GENETIC DIVERSITY FOR HEAT TOLERANCE IN SOME BREAD WHEAT GENOTYPES UNDER UPPER EGYPT CONDITIONS

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Abstract

The present investigation was carried out at Shandaweel Agricultural Research Station, Agricultural Research Center, Egypt, during the three successive seasons from 2004/2005 to 2006/2007. The objectives of the this investigation were to evaluate some bread wheat genotypes under heat stress conditions in Upper Egypt and to identify the most stable genotypes under these conditions. Twelve bread wheat genotypes (*Triticum aestivum L)* were evaluated under nine environments which are the combination among three sowing dates i.e. 25th November, 10 th December and 25 th December during the three winter growing seasons. Randomized completed block design was used for every planting date. The studied characters included days to physiological maturity, plant height, peduncle length, flag leaf area and straw yield (t/ha). Performance of the twelve wheat genotypes showed different responses to the different environments. The combined analysis of variance showed highly significant differences among planting dates and genotypes for all studied traits. Delaying sowing date reduced days to physiological maturity , plant height, peduncle length, flag leaf area, and straw yield in the second and third planting dates by an average of (6.63 &14.00%), (3.85 & 10.33%), (6.85 & 20.21%), (14.45 & 23.59%) and (17.37& 29.76%), respectively, compared with the recommended sowing date. The joint regression analysis of variance indicated highly significant differences among genotypes for all studied characters. Moreover, partitioning mean of squares due to environments plus genotypes x environments interactions as indicated by E + (G x E) to the following items E (Linear) showed highly significance for all studied traits. Meanwhile G×E component mean squares were highly significant and significant for all studied characters except for peduncle length. The remainder sum of squares were highly significant for all studied characters. Data of heat susceptibility index for straw yield under normal and late sowing dates indicated that six genotypes i.e. Line # 3, Line # 7, Line # 8 Gemmeiza 9, El-Nelin and HD 2501 were tolerant to heat stress (late sowing dates).

Key words: *Wheat genotypes, Triticum aestivum, Heat stress, Stability parameters, Heat susceptibility index (HSI).*

INTRODUCTION

Wheat (*Triticum aestivum L.)* is the most widely grown cereal crop in the world and it is the main diet for the Egyptian population. Also, it has been considered the first strategic food crop. Therefore, increasing wheat production becomes an important national goal to reduce the gap between wheat production and consumption and to reduce wheat imports and save foreign currency. It was anticipated that high and stable wheat yield could be achieved by applying the recommended cultural practices and using high yielding cultivars.

Variations in environment can be divided to two sorts, predictable and unpredictable. The first category includes all permanent characters of the environments, such as general features of the climatic and soil type, as well as these characteristics of the environment which fluctuate in a systematic manner, such as day length. It also includes those aspects of environment that are controlled by man and can be fixed more or less as well, such as planting date, sowing density, methods of harvesting and other agronomic practices. The second category includes fluctuation in weather, such as amount and distribution of rainfall and temperature.

Heat stress is a common abiotic stress that causes stunted plants, reduced tillering, and accelerates plant development leading to small heads, shriveled grains and finally low yields. Respecting agronomic traits affected by this abiotic stress such as days to heading, days to maturity, plant height and grain yield are easily identifiable and can be used as indices for heat tolerance. Understanding the nature of genotype x environment interaction empowers breeders to test and select more efficient genotypes. Breeding genotypes with wide adaptability has long been a universal goal among plant breeders. To achieve this goal, evaluating breeding lines over time and locations has become an integral part of any plant breeding program. Adaptability and stability performance of cultivars over environments are important for national policy in crop production. Therefore, a grain producer is interested primarily in growing a cultivar with high yield and stability performance at his location.

Several investigators had attempted to estimate G x E numerically. Two estimates developed by *Eberhart and Russell (1966)*. The first is the regression coefficient (b_i) of a line on environmental indices that estimate its response to favorable conditions while the remainder sums of squares after the regression (S^2d_i) illustrate the latter un-described interaction effects. They defined a stable cultivar as one which has a regression coefficient (b_i) equal to 1.0 and with (S^2d_i) equal to, or does not deviate significantly from 0.0. Apparently, a cultivar that did not meet both qualifications would be closed as unstable. However, an ideal cultivar would have both, high average performance over a wide range of environments plus stability.

