

IMPACT OF SELECTION FOR STOMATA FREQUENCY ON YIELD CHARACTERISTICS UNDER HEAT AND DROUGHT STRESSES IN BREAD WHEAT (*Triticum aestivum* L).

M. M. El-Defrawy

Genetics department, Faculty of Agriculture, Assiut University, Assiut, Egypt.

Email address: mmheldefrawy@yahoo.com

Abstract: Stomata spread all over leaves are important sources for plant canopy temperature depression which might contribute to heat stress tolerance. Two F₂ populations of bread wheat (*Triticum aestivum* L.) were subjected to two cycles of divergent selection for flag leaf stomata frequency. Plants were exposed to heat and drought stresses in order to study the impact of selecting for high and low stomata frequency on yield characteristics. The correlated responses in grain yield/plant and 100-kernel weight were determined.

The response to the first cycle of selection in the high direction in population 1 and 2 amounted to 16.03% and 11.63% of the bulk sample mean, respectively, which were consistently higher than that expected (8.29% and 5.598%). Higher observed response (7.16%) than expected (5.50%) was also observed for low stomata frequency in population 2. Such inflated responses might be attributed to dominance, epistasis or G x E. Asymmetrical responses to selection were evident with the deviation being greater in the high direction. Narrow-sense heritability, as calculated by parent-offspring regression, reached 0.45 and 0.266 in populations 1 and 2, respectively. However, the

realized heritability was higher in the high direction than that in the lower direction in both populations.

The observed responses of the second cycle of selection amounted to 12.71% and 9.39% from the bulk mean were greater than those expected (9.48% and 5.01%) in populations 1 and 2, respectively. In the low stomata frequency direction the observed responses (6.67% and 9.42%) were also higher than those expected (5.32% and 3.63%). Generally, the differences between high and low directions were highly significant over cycles of selection for both populations. The narrow-sense heritabilities were 0.50 and 0.36 in population 1 and 2, respectively. The realized heritability reached 0.62 and 0.44 in the low and high directions, respectively in population 2, while it remained unchanged in population 1. Further expected responses of 7.04% and 9.61% in the low and high directions, respectively in population 1, and of 5.60% and 6.58% in the low and high directions, respectively in population 2 under heat and drought stresses were estimated for the third cycle of selection.

The selected F₄ families of population 1 developed significantly higher 100-

kernel weight but lower grain yield/plant than population 2 in the low and the high direction as well as the two bulks. Such differences were only observed in the high direction where selection led to greater mean of stomata frequency in population 1 than in population 2.

Selecting for stomata frequency did not show correlated responses in 100-kernel weight or in grain yield/plant. No correlated responses were detected for leaf area, which did not differ among selected families and the control or the other studied traits.

Key words: *T. aestivum*, selection, stomata frequency, grain yield/plant, kernel weight, heat and drought stress.

Introduction

Until the year 2020 at least, the demand for wheat is expected to grow by approximately 1.6 percent/year worldwide and by 2 percent/year in developing countries (Rosegrant *et al.*, 1995). Thus, there is an urgent need to develop new and more efficient wheat breeding methodologies to complement existing breeding techniques, as well as to identify new traits, which will drive faster yield gains.

Two of the most important stresses of wheat are heat and drought. Over 7 million ha of spring wheat are grown under continual heat stress, namely environments with mean daily temperatures of greater than 17.5°C in the coolest month (Fischer and Byrlee, 1991). In addition, terminal heat stress can be a problem in up to 40 percent of the irrigated wheat-growing areas in the developing world. Wheat yields can be severely reduced in moisture-stressed environments (Morris *et al.*, 1991), which affect at least 15 million ha of spring wheat alone in the developing world.

A strong body of evidence now indicates that physiological traits may complement early-generation phenotypic selection in wheat in the following three ways: (i) identifying traits that may serve as indirect selection criteria for yield; (ii) developing selection methodologies that increase the efficiency of parental and progeny selection; and (iii) providing insights into the physiological and genetic basis of rising yield potential (Reeves *et al.*, 2000 and Reynolds, 2002).

Stomatal frequency, as one of the morpho-physiological traits, was reported to have negative and nonsignificant association with yield at both genotypic and phenotypic levels in wheat (Nayeem and Nerker, 1988). Later, Khan and Shaik (1997), Khaliq *et al.* (2000) and Usman Khan *et al.*, (2003) reported that stomatal frequency had positive direct effect on grain yield. These controversial results deserve more studies to elucidate the role of stomata frequency and the underlying genetic mechanism controlling it. Flag leaf stomata frequency was reported to be governed by additive gene action

along with partial dominance in bread wheat (Tahir *et. al.*, 1995; Subhani and Chowdhry, 2000; Ambreen *et. al.*, 2002; and Iqbal, 2004) indicating that this character is amenable to selection.

Low stomata frequency on the upper epidermis can be beneficial by increasing water use efficiency, through the reduction of water loss (Kramer, 1969 and Monteiro *et al.*, 1985). Under water deficit conditions, a signal from the roots (abscisic acid) triggers stomata closure which causes slower entrance of CO₂ and slow down photosynthesis (Fay and Knapp, 1993). In *Triticum aestivum*, shoot/root ratio, stomata frequency, and stomata aperture were found to be correlated with the potassium concentration in the leaves. Transpiration rate was also reported to be regulated by varied potassium and sodium concentrations (Brag, 1972). Jiang and Huang (2001) demonstrated that prior exposure to drought stress (drought preconditioning) enhanced heat tolerance in Kentucky bluegrass, which might be attributed to the maintenance of higher osmotic adjustment associated with accumulation of ion solutes, water soluble carbohydrates and development of extensive roots deeper in the soil profile.

Elevated temperatures accelerate senescence, reduce the duration of viable leaf area and diminish

photosynthetic activities (Harding *et al.*, 1990). Heat stress also affects the quality of the harvested product, reducing bread making quality by affecting gliadin synthesis (Blumenthal *et. al.*, 1993) and starch quality by affecting the ratio of A (large) to B (small) starch granule types (Stone and Nicolas, 1995). Rheological dough properties were affected by heat stress in field conditions (Castro, 2006). Numbers of leaf and tiller primordia are determined before spikelet initiation but their subsequent growth and development are controlled by temperature and day length during the differentiation of spikes into spikelets. Similarly, floret number within each spikelet is established by anthesis, at which time the potential grain number per spike is established. High photosynthetic rates at high temperatures do not necessarily support high rates of crop dry matter accumulation. All stages of development are sensitive to temperature, development generally accelerates as temperature increases (Abrol and Ingram, 1996). Although there is a large and valuable literature on physiological responses to temperature, we are far from having a comprehensive understanding of how crops respond to temperature (White and Reynolds, 2001).

