

SELECTION FOR GRAIN YIELD UNDER NORMAL AND DEFICIT IRRIGATION REGIMES IN BREAD WHEAT

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ABSTRACT

The objectives of the present research were to study the direct selection response for grain yield plant⁻¹ under normal and deficit irrigation conditions and estimate the correlated response of other studied traits. Two cycles of selection were practiced on a segregating populations of wheat cross (Sid 1 × Misr 2) in the F₃-F₅ generations. Selection was practiced separately under normal and deficit irrigation conditions. The genotypic variance was slightly less than the phenotypic variance under both environments and generally decreased from the base population (F₃) to the F₅ generation. Broad-sense heritability estimates for grain yield plant⁻¹ after two cycles of selection were 65.66 and 59.95% under normal and deficit irrigation, respectively. The realized heritability under normal irrigation was 47.94 and 53.66% compared to 34.90 and 58.64% under deficit irrigation conditions after the first and second cycles of selection, respectively. The average observed gain for grain yield plant⁻¹ from selection under normal and deficit irrigation groups, evaluated under normal irrigation were (13.92 and 15.48%) over the bulk sample and (9.27 and 10.78%) over the better parent, respectively. While, from selection under normal and deficit irrigation, evaluated under deficit irrigation were (16.87 and 20.08%) over the bulk sample and (15.44 and 18.61%) over the better parent, respectively. Drought susceptibility index (DSI) showed that six families selected under normal irrigation and five families selected under deficit irrigation were superior for drought tolerance and had high grain yield under deficit irrigation in F₅ generation. The antagonistic selection was better than the synergistic selection in changing the mean and decreasing the sensitivity.

Key words: *Selection response, Heritability, Drought susceptibility index, Synergistic vs antagonistic selection.*

1.INTRODUCTION

Wheat is the most important food grain in the world and staple food for the people of 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). In Egypt, wheat production is far below to meet the local consumption of the growing population of the country which resulted in increasing wheat imports. Increasing production per unit area appears to be the main possible alternative to reduce wheat production gap. Drought is an arising threat all over the world. 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 tolerance depends largely on the selection criteria and the selection method used to achieve genetic improvement through selection, in addition to the complexity of drought tolerance itself (Passioura, 2007). Pedigree selection method can be used to identify superior genotypes for grain yield in a cultivar development program. Several workers indicated that pedigree selection is effective in improving grain yield (Kheiralla *et al.*, 2001; Omara *et al.*, 2004; Tammam *et al.*, 2004, Ahmed, 2006 and El-Morshidy *et al.*, 2010). On the other hand, 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), others prefer selection in a target stress condition (Rathjen, 1994), while others yet have chosen a mid-point and believe in selection under both favorable and stress conditions (Byrne *et al.*, 1995). Pedigree selection for grain yield plant⁻¹ needs to evaluate selections under a series of environments such as different water stresses (Attia, 2003; Tammam *et al.*, 2004 and El-Morshidy *et al.*, 2010). Jinks and Connolly (1973 and 1975). Jinks and Pooni (1982) indicated that, environmental sensitivity was reduced if selection and environment effects were in opposite directions, while sensitivity was increased if selection and environment effects were in the same direction. The objectives of the present research were to estimate the direct and correlated responses for grain yield under normal and deficit irrigation, the relative merits of pedigree selection for grain yield plant⁻¹ under normal and deficit irrigation, beside estimates drought susceptibility index and sensitivity to environmental conditions.

2.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 F₃ families traced back to 100 random F₂ plants originated from the cross (Sids1×Misr 2). The pedigree and origin of the parents are 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 2	SAKUZ / BAV 92

In 2013/2014 growing season, 100 F₃ families, original parents and F₃ bulked random sample (a mixture of equal number of grains from each plant to represent the generation mean) were sown on 20th of November in two field experiments using a randomized complete block design with three replications. The first experiment was grown in supplemental water applied regularly as recommended (normal) while the other one did not receive any irrigation after the second irrigation (deficit irrigation). Each plot consisted of a single row 3 m 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. Data were recorded on ten guarded plants from each family for days to heading, days to maturity, number of spikes plant⁻¹, number of kernels spike⁻¹, 100-kernel weight, grain yield plant⁻¹ and biological yield plant⁻¹. Separate analysis of variance of the two treatments was applied on a plot mean basis. The best high yielding 20 plants from the best high yielding 20 families were saved to give the F₄ families in each environment.