Tawfelis (2006 a) studied the performance and stability of forty bread wheat genotypes under eight environments. The joint regression analysis of variance indicated highly significant differences among genotypes for all studied characters. The heterogeneity of linear responses and remainder sums of squares were highly significant for all traits. The regression coefficient was positively correlated with the mean performance indicating that high yielding genotypes had generally, and positive β_i values and revealed a good response to the improving environments.

The objectives of this study were to study the magnitude of G *x* E interactions as well as to assess the stability parameters of morpho-physiological characteristics of twelve bread wheat genotypes under heat stress conditions at Upper Egypt to identify the most stable genotypes under these conditions.

MATERIALS AND METHODS

The present investigation was conducted at Shandaweel Agricultural Research Station, Agricultural Research Center, Egypt. during 2004/2005 to 2006/2007 growing seasons. However, names, pedigree and origin of the twelve bread wheat genotypes under investigation are presented in Table (1).

Table 1. The name, pedigree and origin of twelve wheat genotypes:-

Ent. No.	Entry name	Pedigree	Origin
1	Sids 1	HD2172 / Pavon"s" //1158.57/ Maya 74"s"	Egypt
2	Giza 168	Mill / Buc // Seri	Egypt
3	Line # 3	Caza / Kauz // Kauz.	CIMMYT
4	Sakha 94	Opata / Rayon // Kauz	Egypt
5	Line # 5	SKAUZ*2/SRIMA	Egypt
6	Gemmiza # 10	Maya 74"s"/on // 1160-147 /3/ Bb /4/ Chat"s" /5/ Ctow. Maya"s"/ Crow // Vee"s"	Egypt
7	Line # 7	Maya"s"/Mon"s"/4/CMH7.428/MRC//Jup/3/582/5/A_2.	CIMMYT
8	Line # 8	Sakha8/6/Sakha69 Ald"s"/ Huac"S" //CMH74A.630/5x	CIMMYT
9	Gemmiza # 9	S 948.A_1/7*STE	Egypt
10	El-Nelin	--------	Sudan
11	Debeira	--------	Sudan
12	HD2501		India

Sowing dates were 25th November, 10th and 25th December in the three seasons, respectively. The experimental design was randomized complete blocks (RCBD), with three replications for each planting date. The plot size was 3.5 m long with 2.4 m width (3.5 x 2.4 = 8.4 m^2). Each plot included 12 rows, 20 cm apart between rows and seeds were spaced 5 cm. within rows. The recommended cultural practices of wheat production were applied all over the growing seasons.

Data were recorded for five characteristics as following

1- Days to physiological maturity (MD), the number of days from sowing to physiological maturity.

2- Plant height in cm (PLH), measured from surface of the soil to the top of the spike of ten main stems taken at random from each experimental plot.

3- Peduncle length in cm (PL), the top internode length of the main stem at maturity of ten main stems taken at random from each experimental plot.

4-Flag leaf area in cm^2 (FLA), ten flag leaves at anthesis were taken at random from each plot and FLA is computed according to the formula of Montgomery (1911), where leaf area = 0.75 × (leaf length ×leaf width at the broadest place).

5**-** Straw yield in t /ha (SY), obtained by weighing all the harvested plants in ton (biological yield) subtracting from the grain yield of harvested area, for each plot.

Meteorological Data

The monthly mean temperature differed from season to another (Table 2). The mean of maximum and minimum temperatures from the date of sowing to booting, booting to heading and heading to maturity of favorable and late sowing dates (heat stress) are summarized in Table (2). The differences in the maximum temperature at Sohag between late and favorable sowing dates were 0.1 ^{C}, 1.87^{C} and 2.06 ^{C} during sowing to booting, booting to heading and heading to maturity, respectively.

Table 2. Mean maximum (Mix) and minimum (Min) air temperature (^{C}) during growth stage in normal and late sowing date at Sohag Governorate.

Months	2004 / 2005		2005 / 2006		2006 / 2007	
	Max	Min	Max	Min	Max	Min
November	27.90	11.50	25.90	10.00	24.03	10.69
December	22.10	6.60	23.40	9.00	21.34	6.88
January	20.20	5.40	21.50	6.80	19.33	5.16
February	23.30	7.60	23.50	8.90	27.48	8.52
March	25.60	9.40	26.60	11.00	27.68	11.29
April	36.80	16.20	30.10	14.60	34.67	21.63

Sowing dates	*sowing to booting*		*first booting to heading*		*heading to maturity*	
	Max	*Min*	*Max*	*Min*	*Max*	*Min*
Optimum	22.31	7.38	24.76	08.34	27.48	11.30
Late	22.41	7.08	26.63	10.56	29.54	13.36

Shandaweel 26 36 N, 31 38 E. alt 58.0 m asl.

