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Response to Pedigree Selection for Earliness and Grain Yield in Spring Wheat under Heat Stress

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ABSTRACT

The objectives of this study were to estimate the response to direct selection for early heading and grain yield under favourable and stress environments and to study the correlated response of other studied traits. Two cycles of pedigree selection for earliness and grain yield/plant were completed on a segregating population of wheat in the F_3-F_5 generations. Selection for each trait was, separately and over environments, practiced at favourable, stress and over environments. After two cycles of selection for earliness, the realized gain reached to -2.19, -1.85 and -1.72% from the bulk samples for selection under favourable, stress and over environments, respectively. The realized gains from selection for increasing grain yield/plant were 17.32, 24.16 and 7.48% from the bulk samples for selection under favourable, stress and over environments, respectively. The antagonistic selection was more efficient than synergistic selection in changing the mean and in decreasing the sensitivity to environments. Selection for earliness was accompanied by undesired decrease in all correlated traits over the bulk sample at favourable, stress and over environments. However, selection for grain yield/plant was accompanied by late in days to heading and decrease in 1000-grain weight from the bulk sample at favourable, stress and over environments. Two families; No. 58 and No. 50 could be considered the best selected families resulted from selection for earliness and grain yield/plant, respectively which earlier and higher than the bulk sample under different environments. Pedigree selection for either earliness or grain yield/plant was effective in isolating genotypes for early heading and high grain yield.

Key words: Pedigree selection, grain yield, spring wheat, heat stress

INTRODUCTION

Wheat is the most important grain crop not only in Egypt but also all over the world. Its production in many regions of the world is below average because of adverse environmental conditions. A recent increase in Egyptian wheat production is not sufficient to meet the demands of a growing population (El-Maghraby *et al*., 2005). The use of different planting dates allow for subjecting the plant at different developmental stages to various temperature regimes. However, high temperature during the grain filling period is a major environmental factor which drastically reduces wheat production in Upper Egypt (Kheiralla *et al*., 2001). Heat stress is a major limitation to wheat (*Triticum aestivum* L.) productivity in arid, semiarid, tropical and subtropical regions of the world (Ashraf and Harris, 2005). Consequently, development of heat-tolerant cultivars is of major concern in wheat breeding programs. A detailed understanding of the genetics and physiology of heat tolerance as well as the use of the proper germplasm and selection methods will facilitate the development of heat tolerant cultivars (Mohammadi *et al*., 2007).

Exposure to higher than optimal temperatures reduces yield and decreases quality of cereals (Wardlaw *et al*., 2002). High temperatures during floral initiation and spikelet development (a period of several weeks preceding anthesis) reduce the potential number of grains, thus determining maximum yield potential. Heat stress during the post-anthesis grain-filling stage affects availability and translocation of photosynthates to the developing kernel and starch synthesis and deposition within the kernel, thus resulting in lower grain weight and altered grain quality (Mohammadi *et al*., 2004).

Selection for grain yield is one of the most important and difficult challenges of plant breeding. Pedigree selection method can be used to identify superior genotypes for grain yield in a cultivar development program (Ali *et al*., 2006). In Egypt, earliness has several advantages, for instance, early cultivars are highly needed to fit in new crop intensive rotation as planting cotton after wheat and planting wheat after harvesting short duration vegetable crops, etc. Also, early cultivars are preferable to escape drought, heat, disease, pests and other stress injuries that occur at the end of the growing season (Menshawy, 2007).

Pedigree selection method was effective to produce new lines tolerant to drought stress (Tammam *et al*., 2004). Direct selection for earliness under stress is expected to be more effective than indirect selection were observed by Ali and Abo-El-Wafa (2006). Zakaria (2004), Shamroukh (2006) and El-Morshidy *et al*. (2010) mentioned that selection was effective in improving grain yield but it was associated to undesired increase in late heading. Maich *et al*. (2000) reported that yield increase of 15% after two cycles of selection. El-Shazly *et al*. (2000) and Attia (2003) found that heritability estimates were high for days to heading, 1000-grain weight and grain yield/plant under normal and stress conditions. Evaluating grain yield under heat stress has long been practiced by breeders to identify genotypes better adapted to hot conditions. The objectives of this study were to: (1) estimate the response to direct selection for early heading and grain yield under early (optimum environment) and late (adverse environment) planting (2) Study the correlated response of other studied traits.

