 high yielding plants from the best 20 high yielding families were saved to give the F_4 families in each environment.

In 2014/2015 season (F_4-generation); the 20 F_4 families selected under normal irrigation with the parents and F_4 bulk sample were sown under normal irrigation and the 20 F_4 families selected under water stress with the parents and F_4 bulk sample were sown under water stress. The experimental design, number of replications and cultural practices were properly adopted as the same in the first season. Data were recorded as previously mentioned. At the end of season, each group of families (20 families) for each environment of selection was analyzed separately. The best 10 high yielding plants from the best 10 high yielding families were saved in each environment to give the F_5 families.

In 2015/2016 season (F_5-generation); the 10 high yielding F_5 families selected under normal irrigation + the 10 high yielding F_5 families selected under water stress environment + the two parents + the bulk sample were evaluated under both environments. Data were recorded on ten guarded plants from each family. The studied traits were; days to heading (DH), days to maturity (DM), plant height (PH, cm), number of spikes/plant (NS/P), number of kernels/spike (NK/S), 100-kernel weight (100-KW, g), grain yield/plant (GY/P, g) and biological yield/plant (BY/P, g).
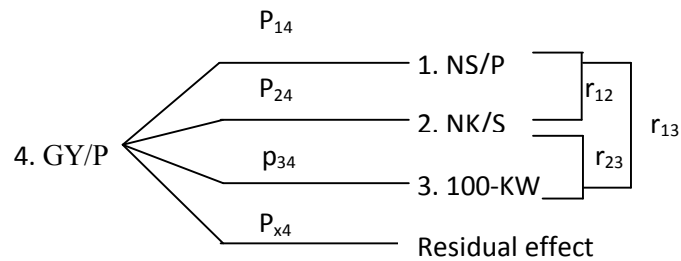
Statistical analysis:

Data were subjected to proper statistical analysis according to Steel and Torrie (1980). Two analysis of variance were done, the first was for (families + parents + bulk sample), and the second was for the selected families to calculate heritability, genotypic and phenotypic coefficient of variations. Genotypes means were compared using Revised Least Significant Differences (RLSD) test at 5 and 1% level of probability, according to El-Rawi and Khalafala (1980). The phenotypic ($\sigma^2 p$) and genotypic ($\sigma^2 g$) variances and heritability in broad sense (H%) were calculated according to Walker (1960). The phenotypic (PCV%) and genotypic (GCV%) coefficients of variability were calculated as outlined by Burton (1952), Realized heritability $h^2 = R/S$ was calculated according to Falconer (1989); where R = response to selection and S = selection differential. Drought susceptibility index (DSI) was computed according to the method of Fischer and Maurer (1978). The sensitivity and relative merits of selected families were assessed as described by Falconer (1990). The relative merits is expressed as the ratio change of mean by antagonistic selection / change of mean by synergistic selection.

The phenotypic correlation coefficients via base population (F_3) and the second cycle of selection (F_5) were calculated among the studied traits as outlined by Al- Jibouri *et al.* (1958), as follows: Phenotypic correlation $rp_{xy} = \text{cov } p_{xy} / (\sigma p_x \cdot \sigma p_y)$.

Path coefficient analysis:

Path coefficient analysis was done according to the procedure followed by Dewey and Lu (1959) for yield and its components under normal irrigation and water stress in the base population and the second cycle of selection. The contributions of number of spikes/plant (NS/P), number of kernels/spike (NK/S), 100-kernel weight (100-KW, g), grain yield/plant (GY/P, g) as well as residual factors (X) were included in the path coefficient analysis as shown in the following diagram:

$r_{14}= P_{14}+ r_{12} P_{24} + r_{13} P_{34}$
$r_{24}= P_{24}+ r_{12} P_{14} + r_{23} P_{34}$
$r_{34}= P_{34}+ r_{13} P_{14} + r_{23} P_{23}$
$1= P^2_{X4}+ P^2_{14}+ P^2_{24}+ P^2_{34}+ 2 P_{14} r_{12} P_{24}+2 P_{14} r_{13} P_{34}+ 2 P_{24} r_{23} P_{34}$

Fig.1: Direct and indirect of NS/P, NK/S, 100-KW and GY/P

Results and Discussion

1. Description of the base population:

The analysis of variance (Table 2) indicated highly significant differences among the F_3 families for all studied traits under normal and water stress environments, indicating that selection in the base population would be effective. Comparing the population mean for grain yield/plant with mean of the two parents indicates over-dominance under normal irrigation, in which population mean (21.39 g) out yielded the higher yielding parent, Misr 1 (20.53 g) and tended to show complete dominance (16.12 g) towards the higher parent Sids 1 (16.44 g) under water stress. The reduction caused by water stress in the F_3 families was 7.79, 5.43, 5.53, 11.91, 6.07, 9.62, 24.64 and 25.43% for days to heading, days to maturity, plant height, number of spikes/plant, number of kernels/spike, 100-kernel weight, grain yield/plant and biological yield/plant, respectively. Mahdy (2012) noted average reduction caused by drought stress of 13.68, 6.38. 12.10, 0.74 and 5.21% for plant height, number of spikes/plant, grain yield /plant, number of grain/spike and 100 grain weight. Soliman *et al.* (2015) came to the same conclusion. The phenotypic (P.C.V.%) and genotypic (G.C.V.%) coefficient of variations were sufficient for selection in the base population, and ranged from (2.95 – 20.64%) and (2.89 – 20.20%) under