In 2014/2015 growing season, the 20 F₄ families selected under normal irrigation with parents and F₄ bulk sample were sown under normal irrigation and the 20 F₄ families selected under deficit irrigation with parents and F₄ bulk sample were sown under water stress. The experimental design, number of replications, planting date and cultural practices were properly adopted as the same in the first season. Data were recorded as previously mentioned. Each group of families (20 families) for each environment of selection was analyzed separately. The best 10 high yielding plants from the best high yielding 10 families were saved in each environment to give the F₅ families.

In 2015/2016 growing season, the 10 F₅ families for each environment of selection, the parents and F₅ bulk sample were evaluated under the two environments in two separate experiments. Again, experimental design, number of replications, field procedures and recorded data were the same as in the first and second seasons.

Statistical analysis

Analysis of variance was performed according to Snedecor and Cochran (1980). Genotype 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 (σ^2_p) and genotypic (σ^2_g) variances and heritability in the broad sense (h^2_{bs}) 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) = cycle mean – bulk mean and S (selection differential) = mean of selections – bulk mean. Drought susceptibility index (DSI) was computed according to the method of Fischer and Maurer (1978) equation:

$$DSI = (1 - Y_d/Y_p)/D$$

Where:

Y_d = Mean yield in stress environment Y_p =
Mean yield in non stress environment

$D = 1 - (\text{mean } Y_d \text{ of all genotypes} / \text{mean } Y_p \text{ of all genotypes})$. The sensitivity and relative merits of selected families were assessed as described by Falconer (1990): The sensitivity of any selected line is the difference between its performance in the high and low environments divided by the same difference in the base population or in a contemporaneous unselected control. The relative merits of the two types of selection in changing the mean is expressed as the ratio:

(Change of mean by antagonistic selection) /
(Change of mean by Synergistic selection)

Synergistic selection: Selection upwards in a good environment or downwards in a bad, environment selection and environment acting in the same direction on the character.

Antagonistic selection: Selection upwards in a bad environment or downwards in a good environment, selection and environment acting in opposite direction on the character.

3.RESULTS AND DISCUSSION

3.1. Base population

The analysis of variance (Table 2) indicated highly significant differences among the F_3 families for all the studied traits under normal and deficit irrigation. This indicates that the genetic variability existed among selected families in these traits and selection in the base population would be effective. The averages of the studied traits were 93.18 and 90.27 day for days to heading, 146.98 and 140.68 day for days to maturity, 11.69 and 10.13 for the number of spikes plant⁻¹, 37.46 and 35.71 for the number of kernels spike⁻¹, 4.42 and 3.39 for 100-kernel weight, 52.92 and 44.42 g for biological yield plant⁻¹ and 20.03 and 15.98 g for grain yield plant⁻¹ under normal and deficit irrigation, respectively. These results indicated that deficit irrigation caused reduction in all the studied traits. Similar results were reported by Kheiralla *et al.* (2004), Mahdy (2007) and Soliman, *et al.* (2015), who reported that deficit irrigation caused a reduction in the number of spikes plant⁻¹, number of kernels spike⁻¹, 100-kernel weight, biological yield plant⁻¹ and grain yield plant⁻¹

The phenotypic (PCV) and genotypic (GCV) coefficient of variability were 5.34 and 4.95% for days to heading, 3.30 and 3.05% for days to maturity, 12.02 and 9.73% for the number of spikes plant⁻¹, 11.43 and 10.11% for

the number of kernels spike⁻¹, 7.91 and 6.87% for 100-kernel weight, 16.51 and 15.15% for biological yield plant⁻¹ and 19.78 and 18.00% for grain yield plant⁻¹, respectively under normal irrigation, while under deficit irrigation they were 5.96 and 5.45%, 3.19 and 2.90%, 13.42 and 10.14%, 11.40 and 10.04%, 10.22 and 8.85%, 16.76 and 14.87% and 22.13 and 19.53%, respectively for the above mentioned traits, respectively. These results indicated the presence of sufficient variability for grain yield among the families in the base population, which are characteristics of the starting population and have a considerable effect on early generation selection. In addition, great response to selection can be achieved from selection in such population having a large amount of phenotypic and genotypic variance. These findings are in line with those reported by Ismail (1995), Amin (2003), Zakaria *et al.* (2008), El-Morshidy *et al.* (2010), Ali (2011), Abd-El-Haleem *et al.* (2012), Ahmed *et al.* (2014) and Soliman *et al.* (2015) who found satisfactory genotypic coefficient of variation in grain yield in the F_3 families.