MATERIALS AND METHODS

Field experiment were conducted at South Valley University Experimental Farm at Qena from 2007/2008 to 2009/2010 seasons. Table 1 shows some physical and chemical properties of a representative soil sample of the experimental site. In this research, the materials used were 100 F_3 families traced back to a random sample from F_2 single plants originated from a cross (Sakha 8 x Sahel 1). The origin and pedigree for parents of this population are presented in Table 2.

Table 1: Some physical and chemical properties of a representative soil sample of the experimental site

Soil property	Value
Sand (%)	74
Silt (%)	16.6
Clay (%)	9.4
Soil texture	Sandy loam
PH (1:1 soil : Water suspension)	8.12
Organic matter (%)	0.35
Total N (%)	0.04
Available P (ppm)	9.4
K^+ (meq/100 g soil)	0.19
Calcium carbonate (%)	13.6

Table 2: The pedigree and origin of the parents used in this study

Parental name	Pedigree	Origin
Sakha 8 (P_1)	Indus 66 x Norteno"S"/PK 3418-65-ISW-OS	ICARDA
Sahel 1 (P_2)	NS 732/PIMA//Veery"S"	ICARDA

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 planting dates, on 15th November (Favourable or recommended planting time in the area) and 15th of December (Stress or late planting) in 2007/2008 growing season. A randomized complete block design with three replications was used for each planting date. Each plot consisted of a single row, 3 m long, 20 cm apart and 10 cm between hills within a row (average 30 individual plants per row). The culture practices were conducted as recommended for wheat production throughout the growing season in the two planting dates. Data were collected from ten random guarded plants in each plot. Separate and combined analyses of variance of the two planting dates were applied on a plot mean basis (Federer, 1963). A plot mean is an average of these ten guarded plants in each plot for every measured trait in this study. The recorded traits were days to heading (days), plant height (cm), spike length (cm), 1000-grain weight (g) and grain yield/plant (g). The family means provided the basis of pedigree selection for days to heading and grain yield/plant. The best plant from each of the best 20 families was saved in each environment; favourable, stress and over environments.

The selections of the favourable environment (15th November) were planted at favourable environment and the selections of the stress environment were planted at stress environment as well as the over environments selections were planted at the two planting dates in 2008/2009 growing season. The experimental design, number of replications, planting dates and cultural practices were properly conducted as the same in the first season. After the analysis of variance the best plant from the best five families were saved for each selection criterion in each environment; favourable, stress and over environments.

All F_5-selected families were compared along with the parents and the bulk sample at the two planting dates in 2009/2010 growing season. The same experimental design, number of replications, planting dates and field procedures were conducted as the same in the first and second seasons.

Weather data included maximum and minimum daily temperature and daily relative humidity measured from planting date to mean date of physiological maturity in each season are shown in Table 3.

Statistical analysis: The analysis of variance and covariance were computed according to Federer (1963). Test of significance were made by using revised LSD method according to El-Rawi and Khalafalla (1980). Estimation of genotypic and phenotypic coefficients of variation was performed on a plot mean basis according to Burton (1952). Heritability in broad sense as outlined by Walker (1960) was calculated.

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 (Falconer, 1990).

RESULTS AND DISCUSSION

The planting dates used to evaluate the selected families performance in this study provided a range of variation in seasonal climate (Table 3). The climatic conditions were different during the three growing seasons. High temperature stress (late planting) during the grain filling period indirectly reduces yield by directly affecting various yield components. Hence, grain yield as a selection criterion to select against heat stress remains the most reliable yardstick.