Statistical analysis

Data were subjected to the standard analysis of variance and the combined analysis of variance over nine environments according to *Gomez and Gomez (1984)* and stability parameters were estimated by the method described by *Eberhart and Russell (1966)*.

A stress-susceptibility index (S) was used to characterize each genotype in the stress environments and the index was calculated using genotype means and a generalized formula *(Fischer and Maurer 1978)* in which *S= (1-YD/ YP)/ D,* were *YD* = mean yield in stress environment, *YP* = potential yield in normal environment, D = environment stress intensity = 1-(mean *YD* of all genotypes / YP of all genotypes).

RESULTS AND DISCUSSION

The combined analysis of variance showed highly significant differences among years for days to physiological maturity, plant height, peduncle length, flag leaf area, and straw yield (Table 3). These results reflect the wide differences in climatic conditions prevailing during the growing seasons. The main effect of sowing dates was highly significant for all studied traits. The studied genotypes had also highly significant differences for all traits, reflecting the wide genetic diversity. The first order interaction of years x dates differed significantly for all traits except for plant height, indicating the different influences of climatic conditions on sowing date. On the other hand, significant interaction between years x genotypes was found for all traits. The combined analysis of variance showed significant interaction between genotypes and sowing dates for all studied traits except for peduncle length, and straw yield (Table 3). Accordingly, there were a differential response between genotypes to sowing dates and years. These results indicate that wheat genotypes responded differently to the different environmental conditions suggesting the importance of assessment of genotypes under different environments in order to identify the best genetic make up for a particular environment. Similar results were obtained by Kheiralla *et. al*. (1997), Abdel-Shafi *et. al*. (1999), El-Morshidy *et. al*. (2001), Tammam and Tawfelis (2004)), Tawfelis (2006) and Al-Otayk (2010).

Table 3. Mean squares of the combined analysis of variance for the studied characters over all sowing dates and seasons.

Source of variation	**D.F**	***Mean squares (M.S.)***				
		Days to maturity	**Plant height "cm"**	**Peduncle length "cm"**	**Flag leaf area "cm^2 "**	**Straw yield "ton/ha"**
Year (Y)	2	526.30 **	92.23 *	254.03 **	718.32 **	101.70**
Rep./Y (Error a)	6	5.61	18.56	8.01	4.04	3.85
Dates (D)	2	11092.2 **	3115.59 **	1744.54 **	3691.26**	490.72**
Y x D	4	213.44 **	29.12	50.35 **	79.70 **	23.89 **
Error b	12	4.95	17.51	6.41	10.78	1.75
Genotypes(G)	11	77.33 **	1243.83 **	143.46 **	658.63 **	6.87**
Y x G	22	23.94 **	51.21 **	26.12**	13.21 *	5.39**
D x G	22	8.96 **	22.55 **	6.39	56.31 **	1.17
Y x D x G	44	4.59 **	20.53 **	9.85 **	5.98	2.25
Pooled error	198	2.20	10.39	4.17	7.49	1.52

* and ** Significant and highly significant at 0.05 and 0.01 levels of probability, respectively.

I) Performance of genotypes

(1) Days to physiological maturity

The performance of the studied genotypes in the nine environments are presented in (Table 4).Sakha 94 cultivar was the earliest in physiological maturity in the three planting dates , while the cultivar Debeira was the latest in physiological maturity in the first sowing date. Meanwhile, line # 7 was the latest in physiological maturity in the second and third sowing dates. It is clear that Sakha 94 was the earliest in physiological maturity in the 1^{st}, 2^{nd} and 3^{rd} sowing dates although it was the latest in number of days to heading.

The average number of days to maturity over all environments ranged from 131.26 days for Sakha 94 to 137.11 days for Line # 7 with an average of 134.73 days. These results indicated that genotypes Giza 168, Line # 3, Sakha 94, Line# 5 and El-Nelin are earlier in maturity than the grand mean over all environments under Upper Egypt conditions.