Heritability estimate is considered one of the most important parameters for selection response in early generations. The current results showed that the broad sense heritability (Table 2) was 86.12 and 83.54% for days to heading, 85.08 and 82.27% for days to maturity, 65.54 and 64.86% for the number of spikes plant⁻¹, 78.29 and 77.61% for the number of kernels spike⁻¹, 75.48 and 75.00% for 100-kernel weight, 84.22 and 78.67% for biological yield plant⁻¹ and 82.74 and 77.93% for grain yield plant⁻¹ under normal and deficit irrigation, respectively. These results indicated that the environmental effects were small as compared to the genetic effects and were higher under normal irrigation than under deficit irrigation. This could mainly be due to the higher estimates of the phenotypic variance of the F_3 population under deficit irrigation than under normal irrigation. Kashif and Khaliq (2004), Cheema *et al.* (2006) and Zakaria *et al.* (2008) reported high broad-sense heritability for grain yield plant⁻¹. Soliman *et al.* (2015) recorded that heritability estimate for grain yield under non-stress conditions was slightly higher than that under stress conditions.

3.2. Selection for grain yield plant⁻¹

3.2.1. Variability and heritability estimates

After two cycles of selection for grain yield plant⁻¹, there were highly significant differences among selected families for the selection criterion; grain yield and other traits either

Table (2): Mean performance, ranges, mean squares (MS), phenotypic (PCV%) and genotypic (GCV%) coefficients of variability and heritability in broad sense (h^2_{bs}) for seven studied traits under normal and deficit irrigation in the base population (F₃ generation).

Environment	Item	Selection criterion	Correlated traits to selection					
		Grain yield plant ⁻¹	Days to heading	Days to maturity	No. of spikes plant ⁻¹	No. of kernels spike ⁻¹	100-kernel weight	Biological yield
Normal irrigation	Sids 1	18.75	94.67	148.33	12.02	38.04	4.11	50.91
	Misr 2	21.00	92.67	144.67	12.21	38.74	4.45	53.64
	F ₃ families	20.03±0.95	93.18±1.06	146.98±1.08	11.69±0.48	37.46±1.15	4.42±0.10	52.92±2.00
	Bulk	17.92	94.67	149.33	12.23	39.35	3.74	45.98
	Range	11.71-29.38	74.00-106.00	132.00-156.67	9.21-14.54	28.20-52.22	3.55-5.47	32.7-74.4
	Rep. MS	6.76	1.40	2.02	0.02	23.24	0.01	22.76
	Families MS	41.69**	67.29**	63.58**	4.55**	47.05**	0.30**	204.98**
	Error MS	2.71	3.42	3.52	0.68	3.98	0.03	12.05
	(PCV%)	19.78	5.34	3.30	12.02	11.43	7.91	16.51
	(GCV%)	18.00	4.95	3.05	9.73	10.11	6.87	15.15
	h^2_{bs}	82.74	86.12	85.08	65.54	78.29	75.48	84.22
Deficit irrigation	Sids 1	15.78	89.67	143.67	11.44	37.99	3.64	42.33
	Misr 2	15.50	87.33	140.67	11.13	36.99	3.79	40.33
	F ₃ families	15.98±0.96	90.27±1.26	140.68±1.05	10.13±0.47	35.71±1.11	3.39±0.1	44.42±1.98
	Bulk	14.00	91.33	144.33	11.08	37.8	3.37	42.00
	Range	7.25-24.79	72.00-100.67	127.67-155.33	7.25-13.00	25.31-49.04	2.58-4.00	29.67-59.67
	Rep. MS	11.81	4.12	1.69	0.36	20.46	0.01	60.08
	Families MS	31.99**	77.41**	53.42**	4.25**	42.28**	0.30**	142.62**
	Error MS	2.76	4.77	3.35	0.65	3.71	0.03	11.82
	(PCV%)	22.13	5.96	3.19	13.42	11.40	10.22	16.76
	(GCV%)	19.53	5.45	2.90	10.14	10.04	8.85	14.87
	h^2_{bs}	77.93	83.54	82.27	64.86	77.61	75.00	78.67

**significant at 1% levels of probability.

selection was practiced under normal or deficit irrigation (Table 3). This reflects the existence of sufficient variability for further improvement. These results agreed with those reported by Zarei *et al.* (2007), El-Morshidy *et al.* (2010), Nazari and Pakniyat (2010), Mahdy, (2012) and Soliman *et al.* (2015).