Base population: Significant differences ($p<0.01$) were observed among selected families for days to heading, plant height, spike length, 1000-grain weight and grain yield/plant in the combined analysis (Table 4). This reflects the genetic variability among selected families in these traits. Significant differences ($p<0.01$) in all traits were also observed between environments and environment x selected families interaction, indicating the differential responses of the selected families to climatic factors prevailed in the two environments. In addition, the highly significant mean squares obtained for selected families vs. bulk, indicated the feasibility of selection for grain

Table 3: Weather data, November to May during experiments where wheat trials were conducted in 2007/2008, 2008/2009 and 2009/2010 seasons

	Average temperature						Relative humidity%					
	Maximum			Minimum			Maximum			Minimum		
Month	2007/ 2008	2008/ 2009	2009/ 2010	2007/ 2008	2008/ 2009	2009/ 2010	2007/ 2008	2008/ 2009	2009/ 2010	2007/ 2008	2008/ 2009	2009/ 2010
15th November	26.5	28.6	25.6	10.2	13.8	13.2	59.2	57.6	71.2	19.6	21.3	26.9
December	23.5	24.6	24.9	9.4	10.4	9.4	63.4	68.2	62.1	20.4	24.9	24.1
January	19.8	23.3	25.2	7.6	8.0	9.5	66.9	61.5	66.7	22.9	23.1	23.9
February	23.4	25.0	28.4	8.7	9.8	13.2	63.0	49.6	49.9	19.6	15.9	17.9
March	31.9	27.7	31.7	16.0	12.3	15.9	43.6	51.0	50.3	8.6	14.3	12.9
April	35.7	35.3	32.7	19.2	19.6	17.7	34.9	33.6	37.6	6.4	7.5	10.3
May	37.1	35.9	38.4	22.5	21.7	22.7	26.9	31.8	32.0	4.5	7.8	7.0

Source: The data introduced from Meteorological station, Qena, Egypt, during 2007/2008-2009/2010

Table 4: Combined analysis of variance for the studied traits in the F_3-generation in 2007/2008 season (base population)

		Mean squares				
Source of variance	df	Days to heading (days)	Plant height (cm)	Spike length (cm)	Grain yield/plant (g)	1000-grain weight (g)
Enviroumeuts (Env.)	1	27868.12**	22656.41**	950.16**	897.76**	2346.31**
Reps/Env.	4	674.44	288.78	6.38	14.13	7.83
Genotypes (G)	102	547.94**	1051.37**	14.53**	63.64**	150.55**
Selected families	99	548.07**	580.20**	9.51**	64.86**	80.33**
Env.×G	102	35.04**	112.76**	2.90**	8.88*	7.04**
Env.×sel. families	99	34.00**	112.21**	2.83**	9.11**	6.98**
Fam. vs. parents	1	55375.13**	58163.56**	963.17**	6489.96**	8088.05**
Fam. vs. bulk	1	54794.42**	57769.88**	942.76**	6422.07**	7973.17**
Error (Genotypes)	408	24.42	29.03	1.27	6.82	4.39
Error (Selected families)	396	24.98	29.41	1.25	6.87	4.24

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

yield/plant and days to heading in this population. These results reflect the importance of evaluating selections under several environments.

Results in Table 5 showed sufficient phenotypic and genotypic coefficients of variability among the selected families for selection criterion; days to heading and grain yield/plant. Broad sense heritability (Table 5) was high in magnitude for days to heading (0.95) and grain yield/plant (0.89). Genetic coefficient of variation together with a heritability estimate would seem to give the best picture of the amount of the genetic advance from selection (Burton, 1952; Sanghi *et al.,* 1964). Similar results were obtained by Wiersma *et al.* (2001), Utz *et al.* (2001), Attia (2003), Zakaria (2004), Tammam *et al.* (2004), Benmoussa and Achouch (2005), Shamroukh (2006) and El-Morshidy *et al.* (2010).

The second cycle of selection: The analysis of variance of the five selected families for selection criteria; earliness and grain yield/plant showed significant ($p<0.01$) differences after two cycles of selection (Table 6). However, the interaction between environments and genotypes was significant ($p<0.01$), either selection was practiced at one or over environments, reflecting differential responses of the selected families to changing in environment. Significant mean squares obtained for families vs. bulk indicated the feasibility of selection for earliness and grain yield/plant in this population. These results reflect the importance of evaluating selections under different environments. Similar results were reported by Attia (2003), Zakaria (2004), Tammam *et al.* (2004), Benmoussa and Achouch (2005), Shamroukh (2006) and El-Morshidy *et al.* (2010).