Al-Yassin *et. al.*, (2005) concluded that, holding all other factors affecting response to selection

constant, concerns about the magnitude of heritability at low-yielding locations are not justified and should not prevent them from being used as selection sites. No firm conclusions were drawn as to the effectiveness of selection for stomata frequency under heat and drought and their impact on yield characteristics. Therefore, the present study was designed to evaluate morpho-physiological response to divergent selection for stomata frequency under heat and drought stresses.

Materials and Methods

Materials used:

Four local landraces of bread wheat (*Triticum aestivum* L.) were chosen from the germplasm accessions collected from farmers' fields in stressful area in Upper Egypt in 1993 (Omara, 1994). The four landraces were evaluated for heat tolerance under field conditions as: 1) heat susceptible group which comprised: P₁ (WA50), P₂ (WA81), and 2) heat tolerant group which comprised: P₃ (45-3-4), P₄ (WA90). In 2001-2002 Season, two crosses were established among the four parental landraces, namely cross1: P₃X P₁ and cross2: P₄X P₂. The F₁'s were grown in 2002-2003 season in order to produce F₂ seeds. Normal agronomic practices were adopted.

II- Selection procedure:

In 2003-2004 season, 200 spaced seeds were sown for each of the two

F₂ populations into the clay-loam fertile soil of Assiut University Experimental Farm in late (December 23rd) sowing date so as to allow the late sown plants to be subjected to the heat stress which usually develop later in the season. The recorded temperatures during February and March 2004 indicated that heat waves have occurred with temperature rising above 34 °C for several days which coincided with the post flowering stages of plant development. At anthesis, fully expanded flag leaf of the main culm of each plant was excised and its bottom part was placed in a capped vial containing Carnoy's solution and was transferred to the laboratory for stomata frequency estimation. At maturity, plants were individually harvested and grain yield per plant was determined. The highest and lowest five plants in stomata frequencies were selected (an 2.5% intensity of selection) for the high and low directions in each population. From each population, an equal number of seeds of each of the 200 F₂ plants was pooled to form the F₃ bulk.

In 2004-2005 season, the five families selected in both directions for each cross, along with the F₃ bulks were planted on the late sowing date (December 22nd) in a randomized complete block design (RCBD) with three replications. Each entry was planted in two rows 3m long, 30cm apart and plants were spaced at 5cm. Fully expanded flag

leaf of the main culms of five plants per replicate were excised for estimating stomata frequency. At maturity, grain yield per plant was determined on individual plant basis. Combined selection (between and within families) was practiced by picking the lowest three and the highest three families (3/5) for stomata frequency from population1 (pop1) and from population2 (pop2). The best three plants (3/15) were then selected within each family and their seeds were bulked to obtain the highest three and the lowest three families in each population (an $3/5 * 3/15 = 12\%$ selection intensity).

In 2005-2006 season, seeds of the selected F_4 families along with their relevant F_4 bulks were planted on the late sowing date (25th December) in a triplicate RCBD. Each entry was planted in five rows 3m long, set 30cm apart and plants were spaced at 5cm. Irrigation regime was as follows: first irrigation was at the 42nd day from establishment, then irrigation was applied at the 81st, 99th and 120th days, thus simulating a strong drought stress. At anthesis, fully expanded five main stem flag leaves were scored for leaf area and stomata frequency. At maturity grain yield was scored on previous plants. A sample of five main stem ears was collected at 10 days intervals, beginning from anthesis onwards, for five consecutive scores to estimate their length, fresh and dry weight.

III- Stomata frequency estimation:

Stomata frequency was determined on flag leaves at anthesis using a light microscope (40X objective) in 10 microscopic fields with an average of 10 fields/mm²/leaf. Difference in stomata frequencies among high and low directions in both populations was statistically tested using t-test in groups. To test whether selected family variances were significantly different from those of the bulks F test was used according to Kearsy and Pooni (1996).

IV- Heritability estimation

Heritability was estimated by parent-progeny regression b_{po} (F_2 - F_3), and b_{po} (F_3 - F_4). Realized heritability was calculated using F_2 (or F_3) plants and their respective F_3 (or F_4) progeny means.

Results and Discussions

Response to selection

After the 1st cycle of selection, the F_3 family means of stomata frequency ranged from 78.224 to 82.757 in the low direction of population1 with an average of 81.232 versus 85.8 for the F_3 bulk, indicating a significant reduction 5.36% from the bulk mean. Meanwhile, the family means in the high direction ranged from 99.2 to 100.2 with an average of 99.6, indicating a significant increase 16.03% from the bulk mean (Tables and Figs.1 and 2). Similar significant responses of 7.25% and 11.63%

respectively were also observed in population 2 (Tables 1 and 2). In both populations there were highly significant differences between the mean of high and low selections (Table 2).

Table(1): Means of stomata frequency (stomata/mm²) for different families selected for high and low stomata frequency in populations 1 and 2 in the first (F₃) and second (F₄) cycles of selection.

Selection direction	Families No.	stomata frequency			
		F ₃		F ₄	
		Pop. (1)	Pop. (2)	Pop. (1)	Pop. (2)
Low	1	82.716	76.940	79.0257	85.517
	2	82.757	73.169	80.470	78.173
	3	78.224	76.539	77.261	78.173
High	1	99.244	89.456	96.997	93.473
	2	99.364	90.218	95.393	93.228
	3	100.166	92.865	93.547	90.046
Bulk		85.829	81.377	84.562	87.129
Mean Low		81.232	75.549	79.293	80.621
Mean High		99.592	90.846	95.313	92.249

The observed average responses to selection which amounted to 16.03% and 11.63% of the population mean were consistently higher than the expected 8.29% and 5.598% in the high stomata frequency direction of populations 1 and 2 respectively (Table 3). Such observed responses in the low direction were 5.36% and 7.16% as compared to the expected responses 6.96 and 5.50% in the two populations indicating that the higher than expected responses occurred in the late heading population 2 (Table 3). Such inflated observed responses in the high direction might be attributed to dominance, epistasis or G x E

(Walsh, 2005). Evidently, the contribution from epistasis is due to favorable combinations of alleles at different loci, specifically those alleles that interact epistatically to change the character in the direction favored by selection. According to Wilson (1972), selection was more successful for frequent than for infrequent stomata in *Lolium perenne* grown in controlled environment.

Asymmetrical responses to selection were evident with the deviation in the high direction being greater than in the low direction in the F₃ (Tables and Figs.1 and 2). According to Tewolde *et.al.*, (2006),

Table (2): Analysis of variance for stomata frequency in different families: family1, family2 and family3 selected for high and low stomata frequency in both populations in the first (F₃) and second (F₄) cycles of selection.