normal irrigation, and from (3.00 – 19.15%) and (2.92 – 18.20%) under water stress; for days to maturity and grain yield/plant, respectively. These results indicates that selection among F_3 families for grain yield could be effective. These findings are in line with those reported by Ismail (1995), Zakaria *et al.* (2008), El-Morshidy *et al.* (2010), Ali (2011), Abd-El-Haleem *et al.* (2012), Mahdy (2012), Ahmed *et al.* (2014) and Soliman *et al.* (2015). Heritability estimate is considered one of the most important parameters for selection response in early generations. Estimates of broad sense heritability were high for all studied traits, and slightly higher under normal irrigation than under wa-

ter stress. Estimates of broad sense heritability at one location in one year were biased upward due to confounding the effects of locations and years with the genetic variances estimates (O'Brien *et al.* 1978). In general, high estimates of broad sense heritabilities (Table 2) indicate that the environmental effects were small compared to genetic effects. These results are in line with those reported by Kashif and Khaliq (2004), Cheema *et al.* (2006) and Zakaria *et al.* (2008). Salous *et al.* (2014) and Soliman *et al.* (2015) found that heritability estimate for grain yield under non-stress conditions was slightly higher than that under stress conditions.

Table 2. Means, Mean squares, phenotypic (P.C.V%) and genotypic (G.C.V.%) coefficients of variability and heritability in broad sense (H%) for the studied traits in the base population (F_3) under normal irrigation and water stress environments.

Env.	Trait	Mean Squares			Mean				Reduction %	P.C.V. %	G.C.V. %	H %
		Reps.	Families	Error	F_3	Bulk	P_1	P_2				
Normal irrigation	Days to heading	10.36	66.41**	2.01	96.85	98.33	94.00	91.00		4.86	4.78	96.97
	Days to maturity	16.01	56.14**	2.24	146.49	148.67	147.00	144		2.95	2.89	96.01
	Plant height ;cm	6.80	93.92**	16.76	106.88	111.33	115.67	110.33		5.24	4.75	82.16
	No. of spikes /plant	3.35	9.41**	0.95	12.59	11.63	12.17	12.24		14.07	13.34	89.90
	No. of kernels /spike	2.42	62.09**	4.71	39.89	37.67	38.28	39.83		11.40	10.96	92.41
	100- kernel weight	0.15	0.290**	0.016	4.26	4.07	4.14	4.22		7.30	7.09	94.48
	Grain yield/plant	9.56	58.46**	2.47	21.39	17.67	19.25	20.53		20.64	20.20	95.74
	Biological yield/ plant	60.79	326.02**	14.80	54.11	44.43	49.25	46.27		19.27	18.82	95.46
Water stress	Days to heading	5.30	79.28**	2.43	89.31	89.00	88.33	86.3	7.79	5.76	5.67	96.93
	Days to maturity	1.76	51.70**	2.52	138.53	140.67	142.33	140.00	5.43	3.00	2.92	95.13
	Plant height	45.01	102.06**	16.33	100.97	107.33	111.00	106.67	5.53	5.78	5.29	84.00
	No. of spikes /plant	1.11	3.77**	0.71	11.09	11.17	11.78	11.33	11.91	10.11	9.11	81.17
	No. of kernels /spike	6.71	74.97**	6.19	37.47	36.22	36.74	38.24	6.07	13.34	12.78	91.74
	100- kernel weight	0.08	0.270**	0.030	3.85	3.71	3.81	3.47	9.62	7.79	7.35	88.89
	Grain yield/plant	3.37	28.60**	2.77	16.12	14.58	16.44	15.00	24.64	19.15	18.20	90.35
	Biological yield/ plant	12.54	115.93**	12.82	40.35	36.77	42.00	40.53	25.43	15.41	14.53	88.94

** Significant at 1% level of probability.

Results of the phenotypic correlation coefficient among all possible pairs of the studied traits in the F_3 population (Table 3) indicated positive and high phenotypic correlation between grain yield/plant and each of plant height (0.565 and 0.489), number of spike/plant (0.851 and 0.728), number of kernels/spike (0.698 and 0.777), biological yield/plant (0.960 and 0.759) under normal irrigation and water stress environments, respectively and 100-kernel weight (0.625) under water stress, indicating that selection for high grain yield/plant could increase these traits. However, grain yield exhibited low and positive phenotypic correlation with days to heading; 100-kernels weight under normal irrigation and days to maturity in both environments. While it indicated negative and low phenotypic correlation with days to heading under water stress conditions. Number of spikes/plant possessed positive and high phenotypic correlation with biological yield/plant under both environments and possessed positive and low with number of kernels/spike and 100-kernel weight under water stress. Moreover, the phenotypic correlation between number of kernels/spike and 100-kernel weight was negative and significant (-0.342) under normal irrigation, while it was positive and significant (0.218) under water stress.

Table 3. phenotypic correlation among the studied traits in the F_3 generation under normal irrigation (above diagonal) and water stress (below diagonal) conditions.

Trait	DH	DM	PH	NS/P	NK/S	100-KW	GY/P	BY/P
DH		0.446**	0.282**	0.214*	0.042	-0.081	0.152	0.141
DM	0.377**		0.228*	0.098	-0.010	0.078	0.092	0.103
PH	0.219*	0.221*		0.456**	0.331**	0.154	0.565**	0.572*
NS/P	-0.043	0.025	0.284**		0.404**	-0.185	0.851**	0.784**
NK/S	0.048	-0.007	0.372**	0.262**		-0.342**	0.698**	0.629**
100-KW	-0.049	0.047	0.388**	0.368**	0.218*		0.064	0.133
GY/P	-0.004	0.021	0.489**	0.728**	0.777**	0.625**		0.960**
BY/P	0.059	0.094	0.391**	0.696**	0.452**	0.547**	0.759**	

*,** Significant at 5 and 1% levels of probability, respectively.

