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Full Length Research Paper

Selection for Heat Tolerance in Bread Wheat (*Triticum aestivum* L.)

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Cell membrane thermostability (CMS) is considered to be one of the major selection indices of drought tolerance in cereals. Therefore, in this context, selection for cell membrane thermostability was performed under heat stress in two F_2 bread wheat populations . The experiment was conducted during winter of 2014 and 2015 at the research farm of South Valley University, Qena, Egypt. The observed responses to selection for CMS were 23.51% in population 1 and 22.28 % in population 2 under heat stress. Significant positive correlations were obtained in grain yield and number of kernel. The dominance gene effects are involved in the inheritance of CMS. For grain yield, family number 1 in population 1 and family number 2 and 3 in population 2 were relatively heat resistance (HIS <1). Family number 1 was the highest grain yield under heat stress.

Keywords: Bread Wheat, *Triticum aestivum* L.

INTRODUCTION

Wheat yield production under heat stress is ascribed to growth acceleration, reduction of the duration physic development stages (Hall, 1992). High temperature represents a major constraint affecting wheat, particularly at the productive stage (Wrigley et al., 1994). Ashraf and Haris (2005) revealed that heat stress is a major production constraint to wheat in arid, tropical, semiarid and subtropical regions of the world. Also, heat stress has various severe effects at different growth stages of wheat, especially at the anthesis and grain filling stage (Reynolds et al., 1994). Exposure to high temperature reduces the yield and quality (Maestri et al., 2002). Ibrahim and Quick (2001b) studied a lot of physiological characters related to heat tolerance including canopy temperature depression (CTD) and cell membrane thermostability for heat tolerance mechanism. Stone (2001) revealed that high temperatures affects through acceleration of phonology and the impairment of the physiology of photosynthesis and grain filling resulting in yield losses. It also causes leaf tissue injuries and increased cellular membrane permeability leading to electrolyte leakage out of cell. Cell membrane stability (CMS) in assayed by the electro conductivity of aqueous solution containing leaf discs that were either water stressed *in vitro* by exposure to a solution of polyethylene glycol (Blum and Ebercon, 1981). Omara et al., (2006) performed divergent phenotypic selection for cell membrane thermostability in wheat (*Triticum aestivum* L.) in 5 F_2 populations derived from crosses established between 8 local landraces quite variable in heat susceptibility index. They found significant responses to selection for CMS were obtained in both directions in the 5 populations which averaged 19.52% in the high and 11.9% in the low CMS direction. Selection for high CMS produced concurrent positive responses in grain weight per spike in the 5 populations which averaged 15.72%, whereas selection for low CMS reduced grain weight per spike in only 2 populations with an average reduction of 5.2%. In another study, Omara et al., (2010)

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reported that selection for higher CMS did not produce any significant correlated response in grain yield under favorable or stress conditions. While, positive correlated responses were obtained in 1000 grain weight under drought and heat stresses. Moreover, the association between cellular membrane thermostability and grain yield under heat stress was reported by Blum et al., (2001) to be reasonably strong but not perfect indicating that heat avoidance besides CMS may also support grain yield under high temperature.

The aim of the present study is to measure the response to selection for CMS and assesses the correlated response in grain yield and 1000 grain weight.

MATERIALS AND METHODS

Plant materials: Two populations in F2 generation of bread wheat (*Triticum aestivum* L.) used in this study were derived from across between Giza-168 X Sids-12 and Shandweel-1 X Qena 25 advanced lines. Sids-12 and Qena 25 are heat tolerant genotypes. The populations were developed as part of an imitative to improve heat tolerant. The used plant materials in this study consisted of 200 F2 seeds were raised for each of the 2 populations at late sowing date. In 2013-2014 season, seeds of 200 F2 plants were raised for of the 2 populations into the field of South Valley University Experimental Farm in late sowing date (22 December) so as to allow the late sown plants to be subjected to the heat stress which usually develop later in the season. The recorder temperatures during March, 2014 indicated that heat waves have occurred with temperature raised above 30 ºC for several days (Figure 1 a) which coincided with the post flowering stages of plant development.

A total of 200 spaced plants were raised for each of the 2 F_2 populations at late sowing date and selection for heat tolerance was produced based on cell membrane thermo-stability. Plants were arranged in rows of 15 plants spaced 50 cm apart with plants within rows set 30 cm from each other. Each individual plant was tagged with a serial number referring to the population. At flowering, fully expended flag leaf of the main culm of each plant was excised and placed in a capped vial containing distilled water and was transferred to the laboratory for cell membrane thermostability assay. Vials were kept in the refrigerator overnight. At maturity, plants were individually harvested and grain yield per plant was determined.