Low direction			High direction			Over all population		
F₃								
Population 1								
S. O. V.	d.f.	M.S.	S. O. V.	d.f.	M.S.	S. O. V.	d.f.	M.S.
Blocks	2	0.8381	Blocks	2	5.1421	Blocks	2	2.4049
Families	3	**29.4286	Families	3	**142.5477	Families	5	**311.8013
L vs B	1	**47.5508	H vs. B	1	**426.1338	L vs. H	1	**1516.7621
among L	2	**20.3675	among H	2	0.7547	among L	2	20.3675
						among H	2	0.7547
Population 2								
Blocks	2	1.7690	Blocks	2	11.3203	Blocks	2	*22.8633
Families	3	**34.0463	Families	3	*73.6626	Families	5	**219.5902
L vs B	1	**76.4048	H vs. B	1	**201.7708	L vs H	1	**1053.0002
among L	2	12.8671	among H	2	9.6085	among L	2	12.8671
						among H	2	9.6085
F₄								
Population 1								
Blocks	2	10.3805	Blocks	2	7.2525	Blocks	2	5.3455
Families	3	29.0481	Families	3	**92.6441	Families	5	**248.5515
L vs B	1	*71.6446	H vs. B	1	**260.0510	L vs. H	1	**1209.3767
among L	2	7.7498	among H	2	8.9406	among L	2	7.7498
						among H	2	8.9406
Population 2								
Blocks	2	1.6258	Blocks	2	17.8513	Blocks	2	13.7109
Families	3	*67.7186	Families	3	26.9753	Families	5	**147.6513
L vs B	1	**95.2859	H vs. B	1	58.9922 ^{ns}	L vs. H	1	**608.4530
among L	2	53.9349	among H	2	10.9668	among L	2	53.9349
						among H	2	10.9668

L= low direction; H= high direction; and B= bulk

early heading, which was characterizing population 1 in this study, is an important and effective single trait defining wheat cultivars adapted to production systems prone to high temperature stress during the post-heading period. Successful selection was expected since Wilson (1971) and Subhani and Chowdhry

(2000) found a considerable additive genetic variation for stomata frequency. Bkagwat and Bhatia (1993) also obtained two selections in the F₉ generation exhibiting significantly higher stomata frequencies than the higher parent. Such successful selection was also expected since both additive and

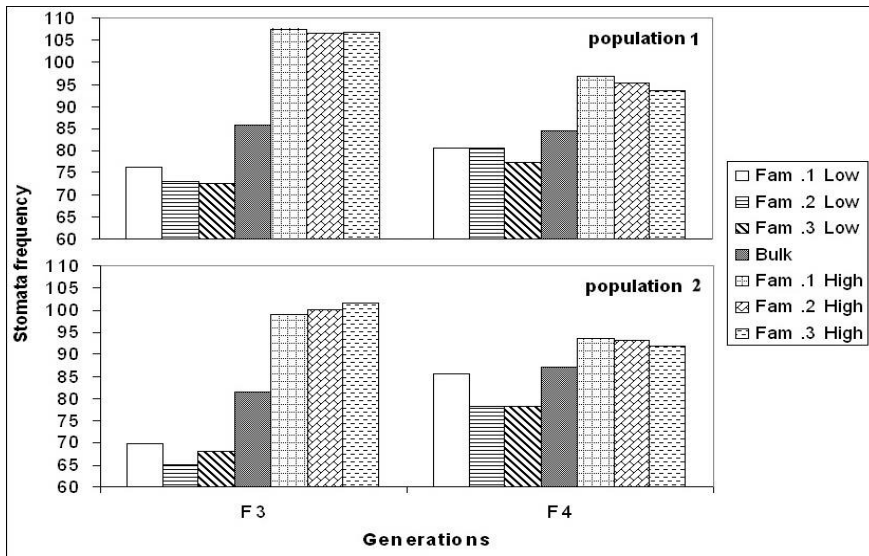


Fig. (1): Means of selected families for high and low stomata frequency (stomata/mm²) in populations 1 and 2 in the first (F₃) and second (F₄) cycles of selection.

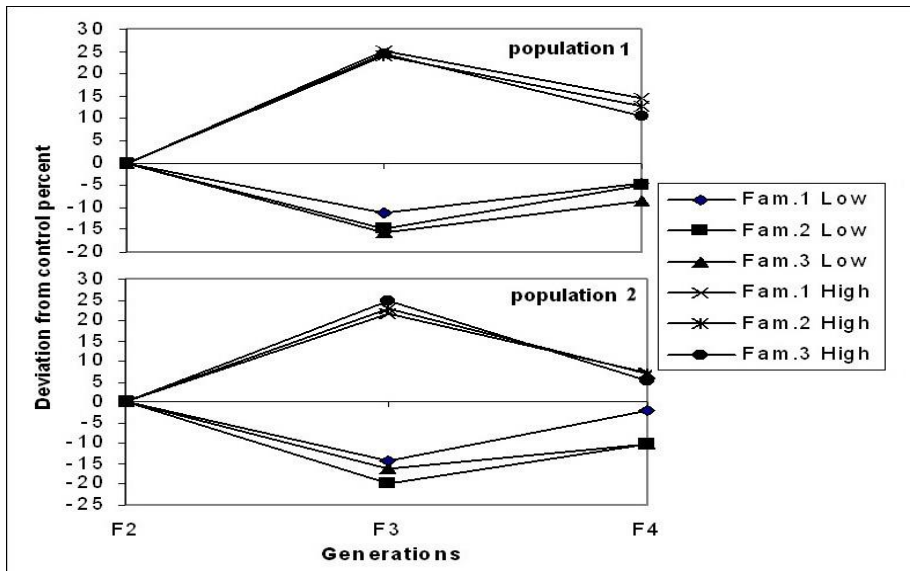


Fig. (2): Stomata frequency deviation percentage from the bulk sample for families selected for high and low directions in populations 1 and 2 in the first and second cycle of selection (F₃ and F₄).

non-additive variances were controlling stomata frequency (Iqbal, 2004, and Riaz 2003), additive gene action along with partial dominance was reported by Tahir *et. al.*, (1995) and Ambreen *et. at.*, (2002). The inconsistent results obtained in this study might be attributable to random genetic drift and/or to the presence of (G x E) which was reported to affect such a trait in alfalfa leaves (Gindel, 1968).

Variances within selected families were not significantly different from those of the bulk which was rather unexpected in the high and low directions of the late flowering populations 2 (Table 3). A similar trend was obtained, in one of the three families, in the low and high directions, while the other two families showed reduced variances in population 1. As rare alleles might have increased in frequency due to the genetic drift, the frequency of the extreme genotypes might have increased and so inflated the additive variance.

The narrow sense heritability calculated by parent-offspring regression was moderate ($h^2=0.45$) in population 1 but low ($h^2=0.266$) in population 2. However, the realized heritability was higher in the high direction, reflecting the effect of inflated responses to selection, and lower in the low direction (Table 3). These results are in accordance with those of Riaz (2003) who found moderate narrow-sense heritability

(0.52) under drought stress. As well, heritability for stomata frequency based on parent-progeny regression was reported to be 0.42 (F_3-F_4) which increased to 0.81 (F_4-F_5) in bread wheat (Bkagwat and Bhatia, 1993). However, Iqbal (2004) obtained high narrow and broad-sense heritability estimates of 0.89 and 0.94 for such a trait in spring wheat under non-stressed conditions.