2. Selection for grain yield/plant
2.1. Variability and heritability estimates:

After two cycles of selection for grain yield/plant, there were significant (p< 0.01) differences among selected families for grain yield/plant and other studied traits under both environments (Table 4). These results indicating the presence of variability for further cycles of selection. Similar results were obtained by Ali (2011),

Mahdy (2012), Ahmed *et al.* (2014), Salous *et al.* (2014) and Soliman *et al.* (2015).

The effect of selection for two cycles on variability and heritability estimates of grain yield plant is shown in Table 5. The phenotypic and genotypic variances in grain yield/ plant was high in the F_3 generation under both normal and water stress conditions and dropped rapidly after cycle one (C_1) and cycle two

(C_2). This may be due to the increase of homozygosity in the F_5 generation. The phenotypic and genotypic variances were larger under normal irrigation (19.48, 7.20 and 6.36%) and (18.66, 6.27 and 5.43) than under water stress (9.53, 4.83 and 5.57) and (8.61, 4.10 and 4.59) in C_0, C_1 and C_3, respectively. The phenotypic (P.C.V.%) and genotypic (G.C.V.%) coefficient of variability under normal irrigation were (20.64 and 20.20%) for grain yield/plant in the base population and decreased to (12.16 and 11.35%) after C_1 and to (10.35 and 9.56%) after C_2. Likewise, The phenotypic and genotypic coefficient of variability under water stress showed the same trend. The P.C.V.% and G.C.V.% under water stress were very close to those under normal irrigation. The GCV% was slightly less than the PCV% under both environ-

ments. The close estimates of phenotypic and genotypic variability resulted in high estimates of broad sense heritability in the two cycle of selection. It is of interest to note that heritability estimates for grain yield /plant were 95.74 and 90.35% in the base population (F_3) and decreased to 87.08 and 84.88% after C_1 and 85.38 and 82.40% after C_2 under normal irrigation and water stress, respectively. This could be due to the decrease in genotypic variance due to selection However, the realized heritability increased from C_1 (40.08 and 40.19%) to C_2 (67.40 and 78.47%) under normal and under water stress conditions, respectively. These results are in agreement with those of Zakaria (2004), Ahmed (2006), Abd El-Kader (2011), Ali (2011), Mahdy (2012), Salous *et al.* (2014) and Soliman *et al.* (2015).

Table 4. Mean squares for families selected for high grain yield/plant and correlated traits in F_4 and F_5 generations under normal irrigation (N) and water stress (D) conditions.

Item	Env.	S. O. V.	d.f	Selection criterion	Correlated traits						
				GY/P	DH	DM	PH	NS/P	NK/S	100KW	BY/P
F₄	N	Rep.	2	1.81	1.06	5.72	5.12	0.09	12.60	0.059	1.17
		Families	19	21.59**	61.85**	51.72**	81.19**	6.72**	39.83**	0.283**	126.82**
		Error	38	2.78	3.40	3.59	12.94	1.18	5.41	0.047	19.66
	D	Rep.	2	3.69	2.72	3.20	8.32	0.23	3.49	0.015	6.16
		Families	19	14.50**	67.03**	47.76**	97.62**	2.73**	24.92**	0.160**	105.95**
		Error	38	2.19	5.69	7.18	15.75	0.36	4.94	0.05	20.32
F₅	N	Rep.	2	2.37	8.02	0.45	0.47	1.52	3.82	0.031	25.50
		Families	19	19.08**	40.10**	28.75**	59.48**	3.40**	13.03**	0.112**	94.46**
		Error	38	2.79	4.28	3.90	10.39	0.74	3.79	0.029	14.87
	D	Rep.	2	3.61	8.75	0.15	20.82	0.22	0.20	0.068	4.84
		Families	19	16.70**	35.13**	23.03**	74.11**	2.42**	15.95**	0.108**	68.60**
		Error	38	2.92	4.01	3.52	16.33	0.46	3.86	0.025	15.78

N = normal irrigation   D = water stress   ** Significant at 1% level of probability.

Table 5. Variability and heritability estimates of grain yield/plant after two cycles of selection under normal irrigation (N) and water stress (D) conditions.

Selection cycle	σ^2_p		$\sigma^2 g$		P.C.V. %		G.C.V. %		H %		Realized heritability	
	N	D	N	D	N	D	N	D	N	D	N	D
F_3 (C_0)	19.48	9.53	18.66	8.61	20.64	19.15	20.20	18.20	95.74	90.35	---	---
F_4 (C_1)	7.20	4.83	6.27	4.10	12.16	12.88	11.35	11.87	87.08	84.88	40.08	40.19
F_5 (C_2)	6.36	5.57	5.43	4.59	10.35	10..48	9.56	9.52	85.38	82.40	67.40	78.47

N = normal irrigation　　　　　　　　D = water stress

2.2. Means and observed gains under normal irrigation evaluation:

The two groups of families selected for high grain yield/plant for two cycles, either under normal irrigation or water stress were evaluated in the F_5 generation under both environments and presented in Table 6. The group of F_5 families selected for high grain yield/plant under normal irrigation and evaluated under normal irrigation ranged from 20.29 for family No. 98 to 28.71 for family No. 56 with an average of 24.37 g/plant. The average direct observed gain from selection significantly (P<0.01) out yielded the bulk sample by 19.58% and from the better parent (P>0.05) by 7.93%. Seven selected families selected for grain yield/plant showed significant or highly significant observed gain from the bulk sample ranged from 14.76 to 40.86%, five of them, i.e., families No. 9, No. 49, No. 56, No. 72 and No. 77 showed significant or highly significant observed gain of 14.24, 17.52, 27.13, 16.86 and 13.25%, respectively from the better parent.