Cell membrane thermostability assay:

Measurements of CMS were made by following the protocol of Blum and Ebercon (1981). After flowering was complete, flag leaf samples were taken from 5 individual plants of each selected and bulk families in the same day. For each sample, a 2 cm^2 segment was taken from the middle of the flag leaf, cut into equal haves, washed 3 times by distilled water and each half was placed in a 10 ml capped via containing 1 ml of distilled water. The treatment tubes were heated in a water bath for 60 min–at 49.5 ºC, while control tubes remained at 30 ºC. After treatment, 9 ml of distilled water was added to all vials (control and treatments) and incubated at 6 ºC for 24 h. Vials were then brought to room temperature and solation conductance was measured with a conductivity meter. After the measurements were taken, vials were autoclaved for 2 min at 120 ºC and their conductance was measured again. CMS was calculated as reciprocal of cell membrane injury after Blum and Ebercon (1981): CMS (%) = [(1-(T1/T2)) / (1-(C1/C2))] x 100, where T and C refer to the treatments and control samples, respectively and 1 and 2 refer to the initial and final conductance readings, respectively.

Selection procedure: In each population, the highest 3 plants in CMS as well as 3 plants with low CMS score were selected. Equal numbers of seed for each population were collected from the other plants to form the F_3 bulk. In 2014-2015 season, the F_3 selected families for the high and low directions along the F_3 bulks were planted in the field of South Valley University Experimental Farm in normal (20 November) and late (20 December) sowing dates in a randomized complete block design with 3 replications. Each family was represented in each block by a 10-plant row with rows spaced 50 cm apart and plant within rows set 30 cm from each other.

In the experiment that comprised selections for CMS, fully expended flag leaf of main culm was excised from each individual plant and each was placed in a capped vial containing distilled water and marked with plant number and vials were transferred to the laboratory and kept at 6 ºC over night until CMS measurement. At maturity, grain yield per plant, number of kernel per spike and 1000 grain weight were determined for each individual plant. The recorder temperature during March, 2015 indicated the occurrence of waves of high temperature (above 30 ºC which coincided with post flowering stages of plant development (Figure 1 b)

Statistical procedures:

I- Expected: The expected response to selection for CMS was calculated according to the (Falconer, 1989) R = $h^2 i\ \delta^2 p$ where R is the expected response, h^2 is the heritability, i is the standardized selection differential and δ^2 P is the phenotypic standard deviation

II- Correlated response to selection: The indirect response to selection (CR_x) was calculated according to the formula of (Falconer 1989): $CR_x = ih^2\delta^2 pr_{xy}$ where r_{xy} is the genetic correlation between the selected trait and unselected trait, i = standardized selection differential, GP = phenotypic standard deviation, h^2 = heritability

III- Brood sense heritability: Heritability is defined according to (Mather and Jinks 1971).