It is clear that, late planting date reduced number of days to maturity in the second and third planting dates by an average of 6.63 and 14.00 %, respectively, compared to the optimum planting date. These findings are also in agreement with the results obtained by *Ismail (1995), Abdel-Shafi et al (1999) and Seleem (2007).*

(2) Plant height (cm)

Gemmeiza 10 was the shortest one of plant height in the three planting dates, while the cultivar Sids1 was the tallest of plant height in the first and second sowing dates, respectively. Meanwhile, cultivar Gemmeiza 9 was the tallest of plant height in the third sowing date (Table 4).

The average of plant height over all environments ranged from 88.67 cm for Gemmeiza 10 to 106.30 cm for Sids 1 with an average of 97.99 cm.

It is clear that, late planting dates caused a reduction in plant height in the second and third planting dates by an average of 3.85 and 10.33 %, respectively as compared with the optimum planting date. These results are in harmony with those obtained by Ismail (1995), Sial *et. al.* (2005) and Seleem (2007).

(3) Peduncle length (cm)

The performance of the studied bread wheat genotypes in the nine environments are presented in (Table 4). Line # 3 was the shortest one of peduncle length in the three planting dates, while the cultivar El-Nelin was the tallest of peduncle length in the first, second and third planting dates, respectively.

Table 4. Means number of days to physiological maturity, plant height (cm) and peduncle length (cm) of the twelve bread wheat genotypes under three planting dates over all seasons.

Genotype	Physiological maturity						Plant Height (cm)						Peduncle length (cm)					
	D 1	D 2	D 3	Mean	Red. % D2	Red.% D3	D 1	D 2	D 3	Mean	Red. % D2	Red. % D3	D 1	D 2	D 3	Mean	Red. % D2	Red. % D3
Sids 1	145.56	137.11	125.22	135.96	5.81	13.97	112.44	107.22	99.22	106.30	4.64	11.76	40.56	36.29	30.81	35.90	10.53	24.04
Giza 168	143.44	134.00	123.44	133.63	6.58	13.94	98.67	93.67	90.56	94.30	5.07	8.22	41.14	37.57	33.91	37.53	8.68	17.57
Line # 3	143.56	134.11	122.67	133.45	6.58	14.55	96.56	94.11	86.44	92.37	2.54	10.48	35.06	31.75	25.41	30.74	9.44	27.52
Sakha 94	140.67	132.00	121.11	131.26	6.16	13.90	109.56	105.78	95.00	103.44	3.45	13.29	39.81	38.03	31.52	36.42	4.47	20.83
Line # 5	144.89	133.33	123.78	134.00	7.98	14.57	98.67	94.11	86.89	93.22	4.62	11.94	37.16	35.72	27.97	33.62	3.88	24.47
Gemmeiza 10	146.11	137.56	127.00	136.89	5.85	13.08	92.22	89.67	84.11	88.67	2.77	8.79	36.83	34.08	28.36	33.12	7.47	23.00
Line # 7	145.33	137.67	128.33	137.11	5.27	11.70	93.00	92.89	85.00	90.30	0.12	8.60	38.34	35.97	29.89	34.74	6.18	22.04
Line # 8	145.00	135.89	126.44	135.78	6.28	12.80	96.89	94.33	84.44	91.89	2.64	12.85	38.46	36.40	31.08	35.31	5.36	19.19
Gemmeiza 9	145.11	137.44	125.22	135.93	5.29	13.71	110.67	104.78	100.78	105.41	5.32	8.94	39.31	36.43	33.16	36.30	8.19	15.64
El-Nelin	144.67	133.56	122.78	133.67	7.68	15.13	110.89	107.00	100.56	106.15	3.51	9.32	42.55	39.75	35.40	39.23	6.58	16.80
Debeira	146.22	134.33	124.44	135.00	8.13	14.90	108.44	104.44	97.11	103.33	3.69	10.45	39.79	37.38	33.92	37.03	6.06	14.75
HD2501	145.56	134.00	122.56	134.04	7.94	15.80	106.33	98.67	96.67	100.56	7.20	9.08	40.62	38.50	33.56	37.49	5.22	17.38
Average	144.68	135.08	124.42	134.73	6.63	14.00	102.85	98.89	92.23	97.99	3.85	10.33	39.14	36.46	31.23	35.62	6.85	20.21