The group of F_5 families which selected for high grain yield/plant under water stress and evaluated under normal irrigation ranged from 22.98 for family No. 16 to 29.62 for family No. 10 with an average of 25.77 g/plant. The average direct observed

gain from selection significantly (P<0.01) out yielded the bulk sample by 26.44% and from the better parent (P<0.05) by 14.12%. Furthermore, all the selected families except family No. 16 showed significant or highly significant observed gain from the bulk sample ranged from 15.88 to 45.35%, five of them showed significant or highly significant observed gain from the better parent ranged from 11.98% for family No. 17 to 31.19% for family No.10.

2.3. Correlated gains under normal irrigation evaluation:

Direct selection for high grain yield/plant for two cycles of selection under normal irrigation and evaluation under normal irrigation (Table 7) was accompanied by insignificant correlated gain for number of spikes/plant (3.38%), number of kernels/spike (8.82%), days to heading (-2.53%) and plant height (-3.67%). However, significant correlated gain was observed for 100-kernel weight (5.95%) and biological yield/plant (10.35%) and days to maturity (-2.38%) from the unselected bulk sample. Respect to the correlated gain from the better parent, insignificant positive correlated gain was recorded for days to heading, days to maturity and number of kernels/spike, while insignificant negative correlated gain was recorded for plant height, num-

ber of spikes/plant, 100-kernel weight and biological yield/plant. Selection for high grain yield/plant for two selection cycles under water stress and evaluation under normal irrigation (Table 7) was accompanied by increase of 5.80, 9.16, 9.84 and 17.98% for number of spikes/plant, number of kernels/spike, 100-kernel weight and biological yield/plant, respectively, compared to bulk sample. However, positive correlated gains for all studied traits from the better parent were obtained, except for number of spikes/plant (-0.68%).

Table 6. Mean grain yield/plant and observed gain from the bulk sample (OG% Bulk) and from the better parent (OG% BP) for the selected families after two cycles of selection for grain yield under normal irrigation and water stress conditions.

Item		Fam. No.	Environment of evaluation					
			Normal irrigation			Water stress		
			Mean	OG% Bulk	OG% BP	Mean	OG% Bulk	OG% BP
Environment of selection	Normal irrigation	1	24.29	19.20**	7.59	19.95	17.47*	3.30
		9	25.80	26.57**	14.24*	22.68	33.59**	17.47*
		44	21.78	6.89	-3.53	20.19	18.90*	4.56
		49	26.54	30.20**	17.52**	24.00	41.34**	24.29**
		56	28.71	40.86**	27.13**	23.10	36.07**	19.65**
		62	20.96	2.85	-7.17	18.28	7.64	-5.35
		72	26.39	29.48**	16.86**	23.89	40.71**	23.73**
		77	25.57	25.48**	13.25*	21.41	26.08**	10.87
		92	23.39	14.76*	3.58	19.06	12.25	-1.29
		98	20.29	-0.46	-10.16	17.40	2.49	-9.87
		Average	24.37	19.58**	7.93	21.00	23.66**	8.73
	Water stress	10	29.62	45.35**	31.19**	25.15	48.14**	30.26**
		16	22.98	12.74	1.76	19.82	16.71*	2.62
		17	25.29	24.07**	11.98*	19.78	16.47*	2.42
		18	23.62	15.88*	4.59	20.36	19.93*	5.45
		20	24.98	22.59**	10.64	23.27	37.06**	20.52**
		27	24.72	21.28**	9.46	21.45	26.34**	11.10
		42	24.66	20.98**	9.20	22.21	30.83**	15.04*
		45	26.83	31.63**	18.80**	24.30	43.11**	25.84**
		51	25.71	26.13**	13.84*	22.79	34.20**	18.01*
		61	29.30	43.77**	29.76**	26.00	53.12**	34.65**
		Average	25.77	26.44**	14.12*	22.51	32.57**	16.57*
		Sids1	21.36			19.31		
		Misr 1	22.58			18.35		
		Bulk	20.38			16.98		
R.LSD $_{0.05}$			2.62			2.65		
R.LSD $_{0.01}$			3.47			3.51		

OG = observed gain   *,** Significant at 5 and 1% levels of probability, respectively.

Table 7. Direct and correlated gains in the two cycles of selection for grain yield/plant in percentages from the bulk (OG%"Bulk") and the better parent (OG%"BP") under normal irrigation (N) and water stress (D) conditions.