Pedigree selection for earliness: After two cycles of selection for earliness, the genotypic coefficient of variability was greatly depleted and ranged from 2.45% for selection under stress environment to 3.64% for selection over environments as estimated from the combined analysis of the data at each environment of selection (Table 7). Estimates of heritability ranged from 0.94 to 0.97 as shown from the combined analysis as well.

Pedigree selection for earliness succeeded in decreasing days to heading after two cycles of selection. The realized gains at each environment showed -2.19 and -1.85% decrease in days to heading over the bulk sample for favourable and stress environment selections, compared to -1.72% for selections over environments (Table 8). This means that selection under favourable environment was the best to that either at stress environment or over environments.

With respect to the correlated response to decrease days to heading (Table 8) grain yield/plant also decreased by -6.64, -4.55 and -2.10% from the bulk sample when selection was practiced at early, late and over the two planting dates, respectively. Herein, responses of plant

Table 5: Means, phenotypic and genotypic coefficients of variability and broad sense heritability for the studied traits in the base population over environments

Item	Days to heading (days)	Plant height (cm)	Spike length (cm)	Grain yield/plant (g)	1000-grain weight (g)
Sakha 8	86.17	83.33	9.00	14.53	29.00
Sahel 1	89.67	76.67	7.67	11.72	32.00
Bulk	87.83	81.67	8.00	11.61	30.67
F_3 selected families	78.30	90.78	8.08	11.16	33.40
p.c.v.%	12.20	10.83	13.52	29.48	10.96
g.c.v.%	11.92	10.55	12.56	27.86	10.66
H%	0.95	0.95	0.87	0.89	0.95

p.c.v., g.c.v: Phenotypic and genotypic coefficients of variability, respectively. H: Broad sense heritability

Table 6: Mean squares of the selected families of the second cycle, parents and bulk sample evaluated at the two planting dates and combined

		Mean squares														
		Favourable environment					Stress environment					Over environment				
		Direct selection	Correlated traits				Direct selection	Correlated traits				Direct selection	Correlated traits			
Source of variance	df	Days to heading (day)	Plant height (cm)	Spike length (cm)	1000-grain weight (g)	Grain yield/plant (g)	Days to heading (day)	Plant height (cm)	Spike length (cm)	1000-grain weight (g)	Grain yield/plant (g)	Days to heading (day)	Plant height (cm)	Spike length (cm)	Grain yield/plant (g)	1000-grain weight (g)
Environments (Env.)	1	954.1**	1408.3**	42.19**	77.52**	75.85**	1220.1**	675.0**	52.08**	80.08**	91.63**	1092.5**	602.1**	56.33**	50.02**	127.14**
Reps/Env.	4	9.5	15.1	0.92	2.67	0.64	10.1	29.7	0.40	1.46	0.98	8.4	16.1	1.21	2.73	0.43
Genotypes (G)	12	79.6**	304.5**	11.33**	42.43**	4.67**	67.8**	346.4**	13.38**	25.70**	8.53**	81.2**	265.2**	6.71**	61.00**	21.23**
Sel. families	9	37.1**	177.1**	18.22**	59.03**	6.45**	22.2**	397.1**	20.03**	21.72**	13.24**	47.7**	78.3**	8.70**	91.78**	35.12**
Env.×G	12	14.3**	77.4**	1.66	2.43	1.58	16.7**	58.3**	1.75*	4.27*	4.11**	13.3**	15.2*	1.33*	1.93	7.24*
Env.×sel. families	9	12.6**	105.4**	2.55*	4.03	1.63	8.6**	82.1*	2.63*	7.25**	5.38**	7.2**	20.0**	1.70*	2.88*	9.58*
Fam. vs. parents	1	224.4**	1084.8**	0.04	0.40	1.13	201.6**	154.8*	3.44*	40.86**	1.13	193.4**	1183.4**	5.26**	7.74**	3.79
Fam. vs. bulk	1	14.5**	3.5	0.94	7.20*	3.09	10.3*	306.8**	6.42**	2.94	1.57	8.9*	6.8	0.01	0.20	0.33
Error (G)	48	2.3	12.1	1.42	1.02	2.43	2.5	16.0	0.68	1.29	1.03	3.4	6.0	0.40	1.23	2.86
Error (Sel. families)	36	1.6	10.0	0.76	1.16	1.36	1.4	18.3	0.68	1.51	0.42	1.5	3.5	0.43	0.71	2.21