L. C. D	Physiological maturity 0.05	Physiological maturity 0.01	Plant Height 0.05	Plant Height 0.01	Peduncle length 0.05	Peduncle length 0.01
Years	0.57	0.77	1.07	1.45	0.64	0.88
Dates	0.57	0.77	1.07	1.45	0.64	0.88
Genotype	0.70	0.91	1.53	1.97	0.97	1.25
Y x D	0.98	1.33	2.15	3.01	1.25	1.76
Y x G	1.24	1.62	3.05	4.01	1.84	2.40
D x G	1.41	1.85	3.83	5.17	3.16	4.57
Y x D x G	3.04	4.05	7.37	10.00	3.83	5.07

Table 5. Means flag leaf area (cm2) and strew yield (t/ha) of the twelve bread wheat genotypes under three planting dates over all seasons.

Genotype	Flag Leaf area (cm^2)						Straw yield (t/ha)					
	D 1	D 2	D 3	Mean	Red.% D2	Red.% D3	D 1	D 2	D 3	Mean	Red.% D2	Red.% D3
Sids 1	**59.01**	49.47	39.24	49.12	16.17	33.50	15.64	13.05	10.82	13.17	16.56	30.82
Giza 168	**46.88**	38.59	35.73	40.40	17.68	23.78	13.45	10.78	9.33	11.19	19.85	30.63
Line # 3	**41.75**	36.32	34.73	37.60	13.01	16.81	13.59	11.30	9.93	11.61	16.85	26.93
Sakha 94	**42.08**	37.13	33.80	37.67	11.76	19.68	14.39	11.83	9.54	11.92	17.79	33.70
Line # 5	**46.96**	40.87	36.89	41.57	12.97	21.44	13.94	12.24	9.76	11.98	12.20	29.99
Gemmeiza 10	**43.10**	38.13	34.11	38.45	11.53	20.86	14.79	11.29	10.16	12.09	23.66	31.30
Line # 7	**40.88**	35.62	30.79	35.76	12.87	24.68	14.07	11.99	10.18	12.08	14.78	27.65
Line # 8	**43.92**	35.50	33.87	37.76	19.17	22.88	14.28	12.13	10.11	12.17	15.06	29.20
Gemmeiza 9	**44.53**	37.85	35.70	39.36	15.00	19.83	14.68	12.49	10.63	12.60	14.92	27.59
El-Nelin	**47.73**	45.26	41.08	44.69	5.17	13.93	13.72	11.35	9.73	11.59	17.27	29.08
Debeira	**54.11**	44.61	38.68	45.80	17.56	28.52	15.12	11.48	9.98	12.19	24.07	33.99
HD2501	**58.80**	48.07	40.73	49.20	18.25	30.73	13.65	11.67	10.22	11.85	14.51	25.13
Average	**47.48**	40.62	36.28	41.46	14.45	23.59	14.28	11.80	10.03	12.04	17.37	29.76

L. C. D	0.05	0.01	L. C. D	0.05	0.01
Years	0.84	1.14	Years	0.22	0.30
Dates	0.84	1.14	Dates	0.22	0.30
Genotype	1.30	1.68	Genotype	0.53	0.70
Y x D	1.63	2.28	Y x D	0.41	0.57
Y x G	3.26	4.39	Y x G	0.97	1.19
D x G	2.46	3.21	D x G	1.70	2.49
Y x D x G	9.05	11.24	Y x D x G	2.65	3.77

The average of peduncle length over all environments ranged from 30.74 cm for Line # 3 to 39.23 cm for El-Nelin with an average of 35.62 cm.

It is clear that, late planting date caused a reduction in peduncle length in the second and third planting dates by an average of 6.85 and 20.21 %, respectively compared with the optimum planting date.

(4) Flag leaf area (cm^2)

Line # 7 was the lowest one of flag leaf area in the first and third planting dates, respectively, while Line # 8 was the lowest one of flag leaf area in the third planting date. Meanwhile, the cultivar Sids 1 was the highest of flag leaf area in the first and second sowing dates, respectively, while the cultivar El-Nelin was the highest of flag leaf area in the third planting date (Table 5).

The average of flag leaf area over all environments ranged from 35.76 cm^2 for Line # 7 to 49.20 cm^2 for HD 2501 with an average of 41.46 cm^2.

It is clear that late planting dates caused a reduction in flag leaf area in the second and third planting dates by an average of 14.45 and 23.59 %, respectively, compared with the optimum planting date.