	Item		GY/P	DH	DM	PH	NS/P	NK/S	100KW	BY/P
Evaluation under normal irrigation	F_4 families (C_1)		22.06	90.58	142.43	108.43	12.92	38.89	4.42	60.68
	Sids 1 (P1)		19.93	93.00	145.00	117.00	12.00	38.70	4.31	57.00
	Misr 1 (P2)		21.08	88.00	138.67	112.00	12.43	40.11	4.27	54.33
	Bulk sample		18.12	96.67	150.33	111.33	11.93	36.33	4.19	53.33
	OG% (Bulk)		21.74**	-6.30**	-5.25**	-2.60	8.3	7.13	5.49	13.78*
	OG% (BP)		4.65	2.93	2.71**	-3.19	3.94	-3.04	2.55	6.46
	R.LSD $_{0.05}$		**2.57**	**2.72**	**2.75**	**5.73**	**1.66**	**3.65**	**0.34**	**7.29**
	R.LSD $_{0.01}$		**3.40**	**3.57**	**3.60**	**7.58**	**2.20**	**4.83**	**0.45**	**9.64**
	F_5 families	N	24.37	96.50	142.20	110.46	12.83	40.97	4.63	64.74
	(C_2)	D	25.77	97.66	142.10	112.30	13.13	41.10	4.80	69.22
	Sids 1 (P1)		21.36	98.67	145.00	116.33	12.05	38.34	4.64	63.33
	Misr 1 (P2)		22.58	95.67	139.33	111.33	13.22	37.96	4.52	65.78
	Bulk sample		20.38	99.00	145.67	114.67	12.41	37.65	4.37	58.67
	OG%	N	19.58**	-2.53	-2.38*	-3.67	3.38	8.82	5.95**	10.35**
	(Bulk)	D	26.44**	-1.35	-2.45*	-2.07	5.80	9.16	9.84	17.98
	OG% (BP)	N	7.93	0.87	2.06	-0.78	-2.95	6.86	-0.22	-1.58
		D	14.12*	2.08	1.99	0.87	-0.68	7.20	3.45	5.23
	R.LSD $_{0.05}$		**2.62**	**3.34**	**2.97**	**5.13**	**1.42**	**3.88**	**0.31**	**6.64**
	R.LSD $_{0.01}$		**3.47**	**4.42**	**3.93**	**6.79**	**1.90**	**5.26**	**0.43**	**8.78**
Evaluation under water stress	F_4 families (C_1)		17.06	87.27	138.95	104.78	11.52	36.21	4.10	51.54
	Sids 1 (P1)		16.12	90.00	140.00	113.33	11.25	35.74	4.04	48.33
	Misr 1 (P2)		15.50	86.00	136.00	108.00	11.13	36.00	3.87	43.00
	Bulk sample		14.52	93.67	142.33	107.33	11.00	33.75	3.91	42.67
	OG% (Bulk)		17.49*	-6.83**	-2.37	-2.38	4.73	7.29	4.86	20.79*
	OG% (BP)		5.83	1.48	2.17	-2.98	2.40	0.58	1.49	6.64
	R.LSD $_{0.05}$		**2.23**	**3.44**	**4.01**	**6.32**	**0.92**	**4.51**	**0.49**	**6.81**
	R.LSD $_{0.01}$		**2.95**	**4.50**	**5.31**	**8.36**	**1.21**	**6.11**	**0.68**	**9.01**
	F_5 families	N	21.00	93.66	138.93	104.97	12.09	39.61	4.38	57.22
	(C_2)	D	22.51	91.70	138.67	107.80	12.26	40.02	4.59	59.02
	Sids 1 (P1)		19.31	95.00	141.00	113.00	11.66	37.76	4.45	58.44
	Misr 1 (P2)		18.35	93.00	136.67	107.33	11.45	37.24	4.31	55.25
	Bulk sample		16.98	94.67	142.33	110.00	12.00	35.03	4.10	51.56
	OG%	N	23.66**	-1.07	-2.39*	-4.57	0.75	13.07**	6.83	10.98
	(Bulk)	D	32.57**	-3.14	-2.57*	-2.00	2.17	14.25**	11.95**	14.49*
	OG% (BP)	N	8.73	0.71	1.65	-2.20	3.69	4.90	-1.57	-2.09
		D	16.57*	-1.40	1.46	0.44	5.15	5.99	3.15	1.01
	R.LSD $_{0.05}$		**2.65**	**3.06**	**2.86**	**6.83**	**1.04**	**3.42**	**0.32**	**7.41**
	R.LSD $_{0.01}$		**3.51**	**4.05**	**3.79**	**9.14**	**1.37**	**4.57**	**0.43**	**10.05**

N= group selected under normal irrigation   D= group selected under water stress
OG = observed gain   *, **significant at 5 and 1% levels of probability, respectively

2.4. Means and observed gains under water stress evaluation:

The group of F_5 families which selected for high grain yield/plant for two cycle under nor-

mal irrigation and evaluated under water stress ranged from 17.40 for family No. 98 to 24.00 for family No. 49 with an average of 21.00 g/plant (Table 6). The average direct observed gain from selection was highly significant (23.66%) from the bulk sample and it was not significant (8.75%) from the better parent. Furthermore, seven selected families which selected for grain yield/plant showed significant or highly significant observed gain from the bulk sample ranged from 17.47 to 41.34%, four of them, i.e., families No. 9, No. 49, No. 56 and No. 72 showed significant or highly significant observed gain of 17.47, 24.29, 19.65 and 23.73 %, respectively from the better parent.

Mean of the group of F_5 families which selected for high grain yield/plant under water stress and evaluated under water stress ranged from 19.78 for family No. 17 to 26.00 for family No. 61 with an average of 22.51 g/plant. The average direct observed gain from selection, significantly (P<0.01) out yielded the bulk sample by 32.57% and from the better parent (P<0.05) by 16.57%. All the selected families showed significant or highly significant observed gain from the bulk sample ranged from 16.47 for family No. 17 to 53.12% for family No. 61, six of them showed significant or highly significant observed gain from the better parent and ranged from 15.04% for family No. 42 to 34.65% for family No.61.

2.5. Correlated gains under water stress evaluation:

Selection for high grain yield/plant for two cycles of selection under normal irrigation and evaluation under water stress (Table 7) showed significant correlated gain for number of kernels/spike (13.07%) and days to maturity (-2.39%), while showed insignificant correlated gain for days to heading (-1.07%), plant height (-4.57%), number of spikes/plant (0.75%), 100-kernel weight (6.83%) and biological yield/plant (10.98%) than the bulk sample. However, positive correlated gains of 0.71, 1.65, 3.69 and 4.90% for days to heading, days to maturity, number of spikes/plant and number of kernels/spike and negative correlated gains of -2.20, -1.57 and -2.09% for plant height, 100-kernels weight and biological yield/plant, respectively, were obtained from the better parent