The significant responses obtained in the first cycle of selection under heat stress prompted the superimposition of moisture stress, which concurrently occurs with sporadic heat waves in arid regions, in the second cycle of selection. Family means of stomata frequency ranged from 77.26 to 80.47 in the low direction with an average of 79.29 and ranged from 93.55 to 97.00 with an average of 95.313, in the high direction, versus 84.56 for the bulk of population 1 (Table1). After the second cycle of selection, the significant observed response which averaged 12.71% of the population mean was higher than the expected 9.48% in populations 1 in the high stomata frequency direction (Table 2 and 3). The observed average response of 9.39% exceeded also the expected 5.01% in population 2 in the high direction but such difference was not significant (Table 3 and 2). In the low stomata frequency direction observed responses 6.67% and 9.42% respectively, were higher

than those expected 5.32% and 3.63% in population 1 and 2, respectively. Generally, the difference between high and low direction was highly significant all over the cycles of selection in both populations (Table2).

Responses to selection in the second cycle were less than those obtained in the first cycle which might probably be due to the effect of drought on stomata frequency per wheat leaf in accordance with Quarrie and Jones (1977) who found that water stress reduced the number of stomata per leaf. Moisture stress decreased also the length and breadth of stomata, leaf water potential and relative water content in *Solanum melongena* L. (Prakash and Ramachandran, 2000). The variety with the lesser stomatal frequency and higher total leaf resistance to water loss had nevertheless faster net photosynthesis than the variety with the greater stomatal frequency, demonstrating the importance of the so-called mesophyll resistance in maize (Heichel, 1971).

Generally, there were no significant differences between selected and bulk variances overall families and populations in the second cycle of selection which might be due also to the severe stress to which plants were exposed. Heritability was also inflated whether calculated as parent-offspring regression or realized

heritability which lend further support to the inflated additive variance. The narrow-sense heritability calculated as parent-offspring regression was moderate ($h^2=0.497$) in population 1 and low ($h^2=0.363$) in population 2, but still higher than those observed in the first cycle of selection. Similar increase for h^2 of this trait was reported by Bkagwat and Bhatia, (1993). Here again, the realized heritability was higher (0.620) in the low stomata direction of population 2, reflecting the inflated response to selection and indicating that drought stress reversed the situation which was apparent in the first cycle of selection in this population. In the other cases, the realized heritability became slightly higher than those estimated by parent-offspring regression basis. For some abiotic stresses and many biotic stresses, heritability was higher in the presence of stress (Baker, 1993). Kanemasu *et. al.*, (1969) have reported that varieties that offer more resistance to water flow from stomata into the atmosphere have beneficial traits towards drought tolerance. Drought improved water-soluble carbohydrates mobilization efficiency in the peduncle, penultimate, and lower internodes by 33, 17, 11%, respectively (Ehdaie *et. al.*, 2006). Prior exposure to drought stress (drought preconditioning) affected turfgrass tolerance to subsequent heat stress (Jiang and Huang 2000, 2001).

Drought stress resulted in a significant increase in the thermal stability of Photosystem II in wheat (Dulai *et. al.*, 2006).

By comparing the absolute mean values, it was apparent that a significantly higher stomata frequency was reached in population 1 than that in population 2 after the second cycle of selection (Tables 1&4). Whereas, no significant difference was detected between the low direction in population 1 and that of population 2, the bulk exhibited also a similar trend

(Tables 1&4). These results indicated the success of divergent selection for changing this trait under both heat and drought stresses. Further responses to selection based on 13.33% selection intensity are expected to amount to 7.04% and 9.61% in the low and high stomata directions, respectively in population 1, and to 5.60% and 6.58% in the low and high stomata directions, respectively in population 2 under both heat and drought stresses in the third cycle of selection.

Table(4): Testing the differences between population 1 (Pop.1) and population 2 (Pop.2) means for stomata frequency, grain yield per plant and 100-kernel weight among the selected families in the low direction [Low(Pop.1) - Low(Pop.2)], in the high direction [High(Pop.1) - High(Pop.2)] and among non-selected bulks [Bulk(Pop.1) - Bulk(Pop.2)] after the second cycle of selection.

Pop.1 mean – Pop.2 mean	Obtained t values for each character		
	Stomata frequency	Grain yield per plant	100-kernel weight
Low(Pop. 1) - Low(Pop.2)	-1.25	-5.74**	3.47**
High(Pop. 1) - High(Pop.2)	2.02*	-7.54**	9.01**
Bulk(Pop. 1) - Bulk(Pop.2)	-1.2	-4.2**	5.8**

t test for [Pop.1 mean – Pop.2 mean] : *= significant (P<0.05), **= highly significant (P<0.01)

Correlated response to selection

I- 100-kernel weight

Correlated responses in 100-kernel weight for the different families selected for the high and

low stomata frequency directions in populations 1 and 2 in the first and second cycles of selection are presented in Table (5). The first cycle of selection did not produce correlated responses in 100-kernel

weight in population 1 in either directions. Both high and low selections did not deviate from each other or from the control. Meanwhile, significant reductions of 1.37% and 2.51% of the bulk mean were obtained in the low and high directions respectively, in population 2 (Tables 5 and 6). Surprisingly, selected families within low direction in population 1 and both low and high directions in population 2 showed significantly different performances as revealed by the highly significant among low as well as among low and high families mean squares (Table 6), indicating different genetic potentialities for assimilate partitioning in these families. The different performances of selected families might reflect their differential sensitivities to elevated temperatures or light conditions after anthesis. Schlüter *et. al.*, (2003) working with a mutant of *Arabidopsis* *sdd1-1* having 2.5-fold higher stomatal densities reported that upon exposing it to constant light intensities it did not differ significantly from the wild type. Whereas, plants receiving low light quantities during their development of the photosynthetic apparatus, elevated stomatal density caused only minimal differences in stomatal conductance since the synthesis of many proteins involved in photosynthesis, for example Rubisco, depends on stimulation by light. They concluded that stomatal

initiation could be of particular importance for plants where leaves develop over a relatively short period but serve longer as a source of carbohydrates. This study stresses upon the other systems governing assimilates accumulation in addition to stomata frequency. Such conditions which might have occurred due to enhanced growth by high temperatures in this study may explain the differential assimilates accumulation in selected families in high and low directions. Meanwhile, high temperature of soil alone (26/38°C) or high temperature of both air and soil (38/38°C) caused a reduction in the chlorophyll content and grain-filling duration, and increased carbohydrate remobilization. Genotypic differences in the responses to high soil temperature and high air/soil temperature were also observed (Tahir *et. al.*, 2006). Evidently, moderate to high heat stress at mid-grain fill increased thousand kernel weight. However, higher heat stress under controlled environment caused a decrease in thousand kernel weight, without any difference in relation to duration or timing of stress (Castro 2006). Cereals possess a degree of developmental plasticity that allows for increases in kernels/spike or kernel weight to compensate for losses in tiller number if environmental conditions and assimilate availability improves after the stem elongation stage (Kirby and Jones, 1977).