(5) Straw yield (t/ha)

The performance of the studied bread wheat genotypes in the nine environments are presented in (Table 5). The cultivar Giza 168 was the lowest of straw yield in the three planting dates, respectively, while the cultivar Sids 1 was the highest of straw yield in the three planting dates, respectively.

The average of straw yield over all environments ranged from 11.19 t/ha for Giza 168 to 13.17 t/ha for Sids 1 with an average of 12.04 t/ha. These results indicated that Sids 1and Gemmeiza 9 produced the highest straw yield compared with the grand mean over all environments under Upper Egypt conditions.

It is clear that, late planting caused a reduction in straw yield in the second and third planting dates by an average of 17.37 and 29.76 %, respectively as compared with the optimum planting date. Similar results were obtained by *Ismail (1995) and Tammam and Tawfelis (2004).*

II) Genotype × environment interaction and stability analysis

The impact of genotype by environment interaction (GxE) on the relative performance and stability of a genotype across environments is so important that it forms challenging difficulty to the breeder in developing superior cultivars broadly adapted *(Eberhart and Russell, 1966)*. The mechanisms by which environmental stresses affect plant metabolism, thereby reducing growth and development, are still not completely understood *(Pessarakli, 1994)*. Furthermore, (GxE) interaction has been shown to reduce progress from selection *(Comstock and Moll, 1963)*.

An ideal cultivar would have both a high average performance over a wide range of environments plus stability. *Finlay and Wilkinson (1963)* used two values as a measure of both stability and adaptation. Cultivars with $b_i < 1.0$ were considered above average in stability and specially adapted to unfavorable environments. Cultivars with $b_i = 1.0$ were described as average in stability and either poorly or well adapted to all environments, depending upon the cultivar mean yield.

Table 6. Joint regression analysis for characters of the twelve genotypes under three sowing dates in the three growing seasons.

Source of variation	D.F	***Mean squares (M.S.)***				
		Days to maturity	**Plant height "cm"**	**Peduncle length "cm"**	**Flag leaf area "cm^2"**	**Straw yield "ton/ha"**
Genotypes	11	77.33 **	1243.76 **	143.06 **	588.13 **	7.02 **
Env.+(G x Env.)	96	260.59 **	94.37 **	55.94 **	105.11 **	15.83 **
a- Env.(linear)	1	24090.86**	6532.73 **	4213.93 **	8243.73**	1276.57**
b- G x Env.(linear)	11	13.15 **	25.94 **	3.86	69.93 **	3.04*
c- Pooled dev.	84	9.30 **	26.69 **	13.26 **	12.82 **	2.49**
Pooled error	198	2.40	10.85	4.48	8.06	1.61

** and ** Significant and highly significant at 0.05 and 0.01 levels of probability, respectively.*

(1) Days to physiological maturity

The joint regression analysis of variance Table (6) revealed that the component of Env. + (G×E) was highly significant for days to physiological maturity. In addition, partitioning Env. component mean squares and G×E component mean squares were highly significant. Indicating that the environments effect were linear function and the interaction of genotypes and environments were linear function for such trait.

The stability parameters (b_i and S^2d_i) and the mean performance ($\bar{x}$) of the individual genotypes are presented in Table (7). The regression coefficients (b_i) for Sids 1, Giza 168, Sakha 94 and Line # 5 were statistically equal unity and the deviations from regression (S^2d_i) of those genotypes differed insignificantly from zero indicating that these genotypes may be considered as stable for such trait. Sids1 and Sakha 94 were considered specially adapted to heat stress environment because the regression coefficients of these genotypes were less than one (b_i <1). However, according to Eberhart and Russell (1966), an ideal genotype would have both a high average performance over a wide range of environments plus stability, the most desirable genotypes based on the three stability parameters ($\bar{x}$, b_i and S^2d_i) were Giza 168 and Sakha 94 and Line # 5 for days to physiological maturity because they had

Table 7. Mean and estimated stability parameters of days to physiological maturity , plant height (cm) , peduncle length (cm), flag leaf area (cm2) and straw yield (t/ha)of each accession (G) of wheat genotypes over the used environments (E).