Direct selection for high grain yield/plant for two cycles of selection under water stress and evaluation under water stress was accompanied by significant decrease for days to maturity (-2.57%); insignificant decrease for days to heading (-3.14%) and plant height (-2.00%) from bulk sample; significant increase for number of kernels/spike (14.07%), 100-kernel weight (11.95%) and biological yield/plant (14.49%) and insignificant increase for number of spikes/plant (2.17%) from bulk sample. However, positive correlated gains for all studied traits from the better parent were obtained, except days to heading (-1.40%). These results indicated that pedigree method of selection was effective in isolating high yield genotypes and the direct selection for grain yield *per se* was effective. Generally, it can be concluded that selection for high grain yield/plant for two cycles under water stress was better

than selection under normal irrigation either evaluation was practiced under normal irrigation or under water stress. These results are in line with those reported by many investigators. Ismail (1995) reported genetic gains in grain yield over the bulk sample and the better parent of 8.47 and 4.86 in a population and 6.96 and 6.41% in another population, respectively. Attia (2003), Zakaria (2004) and Ahmed (2006) came to the same conclusion. Kheiralla *et al*. (2006) after two cycles of selection for grain yield/plant achieved genetic gain of 20.21 and 7.62% from the bulk sample and the better parent, respectively. Ali (2011) indicated that pedigree selection for grain yield was effective in increasing grain yield. Mahdy (2012) concluded that selection for high grain yield/plant for three cycles under drought stress was better than selection under normal irrigation either evaluation was practiced under normal irrigation or under drought stress. Salous *et al*. (2014) and Soliman *et al*. (2015) are in line with our results.

2.6. Average observed gain from selection for grain yield/plant in two cycles:

The observed gain from selection for high grain yield/plant under normal irrigation (Table 7) was 21.74 and 4.65% for cycle 1 and 19.58 and 7.93% for cycle 2 from the bulk sample and the better parent, respectively. The observed gain from selection for high grain yield/plant under water stress in the two cycles was 17.49 and 5.83% for cycle 1 and 32.57 and 16.57% for cycle 2 from the unselected bulk sample and the better parent, respectively. These results indi-

cated that selection for high grain yield/plant under water stress from the F_4 generation was more effective than selection from F_3. This may due to the increase of level of homozygosity in the F_4 generation, and it was easy to identify the genetically superior genotypes. Therefore, results suggest delaying selection for grain yield/plant to the F_4 generation, till homozygosity reach acceptable level to save costs, effort and avoid loss of the best genotypes.

The second cycle selection was evaluated under both environments. The observed gain in normal irrigation group were (19.58 and 23.67%) from bulk sample and (7.93 and 8.75%) from the better parent compared to (26.44 and 32.57) from bulk sample and (14.13 and 16.57%) from the better parent for water stress group under normal irrigation and water stress, respectively It is obvious that selection under water stress was better than selection under normal irrigation. In other words antagonistic selection for grain yield was better than synergistic selection.

2.7. Drought susceptibility index and sensitivity to environments:

The drought susceptibility index (DSI) and sensitivity to environments of the selected families for grain yield/plant are presented in Table 8. The results of the selected families for two cycles under normal irrigation (normal group) when evaluated under both environments indicated that five families, i.e., No. 9, No. 44, No. 49, No. 62 and No. 72 showed drought susceptibility index (DSI) of 0.87, 0.53, 0.69, 0.92 and 0.68, respectively. The five families which gave DSI less than one, gave

also values less than one (less sensitive) in sensitivity test. These families could be used as source of drought tolerance. Furthermore, it could be noticed that three superior families, No. 9, No. 49 and No. 72 were less susceptible and less sensitive to drought and showed significant observed gain over the better parent under normal irrigation and water stress. These families could be promising families. The results of families which selected under water stress and evaluated under both environments showed that, five families, No. 20, No. 42, No. 45, No. 51and No. 61 gave drought susceptibility index of 0.54, 0.78, 0.75, 0.90 and 0.89, indicating less susceptibility. All these families gave also values less than one in sensitivity test. Sids 1 showed less susceptibility, however, Misr 1

and the bulk sample were susceptible. It is of interest to indicate that the three superior families, i.e., No. 45 No. 51 and No. 61 were less susceptible and less sensitive to drought and showed significant observed gain over the better parent under normal irrigation and water stress. The mean sensitivity to drought of the selected families for high grain yield/plant under normal irrigation was 0.99, while it was 0.96 for the selected families under deficit water (Table 8).

The relative merit after two cycles of selection for high grain yield was 1.35 when selection was under normal and water deficit and evaluation under normal irrigation, while it was 1.37 when selection was under normal and water deficit and evaluation under water stress.

Table 8. Drought susceptibility index (DSI) and sensitivity (S) to environments of selected families under normal irrigation and water stress after two cycles of selection for grain yield/plant.

Environment of selection									
Normal irrigation selections					**Water stress selections**				
Fam. No.	**N**	**D**	**DSI**	**S**	**Fam. No.**	**N**	**D**	**DSI**	**S**
1	24.29	19.95	1.29	1.28	10	29.62**	25.15**	1.19	1.31
9	25.80*	22.68*	0.87	0.92	16	22.98	19.82	1.09	0.93
44	21.78	20.19	0.53	0.47	17	25.29*	19.78	1.72	1.62
49	26.54**	24.00**	0.69	0.75	18	23.62	20.36	1.09	0.96
56	28.71**	23.10**	1.41	1.65	20	24.98	23.27**	0.54	0.50
62	20.96	18.28	0.92	0.79	27	24.72	21.45	1.05	0.96
72	26.39**	23.89**	0.68	0.73	42	24.66	22.21*	0.78	0.72
77	25.57*	21.41	1.18	1.23	45	26.83**	24.30**	0.75	0.74
92	23.39	19.06	1.34	1.27	51	25.71*	22.79*	0.90	0.86
98	20.29	17.40	1.03	0.85	61	29.30**	26.00**	0.89	0.97
average	**24.37**	**21.00**		0.99	Mean	**25.77***	**22.51***		0.96
Sids 1	**21.36**	**19.31**	0.69	0.60	Sids 1	**21.36**	**19.31**	0.69	0.60
Misr 1	**22.58**	**18.35**	1.36	1.25	Misr 1	**22.58**	**18.35**	1.36	1.25
Bulk	**20.38**	**16.98**	1.20		Bulk	**20.38**	**16.98**	1.20	

N = normal irrigation   D = water stress   S = sensitivity

* and **; significant observed gain from the better parent at 0.05 and 0.05 level of probability; respectively.