The effect of selection for two cycles on variability and heritability estimates of grain yield plant⁻¹ is shown in Table (4). The phenotypic variance in grain yield plant⁻¹ was high in the F₃ generation under both normal and deficit irrigation and dropped rapidly after cycle 1 and 2. The phenotypic variance under normal irrigation was 15.70, 9.00 and 6.38 in the base population, after C₁ and C₂, respectively. Under deficit irrigation, the phenotypic variance was 12.50 in the base population and decreased to

4.39 and 2.80 in C₁ and C₂, respectively. This may be due to the increase of homozygosity in the F₅ generation, which could result in separate different lines. The genotypic variance goes in line with the phenotypic variance. The phenotypic and genotypic coefficient of variability under normal irrigation were (19.78 and 18%), (13.89 and 12.11%) and (10.49 and 8.50%) for base population, F₄ (C₁) and F₅ (C₂), respectively. While, they were (22.13 and 19.53%), (12.72 and 10.81%) and (7.94 and 6.15%) under deficit irrigation for base population, F₄ (C₁) and F₅ (C₂), respectively. It appears that PCV % and GCV % were decreased after two cycles of selection for grain yield plant⁻¹, but still sufficient for further cycles of selection. The GCV% was slightly less than the PCV% under both environments.

Table(3): Mean squares for families selected for high grain yield plant⁻¹ and correlated traits in F₄ and F₅ generations under normal (N) and deficit irrigation (D) regimes.

Generation	Environment	S. O. V.	d f	Selecti on criteri	Correlated traits					
				Grain yield plant ⁻¹	Days to heading	Days to maturity	No. of spikes plant ⁻¹	No. of kernels spike ⁻¹	100- kernel weight	Biologi cal yield
F ₄	N	Rep.	2	0.42	0.62	19.11	0.42	3.57	0.05	17.11
		Fam.	19	22.69*	65.31**	48.28**	4.47**	29.16**	0.18**	157.87**
		Error	38	2.15	3.65	3.76	0.73	3.45	0.02	16.53
	D	Rep.	2	2.83	2.51	26.31	0.08	1.22	0.19	1.86
		Fam.	19	10.74*	79.85**	52.89**	3.28**	26.53**	0.29**	72.86**
		Error	38	1.22	6.62	4.93	0.61	3.16	0.03	11.63
F ₅	N	Rep.	2	1.28	1.85	4.11	0.27	0.32	0.03	16.16
		Fam.	19	14.75*	32.15**	23.11**	2.79**	17.63**	0.22**	283.55**
		Error	38	2.19	2.13	1.90	0.56	2.81	0.31	33.87
	D	Rep.	2	1.18	3.26	4.01	0.42	1.14	0.05	8.45
		Fam.	19	6.14**	31.26**	33.70**	2.41**	10.93**	0.21**	154.55**
		Error	38	1.25	3.58	5.01	0.52	1.84	0.03	22.05

N = normal irrigation

D = deficit irrigation

** Significant at 1% level of probability.

Table (4): Variability and heritability estimates of grain yield plant⁻¹ after two cycles of selection under normal (N) and deficit irrigation (D) regimes.

Selection cycle	σ^2_p		σ^2_g		PCV %		GCV %		h^2_{bs} %		Realized heritability	
	N	D	N	D	N	D	N	D	N	D	N	D
Base population (F ₃)	15.70	12.50	12.99	9.74	19.78	22.13	18.00	19.53	82.74	77.93	---	---
F ₄ families (C ₁)	9.00	4.39	6.85	3.17	13.89	12.72	12.11	10.81	76.10	72.23	47.94	34.90
F ₅ families (C ₂)	6.38	2.80	4.19	1.68	10.49	7.94	8.50	6.15	65.66	59.95	53.66	58.64

N = normal irrigation

D= deficit irrigation

Heritability in a broad sense for grain yield plant⁻¹ under normal and deficit irrigation were (82.74 and 77.93%), (76.10 and 72.23%) and (65.66 and 59.95%) for base population, F₄ selected families (C₁) and F₅ selected families (C₂), respectively. It is of interest to note that heritability estimates for grain yield plant⁻¹ decreased from the F₃ to the F₅ generation. This could be due to the increase in experimental

error; in other words the environmental variance as the homozygosity of the lines increased, which maximized the phenotypic relative to the genotypic variance. Also the realized heritability increased from C₁ (47.94 and 34.90%) to C₂ (53.66 and 58.64%) under normal and deficit irrigation, respectively. These results are in agreement with those reported by Zakaria (2004), Ahmed (2006), Abd El-Kader (2011),

Ali (2011), Mahdy *et al.* (2012) and Soliman *et al.* (2015).