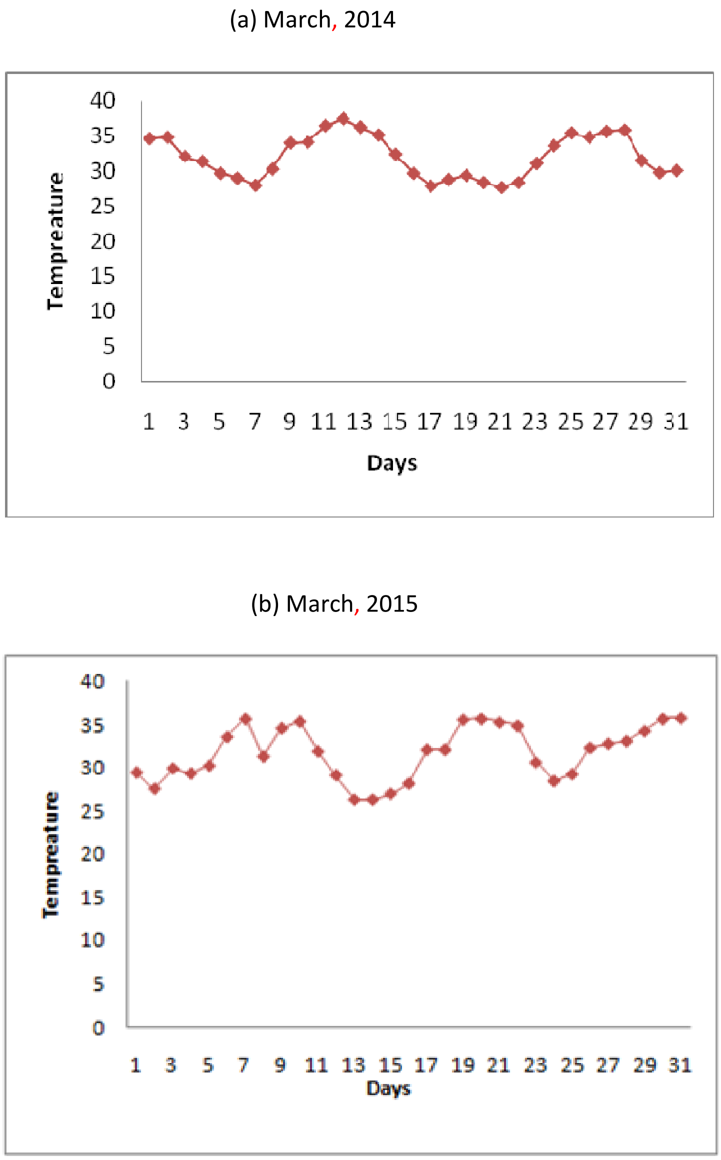

Figure (1): Maximum daily temperatures during March, 2014(a) and March, 2015(b) at the experimental site.

RESULTS

I-Response to selection for CMS of F3 families

The means of F_3 selection families and F_3 bulk with observed response to selection are given in Table 1. In Table 3, ANOVA revealed significant difference among genotypes as well as significant differences among F_3 selected families in the first and late sowing date of population 1. A significant positive response to selection for CMS was obtained (Table 3). In the population 1, observed response to selection for CMS was 52.25 and 23.51 in the first and second sowing date; in population 2 were 24.86 and 22.28 in both sowing dates, respectively. The observed response to selection in first and second sowing dates were greater than predicted response indicating that the dominance gene effects are involved in the inheritance of that trait. In the low direction, the observed response to selection was negative -26.17 of population 1 and -24.21 of population 2.

II- Correlated response to selection for CMS

Uniformly, significant correlated response to selection for grain yield was obtained in the first and second sowing dates of the 2 populations (Table 3). In population 1 the correlated response to selection was 15.51 and 20.61 in both sowing dates, while in population 2 was 22.41 and

Table (1): Means of CMS and grain yield of F3 selected and bulk families in the high and low directions

Generation	CMS						Grain yield					
	1st			2nd			1st			2nd		
	Mean	O%	P%	Mean	O%	P%	Mean	CR%	P%	Mean	CR%	P%
Population 1												
F3 bulk	13.37			35.38			2.45			1.99		
F3 selected (H)	20.36	52.25	7.55	43.70	23.51	9.54	2.83	15.51	1.84	2.40	20.6	0.83
F3 selected (L)	9.36	-29.99	5.6	26.12	-26.17	10.92	2.23	-8.97	0.099	1.57	21.11	0.052
Population 2												
F3 bulk	14.78			44.52			2.32			1.70		
F3 selected (H)	18.08	24.86	6.52	54.44	22.28	12.09	2.84	22.41	0.036	2.43	42.94	0.13
F3 selected (L)	9.43	-34.87	5.12	33.74	-24.21	10.61	2.21	-4.74		1.41	17.06	

Table (2): Means of number of kernel and 1000 grain weigh of F3 selected families and bulk in the high and low directions

Generation	Number of kernel						1000 grain weigh					
	1st			2nd			1st			2nd		
	Mean	CR%	P%	Mean	CR%	P%	Mean	CR%	P%	Mean	CR%	P%
Population 1												
F3 bulk	60.33			57.66			40.66			34.63		
F3 selected (H)	70.77	17.3	0.42	63.44	10.02	4.06	40.36	-0.74	12.38	36.61	5.71	4.21
F3 selected (L)	66.22	9.97	4.88	62.22	8.10	3.28	32.08	-21.1	3.42	25.32	26.88	3.28
Population 2												
F3 bulk	67.00			62.00			34.85			27.47		
F3 selected (H)	58.11	-13.27	14.24	59.55	-3.95	6.46	50.36	44.51	2.77	41.02	49.32	1.85
F3 selected (L)	59.55	-11.12	2.56	54.33	-12.37	3.26	37.42	7.37	1.96	25.98	-5.42	0.41

