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Pedigree Selection for Grain Yield in Spring Wheat (*Triticum aestivum* L.) under Drought Stress Conditions

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ABSTRACT

The objective of this study was to estimate the response to direct selection for grain yield/plant under normal and water stress conditions and study the correlated response of other studied traits. Two cycles of pedigree selection for grain yield/plant were practiced on a segregating population of wheat (Giza 168×Sids 1) in the F_3-F_5 generations. Selection was practiced separately and over environments, at normal irrigation environment and drought stress irrigation environment. After the second cycle, the F_5 selected families were evaluated at the two environments. Pedigree selection for the two cycles at each environment showed 25.00 and 25.54% increase in grain yield/plant over the bulk samples for normal and drought stress selections, respectively, compared to 22.60% for selections over environments. The antagonistic selection was more efficient than synergistic selection in changing the mean. Selection for grain yield/plant was accompanied by late in heading date of 1.76, 4.07 and 0.13%, increase in plant height of 13.09, 9.79 and 7.38% and with decrease in 1000-grain weight of -2.01, -2.02 and -4.31% over the bulk sample when selection was practiced under normal, drought stress and over environments, respectively. Drought Susceptibility Index (DSI) was estimated for grain yield/plant. Four selected families i.e., No. 9 under normal environment, no. 71 under drought stress environment and no. 10 and 70 under over environments displayed DSI values less than one and the highest grain yield/plant. These families could be considered the best selected families resulted from selection for grain yield/plant. Pedigree selection for improving grain yield/plant was effective in isolating high yielding and drought tolerant genotypes.

Key words: Pedigree selection, grain yield, spring wheat, drought stress, drought susceptibility index

INTRODUCTION

Spring wheat (*Triticum aestivum* L.) is the strategic cereal crop in Egypt as well as the world. It plays an important role as an industrial and food crop. A recent increase in Egyptian wheat production is not sufficient to meet the demands of a growing population (El-Maghraby *et al.*, 2005). Throughout the growing season, it is exposed to different stresses (drought, heat, salinity and low soil fertility) causing reductions in crop yield particularly in new reclaimed area (Ali and Abo-El-Wafa, 2006). Selection for yield is one of the most important and difficult challenge of plant breeding. The efficiency of a breeding program for drought tolerance 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). Growth of wheat grain is reduced depending upon degree of water stress and on the rate of stress development, thereby limiting final wheat yield (Plaut *et al.*, 2004).

Drought and salinity are the most serious threats to agriculture and are far more important globally (Altman, 2003), water stress is major harmful factor in arid and semi-arid regions worldwide (Roy *et al.*, 2006). Breeding for drought tolerance by selecting solely for grain yield is difficult, because the heritability of yield under drought conditions is low, due to small genotypic variance or to large genotype-environment interaction variances (Blum, 1988).

The relative limitation of yield by source or sink is influenced by several factors and varies in different environments (Ahmadi *et al.*, 2009). The water is main abiotic limiting factors in many wheat producing areas of the world. Due erratic spatial and temporal distribution of rainfall, it is important to have cultivars with superior yield performance under limiting and non limiting soil moisture conditions. The uncertainly of water availability and of the temperature conditions during the crop growth period calls for better resilience under fluctuating water and temperature regimes (Singh and Chaudhary, 2006).

Pedigree selection method can be used to identify superior genotypes for grain yield in a cultivar development program. Pedigree selection for grain yield/plant needs to evaluate selections under a series of environments such as different planting dates (Kheiralla *et al.*, 2001; Zakaria, 2004; Ali and Abo-El-Wafa, 2006); different water stress (Attia, 2003; Tammam *et al.*, 2004; Shamroukh, 2006; Golabadi *et al.*, 2006; El-Morshidy *et al.*, 2010). A major challenge to breeders and physiologists in these environments is to devise the most effective strategies for maximizing genetic gain and increase production (Kimurto *et al.*, 2005).