3.2.2. Means and observed gains under normal irrigation evaluation

The group of F₅ families selected for high grain yield plant⁻¹ under normal irrigation and evaluated under normal irrigation (Table 5), ranged from 21.32 to 26.80 g with an average of

23.92 g plant⁻¹ (Table 5). The average observed gain was 13.92 and 9.27% g plant⁻¹ from the bulk and better parent, respectively. The selected families of No. 17, 27, 37, 67 and 74 showed significant observed gain over the bulk sample, four of them significantly surpassed the better parent. The group of F₅ families selected under deficit irrigation and evaluated under normal

Table (5): Mean grain yield plant⁻¹ and observed gain over the bulk sample (OG% Bulk) and over the better parent (OG% BP) for the high grain yield plant⁻¹ selected families after two cycles of selection under normal and deficit irrigation regimes.

Item	Fam. No.	Environment of evaluation						
		Normal irrigation			Deficit irrigation			
		Mean	OG% Bulk	OG% BP	Mean	OG% Bulk	OG% BP	
Environment of selection	Normal irrigation	7	23.39	11.36	6.83	21.52	21.05**	19.57**
		17	26.13	14.43**	19.37**	21.17	19.09**	17.63**
		23	21.32	1.52	-2.60	18.65	4.87	3.59
		27	25.51	21.46**	16.52**	21.00	18.14**	16.69**
		37	26.45	25.93**	20.81**	20.66	16.19**	14.77**
		47	22.45	6.90	2.55	21.37	20.18**	18.72**
		57	22.24	5.89	1.58	17.92	0.79	-0.44
		67	26.80	27.92**	22.72**	23.67	32.58**	30.96**
		74	23.51	11.94*	7.39	21.72	22.14**	20.65**
		91	21.34	1.60	-2.53	20.23	13.77**	12.38**
	Average	23.92	13.92*	9.27	20.78	16.87**	15.44**	
	Deficit irrigation	8	23.69	12.79*	8.21	21.41	20.41**	18.94**
		9	25.56	21.71**	16.76**	23.70	33.28**	31.65**
		11	25.44	21.13**	16.20**	20.80	17.00**	15.57**
		13	28.67	36.54**	30.99**	22.66	27.47**	25.91**
		16	21.55	2.62	-1.55	20.71	16.46**	15.04**
		32	24.18	15.14*	10.46	20.81	17.05**	15.62**
		41	22.63	7.77	3.39	21.67	21.87**	20.38**
		50	26.94	28.29**	23.07**	22.23	25.00**	23.48**
		59	21.35	1.66	-2.48	20.23	13.77**	12.38**
64		22.51	7.20	2.84	19.34	8.75*	7.42	
Average	24.25	15.48*	10.78	21.35	20.08**	18.61**		
R.L.S.D. 0.05		2.48	-----	-----	1.64	-----	-----	
R.L.S.D. 0.01		3.29	-----	-----	2.16	-----	-----	
Sids1		19.98	-----	-----	18.00	-----	-----	
Misr 2		21.89	-----	-----	17.80	-----	-----	
Bulk		21.00	-----	-----	17.78	-----	-----	

OG = observed gain

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

irrigation, ranged from 21.35 to 28.67 g with an average of 24.25 g plant⁻¹. The average observed gain significantly out yielded the bulk sample by 15.48% and the better parent by 10.78%. Six out of these families (No. 8, 9, 11, 13, 32 and 50) showed significant and highly significant observed gain over the bulk sample, four of them *i.e.*, No. 9, 11, 13 and 50, showed highly significant observed gain over the better parent.

3.2.3. Correlated response to selection

Estimates of direct and correlated gain for grain yield plant⁻¹ under normal and deficit irrigation after the first and second cycles are shown in Table (6). Direct selection for high grain yield plant⁻¹ for two selection cycles under normal irrigation and evaluated under normal irrigation increased the number of spikes plant⁻¹ (9.17%), number of kernels spike⁻¹ (8.23%) and biological the yield plant⁻¹ (36.52%), while it decreased days to heading (-4.93%), days to maturity (-3.08%) and 100-kernel weight (-2.32) than the bulk sample. Also, this direct selection increased days to heading (1.53%), the number of spikes plant⁻¹ (3.27%), number of kernels spike⁻¹, (4.22%), 100-kernel weight (1.76) and biological yield plant⁻¹ (27.64%), while it decreased days to maturity (-0.59%) than the better parent. Direct selection for high grain yield plant⁻¹ for two cycles under deficit irrigation and evaluated under normal irrigation increased the number of spikes plant⁻¹ (14.10%), the number of kernels spike⁻¹ (10.51%) and biological yield plant⁻¹ (20.73%) and decreased days to heading (-2.15 %), days to maturity (-1.44%) and 100-kernel weight (-8.02) than the bulk sample, while it increased days to heading (4.50%), days to maturity 1.09%) the number of spikes plant⁻¹ (7.94%), number of kernels spike⁻¹, (6.41%), and biological yield plant⁻¹ (12.87%) and decreased 100-kernel weight (-4.18%) than the better parent.