Table (5): Means of 100-kernel weight for different families selected for high and low stomata frequency in populations1 (Pop.1) and 2 (Pop.2) in the first (F₃) and second (F₄) cycles of selection.

Selection direction	Families No.	100-kernel weight			
		F ₃		F ₄	
		Pop (1)	Pop (2)	Pop (1)	Pop (2)
Low	1	4.99	4.18	4.82	4.61
	2	4.98	3.89	4.69	4.19
	3	4.47	3.70	4.64	4.19
High	1	4.71	4.04	4.99	4.46
	2	4.75	4.19	4.86	4.33
	3	4.80	3.80	5.42	4.04
Bulk		4.82	4.13	4.87	4.39
Mean Low		4.81	3.92	4.72	4.33
Mean High		4.75	4.01	5.09	4.28

Table (6): Summary of the analysis of variance for 100-kernel weight in different families selected for high and low stomata frequency in populations1 and 2 in the first (F₃) and second (F₄) cycles of selection.

Low direction			High direction			Over all population		
F ₃								
Population 1								
S. O. V.	d.f.	M.S.	S. O. V.	d.f.	M.S.	S. O. V.	d.f.	M.S.
Blocks	2	0.3469	Blocks	2	0.8575	Blocks	2	0.2180
Families	3	17.8524**	Families	3	0.7554	Families	5	11.2655**
L vs B	1	0.0239	H vs B	1	1.1406	L vs H	1	1.6684
among L	2	26.7667**	among H	2	0.5628	among L	2	26.7667**
						among H	2	0.5628
Population 2								
Blocks	2	5.7891	Blocks	2	9.5947**	Blocks	2	11.0689**
Families	3	14.7110**	Families	3	8.5184**	Families	5	12.0299**
L vs B	1	9.7095*	H vs B	1	3.2616*	L vs H	1	3.4322
among L	2	17.2117**	among H	2	11.1468**	among L	2	17.2117**
						among H	2	11.1468**
F ₄								
Population 1								
Blocks	2	0.044636	Blocks	2	0.003417	Blocks	2	0.002214
Families	3	0.036223	Families	3	0.202729	Families	5	0.238179*
L vs B	1	0.05728	H vs B	1	0.105625	L vs H	1	0.636944**
among L	2	0.025694	among H	2	0.251281	among L	2	0.025694
						among H	2	0.251281*
Population 2								
Blocks	2	0.002615	Blocks	2	0.024214	Blocks	2	0.018389
Families	3	0.125961	Families	3	0.1035	Families	5	0.131893*
L vs B	1	0.009801	H vs B	1	0.030976	L vs H	1	0.011858
among L	2	0.184041*	among H	2	0.139761	among L	2	0.184041*
						among H	2	0.139761*

L= low direction; H= high direction; and B= bulk

After the second cycle of selection, a highly significant difference was obtained between high (5.09g) and low (4.72g) stomata directions for 100-kernel weights, although each of which did not deviate significantly from the control (4.87g) in populations 1. By comparing the absolute mean values, it was apparent that a significantly higher 100-kernel weight was reached in population 1 than that in population 2 after the second cycle of selection in the low and the high direction as well as the two bulks (Tables 5 and 4). Kernel weight can be reduced when the length of the grain filling period is restricted by drought and heat stress after anthesis (Warrington *et al.*, 1977). These results are also in accordance with Guttieri *et al.*, (2001) who suggested that the overall moisture-deficit-induced reduction in yield was primarily due to reduction in kernel weight. According to Duggan and Fowler, (2006) large differences in kernels/spikelet and kernel weight indicated that these two variables were responsible for yield adjustments to dryland stress during the spikelet and kernel development phase. Hundred-kernel weight is a vital yield component and is more or less stable character of wheat cultivars. Under drought 100- kernel weight may be affected to a greater extent due to the shortage of moisture which forces plants to complete its grain formation in relatively lesser time (Riaz, 2003).

Such results might suggest that selection operating on the genetic system underlying the control of stomata frequency and 100-kernel weights might have changed their allelic frequencies differently, genetic drift have also also been responsible for such differential performances or that the other systems controlling photosynthesis show plasticity in this regard.

Grain yield/plant

No correlated response to selection for stomata frequency were obtained in grain yield/plant. However, significant differences were detected among families selected for high and low stomata frequency in population 2 after the first cycle of selection, indicating differential assimilates partitioning among these families as was previously observed for 100-kernel weight (Tables 7 and 8). Following the first cycle of selection, means of grain yield/plant in low stomata frequency direction (25.92g and 31.06g) were slightly higher than those of the high (23.82g and 27.54g) as well as those of the bulk (24.55 g and 25.94 g) in population 1 and 2 respectively. However, such differences were non-significant. After the second cycle of selection, such slight increases over the bulk disappeared in population 1 where both high (19.79g) and low (20.91g) stomata frequency directions were slightly lower in grain yield (21.42g for the bulk). Whereas, in population

Table (7): Means of grain yield for different families selected for high and low stomata frequency in populations 1 (Pop.1) and 2 (Pop.2) in the first (F₃) and second (F₄) cycles of selection.

Selection direction	Families No.	Grain yield			
		F ₃		F ₄	
		Pop (1)	Pop (2)	Pop (1)	Pop (2)
Low	1	26.73	35.75	21.25	31.55
	2	24.89	32.02	20.06	35.94
	3	26.13	25.41	21.43	34.39
High	1	21.54	24.05	20.18	34.86
	2	22.87	24.83	17.03	31.66
	3	27.04	33.75	22.17	38.35
Bulk		24.55	25.94	21.42	31.02
Mean Low		25.92	31.06	20.91	33.96
Mean High		23.82	27.54	19.79	34.96

Table (8): Summary of the analysis of variance for grain yield in different families selected for high and low stomata frequency in populations 1 and 2 in the first (F₃) and second (F₄) cycles of selection.