Attia (2003) observed yield improvement over the bulk sample after two cycles of selection. Zakaria (2004) and El-Morshidy *et al.* (2010) achieved increased in grain yield with increase in grain weight but it was associated to undesired late in heading. Maich *et al.* (2000), Golabadi *et al.* (2006) and Shamroukh (2006) mentioned that selection was effective in improving grain yield under normal and drought conditions. Pedigree selection method was effective to produce new lines tolerant to drought stress (Tammam *et al.*, 2004). The objective of this study was to estimate the response to direct selection for grain yield/plant under normal and water stress conditions and study the correlated response of other studied traits.

MATERIALS AND METHODS

This investigation was carried out at South Valley University Experimental Farm at Qena from 2007/2008 to 2009/2010 seasons. The soil type was sandy loam. Table 1 shows some physical and chemical properties of a representative soil sample of the experimental site.

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

Trait	Value
Sand (%)	74
Silt (%)	16.6
Clay (%)	9.4
Soil texture	Sandy loam
Field capacity	16.5%
Wilting point	8.0%
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

[†]Data supplied by the department of soils, Factory of Agriculture, South Valley University, Qena, Egypt

The materials used were 100 F_3 families tracing back to a random sample of F_2 single plants originated from the cross (G 168×Sids 1).

In 2007/2008 growing season, 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 on 15th November in two field experiments. The first experiment was grown in supplemental water applied regularly as recommended (Normal) while the other one did not receive any irrigation after jointing stage (drought stress). A randomized complete block design with three replications was used for each experiment. 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/row). The cultural practices were applied as recommended for wheat production in the two treatments. Data were collected from ten random guarded plants in each plot. Separate and combined analyses of variance of the two treatments were applied on a plot mean basis. 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 heading date (days), plant height (cm), 1000-grain weight (g) and grain yield/plant (g). The family means provided the basis of pedigree selection for grain yield/plant. The best plant in grain yield from each of the best 20 families was saved in each and over environments.

In 2008/2009 growing season, the selections from the normal environment (normal irrigation) were planted under normal irrigation and the selections from the water stress environment were planted under water stress as well as the over environments selections were planted at the two environments. The experimental design, number of replications, planting date and cultural practices were properly adopted as the same in the first season. After the analysis of variance the best plant from the best five families were saved in each environment and over environments.

In 2009/2010 growing season, all selections in the F_5-generation were compared along with the parents and the bulk sample at the two environments. The same experimental design, number of replications, planting date and field procedures were the same as in the first and second seasons.

Statistical analysis: The analyses of variance of trait means and covariance between pairs of traits were computed according to Snedecor and Cochran (1980). Differences between means were tested by the revised LSD according to El-Rawi and Khalafalla (1980). Genotypic and phenotypic coefficients of variation were computed on plot means according to Burton (1952). Broad sense Heritability was estimated following Walker (1960). Drought Susceptibility Index (DSI) was computed according to the method of Fischer and Maurer (1978) Equation:

$$DSI = (1 - Yd/Yp)/D$$

Where:

DSI = Drought susceptibility index

Yd = Mean yield in stress environment

Yp = mean yield in non-stress environment

D = Environmental stress intensity = 1-(Mean Yd of all genotypes/mean Yp of all genotypes)

RESULTS AND DISCUSSION

Base population: The combined analysis of variance over environments revealed significant differences ($p<0.01$) among selected families for days to heading, plant height, 1000-grain weight and grain yield/plant (Table 2). This indicates the genetic variability among selected families in these traits. However, significant differences ($p<0.01$) in all traits were also observed between

Table 2: Combined analysis of variance for the studied traits in the F_3-generation in 2007/2008 season (based population)

		Mean squares			
Source of variation	df	Days to heading (days)	Plant height (cm)	Grain yield plant (g^{-1})	1000-grain weight (g)
Environments (Env.)	1	12959.39**	23328.82**	1492.29**	165.70**
Reps/Env.	4	559.61	95.21	7.01	5.58
Genotypes (G)	102	609.68**	635.95**	48.10**	54.22**
Selected families	99	617.14**	641.46**	49.34**	53.14**
Env.×G	102	43.59**	78.45**	5.40**	46.18**
Env.×sel. families	99	45.06**	79.55**	5.55**	46.73**
Fam. vs. parents	1	50595.58**	64853.50**	4906.53**	5500.60**
Fam. vs. bulk	1	49378.14**	63519.06**	4884.27**	5292.30**
Error (Genotypes)	408	28.36	21.02	2.79	5.13
Error (Selected families)	396	29.08	20.42	2.86	5.19