42.94 in the first and second sowing dates. Generally, the dominance gene effects are involved in the inheritance of that trait since the correlated response was greater than predicted response (Table 1). Regard to number of kernel, correlated response to selection was significant in the first but not significant in the second sowing date in the 2 populations. However, the means of F_3 selected families and bulk with correlated response is described in Table 2. The correlated response to selection for SMS in number of kernel was grater in the first than second sowing date in population 1, but the reverse was true in F_3 selected low. The correlated responses to selection for number of kernel

Table (3): Analysis of variance of F3 families in the high and low directions for CMS and grain yield.

Items	Population 1				Population 2			
	1st		2nd		1st		2nd	
	CMS	Grain yield	CMS	Grain yield	CMS	Grain yield	CMS	Grain yield
Among F3 families (H)	28.86**	1.44*	77.85**	0.36**	42.24**	0.54**	115.57**	0.41**
Among F3 selected (H)	24.49**	0.53**	39.99**	0.35**	18.36**	0.041**	62.73**	0.02
F3 selected vs F3 bulk	109.86**	0.33**	156.41**	36.93**	29.1**	0.61**	216.97**	1.19**
Error	0.03	0.023	0.024	0.003	0.045	0.01	0.07	0.01
Among F3 families (low)	19.14**	0.04	98.35**	0.13**	28.64**	0.07	119.46**	0.062**
Among F3 selected (low)	13.46**	0.097*	51.13**	0.001	11.27**	0.01	48.33**	0.001
F3 selected vs F3 bulk	36.32**	0.14**	192.8**	0.39**	57.42**	0.03	261.7**	0.18**
Error	0.011	0.01	0.011	0.01	0.02	0.027	0.08	0.01

*, ** Significant at 5% and 1%, respectively.

Table (4): Analysis of variance of F3 families in the high and low directions for number of kernel and 1000 grain weight.

Items	Population 1				Population 2			
	1st		2nd		1st		2nd	
	Number of kernel	1000 grain weight	Number of kernel	1000 grain weight	Number of kernel	1000 grain weight	Number of kernel	1000 grain weight
Among F_3 families (H)	69.11**	78.51*	25.33	27.81	18.33	82.36**	31.66	140.92**
Among F_3 selected (H)	11.44**	89.41**	0.44	37.33	98.11**	11.97*	40.77	4.80
F_3 selected vs F_3 bulk	245.4*	0.15	75.1	1906.7**	177.7**	539.2**	13.44	421.8**
Error	1.69	2.58	10.08	9.99	7.41	1.67	19.25	2.021
Among F_3 families (low)	0.97	7.94	17.63	65.53**	12.97	11.23**	46.75	1.82
Among F3 selected (low)	18.77	8.19	3.11	0.635	0.77	0.097	4.00	0.32
F3 selected vs F3 bulk	78.02**	165.9**	46.69	230.7**	124.6**	15.39**	132.2*	4.08
Error	7.63	.3.23	25.31	1.69	4.55	0.83	25.33	2.44

*, ** Significant at 5% and 1%, respectively.

were 13.27 and 3.95 in the first and second sowing dates of population 2. In respect to 1000 grain weight, the correlated responses were highly significant in all cases except in population 1 in the first sowing date. The correlated response to selection in 1000 grain weight was 5.71% and 42.94 in the second sowing date.

III-Mean performance of F_3 families under heat stress conditions

The means of CMS and grain yield of the F_3 families with HIS are given in Table 5. ANOVA of Table 6 revealed highly significant for genotype environment interaction which indicate differential response of different F_3 families to heat stress. For CMS in the population 1 and 2 the 4 families displayed HIS values <1 indicating relative resistance to heat stress. With respect to grain yield family number 1, it displayed HIS value <1 in population 1, while families number 2 and 3 manifested HIS values <1 (0.72 and 0.62) confirming resistance to heat stress.