Low direction			High direction			Over all population		
F ₃								
Population 1								
S. O. V.	d.f.	M.S.	S. O. V.	d.f.	M.S.	S. O. V.	d.f.	M.S.
Blocks	2	3.4668	Blocks	2	5.6774	Blocks	2	5.9015
Families	3	3.1801	Families	3	16.8750	Families	5	14.9175
L vs B	1	4.2244	H vs B	1	1.1983	L vs H	1	19.8450
among L	2	2.6579	among H	2	24.7134	among L	2	2.6579
						among H	2	24.7134
Population 2								
Blocks	2	8.1948	Blocks	2	24.2596	Blocks	2	19.2149
Families	3	74.4321*	Families	3	60.0083*	Families	5	78.8671*
L vs B	1	58.9824	H vs B	1	5.7600	L vs H	1	55.7568
among L	2	82.1569*	among H	2	87.1324*	among L	2	82.1569*
						among H	2	87.1324*
F ₄								
Population 1								
Blocks	2	3.946209	Blocks	2	33.05287	Blocks	2	57.76961
Families	3	1.302369	Families	3	15.40945	Families	5	9.846337
L vs B	1	0.583187	H vs B	1	5.987809	L vs H	1	5.667222
among L	2	1.66196	among H	2	20.12027	among L	2	1.66196
						among H	2	20.12027
Population 2								
Blocks	2	74.4391	Blocks	2	34.77211	Blocks	2	95.27161
Families	3	16.42155	Families	3	34.05137	Families	5	20.29937
L vs B	1	19.47996	H vs B	1	34.91234	L vs H	1	4.470382
among L	2	14.89235	among H	2	33.62089	among L	2	14.89235
						among H	2	33.62089

L= low direction; H= high direction; and B= bulk

2 both high (34.96g) and low (33.96g) stomata frequency directions were higher in grain yield versus 31.02g in the bulk of F₄, but again the differences were non-significant. It seems that the relationship between stomata frequency and yield is tenuous. By comparing the absolute mean values, it was apparent that a significantly lower grain yield per plant was reached in population 1 than that in population 2 in the second cycle of selection in the low and the high direction as well as the two bulks (Tables 7&4). Evidently, selection for one trait (stomata frequency) might not affect other traits (100-kernel weight and grain yield) since high temperature significantly decreased grain yield by decreasing grain weight (Tahir, *et. al.*, 2006).

No correlated responses were detected for leaf area, which did not differ among selected families and from the bulk (analysis of variance not presented) in disagreement with Bkagwat and Bhatia (1993) who found that stomata frequency was negatively correlated with the flag leaf blade area. It appears that leaf area generally decreased in the same way all over selected families and bulks due to the severe drought stress which blurred the variability in this trait in accordance with (Fischer, 1984) who reported that if growth resources (water, nutrients and radiation) are limited under heat stress, then the size of plant organs such as leaves, tillers, and spikes is reduced. Moreover, (Mosaad *et. al.*, 1995) reported that

leaf area decreased with increasing moisture stress in *Triticum aestivum* and *T. durum*.

The paucity and partial information generated by stomata frequency studies, are due to the tedious work needed and its' hard applicability to great number of genotypes which diminish its use in large scale breeding programs and urge for more studies offering new avenues for crop improvement using marker assisted selection. We are still far from having a comprehensive understanding of how crops respond to temperature (White and Reynolds, 2001). Results demonstrated that heat tolerance of common wheat is controlled by multiple genes and suggested that marker-assisted selection with microsatellite primers could be useful in accelerating selection studies and developing improved cultivars (Yang *et al.*, 2002). The genetic architecture of stomata frequency should be dissected into a genetic network of interacting loci. These interactions, explored by epistatic QTL mapping, in a radial network may mediate a considerably larger selection response than predicted. A more in-depth understanding of genome-wide mechanisms necessitates explorations beyond the statistical estimates of these QTL effects. The ability of the loci in their network to release or suppress genetic variation is also related to the mechanisms shown by capacitors of cryptic genetic variation that have been described earlier in

situations resulting from induced environmental or genetic perturbations (Carlborg *et. al.*, 2006). Stress-induced genomic responses give more insight about transposon activation, transposition, and structural genome changes which may explain such unexpected selection results. Like other stress responses transposon-mediated alterations in transcriptional activity of affected genes might lead to avoidance or tolerance of the stress. Unlike many other stress responses, however, transpositional activation is a hit-or-miss approach to finding an appropriate way of handling an unusual challenge Madlung and Comai (2004). Using genetic mapping to dissect the inheritance of different complex traits, using molecular techniques, in the same segregating population can be a powerful means to distinguish common heredity from casual associations between such traits and might be a good alternative (Schlüter *et. al.*, 2003).

References

- Abrol Y. P and K. T. Ingram 1996. Global climate change and agricultural production. Direct and indirect effects of changing hydrological, pedological and plant physiological processes.6. Effects of higher day and night temperatures on growth and yields of some crop plants. Edited by Fakhri Bazzaz (Harvard University, USA) and Wim Sombroek F.A.O., Italy Published 1996 by John Wiley & Sons Ltd, Baffins Lane, Chichester, West Sussex PO19 1UD, England.
- Al-Yassin, A.; S. Grando ; O. Kafawin,; A. Tell and S. Ceccarelli 2005. Heritability estimates in contrasting environments as influenced by the adaptation level of barley germplasm. *Annals of Applied Biology* Volume 147, Issue 3.p. 235.
- Ambreen, A.; M. As. Chowdhry; I. Khaliq and R. Ahmad, 2002. Genetic Determination for Some Drought Related Leaf Traits in Bread Wheat. *Asian Journal of Plant Sciences*, Volume 1 Number 3: 232-234.
- Baker, R. J. 1993. Breeding methods and selection indices for improved tolerance to biotic and abiotic stresses in cool season food legumes. *Euphytica*, Volume 73, No. 1-2, p. 67-72.
- Bhagwat S. G. and C. R. Bhatia 1993. Selection for flag leaf stomatal frequency in bread wheat. *Plant breeding* :, vol. 110, n^o2, pp. 129-136.
- Blumenthal CS; E.W.R. Barlow and C.W. Wrigley 1993. Growth environment and wheat quality: the effect of heat stress on dough properties and gluten proteins. *Journal of Cereal Science* 18, 3–21.
- Brag, H. 1972. The Influence of Potassium on the Transpiration

- Rate and Stomatal Opening in *Triticum aestivum* and *Pisum sativum*. *Physiologia Plantarum*, Vol.:26, Issue: 2. Page 250.
- Carlborg, O.; L. Jacobsson; P. Ahgren; P. Siegel and L. Andersson, 2006. Epistasis and the release of genetic variation during long-term selection. *Nature Genetics*, 38: pp 418-420.
- Castro, D. Marina 2006. Influence of heat stress on grain yield, grain quality, and protein composition of spring wheat. PhD thesis in Crop Science, Oregon State University, 127 pages.
- DE Pereira-Netto, A. B.; G. A. Carlos and H. S. Pinto 1999. Aspects of leaf anatomy of Kudzu (*Pueraria lobata*, Leguminosae-Faboideae) related to water and energy balance. *Pesq. agropec. bras.* vol.: 34 no.8, Brasília.
- Duggan, B. L. and D. B. Fowler 2006. Yield Structure and Kernel Potential of Winter Wheat on the Canadian Prairies. *Crop Sci* 46:1479-1487.
- Dulai, S.; I. Molnar; J. Pronay; A. Csernak; R. Tarnai and M. Molnar-Lang, 2006. Effect of drought on photosynthetic parameters and heat stability of PSII in wheat and *Aegilops* species originating from dry habitats. *Acta biologica Szegediensis*, 50: 11-17.
- Ehdaie, B.; G.A. Alloush; M.A. Madore, and J.G. Waines, 2006. Genotypic variation for stem reserves and mobilization in wheat II: Postanthesis changes in internode water-soluble carbohydrates. *Crop Sci.* 46: 2093-2103.
- Fay P. A. and A. K. Knapp 1993. Photosynthetic and Stomatal Responses of *Avena sativa* (Poaceae) to a Variable Light Environment. *American Journal of Botany*, 80: pp. 1369-1373.
- Fischer, R.A. 1984. Physiological limitations to producing wheat in semi-tropical and tropical environments and possible selection criteria. p. 209-230. *In* *Wheats for more tropical environments*. Proc. Int. Symp., Mexico City. 24-28 Sept. 1984. CIMMYT, Mexico City.
- Fischer, R.A. and D.B. Byerlee 1991. Trends of wheat production in the warmer areas: major issues and economic considerations. *In* *Wheat for the Non-traditional Warm Areas*. Proc. of Conf., Iguazu, Brazil, 29 Jul.-3 Aug. 1990, p 3-27. Mexico, DF, CIMMYT.
- Gindel, I. 1968. Dynamic modifications in alfalfa leaves growing in subtropical conditions. *Physiologia Plantarum*, Vol. 21: 1287-1295.
- Guttieri, Mary J.; J.C. Stark; O'Brien, and E. Souza, 2001. Relative sensitivity of spring wheat grain yield and quality parameters to moisture deficit. *Crop. Sci.* 41:327-335.