*, ** Significant at 0.05 and 0.01 probability levels, respectively. df: Degrees of freedom

Table 3: 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)	Grain yield/plant (g)	1000-grain weight (g)
Geza 168	73.50	69.33	10.20	28.67
Sids 1	93.00	88.00	12.72	31.67
Bulk	79.50	75.17	10.98	32.33
F_3 selected families	80.58	73.58	10.93	36.15
p.c.v.%	12.58	14.05	26.26	8.24
g.c.v.%	12.29	13.81	25.43	7.83
H%	0.95	0.97	0.94	0.90

p.c.v, g.c.v are phenotypic and genotypic coefficients of variability, respectively. H: Heritability in broad sense

environments and environment×selected families interaction, reflecting the differential responses of the selected families under different water treatments. In addition, the highly significant mean squares obtained for selected families vs. bulk, indicated the feasibility of selection for grain yield/plant in this population. These results reflect the importance of evaluating selections under drought stress conditions. Moreover, sufficient genetic variability in grain yield/plant among the selected families for further improvement was recognized by significant differences among families and estimated values of both g.c.v. (25.43%) and p.c.v. (26.26%) (Table 3). High estimates of heritability in broad sense were obtained for all studied traits (Table 3). 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). In contrast, many investigators obtained low g.c.v. values ranged from 3.4 to 13.2% under normal environment and from 1.4 to 15.1% under stress environment (Attia, 2003; Zakaria, 2004; El-Morshidy *et al*., 2010). The heritability estimates were comparable to those reported in other studies. Wiersma *et al*. (2001), Utz *et al*. (2001) and Singh and Chaudhary (2006) reported that broad sense heritability ranged between 26.0 and 74.0% for grain yield/plant. Kheiralla *et al*. (2001) and Shamroukh (2006) obtained high value of heritability in broad sense for days to flowering, plant height 1000-grain weight and grain yield. These results are in line with those obtained by Subhani and Chowdhry (2000), Asif *et al*. (2003), Sadeghzadeh and Alizadeh (2005), Zarei *et al*. (2007) and Nazari and Pakniyat (2010).

Pedigree selection for grain yield/plant: After two cycles of selection for grain yield/plant, there were significant ($p<0.01$) differences among genotypes and selected families for grain yield/plant, days to heading, plant height, 1000-grain weight either selection was practiced under normal environment, drought stress environment or over the two environments (Table 4). This reflects the existence of sufficient variability for further improvement. Moreover, environments and environments×genotypes interaction were significant ($p<0.01$), indicating differential responses of the selected families to changing in water treatments. Significant ($p<0.01$) mean squares obtained for families vs. bulk indicated the feasibility of selection for grain yield/plant in this population. These results reflect the importance of evaluating selections under different environments. These results agreed with those reported by Subhani and Chowdhry (2000), Asif *et al.* (2003), Attia (2003), Zakaria (2004), Tammam *et al.* (2004), Sadeghzadeh and Alizadeh (2005), Benmoussa and Achouch (2005), Shamroukh (2006), Zarei *et al.* (2007), El-Morshidy *et al.* (2010) and Nazari and Pakniyat (2010).

Table 5 revealed sufficient genotypic coefficient of variability among the five selected families was remained after two cycles of selection for increasing grain yield/plant. The estimated g.c.v. from the combined data was 14.78, 11.51 and 13.73% when selection was practiced under normal, drought stress and over environments, respectively over the bulk sample. 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, 0.95 and 0.95 for the selection at normal, drought stress and over environments, respectively.