		Direct selection	Correlated traits				Direct selection	Correlated traits				Direct selection	Correated traits			
Source of variance	df	Grain yield/plant (g)	Days to heading (day)	Plant height (cm)	Spike length (cm)	1000-grain weight (g)	Grain yield/plant (g)	Days to heading (day)	Plant height (cm)	Spike length (cm)	1000-grain weight (g)	Grain yield/plant (g)	Days to heading (day)	Plant height (cm)	Spike length (cm)	1000-grain weight (g)
Environments (Env.)	1	173.77**	1170.2**	1102.1**	90.75**	161.33**	83.71**	1150.5**	602.1**	52.08**	126.8**	99.02**	945.2**	1408.3**	44.08**	325.5**
Reps/Env.	4	0.79	7.8	8.9	1.17	0.15	0.66	6.2	14.6	0.92	0.8	0.45	9.9	17.7	1.27	6.0
Genotypes (G)	12	22.34**	87.3**	223.8**	10.43**	23.67**	23.24**	66.7**	178.3**	2.48*	21.1**	22.64**	79.9**	253.6**	11.86**	27.9**
Sel. families	9	26.78**	94.5**	138.3**	16.38**	9.33**	17.72**	52.9**	44.6*	2.55**	6.2**	36.54**	81.6**	340.4**	14.17**	14.9**
Env.×G	12	8.52**	24.7**	67.6**	0.99	5.76**	4.36**	20.2**	42.6**	3.46*	3.6*	2.79*	20.2**	53.6**	0.89	10.6**
Env.×sel. families	9	9.22**	24.5**	96.7**	0.78	7.20**	6.08**	17.3**	67.9**	5.58**	4.9*	2.90*	23.3**	56.3**	1.13*	4.5
Fam. vs. parents	1	35.59**	20.6**	760.1**	1.37	57.20**	68.24**	58.7**	814.8**	0.61	0.1	7.11*	20.6**	64.8*	11.67**	0.9
Fam. vs. bulk	1	19.69**	17.4**	50.1*	0.36	6.81*	38.32**	3.2*	61.3*	0.80	66.0**	3.68**	17.4**	61.3*	13.89**	82.7**
Error (G)	48	0.71	3.2	10.6	0.90	1.03	0.70	4.2	12.2	0.92	1.3	0.80	3.2	9.4	0.72	2.3
Error (Sel. families)	36	0.54	1.5	8.8	0.58	1.14	0.64	1.9	13.1	0.54	1.3	0.79	1.1	9.0	0.35	2.1

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

Table 7: Means, p.c.v., g.c.v. and heritability in broad sense in the F_5 selected families resulted from practicing pedigree selection for two cycles for days to heading and grain yield/plant

		Environment of selection								
		Favourable environment (Environment of evaluation)			Stress environment (Environment of evaluation)			Combined over environments (Environment of evaluation)		
Selection criteria	Item	Favourable envi.	Stress envi.	Combined over envi.	Favourable envi.	Stress envi.	Combined over envi.	Favourable envi.	Stress envi.	Combined over envi.
Days to heading (days)	F_5 sel. fam.	80.67	70.93	75.80	81.87	70.27	76.07	81.53	70.80	76.17
	Bulk sample	82.67	72.33	77.50	82.67	72.33	77.50	82.67	72.33	77.50
	p. c. v. %	3.51	4.13	3.28	2.42	3.59	3.53	3.15	4.83	3.70
	g. c. v. %	3.48	3.89	3.21	2.15	3.56	2.45	2.93	4.81	3.64
	H %	0.99	0.89	0.96	0.79	0.99	0.94	0.87	0.99	0.97
Grain yield/plant (g)	F_5 sel. fam.	15.82	11.07	13.44	15.67	12.79	14.23	13.94	10.69	12.32
	Bulk sample	13.25	9.67	11.46	13.25	9.67	11.46	13.25	9.67	11.46
	p. c. v. %	18.93	15.72	15.71	16.04	9.70	12.07	21.22	19.62	20.03
	g. c. v. %	18.58	15.65	15.55	15.59	9.95	11.86	20.69	19.40	19.82
	H %	0.96	0.99	0.98	0.95	0.95	0.96	0.95	0.98	0.98