Genotype	Physiological maturity (days)			Plant height (cm)			Peduncle length (cm)			Flag leaf area (cm^2)			Straw yield (t/ha)		
	Mean	**b_i**	**S^2d_i**	**Mean**	**b_i**	**S^2d_i**	**Mean**	**b_i**	**S^2d_i**	**Mean**	**b_i**	**S^2d_i**	**Mean**	**b_i**	**S^2d_i**
Sids 1	135.96	0.995	2.416	106.30	1.312	37.481**	35.90	1.071	21.275**	49.24	1.488	37.921**	13.17	1.090	0.958
Giza 168	133.63	1.007	3.926	94.30	0.706*	6.969	37.53	0.934	5.835	40.40	0.892	14.610	11.19	1.005	1.647
Line # 3	133.45	1.020	7.886**	92.37	0.926	24.906*	30.74	1.217	16.890**	37.60	0.655**	3.054	11.60	0.729 *	1.118
Sakha 94	131.26	0.971	3.089	103.44	1.329	41.065**	36.42	1.071	4.625	37.67	0.768**	1.944	11.86	1.031	2.766
Line # 5	134.00	1.029	3.017	93.22	1.057	14.774	33.62	1.073	17.581**	41.57	0.973	24.516**	11.98	0.751	5.561**
Gemmeiza 10	136.89	0.977	3.037**	88.67	0.732	16.002	33.12	0.999	6.589	38.45	0.813	13.566	12.12	1.084	1.904
Line # 7	137.11	0.876	10.225**	90.30	0.801	19.440	34.74	1.054	1.702	35.67	0.872	6.883	12.08	0.897	0.621
Line # 8	135.78	0.862	18.009**	91.89	1.237	7.395	35.31	0.915	20.438**	37.76	1.047	14.165	12.14	0.920	0.545
Gemmeiza 9	135.93	0.973	9.452**	105.41	0.989	71.536**	36.30	0.908	18.562**	39.36	0.789	5.727	12.64	1.131	4.162*
El-Nelin	133.67	1.066	12.391**	106.15	1.042	20.801	39.23	0.944	3.421	44.69	0.704	15.632	11.60	1.064	3.110
Debeira	135.00	1.067	8.056**	103.33	1.087	22.417*	37.03	0.821	7.220	45.80	1.426*	10.999	12.19	1.349	5.353
HD2501	134.04	1.159	26.104**	100.56	0.784	37.434**	37.49	0.993	34.954**	49.20	1.573**	4.859	11.85	0.948	2.169
Grand mean	134.73	--	--	97.99	--	--	35.62	--	--	41.46	--	--	12.04	--	--
L.S.D 0.05	0.70	--	--	1.53	--	--	0.97	--	--	1.30	--	--	0.53	--	--

** and ** Significant and highly significant at 0.05 and 0.01 levels of probability, respectively.*

desired performance (earliness), b_i did not differ significant from unity and least deviation from regression did not differ significantly from zero. These genotypes may have genetic systems controlling earliness and able to work consistently over environments. These results are in line with those reported by Kheiralla et. al. (1997), Tawfelis (2006 a) and Seleem (2007).

(2) Plant height (cm)

The joint regression analysis of variance Table (6) revealed that the component of Env. + (G×E) was highly significant for plant height. In addition, partitioning Env. component mean squares and G×E component mean squares were highly significant indicating that the environmental effect and the interaction of genotypes and environments were linear function for such trait.

The stability parameters (b_i and S^2d_i) and the mean performance ($\overline{x}$) of the individual genotypes are presented in Table (7). The regression coefficients (b_i) for Line # 5, Gemmiza 10, line # 7, line # 8 and El-Nelin were statistically equal to unity and the deviations from regression (S^2d_i) of those genotypes were also insignificantly different from zero, indicating that these genotypes may be considered as stable for such trait. Gemmiza 10, and Line # 7 were considered specially adapted to heat stress environment because the regression coefficients of both genotypes were insignificantly from one and less than unity ($b_i < 1$). Otherwise, the " b_i" was insignificantly from one and more than unity ($b_i > 1$) in Line # 5 and Line # 8 which appeared to be more adapted to favorable environments. The most desirable genotypes based on the three stability parameters ($\overline{x}$, b_i and S^2d_i) were Line # 5, Gemmiza 10, Line # 7 and Line # 8 for plant height because they had desired performance, b_i did not significantly differ from unity and least deviation from regression did not significantly differ from zero. These results are in line with those reported by Ismail (1995) and Seleem (2007).