Realized gains to selection for grain yield/plant: The realized gains for grain yield/plant (Table 6) accounted for 25.00, 25.54 and 22.60% from the bulk sample when selection was practiced at normal, drought stress and over environments, respectively. This indicates that selection under drought stress was the best to that either under normal environment or over environments. Moreover, the selected families showed that the best increase over the bulk sample when they were evaluated at drought stress environment which accounted 31.41, 30.81 and 21.31% for normal, drought stress and over environments selection, respectively. It is worth to indicate that the five selected famihes under normal irrigation environment are completely different from that selected under drought stress environment as well as under different environment.

Correlated response to selection: Two cycles of pedigree selection for increasing grain yield/plant (Table 6) also increased days to heading and plant height. The increase in days to heading accounted to 1.76, 4.07 and 0.13% from the bulk sample when selection was practiced at normal, drought stress and over environments, respectively. Favourable increase in plant height over the bulk sample accompanied pedigree selection for grain yield/plant under normal (13.09%), drought stress (9.79%) and over environments (7.38%). However, respective decreases were observed for 1000-grain weight which reached -2.01, -2.02 and -4.31% from the mean bulk sample when selection was practiced at normal, drought stress and over environments, respectively. It could be concluded that pedigree selection for grain yield/plant was accompanied with unfavourable effects on the correlated traits, days to heading and 1000-grain weight. These results agreed with the findings of Attia (2003), Zakaria (2004), Tammam *et al.* (2004), Benmoussa and Achouch (2005), Shamroukh (2006) and El-Morshidy *et al.* (2010).

The family means for the three types of selection are presented in Table 7. It could be noticed that the overall family mean ranged from 13.2 to 15.5 g/plant for normal environment selections,

Table 4: Mean squares of the selected families of the second cycle, parents and bulk sample evaluated under normal, drought stress and over environments

		Mean squares											
		Normal environment				Drought stress environment				Over environment			
		Direct selection	Correlated traits			Direct selection	Correlated traits			Direct selection	Correlated traits		
Source of variation	df	Grain yield/ plant (g)	Days to heading (days)	Plant height (cm)	1000- grain weight (g)	Grain yield/ plant (g)	Days to heading (days)	Plant height (cm)	1000- grain weight (g)	Grain yield/ plant (g)	Days to heading (days)	Plant height (cm)	1000- grain weight (g)
Environments (Env.)	1	69.96**	858.5**	1365.3**	136.69**	79.13**	1111.7**	1621.7**	247.52**	133.73**	833.3**	1716.0**	114.08**
Reps/Env.	4	1.47	30.6	4.9	2.00	2.47	1.6	8.6	2.42	3.11	30.6	2.9	1.90
Genotypes (G)	7	31.45**	217.6**	262.4**	19.09**	26.22**	183.4**	168.1**	19.64**	26.63**	193.9**	172.1**	22.65**
Selected families	4	27.57**	78.2**	82.5**	21.63**	17.37**	57.6**	51.3**	22.38**	23.45**	23.9**	132.5**	23.05**
Env.×G	7	3.97**	10.8*	30.3**	2.54	1.92*	25.9**	18.2*	9.00*	3.30**	17.7**	21.7*	2.65
Env.×sel. families	4	6.75**	16.4**	21.7*	4.03*	3.22*	39.9**	12.1*	13.78**	4.65*	28.4**	21.7*	3.45
Fam. vs. parents	1	75.08**	47.3**	990.5**	0.86	78.26**	13.8*	574.0**	2.00	61.78**	114.2**	342.0**	14.86*
Fam. vs. bulk	1	41.17**	9.8*	516.8**	2.69	42.97**	52.3**	288.8**	2.69	33.66**	0.1	164.4**	12.27*
Error (G)	28	1.02	4.3	7.7	1.24	0.62	1.8	6.8	3.70	0.85	4.1	8.8	2.54
Error (Sel. families)	16	0.58	1.3	5.9	1.06	0.86	2.4	3.4	2.48	1.08	1.0	7.1	2.13

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

Table 5: Means, p.c.v., g.c.v. and heritability in broad sense of pedigree selection for grain yield/plant (g) after the second cycle of selection, 2009/2010