3.2.4. Means and observed gains under deficit irrigation evaluation

The group of F₅ families selected under normal irrigation and evaluated under deficit irrigation (Table 5), ranged in grain yield plant⁻¹ from 17.92 to 23.67 with an average of 20.78 g plant⁻¹. The observed gain significantly ($P < 0.01$) out-yielded the bulk sample and better parent by 16.87 and 15.44%, respectively, and it varied from 0.79% for family No. 57 to 32.58% for family No. 67 and from -0.44% for family No. 57 to 30.96% for family No. 67 compared to the bulk sample and better parent, respectively. All selected families, except family No. 23 and No.

57 significantly ($P < 0.01$) out-yielded the bulk sample and better parent. On the other hand, grain yield of the group of F₅ families selected under deficit irrigation and evaluated under deficit irrigation, ranged from 19.34 to 23.70 g with an average of 21.35 g plant⁻¹. The observed gain significantly ($P < 0.01$) out-yielded the bulk sample and better parent by 20.08 and 18.61%, respectively and it varied from 8.75% for family No. 64 to 33.28% for family No. 9, and from 7.42% for family No. 64 to 31.65% for family No. 9, as compared to the bulk sample and better parent, respectively. All selected families showed significant ($P < 0.01$) observed gain over the bulk sample, while all selected families except family No. 64 showed highly significant observed gain over the better parent.

3.2.5. Correlated response to selection

Selection for high grain yield plant⁻¹ for two cycles under normal irrigation and evaluated under deficit irrigation (Table 6) increased the number of spikes plant⁻¹ (6.30%), the number of kernels spike⁻¹, (11.06%) and biological yield plant⁻¹ (35.98%) and decreased days to heading (-4.46%), days to maturity (-4.01%) and 100-kernel weight (-0.66%) than the bulk sample, while it increased the number of spikes plant⁻¹ (8.45%), the number of kernels spike⁻¹ (3.29%), 100-kernel weight (0.45%) and biological yield plant⁻¹ (28.42%) and decreased days to heading (-1.37%) and days to maturity (-1.73%) than the better parent. On the other hand, selection for high grain yield plant⁻¹ for two cycles under deficit irrigation and evaluated under deficit irrigation increased number of spikes plant⁻¹ (11.52 and 13.77%), number of kernels spike⁻¹ (14.00 and 6.02%) and biological yield plant⁻¹ (22.99 and 16.15%) and decreased days to heading (-4.15 and -1.05%) and days to maturity (-2.97 and -0.67%) and 100-kernel weight (-5.30 and -4.24%) than the bulk sample and better parent, respectively.

These results indicated that the pedigree method of selection was effective in isolating high yield genotypes and the direct selection for grain yield *per se* was effective. Also, the current results stated that selection for high grain yield plant⁻¹ for the two cycles under deficit irrigation was better than selection under normal irrigation either evaluation was practiced under normal or under deficit irrigation. These results are in line with those reported by Attia (2003), Zakaria (2004), Ahmed (2006), Abd El-Kader (2011), Mahdy *et al.* (2012), Mahdy (2012) and Soliman *et al.* (2015). Ali (2011) indicated that

Table (6): Direct and correlated gain for grain yield plant⁻¹ in the two cycles of selection in percentages over the bulk OG % (Bulk) and the better parent OG% (BP) under normal irrigation (N) and deficit irrigation (D) regimes.