These results indicate that the antagonistic selection was better than synergistic selection to increase grain yield/plant in these materials, either evaluation made under normal irrigation or under water stress. However,

the antagonistic selection reduced sensitivity to drought stress while, synergistic selection increased it. These results were in agreement with that found by Jinks and Connolly (1973 and 1975) on *Schizophyllum Commune*, Jinks and Pooni (1982) on *Nicotiana rustica.*, Ceccarelli and Grando (1991 a and b) on barley and Mohamed (2001) on cotton. Falconer (1990) stated that, when selection and environment change the character in opposite direction this is antagonistic selection, i.e. selection upwards in a low environment or downwards in a high environment. Synergistic selection is the reverse; upwards in a high environment or downwards in a low environment, when selection and environment change the character in the same direction. Kheiralla *et al.* (2006) found that selection under early planting (synergistic selection) increased sensitivity of the selected families, while selection under late planting (antagonistic selection) decreased it**.** Mahdy (2012) found that the antagonistic selection was better than synergistic selection to increase grain yield/plant either evaluation made under normal irrigation or under drought stress and the antagonistic selection reduced sensitivity of the selected families, while the synergistic selection increased it.

2.8. The phenotypic correlation after two cycles of selection for grain yield/plant:

The phenotypic correlations among traits after two cycles of selection for grain yield/plant under normal irrigation and water stress are shown in Table 9. After two cycles of selection the coefficients of phenotypic correlation under normal irrigation between grain yield/plant and each of days to heading, days to maturity, plant height, number of spikes/plant, number of kernels/spike, 100-kernel weight and biological yield/plant were 0.468, 0.441. 0.196, 0.847, 0.519, 0.134 and 0.930, respectively. These results indicate that the most effective components in grain yield of wheat would be number of spikes/plant, number of kernels/spike and biological yield/plant. This means that, selection played on the highest correlated trait with grain yield/plant (number of spikes/plant, number of kernels/spike and biological yield/plant) in the base population.

The coefficients of phenotypic correlation under water stress were 0.368, 0.205, 0.354, 0.762, 0.600, 0465 and 0.810 between grain yield/plant and the above mentioned traits, respectively. These results indicated that selection under water stress increased the correlation between grain yield and each of number of kernels/spike and 100-kernel weight and turned the correlation between number of kernels/spike and 100-kernel weight from insignificant negative to insignificant positive.

Positive genotypic correlation was recorded between yield and each of number of spikes/plant (Ahmed 2006, Sharma *et al.* 2006, Anawar *et al.*, 2009), biological yield/plant (khan *et al.* 2010, Moustafa, 2015 and Khames, *et al.* 2016). Mahdy (2012) indicated that high and positive phenotypic correlation between grain yield/plant and each of number of spikes/plant and biological yield/plant under normal irrigation and drought stress.

2.9. Path coefficient analysis in base population (F_3) and after two cycles (F_5) of selection for grain yield/ plant:

The Partitioning of phenotypic correlation into direct and indirect effects by path analysis under normal irrigation revealed that the highest direct effect on grain yield/plant was exerted by number of spikes/plant in base population 0.673 and in cycle two of selection 0.813 (Table 10). Moreover, the highest indirect effects were correlated also with number of spikes/plant across the base population 0.272 and cycle two of selection 0.132 via number of kernels/spike. These results suggested that number of spikes/plant has exhibited to be powerful traits as a yield component and must be given preference in selection to improve grain yield/plant. It is clear that the effect of residual factor was decreased from 0.173 in base to 0.071 in the second cycle of selection. Consequently, the strong effects were found for current studied traits on grain yield/plant of wheat.

The Partitioning of phenotypic correlation into direct and indirect effects by path analysis under water stress revealed that the highest direct effect on grain yield/plant was exerted by number of kernels/spike in base population 0.586 and by number of spikes/plant in cycle two of se- lection 0.690 (Table 10). Moreover, the highest indirect effects were cor- related also with number of spikes/plant across the base popula- tion and cycle two of selection. The estimates of these indirect effects were 0.167 and 0.070 via 100-kernel weight followed by 0.119 and 0.052 via number of kernels/spike in base population and cycle two, respec- tively. These results, indicated that the direct effect of number of spikes/plant exhibited superiority on grain yield /plant for selection in the cycle two of selection compared to their base population. It concluded that the number of spikes/plant fol- lowed by number of kernels/spike and 100-kernel weight are important for selection of high yielding in wheat.

Different estimates of direct and indirect effects of yield components on grain yield of wheat revealed by many studies according the studied populations such as Kashif and Khaliq (2004), Abd El-Mohsen and Abd El-Shafi (2014), Nasri *et al.* (2014), Khames *et al.* (2016). Abd El-Kareem (2014) indicated that the most important sources of variation in grain yield are the direct effect of number of spikes/plant followed by number of kernels/spike and 100-kernel weight under water stress con- ditions.

Table 9. Phenotypic correlation among the studied traits for the F₅ generation under normal (above diagonal) and water stress (below diagonal) conditions.