DISCUSSION

I- Direct response to selection: The observed response to selection in F_3 families under heat stress (second sowing date) were significant in the 2 populations. However, the observed responses to selection for CMS were 23.51% for population 1 and 22.28 in population 2 under heat stress. Omara et al., (2006, 2010) found simultaneous improvement of CMS in the F_3 families. Pronay (2017)

Table (5): Means of CMS and grain yield of the F3 families with HSI in the first and second dates

Items	Population 1							
	CMS				Grain yield			
	1st	2nd	Mean	HSI	1st	2nd	Mean	HSI
1	20.38	47.42	34.05	-0.91	2.91	2.79	2.85	0.25
2	18.38	43.43	30.91	-0.93	2.90	2.23	2.57	1.42
3	15.46	40.22	27.84	-1.09	2.71	2.16	2.44	1.25
4	13.37	35.38	24.37	-1.12	2.45	1.99	2.22	1.15
	Population 2							
	CMS				Grain yield			
	1st	2nd	Mean	HSI	1st	2nd	Mean	HSI
1	23.26	59.43	41.34	-0.64	3.31	2.49	2.9	1.49
2	20.27	53.44	36.85	-0.67	2.55	2.46	2.51	0.72
3	17.54	50.45	33.99	-0.77	2.61	2.33	2.47	0.64
4	14.48	44.52	29.5	-0.85	2.32	1.70	2.01	1.6

Table (6): Analysis of variance of four selected families tested in optimal and late sowing date.

Item	Population 1			Population 2		
	Df	SMS	Grain yield	Df	SMS	Grain yield
Sowing date	1	5756.28	5.441	1	208.63	0.001
Genotype	3	232.41**	0.224**	3	246.15**	1.16**
G x E	3	30.63**	0.044**	3	0.614**	0.22**
Error	8	0.031	0.014	8	0.038	0.10

studied the evaluation of heat tolerance of wheat genotypes through membrane thermostability; genotypes BAW-1143, BAR-I Gom-25 and BAR I. 26 were considered as heat tolerant. The observed response to selection for CMS was greater than the predicted response indicating dominance genes effects are controlled in the expression of that trait. Dhanda and Munial, (2006) reported significance of SCA and GCA variation indicated the presence of both additive and dominance types of gene action for CMS. The above findings of the present study was similar to Blum et al., (2001) who studied 49 breeding lines which were varied significantly (P<0.01) for CMS and yield under heat stress. The mean square for general combining ability (GCA) was 4 times that of specific combining ability, indicating the importance of additive gene effects in acquired thermal tolerance (Amir and James, 2001)

II-Indirect response to selection: The correlated response to selection in grain yield, number of kernel and 1000 grain weight selecting for CMS could be attributed to the strong positive correlation found between CMS and grain yield, number of kernel and 1000 grain weight. Omara et al., (2010) using selection for CMS in F_3 generation did not produce correlated response in grain yield under either favorable or drought stress conditions. Positive and significant correlated response to selection for high CMS in the F4 were obtained in 1000 grain weight which was ranged from 5.01 to 7.53. Also, it showed positive correlation between CMS and grain yield. Elameen et al., (2013) using selection for bread wheat under drought stress found significant positive correlations for 1000 grain weight (32.34) and number of kernel 24.8%. In our present study, significant positive correlated response was 20.61% and 42.94%, under heat stress for grain yield in the 2 populations, respectively. Similar results were obtained by Ibrahim and Quick (2001a) who revealed positive associations between CMS and grain yield in wheat under heat stress. The fact that the correlated responses in the F4 families selected for high CMS in 1000 grain weight were displayed under heat stress (Saadalla et al.,1990).

III-Effect of heat stress on grain yield: Combined analysis variance indicated that there were significant differences among the F_3 families in CMS and grain yield. Similar results were obtained by Hamam and Abdel-sabour (2009) and Elameen (2012). Shanhan et al., (1990) studied the CMS and heat tolerance; high temperature stress during the grain fill period is a major constraint to increased productivity of spring wheat. Genotypes were derived from 2 crosses involving parents adapted and un-adapted to thermal aspects of the climate. Based on MT values, genotypes were grouped as heat tolerant, (HT), heat sensitive (HS). However, the HT group of genotypes produced 21% more grain yield than HS group. Bahar et al., (2008) investigated the effect of canopy temperature depression (CTD) on grain yield components in bread wheat; their results revealed that CTD of bread wheat ranged from 0.22 to 0.57 ºC. Heat susceptibility index is measure of yield stability (Ahmed et al., 2003). Stability in grain yield for each genotype can be estimated by the HIS, derived from the yield differences between stress and non stress environment.

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