Item	Grain yield plant ⁻¹	Days to heading	Days to maturity	No. spikes plant ⁻¹	No. kernels spike ⁻¹	100-kernel weight	Biological yield	
Evaluation under normal irrigation								
F₄ families (C₁)	21.60	89.53	141.43	12.60	38.21	4.50	62.18	
Bulk sample	17.98	93.33	147.33	12.14	34.08	4.38	48.67	
Sids 1 (P1)	19.83	92.00	144.33	11.92	38.72	4.30	55.00	
Misr 2 (P2)	20.97	88.33	140.67	12.53	39.41	4.34	53.33	
OG% (Bulk)	20.13*	-4.07*	-4.00**	3.79	12.12*	2.74	27.76**	
OG% (BP)	3.0	1.36	0.54	0.56	-3.04	3.69	13.05*	
F₅ families (C₂)	N	23.92	94.76	141.83	12.62	41.28	4.63	74.17
	D	24.25	97.53	144.23	13.19	42.15	4.36	65.59
Bulk sample	21.00	99.67	146.33	11.56	38.14	4.74	54.33	
Sids 1 (P1)	19.98	96.00	144.33	11.78	37.32	4.55	54.00	
Misr 2 (P2)	21.89	93.33	142.67	12.22	39.61	4.53	58.11	
OG% (Bulk)	N	13.92**	-4.93*	-3.08**	9.17	8.23*	-2.32	36.52**
	D	15.48*	-2.15*	-1.44*	14.10**	10.51**	-8.02**	20.73**
OG% (BP)	N	9.27**	1.53	-0.59	3.27	4.22	1.76	27.64**
	D	10.78	4.50**	1.09	7.94	6.41	-4.18	12.87**
Evaluation under deficit irrigation								
F₄ families (C₁)	16.48	87.96	138.46	11.51	38.01	3.66	54.83	
Bulk sample	14.26	91.67	141.67	11.27	32.58	3.89	42.33	
Sids 1 (P1)	15.96	89.00	139.33	11.25	35.99	3.95	45.67	
Misr 2 (P2)	15.83	86.33	136.33	10.73	38.79	3.84	44.00	
OG% (Bulk)	15.57**	-4.05	-2.27	2.13	16.67**	-5.91	29.53**	
OG% (BP)	3.26	1.89	1.56	2.31	-2.14	-7.34	20.06**	
F₅ families (C₂)	N	20.78	91.40	138.23	11.81	39.27	4.50	61.64
	D	21.35	91.70	139.73	12.39	40.31	4.29	55.75
Bulk sample	17.78	95.67	144.00	11.11	35.36	4.53	45.33	
Sids 1 (P1)	18.00	94.67	142.67	10.89	37.06	4.48	48.00	
Misr 2 (P2)	17.80	92.67	140.67	10.67	38.03	4.40	46.00	
OG% (Bulk)	N	16.87**	-4.46**	-4.01**	6.30	11.06**	-0.66	35.98**
	D	20.08**	-4.15**	-2.97*	11.52*	14.00**	-5.30	22.99**
OG% (BP)	N	15.44**	-1.37	-1.73	8.45	3.29	0.45	28.42**
	D	18.61**	-1.05	-0.67	13.77**	6.02	-4.24	16.15*

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

pedigree selection for grain yield was effective in increasing grain yield. Also he found a decrease in 100-kernel weight from the bulk sample when selection was practiced at normal and drought stress.

3.3. Drought susceptibility index and sensitivity to environments

The drought susceptibility index (DSI) and sensitivity to environments of the selected

families for grain yield plant⁻¹ are presented in Table(7). The present results indicated that among the families which were selected under normal irrigation and evaluated under both regimes, six families (No. 7, 23, 47, 67, 74 and 91) showed DSI of 0.61, 0.96, 0.37, 0.94, 0.58 and 0.40, respectively. The six families which gave DSI less than one gave less than one (less sensitivity) in the sensitivity test. These families

Table (7): Drought susceptibility index (DSI) and sensitivity (S) to environments of selected families under normal irrigation and deficit irrigation after two cycles of selection for grain yield plant⁻¹.

	Environment of selection									
	Normal irrigation					Deficit irrigation				
	Environment of evaluation					Environment of evaluation				
	Fam. No.	N	D	DSI	S	Fam. No.	N	D	DSI	S
F₅ selected families	7	23.39	21.52	0.61	0.58	8	23.69	21.41	0.81	0.71
	17	26.13	21.17	1.46	1.54	9	25.56	23.70	0.61	0.58
	23	21.32	18.65	0.96	0.83	11	25.44	20.80	1.52	1.44
	27	25.51	21.00	1.35	1.40	13	28.67	22.66	1.75	1.87
	37	26.45	20.66	1.68	1.80	16	21.55	20.71	0.32	0.26
	47	22.45	21.37	0.37	0.34	32	24.18	20.81	1.16	1.05
	57	22.24	17.92	1.46	1.34	41	22.63	21.67	0.35	0.30
	67	26.80	23.67	0.94	0.97	50	26.94	22.23	1.46	1.46
	74	23.51	21.72	0.58	0.56	59	21.35	20.23	0.44	0.35
	91	21.34	20.23	0.40	0.34	64	22.51	19.34	1.17	0.98
	Mean	23.92	20.78		0.97	Mean	24.25	21.35		0.90
Sids 1	19.98	18.00	0.76	0.61	Sids 1	19.98	18.00	0.76	0.61	
Misr 2	21.89	17.80	1.43	1.27	Misr 2	21.89	17.80	1.43	1.27	
Bulk	21.00	17.78	1.18		Bulk	21.00	17.78	1.18		