Favourable environment: Early planting date (15th November). Stress environment: Late planting date (15th December). p. c. v. and g. c. v.: Phenotypic and genotypic coefficients of variability, respectively

height and spike length were also decreased at various environments of selection. In this respect, 1000-grain weight was decreased when selection was practiced at favourable environment (-3.32%) and over the planting dates, however, it was increased (2.12 and 0.66%) when selection performed at stress environment and over environments, respectively.

The means of days to heading of the selected families (Table 9) ranged from 70.8 to 80.5 days with an average of 75.8 days for favourable environment selections, from 70.3 to 81.9 days with an average of 76.1 days for stress environment selections and from 70.8 to 81.5 days with an average of 76.2 days over environments selections. Based on the definition of Jinks and Connolly (1973) in which antagonistic selection is selection downward in a good environment and synergistic selection is selection downward in a bad environment, so selection for decreasing days to heading at favourable environment (early planting date) is antagonistic and at stress environment (late planting date) is synergistic selection. The results indicated that antagonistic selection decreased sensitivity to 0.90 (Table 9). Kheiralla *et al.* (2001) reached the same conclusion. In contrast to these results, Mohamed (2001) and Zakaria (2004) found that synergistic selection was better than antagonistic selection for earliness.

Pedigree selection for grain yield/plant: Sufficient genetic variability was remained after two cycles of pedigree selection for increasing grain yield/plant. The estimated g.c.v. from the combined data was 15.55, 11.86 and 19.40% when selection was practiced at early, late and over the two planting dates, respectively (Table 7). The slight discrepancy between p.c.v. and g.c.v. resulted in high estimates of broad sense heritability for grain yield/plant. It accounted 0.98, 0.96 and 0.98 for the selections under favourable, stress and over environments, respectively.

The combined analysis for the collected data at each environment of selection indicated that the realized gains from pedigree selection for increasing grain yield/plant accounted for 17.32, 24.16 and 7.48% from the bulk sample when selection practiced at favourable, stress and over environments, respectively (Table 8). This reflects that selection at stress environment was superior

Table 8: Realized direct and correlated responses to pedigree selection measured in percentage from the bulk sample and better parent for days to heading (days) and grain yield/plant (g)