Environment of selection	Environment of evaluation		Days to heading (days)	Plant height (cm)	Grain yield/ plant (g)	1000-grain weight (g)
Normal environment	Normal environment	Sel. F_5 Fam.	85.13	92.00	15.50	37.40
		Bulk sample	83.67	83.67	12.92	38.67
		p. c. v. %	3.84	3.24	16.12	5.54
		g. c. v. %	3.78	2.80	15.74	5.30
		H %	0.97	0.74	0.95	0.91
	Drought stress environment	Sel. F_5 Fam.	76.67	83.67	13.20	34.13
		Bulk sample	75.33	71.67	10.04	34.33
		p. c. v. %	5.95	6.07	17.28	6.05
		g. c. v. %	5.88	5.87	17.11	5.80
		H %	0.97	0.93	0.98	0.92
	Combined over environments	Sel. F_5 Fam.	80.90	87.83	14.35	35.77
		Bulk sample	79.50	77.67	11.48	36.50
		p. c. v. %	4.46	4.22	14.93	5.31
		g. c. v. %	4.26	4.07	14.78	5.18
		H %	0.98	0.93	0.98	0.95
Drought stress environment	Normal environment	Sel. F_5 Fam.	88.00	90.20	15.69	7.33
		Bulk sample	83.67	83.67	12.92	38.67
		p. c. v. %	2.93	4.18	12.41	6.84
		g. c. v. %	2.89	3.98	12.09	0.87
		H %	0.97	0.91	0.95	38.13
	Drought stress environment	Sel. F_5 Fam.	77.47	80.33	13.14	33.07
		Bulk sample	75.33	71.67	10.04	34.33
		p. c. v. %	6.56	3.28	13.36	6.23
		g. c. v. %	6.38	3.03	12.51	5.74
		H %	0.95	0.85	0.88	0.85
	Combined over environments	Sel. F_5 Fam.	82.73	85.27	14.41	33.07
		Bulk sample	79.50	77.67	11.48	36.50
		p. c. v. %	3.74	3.43	11.82	5.43
		g. c. v. %	3.66	3.31	11.51	5.12
		H %	0.96	0.93	0.95	0.89
Combined over environments	Normal environment	Sel. F_5 Fam.	83.73	88.60	15.97	36.13
		Bulk sample	83.67	83.67	12.92	38.67
		p. c. v. %	3.44	6.67	13.31	5.82
		g. c. v. %	3.37	6.44	12.92	5.52
		H %	0.96	0.93	0.94	0.90
	Drought stress environment	Sel. F_5 Fam.	75.47	78.20	12.18	33.40
		Bulk sample	75.33	71.67	10.04	34.33
		p. c. v. %	4.01	5.19	18.06	7.05
		g. c. v. %	3.94	4.81	17.20	5.54
		H %	0.97	0.86	0.91	0.78
	Combined over environments	Sel. F_5 Fam.	79.60	83.40	14.07	34.77
		Bulk sample	79.50	77.67	11.48	36.50
		p. c. v. %	1.99	5.63	14.05	5.64
		g. c. v. %	1.93	5.48	13.73	5.37
		H %	0.96	0.95	0.95	0.91

p. c. v. and g. c. v. are phenotypic and genotypic coefficient of variability, respectively. H: Heritability in broad sense

Table 6: Realized gains and correlated responses to pedigree selection measured in percentage from the bulk sample and better parent for grain yield/plant (g)

			Direct selection	Correlated traits		
Environment of selection	Environment of evaluation		Grain yield plant (g^{-1})	Days to heading (days)	Plant height (cm)	1000-grain weight (g)
Normal environment	Normal environment	F_5-BP	11.90*	8.22**	2.22	-5.71*
		F_5-Bulk	20.01**	1.75*	9.96**	-3.28
	Drought stress environment	F_5-BP	19.62**	12.20*	14.09**	-6.06*
		F_5-Bulk	31.41**	1.77	16.74**	-0.58
	Combined over environments	F_5-BP	15.32**	10.07**	7.55**	-5.88**
		F_5-Bulk	25.00**	1.76*	13.09**	-2.01
Drought stress environment	Normal environment	F_5-BP	13.23**	11.86**	0.22	-3.87
		F_5-Bulk	21.44**	5.18**	7.81**	-1.38
	Drought stress environment	F_5-BP	19.07*	13.37**	9.55**	-8.99**
		F_5-Bulk	30.81**	2.83	12.09**	-3.69
	Combined over environments	F_5-BP	15.82	12.56**	4.41**	-6.32*
		F_5-Bulk	25.54*	4.07*	9.79**	-2.47
Combined over environments	Normal environment	F_5-BP	15.25**	6.44**	-1.56	-8.91**
		F_5-Bulk	23.60**	0.08	5.90*	-6.55**
	Drought stress environment	F_5-BP	10.43	10.44**	6.64**	-8.07*
		F_5-Bulk	21.31*	0.18	9.12**	-2.72
	Combined over environments	F_5-BP	13.11**	8.30**	2.12	-8.51**
		F_5-Bulk	22.60**	0.13	7.38**	-4.75*