Trait	DH	DM	PH	NS/P	NK/S	100KW	GY/P	BY/P
DH		0.845**	0.360	0.496*	0.275	-0.273	0.468*	0.573**
DM	0.834**		0.109	0.476*	0.161	-0.166	0.441	0.528*
PH	0.425	0.213		0.248	0.088	-0.202	0.196	0.242
NS/P	0.392	0.127	0.379		0.162	-0.122	0.847**	0.695**
NK/S	0.338	0.352	0.186	0.075		-0.282	0.519*	0.570**
100KW	-0.278	-0.225	-0.157	0.102	0.118		0.134	0.195
GY/P	0.368	0.205	0.354	0.762**	0.600**	0.465*		0.930**
BY/P	0.225	0.240	0.307	0.433	0.699**	0.365	0.801**	

*,** Significant at 5 and 1% levels of probability, respectively.

Table 10. Partitioning of phenotypic correlation coefficients into direct and indirect effects by path coefficient analysis for base population (F₃) and cycle two (F₅) of pedigree selection for grain yield /plant under normal and water stress conditions.

Correlation		Normal irrigation		Water stress	
		Base pop. (F₃)	Cycle two (F₅)	Base pop. (F₃)	Cycle two (F₅)
1- Number of spikes/plant vs. Grain	**r**	0.851	0.847	0.728	0.762
Direct effect	P_{14}	0.673	0.813	0.453	0.690
Indirect effects via number of kernels/spike	$r_{12}P_{24}$	0.218	0.080	0.154	0.038
Indirect effects via 100-kernel weight	$r_{13}P_{34}$	-0.040	-0.046	0.121	0.034
	Total	0.851	0.847	0.728	0.762
2-Number of kernels/spike vs. Grain	**r**	0.698	0.519	0.777	0.600
Direct effect	P_{24}	0.539	0.493	0.586	0.508
Indirect effects via number of spikes/plant	$r_{12}P_{14}$	0.272	0.132	0.119	0.052
Indirect effects via 100-kernel weight	$r_{23}P_{34}$	-0.113	-0.106	0.072	0.040
	Total	0.698	0.519	0.777	0.600
3-100-kernel weight vs. Grain yield/plant	**r**	0.064	0.134	0.625	0.465
Direct effect	P_{34}	0.329	0.372	0.330	0.335
Indirect effects via number of spikes/plant	$r_{13}P_{14}$	-0.081	-0.099	0.167	0.070
Indirect effects via number of kernels/spike	$r_{23}P_{24}$	-0.184	-0.139	0.128	0.060
	Total	0.064	0.134	0.625	0.465
	1-R^2	0.97	0.995	992	0.984
Residual factor		0.173	0.071	0.089	0.126

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كفاءة الانتخاب لمحصول الحبوب تحت ظروف الري العادي والإجهاد المائي في قمح الخبز

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الملخص

يهدف هذا البحث إلى دراسة كفاءة الانتخاب المنسب لتحسين محصول الحبوب/النبات تحت ظروف الري العادي والإجهاد المائي. تم تنفيذ دورتين من الانتخاب لمحصول الحبوب/النبات بشكل منفصل تحت الري العادي والإجهاد المائي. كانت العشيرة القاعدية عبارة عن الجيل الثالث للهجين سدس ١ × مصر ١. في الموسم الثالث تم تقيم منتخبات الري العادي والإجهاد المائي تحت ظروف البيئتين. كان التباين المظهري أكثر قليلا من التباين الوراثي وانخفض تدريجيا من الجيل الثالث إلى الجيل الخامس ، كانت كفاءة التوريث بالمعنى الواسع لصفة محصول النبات ٨٧,٠٨ ، ٨٥,٣٨% تحت الري العادي مقابل ٨٤,٨٨، ٨٢,٤٠% تحت الإجهاد المائي للدورة الأولى والثانية على التوالي. كان معامل التوريث المحقق ٤٠,٠٨ ، ٦٧,٤٠% تحت ظروف الري العادي مقابل ٤٠,١٩ ، ٧٨,٤٧% تحت ظروف النقص المائي للدورة الأولى والثانية على التوالي. كانت الزيادة المحققة في المحصول لمنتخبات الري العادي ١٩,٥٨ ، ٢٣,٦٦% بالنسبة لإجمالي العشيرة و ٧, ٩٣ ، ٨,٧٣% بالنسبة للأب الأفضل، بينما كانت الزيادة المحققة في المحصول لمنتخبات الإجهاد المائي ٢٦,٤٤ ، ٣٢,٥٧% بالنسبة لإجمالي العشيرة و ١٤,١٢، ١٦,٥٧% بالنسبة للأب الأفضل عند تقيمهما تحت ظروف الري العادي والإجهاد المائي على التوالي . أوضحت النتائج أن الانتخاب المتضاد كان أفضل من الانتخاب المتوافق في تغير المتوسط وكذلك نقص الحساسية للجفاف. ارتبط محصول الحبوب/النبات بقيم عالية وموجبة بصفة المحصول البيولوجي/النبات، عدد السنابل/النبات وعدد الحبوب/سنبلة تحت ظروف الري العادي والإجهاد المائي ، ووزن ال١٠٠ حبة تحت ظروف الإجهاد المائي في العشيرة الأساسية وبعد دورتين من الانتخاب لمحصول الحبوب/النبات. كما أوضح تحليل معامل المرور أن صفة عدد السنابل/النبات كان لها التأثير المباشر الأعلى على المحصول يليها عدد الحبوب/السنبلة ثم وزن ال١٠٠ حبة بعد دورتين من الانتخاب المنسب لمحصول الحبوب/النبات تحت ظروف الري العادي والإجهاد المائي.