- Harding SA, J. A. Guikema; GM. Paulsen 1990. Photosynthetic decline from high temperature stress during maturation of wheat. I. Interaction with senescence processes. *Plant Physiology* 92, 648–653.
- Heichel G. H. 1971. Stomatal Movements, Frequencies, and Resistances in Two Maize Varieties Differing in Photosynthetic Capacity *Journal of Experimental Botany*, Volume 22, Number 3 , Pp. 644-649
- Iqbal, M. 2004. Diallelic analysis of some physio-morphological traits in spring wheat. Ph.D. thesis, Faculty of Agriculture, University of Agriculture, Faisalabad, Pakistan.
- Jiang, Y. and B. Huang 2000. Effects of Drought or Heat Stress Alone and in Combination on Kentucky Bluegrass *Crop Science* 40:1358-1362.
- Jiang, Y. and B. Huang 2001. Osmotic Adjustment and Root Growth Associated with Drought Preconditioning-Enhanced Heat Tolerance in Kentucky Bluegrass. *Crop Science* 41:1168-1173.
- Kanemasu, E.T., G.M. Thurtell and C.B. Tanner. 1969. Design calibration and field use of a stomata diffusion parameter. *Plant Physiology* 44: 881-885.
- Kearsey, M. J. and H. S. Pooni 1996. The genetical analysis of quantitative traits. Chapman and Hall, London, U.K., p 42.
- Khaliq, I.; S.A.H. Shah; M. Ahsan, and M. Khalid, 2000 . Evaluation of spring wheat (*Triticum aestivum* L.) for drought field conditions. A morphological study. *Pak. J.Bio.Sci.*, 2:1006-1009.
- Khan, H.A. and M. Shaik, 1997. Character association and path coefficient analysis of grain yield and yield components in wheat. *Crop Res.*, 17: 229-233.
- Kirby, E.J.M., and H.G. Jones 1977. The relations between main shoot and tillers in barley plants. *J. Agric. Sci. (Cambridge)* 88:381–389.
- Kramer, P.J. 1969. *Plant and soil water relationships: a modern synthesis*. New York: McGraw-Hill, 482p (C.F.: Pereira-Netto, *et al.*, 1999).
- Madlung, A. and L. Comai 2004. The Effect of Stress on Genome Regulation and Structure. *Annals of Botany* 94(4):481-495
- Monteiro, W.R.; M.M. Castro, and A.M. Giulietti, 1985. Aspects of leaf structure of some species of *Leiothrix* Ruhl. (Eriocaulaceae) from the Serra do Cipó (Minas Gerais, Brazil). *Revista Brasileira de Botânica*, v.8, p.109-125 (C.F.: Pereira-Netto, *et al.*, 1999).
- Morris, M.L., A. Belaid, and D. Byerlee, 1991. Wheat and barley production in rainfed marginal environments of the developing

- world. 1990-91 CIMMYT world wheat factors and trends. Mexico, DF, CIMMYT.
- Mosaad, M. G.; G. Ortiz-Ferrara; V. Mahalakshmi, and J. Hamblin, 1995. Leaf development and phenology of *Triticum aestivum* and *T. durum* under different moisture regimes. *Plant and Soil* Volume 170, Number (2): p. 377-381.
- Nayeem, K.A. and Y.S. Nerker, 1988. Association of drought and heat tolerance parameters in wheat. *Indian J. Genet. And Pl. Br.*, 48: 371-376.
- Omara, M.K. 1994. Collection, maintenance, and gene banking of germplasm of wheat, barley, berseem clover, maize and sorghum from moisture deficient areas in Upper Egypt. Final Report of project No. A-5-4, NARP, Egypt.
- Prakash, M. and K. Ramachandran 2000. Effects of Chemical Ameliorants on Stomatal Frequency and Water Relations in Brinjal (*Solanum melongena* L.) under Moisture Stress Conditions. *J. of Agronomy and Crop Science*, Vol.185, No.4, Page237.
- Quarrie, S. A. and H. G. Jones 1977. Effects of Abscisic Acid and Water Stress on Development and Morphology of Wheat. *J. Experimental Botany*, Vol.28, No.1:p.192-203.
- Reeves T. G., S. Rajaram, M. I Ginke, R. Trethowan, H. Braun, and K. Cassaday 2000. International Maize and Wheat Improvement Centre (CIMMYT). Department of Agriculture, Western Australia, Crop Updates 2000 : Cereals, New Wheats for a Secure, Sustainable Future 2000.
- Reynolds, M.P. 2002. Physiological approaches to wheat breeding. In: Bread wheat, Improvement and production, B.C. Curtis, S. Rajaram and H. Gómez Macpherson (eds.), Series-title: FAO Plant Production and Protection, pg 567.
- Riaz, R. 2003. Genetic analysis for yield and yield components in spring wheat under drought conditions. PhD thesis, University of Agriculture, Faculty of Agriculture, dept. Plant Breeding and Genetics, Faisalabad, Pakistan.
- Rosegrant, M.W., M. Agcaoili-Sombilla, and N.D. Perez 1995. Global food projections to 2020: implications for investment. Washington, DC, IFPRI.
- Schlüter, U.; M. Muschak; D. Berger and T. Altmann, 2003. Photosynthetic performance of an *Arabidopsis* mutant with elevated stomatal density (sdd1-1) under different light regimes. *Journal of Experimental Botany*, Vol. 54, No. 383, pp. 867-874
- Stone PJ, and ME. Nicolas 1995. A survey of the effects of high