			Days to heading (days)					Grain yield/plant (g)				
			Direct selection	Correlated traits				Direct selection	Correlated traits			
Environment of selection	Environment of evaluation	Item	Days to heading (days)	Plant height (cm)	Spike length (cm)	1000-grain weight (g)	Grain yield/ plant (g)	Grain yield /plant (g)	Days to heading (days)	Plant height (cm)	Spike length (cm)	1000-grain weight (g)
Favourable environment	Favourable environment	F_5-BP	-0.82	9.29**	-8.33	7.72**	-4.07	21.80**	4.51**	6.79**	-0.56	17.43**
		F_5-Bulk	-2.42*	-1.29	-2.94	-2.86	-6.00	19.35**	2.82**	4.91*	-0.56	-0.34
	Stress environment	F_5-BP	-2.39	5.49	-2.14	6.32*	-11.47*	1.78	1.47	3.92	-5.00	10.95**
		F_5-Bulk	-1.94	-0.37	-5.52	-3.81	-7.47	14.52**	1.94*	1.92	-5.00	-5.89**
	Combined over environments	F_5-BP	-1.56	7.48**	-5.63	7.04**	-7.44	12.68**	3.07**	5.42**	-2.50	14.29**
		F_5-Bulk	-2.19*	-0.86	-4.13	-3.32*	-6.64	17.32**	2.41**	3.49*	-2.50	-3.03*
Stress environment	Favourable environment	F_5-BP	0.66	-1.07	-12.78*	13.66**	2.28	20.67**	3.11*	5.00	-6.11	9.11**
		F_5-Bulk	-0.97	-10.65*	-7.65	2.50	-6.81*	18.24**	1.45	3.16	-6.11	-7.39**
	Stress environment	F_5-BP	-3.30**	0.39	-11.43	12.42**	-5.71	17.55**	0.09	6.67*	-0.71	4.21
		F_5-Bulk	-2.86**	-5.19	-14.48*	1.71	-1.45	32.27**	0.55	4.62	-0.71	-11.61**
	Combined over environments	F_5-BP	-1.21	-0.37	-12.19**	13.06**	-1.36	19.25**	1.69	5.79*	-3.75	6.73**
		F_5-Bulk	-1.85*	-8.10**	-10.79*	2.12	-4.55	24.16**	1.03	3.85	-3.75	-9.44**
Combined over environments	Favourable environment	F_5-BP	0.25	7.14**	-2.70	8.71**	7.64	7.38	3.52**	0.71	-18.89**	12.48**
		F_5-Bulk	-1.37	-1.64	-2.70	-0.18	-1.93	5.22	1.85*	-1.05	-16.57**	-4.54*
	Stress environment	F_5-BP	-2.57**	9.02**	4.29	9.89**	-6.55	-1.72	2.57	-5.10	-15.00**	-2.11
		F_5-Bulk	-2.12**	-0.71	-2.67	1.36	-2.33	10.59*	3.04*	-6.92*	-15.00**	-16.96**
	Combined over environments	F_5-BP	-1.08	8.04**	0.31	9.39**	1.17	3.23	3.07**	-2.06	-17.19**	5.41*
		F_5-Bulk	-1.72*	-1.20	-2.69	0.66	-2.10	7.48	2.41*	-3.85*	-15.87**	-10.56**

Favourable environment: Early planting date (15th November). Stress environment: Late planting date (15th December)

Table 9: Means and sensitivity of the five selected family after two cycles of pedigree selection for days to heading (days) and grain yield/plant (g)

Selection criterion	Environment of selection: Favourable environment				Stress environment				Over environment			
	Family No.	Favo.	Stress	S	Family No.	Favo.	Stress	S	Family No.	Favou.	Stress	S
Days to heading (days)	19	80.0	75.0	0.5	2	82.7	67.7	1.4	26	85.7	76.7	1.0
	28	85.7	73.0	1.2	8	83.7	74.3	0.9	58	79.0	69.7	1.1
	58	79.0	69.7	0.9	36	80.7	69.0	1.1	59	82.0	68.0	1.6
	71	79.0	68.3	1.0	56	83.3	70.7	1.2	65	80.0	70.7	1.1
	92	79.3	68.7	1.0	58	79.0	69.7	0.9	80	81.0	69.0	1.4
	Mean	80.5	70.8	0.9	Mean	81.9	70.3	1.1	Mean	81.5	70.8	1.2
	Sakha 8	81.3	72.7									
	Sahel 1	86.7	83.0									
	Bulk	82.7	72.3									
Revised $LSD_{0.05}$		0.8	2.5			2.4	0.7			2.4	0.8	
Revised $LSD_{0.01}$		1.2	3.8			3.7	1.1			3.7	1.2	
Grain yield/plant (g)	50	19.2	14.1	1.4	21	12.3	11.5	0.2	14	12.7	9.4	0.9
	54	15.6	9.9	1.6	50	19.2	14.1	1.4	18	12.6	9.4	0.9
	59	15.6	10.1	1.5	56	16.4	11.4	1.4	49	12.7	9.2	1.0
	69	17.5	10.5	1.9	68	15.0	13.1	0.5	50	19.2	14.1	1.4
	93	11.2	10.7	0.1	74	15.4	13.8	0.4	97	12.4	11.3	0.3
	Mean	15.8	11.1	1.3	Mean	15.7	12.8	0.8	Mean	13.9	10.7	0.9
	Sakha 8	13.0	10.9									
	Sahel 1	11.4	10.4									
	Bulk	13.3	9.7									
Revised $LSD_{0.05}$		1.8	1.4			1.9	1.5			1.4	2.4	
Revised $LSD_{0.01}$		2.8	2.1			2.9	2.3			2.2	3.6	

S: Sensitivity, Favourable environment: Early planting date (15th November). Stress environment: Late planting date (15th December)

to that either at favourable environment or over environments. Moreover, the selected families showed the best increase over the bulk sample when they were evaluated at stress environment which accounted 15.26, 25.46 and 14.30% for favourable, stress and over environments selections, respectively.