N = normal irrigation

D = deficit irrigation

S = sensitivity

could be used as a source of drought tolerance or factors contributing to general adaptation. It could be noticed that the superior family No. 67 was less susceptible and less sensitive to drought and showed significant observed gain over the better parent under normal and deficit irrigation, so it can be a good and stable cultivar. The results of deficit irrigation group of families showed that five families (No. 8, 9, 16, 41 and 59) gave DSI of 0.81, 0.61, 0.32, 0.35 and 0.44, respectively, and all these families gave lower values of sensitivity. The families No. 11, 13 and 50 had high grain yield plant⁻¹ under normal and deficit irrigation, but they had DSI more than unity. On the other hand, the family No. 9 was less susceptible and less sensitive to drought, and showed significant observed gain over the better parent under normal and deficit irrigation, so it can be a good and stable cultivar.

The mean sensitivity to drought of the selected families for high grain yield plant⁻¹ under normal irrigation was 0.97, while it was 0.90 for the selected families under deficit irrigation (Table 7). These results concluded that

the antagonistic selection reduced sensitivity to drought stress and synergistic selection increased it. The relative merit after two cycles of selection for high grain yield was 1.11 when selection was under normal and deficit irrigation and evaluated under normal irrigation, while it was 1.19 when selection was under normal and deficit irrigation and evaluated under deficit irrigation. These results indicated that antagonistic selection was better than synergistic selection to increase grain yield plant⁻¹ in these materials, either evaluation was under normal or deficit irrigation. Similar results have been reported by Jinks and Connolly (1973 and 1975), Jinks and Pooni (1982), Ceccarelli and Grando (1991 a and b), Mohamed (2001) and Kheiralla *et al.* (2006). Mahdy (2012) found that antagonistic selection reduced sensitivity of the selected families, while antagonistic selection decreased it. Falconer (1990) reported that to increase the mean performance, selection should be made upwards in a bad environment, and conversely, to decrease mean performance downwards selection should be made in a good environment.

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الإنتخاب لمحصول الحبوب تحت نظامي الري العادي والري المنخفض في قمح الخبز

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ملخص

يهدف هذا البحث إلى دراسة الاستجابة للانتخاب المباشر لمحصول الحبوب/النبات في قمح الخبز تحت ظروف الري العادي والري المنخفض وكذلك تقدير الاستجابة المرتبطة للصفات الأخرى تحت الدراسة. تمت ممارسة الانتخاب لمدة دورتين على عشيرة من القمح (سدس 1×مصر 2) من الجيل الثالث إلى الجيل الخامس تحت كل نظام ري منفصلاً. كان مقدار التباين الوراثي منخفض قليلاً عن التباين المظهري تحت النظامين وبصفة عامة انخفض تدريجياً من الجيل الثالث إلى الجيل الخامس. كانت كفاءة التوريث بالمعنى الواسع لمحصول الحبوب/النبات بعد دورتين من الانتخاب (65.66، 59.95%) تحت ظروف الري العادي والري المنخفض على التوالي. كما كانت كفاءة التوريث المدركة تحت الري العادي (47.94، 53.66%) بينما كانت (34.90، 58.64%) تحت الري المنخفض بعد الدورة الأولى والثانية على التوالي. أدى الانتخاب لمحصول الحبوب تحت ظروف الري العادي والري المنخفض والتقييم تحت ظروف الري العادي إلى زيادة في محصول الحبوب بنسبة (13.92، 15.48%) بالنسبة لإجمالي العشيرة و (9.27، 10.78%) بالنسبة للأب الأفضل. بينما أدى الانتخاب لمحصول الحبوب تحت ظروف الري العادي والري المنخفض والتقييم تحت ظروف الري المنخفض إلى زيادة بنسبة (16.87، 20.08%) بالنسبة لإجمالي العشيرة و (15.44، 18.61%) بالنسبة للأب الأفضل. أظهر دليل الحساسية للجفاف أن 6 عائلات من العائلات المنتخبة تحت الري العادي وكذلك 5 عائلات من العائلات المنتخبة تحت ظروف الري المنخفض كانت متحملة للإجهاد المائي وذات محصول عالي تحت ظروف الري المنخفض. كان الانتخاب المتضاد أفضل من الانتخاب المتوافق في تحسين المتوسط وكذلك خفض الحساسية للإجهاد المائي لصفة محصول الحبوب/النبات.

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