- temperature during grain filling on yield and quality of 75 wheat cultivars. *Australian Journal of Agricultural Research* 46, 475–492.
- Subhani, G.M. and M.A. Chowdhry, (2000). Genetic studies in bread wheat under irrigated and drought stress conditions. *Pak.J.Biol.Sci.*, 3:1793-1798.
- Tahir, M. S.; K. Alam; M.A. Chowdhry; and J. Ahmad 1995. Diallel analysis of some morpho-physiological traits in bread wheat (*Triticum aestivum* L.). *Gomal Univ. J. Res.*, 15:45-51.
- Tahir, I. S. A.; N.Nakata; A. M. Ali; H.M. Mustafa; A. S. I.Saad , K.Takata, N. Ishikawa, and O. S. Abdalla 2006. Genotypic and temperature effects on wheat grain yield and quality in a hot irrigated environment *Plant Breeding*, Vol. 125, p. 323.
- Tewelde, H.; C.J. Fernandez; C. A. Erickson, 2006. Wheat Cultivars Adapted to Post-Heading High Temperature Stress. *J. Agron. Crop Science*, Vol. 192, No. 2, pp. 111-120.
- Usman Khan, M., M. A. Chowdhry, Khaliq, Ihsan and R. Ahmad, 2003. Morphological Response of Various Genotypes to Drought Conditions. *Asian Journal of Plant Sciences* 2 (4): 392-394.
- Walsh, B. 2005. The struggle to exploit non-additive variation. *Australian J. Agric. Res.*,56, 873-881.
- Warrington, I.J.; R.L. Dunstone; and L.M. Green 1977. Temperature effects at three development stages on the yield of the wheat ear. *Aust. J. Agric. Res.* 28:11–27.
- White, J.W., and M.P. Reynolds 2001. A physiological perspective on modeling temperature response in wheat and maize crops. In: *Modeling temperature response in wheat and maize. Proceedings of a workshop, CIMMYT, El Batan, Mexico, 23-25 April 2001.* Jeffrey W. White, Editor.
- Wilson, D. 1971. Selection responses of stomatal length and frequency, epidermal ridging, and other leaf characteristics in *Lolium perenne* L. ‘Grasslands Ruanui’ *N.Z. Agric. Res.*,14,761.
- Wilson, D. 1972. Effect of selection for stomatal length and frequency on theoretical stomatal resistance to diffusion in *Lolium perenne* L. *New Phytol.* 71, 811-817.
- Yang, J.; R.G. Sears; B.S. Gill and G.M. Paulsen, 2002. Quantitative and molecular characterization of heat tolerance in hexaploid wheat. *Euphytica*, Vol. 126, NOo. 2, pp: 275-282.

تأثير الانتخاب لتكرار الثغور على خصائص المحصول تحت الاجهادات الحرارية والمائية في قمح الخبز (*Triticum aestivum* L).

محمد محمود حسيب الدفراوي

قسم الوراثة، كلية الزراعة، جامعة أسيوط، أسيوط، جمهورية مصر العربية

تعتبر الثغور المنتشرة على أوراق النبات مصدرا هاما لخفض درجة الحرارة بكف النباتات، ولذا استخدمت عشيرتين في الجيل الثاني، إحداهما مبكرة الإزهار والثانية متأخرة الإزهار، لإجراء دورتي انتخاب في اتجاهين متعاكسين لصفة تكرار الثغور على ورقة العلم في نبات القمح. وقد عرضت النباتات للإجهادات الحرارية والمائية وتم الانتخاب لمعرفة مدى ذلك في فصل العشيبة إلى عائلات مختلفة ومدى تأثير ذلك على خصائص المحصول. وجمعت أوراق علم من خمس سوق رئيسة في وقت إنتثار حبوب اللقاح ثم جمعت تلك النباتات لتقدير محصول الحبوب ووزن المائة حبة فيها عند النضج.

وكانت متوسطات الاستجابة المشاهدة للانتخاب في الدورة الأولى في العشيبة الأولى 16.03% و 11.63% كانحراف عن الشاهد (المقارنة) أكبر من المتوقعة 8.29% و 5.598% في العشيرتين الأولى والثانية على التوالي في اتجاه زيادة تكرار الثغور. بينما ظهرت زيادة الاستجابة المشاهدة 7.16% عن المتوقعة 5.50% فقط في اتجاه نقصان الثغور في العشيبة الرابعة. ومن المحتمل أن تعزى تلك الزيادة المتضخمة إلى السيادة والتفوق أو التفاعل بين الوراثة والبيئة. وكانت الإستجابة للإنتخاب غير متناظرة، إذ كان انحراف الإتجاه المزيد للثغور أكبر من الإتجاه المنقص لها. وكان معامل التوريث بالمعنى الضيق محسوبا كإرتداد الأبناء على متوسط الأبء أعلى في العشيبة الأولى 0.45 عنة في الثانية 0.266، بينما كان معامل التوريث المتحقق أعلى في الإتجاه المزيد عن المنقص في العشيرتين على التوالي.

وكانت الاستجابة المشاهدة 12.71% و 9.39% في صورة انحراف عن الشاهد أكبر من المتوقعة في العشيرتين الأولى والثانية على التوالي في دورة الانتخاب الثانية في اتجاه زيادة الصفة. كما كانت الاستجاب المشاهدة أعلى في اتجاه نقصان الصفة 6.67% و 9.42% في العشيرتين على التوالي. وكان الفرق بين الإتجاه المزيد والمنقص للصفة معنويا جدا في العشيرتين مما يشير إلى جدوى الانتخاب. كما كان معامل التوريث بالمعنى الضيق أعلى في العشيبة الأولى 0.50 عنة في العشيبة الثانية 0.36. وكان معامل التوريث المتحقق أعلى في اتجاه زيادة 0.62 عنة في اتجاه نقصان 0.44 تكرار الثغور في العشيبة الثانية. بينما لم يبدي معامل التوريث المتحقق تغيرا ملموسا في العشيبة الأولى. ومن المتوقع الحصول على مزيد من الاستجابة للإنتخاب فيما لو أجريت دورة ثالثة لو استخدمت شدة انتخاب 13.33% وباستخدام معامل التوريث بالمعنى الضيق المتحصل عليه في الدورة الثانية من الانتخاب بمقدار 7.04% و 9.16% في الإتجاه المنقص والمزيد للثغور في العشيبة الأولى و 5.60% و 6.58% في العشيبة الثانية.

وعموما كان وزن المائة حبة أعلى في نهاية التجربة في العشيبة الأولى منه في العشيبة الثانية في المنتخبات والشاهد بينما كان العكس حادثا بالنسبة للمحصول في اتجاه نقصان تكرار الثغور، إذ كان هذا الفرق معنويا فقط في اتجاه زيادة تكرار عدد الثغور حيث أدى الانتخاب إلى تكرار أعلى في العشيبة الأولى منه في الثانية. ولم يظهر الانتخاب الناجح والمعنوي لزيادة أو نقصان الثغور إلى أي استجابة متلازمة في وزن المائة حبة أو المحصول.