Two cycles of pedigree selection for grain yield/plant increased days to heading from the mean bulk sample by 2.41, 1.03 and 2.41% when selection was practiced at favourable, stress and over environments, respectively (Table 8). Herein, responses of plant height were also increase at various environments of selection. In contrast, spike length and 1000-grain weight were generally decreased with the increase in grain yield/plant. These results are in line with those reported by Kheiralla *et al.* (2001), Mohamed (2001) and Zakaria (2004).

The family means for the three types of selection are presented in Table 9. It could be noticed that the overall family mean ranged from 15.8 to 11.1 g plant^{-1} for favourable environment selections, from 15.7 to 12.8 g plant^{-1} for stress environment selections and from 13.9 to 10.7 g plant^{-1} for selection over environment when selections were evaluated at favourable and stress environment, respectively, indicating that selection based on a range of environments or selection under stress environment may result in stable genotypes which performed well under different environments.

Table 10: Realized gains in percentages from the bulk sample for the best individual selected families resulted from practicing pedigree selection for plant criteria used in this study

		Days to heading (days)		Plant height (cm)		Spike length (cm)		1000-grain weight (g)		Grain yield/plant (g)	
Selection criterion	Family No.	Favourable envi.	Stress envi.	Favourable envi.	Stress envi.	Favourable envi.	Stress envi.	Favourable envi.	Stress envi.	Favourable envi.	Stress envi.
Days to heading (days)	58	-4.47	-3.60	1.63	3.58	8.57	6.70	10.91	15.55	12.60	7.24
Grain yield/plant (g)	50	-1.21	-3.22	7.02	1.92	2.83	3.64	0.86	1.79	44.36	45.36

Favourable environment: Early planting date (15th November). Stress environment: Late planting date (15th December)

The sensitivity of the selected families (Table 9) was less than unity and reached 0.80 at stress environment (antagonistic selection) but it was 1.30 at favourable environment (synergistic selection). These results indicated that selection for grain yield/plant at stress environment reduced the sensitivity, while selection at favourable environment increased the sensitivity. These results are in harmony with Jinks and Connolly (1973) and with the modification of Falconer (1990). This reflects that selection over environments was the best and the antagonistic selection was more efficient in changing the mean than synergistic one. Similar results were obtained by Kheiralla *et al.* (2001), Mohamed (2001) and Zakaria (2004).

It is of interest to recall that the breeder in practicing pedigree selection in autogamous crops concerns with the performance of individual selected families which is masked in most cases by the mean of selected families. Selection for decreasing days to heading resulted in one superior family; no. 58 which was earlier than the bulk sample by -4.47 and -3.60%, taller in plant height by 1.63 and 3.85%, higher in spike length by 8.57 and 6.70%, heavier in grain weight by 10.91 and 15.55% and out yielded it by 12.60 and 7.24% under favourable and stress, respectively (Table 10). Moreover, selection for increasing grain yield/plant resulted in one superior family; No. 50 which was higher than the bulk sample by 44.36 and 45.36%, earlier than it by -1.21 and -3.22%, taller in plant height by 7.02 and 1.92%, heavier in grain weight by 0.86 and 1.79% under favourable and stress environments, respectively. Similar results were reported by Attia (2003), Zakaria (2004), Tammam *et al.* (2004), Shamroukh (2006) and El-Morshidy *et al.* (2010).

CONCLUSION

These results indicated that the antagonistic selection was more efficient than synergistic selection in changing the mean and in decreasing the sensitivity to environments for selection criteria; earliness and grain yield/plant. Furthermore, pedigree selection for either earliness or grain yield/plant was effective in isolating genotypes for early heading and high grain yield in this material.

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