*, ** Significant at 0.05 and 0.01 probability levels, respectively. BP: Better parent

Table 7: Means and drought susceptibility index (DSI) of the five selected families after two cycles of pedigree selection for grain yield plant (g)

	Environment of selection											
	Favourable environment				Stress environment				Over environment			
Selection criterion	Family No.	Normal envi.	Stress envi.	DSI	Family No.	Normal envi.	Stress envi.	DSI	Family No.	Normal envi.	Stress envi.	DSI
GY	9	15.2	14.1	0.5	21	14.1	12.8	0.6	10	18.2	15.1	0.7
(g)	11	19.2	16.2	1.1	47	15.2	13.3	0.8	19	16.2	12.3	1.0
	73	14.8	9.9	2.2	61	14.1	12.3	0.8	31	12.5	10.0	0.8
	74	16.1	12.9	1.3	63	16.3	11.3	1.9	70	16.1	13.4	0.7
	80	12.9	12.3	0.3	71	18.8	16.0	0.9	77	16.8	10.0	1.7
	Mean	15.5	13.2		Mean	15.7	13.1		Mean	16.0	12.2	
	Giza 168	13.9	11.0									
	Sids 1	11.4	9.3									
	Bulk	12.9	10.0									
Revised $LSD_{0.05}$		3.0	2.5			1.1	1.6			1.3	1.7	
Revised $LSD_{0.01}$		4.5	3.9			1.7	2.4			2.0	2.6	

from 13.1 to 15.7 g/plant for drought stress environment selections and from 12.2 to 16.0 g/plant for selection over the two environments. This indicates that selection based on a range of environments or selection under normal and drought stress environment may result in stable genotypes which performed well under different environments. With respect to the performance

of the parental lines, it could be noticed that the two parents showed similar behavior in yielding ability under normal and drought stress environment. Also, the unselected bulk sample showed similar behavior. It should be recalled that in pedigree selection the breeder is concerned with the performance of the individual selected families, since the overall selected families mean masks the performance of the superior families. Selection under normal environment resulted in two superior families (no. 9 and 11) which exceeded the better parent (Giza 168) by 17.67 and 42.17% and outyielded the bulk sample by 27.95 and 54.59%, respectively. Also, selection at stress environment resulted in one superior family (no. 71) which outyielded the better parent (Giza 168) by 28.51% and outyielded the bulk sample by 39.74%, respectively. Selection over environment resulted in one superior family (No. 10) which outyielded Giza 168 by 33.73% and the bulk sample by 45.41%.

Drought susceptibility index (DSI): Application of DSI based on grain yield/plant (Table 7), it is showed that two families (no. 9 and 80) under normal environment, all families except no. 63 family under drought stress environment and three families (no. 10, 31 and 70) under over environments were relatively drought tolerance. Data in Table 7 indicated that four selected families i.e., 9 under normal environment, 71 under drought stress environment and 10 and 70 under over environments were low values than one of DSI and the highest grain yield. These families could be considered the best selected families resulted from selection for grain yield/plant.

CONCLUSION

It could be concluded that applying pedigree selection for improving grain yield/plant was effective in isolating high yielding and drought tolerant genotypes. However, two cycles of selection for grain yield under normal and drought stress and over both environments was accompanied with increased plant height, unfavourable delay in heading date and decreased in grain weight.

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