(3) Peduncle length (cm)

The joint regression analysis of variance in Table (6) revealed that the component of Env. + (G×E) was highly significant for peduncle length. In addition, partitioning Env. component mean squares was highly significant, while G×E component mean squares was not significant. Indicted that the environments effect were linear function but the interaction of genotypes and environments were not linear function for such trait.

The stability parameters (b_i and S^2d_i) and the mean performance ($\overline{x}$) of the individual genotypes are presented in Table (7). The regression coefficients (b_i) for Giza 168, Sakha 94, Gemmiza 10, line # 7, El-Nelin and Debeira were statistically equal unity and the deviations from regression (S^2d_i) of those genotypes were also insignificantly different from zero, indicating that these genotypes may be considered as stable for such trait. Giza 168, Gemmiza

10, El-Nelin and Debeira were considered specially adapted to heat stress because the regression coefficients of these genotypes were less than one (b_i <1). These results are in line with those reported by Tawfelis (2006) and Seleem (2007).

(4) Flag leaf area

Stability analysis of variance of flag leaf area (Table 6) indicated highly significant mean squares of wheat genotypes, revealing that wheat genotypes were genetically different for genes controlling flag leaf area. Highly significant environment + (G×E) component and environment (linear) mean squares, indicating that flag leaf area was highly influenced by the combination of environmental components (season and sowing dates). Highly significant G×E (linear) interaction was shown for flag leaf area, indicating that wheat genotypes responded differently to various environments.

The stability parameters (b_i and S^2d_i) and the mean performance ($\bar{x}$) of the individual genotypes are presented in Table (7). The regression coefficients (b_i) for Giza 168, Gemmeiza 10, line # 7, line # 8, Gemmeiza 9 and El-Nelin were statistically equal unity and the deviations from regression (S^2d_i) of those genotypes were also non-significantly differ from zero, indicating that these genotypes may be considered as stable for such trait. Gemmeiza 10, line # 7, Gemmeiza 9 and El-Nelin were considered specially adapted to heat stress environment because the regression coefficients of this genotype was less than one (b_i <1) and stable genotype for flag leaf area.

(5) Straw yield (t/ha)

The joint regression analysis of variance in Table (6) revealed that the component of Env. + (G×E) was highly significant for straw yield. In addition, partitioning Env. component mean squares and G×E component mean squares were highly significant and significant, respectively. Indicted that the environments effect and the interaction of genotypes and environments were linear function for such trait.

The stability parameters (b_i and S^2d_i) and the mean performance ($\bar{x}$) of the individual genotypes are presented in Table (7).The regression coefficients (b_i) for genotypes Sids 1, Giza 168, Sakha 94, Gemmeiza 10, line # 7, line 8, El-Nelin, Debeira and HD 2501were statistically equal unity and the deviations from regression (S^2d_i) of those genotypes were also non-significantly differ from zero, indicating that these genotypes may be considered as stable for such trait. Otherwise, the " b_i" was insignificantly from one and more than unity (b_i >1) in Sids 1 which appeared to be more adapted to favorable environments. These results are in line with those reported by Ismail (1995), Tawfelis (2006) and Seleem (2007).

Heat susceptibility index (HSI)

The heat susceptibility indices "HSI" based on straw yield for genotypes are presented in (Table 8). These indices were used to estimate the relative stress injury (heat) because it is accounted as variation in yield potential and stress intensity. Higher values indicated higher degree of susceptibility and vice versa (Fischer and Maurer, 1978).

It is worthy to mention here that *HSI* provides a measure of tolerance based on minimization of yield loss under stress rather than non-stress yield *per se*. Therefore, the stress tolerant genotypes as defined by S values do not need to have a high yield potential. These genotypes should contain resistance (tolerance) mechanisms, which may need to be incorporated into germplasm with higher yield potential for development of high yielding stress tolerant cultivars.

Table 8. Straw yield (t /ha) under normal (D1) and late sowing dates (D3) and heat susceptibility index (HSI) over all environments between 1st and 3rd sowing dates for twelve wheat genotypes.

Genotype	**Date 1**	**Date 3**	**HSI**
Sids 1	15.64	10.82	1.04
Giza 168	13.45	9.33	1.03
Line # 3	13.59	9.93	0.91
Sakha 94	14.39	9.54	1.13
Line # 5	13.94	9.76	1.01
Gemmeiza 10	14.79	10.16	1.05
Line # 7	14.07	10.18	0.93
Line # 8	14.28	10.11	0.98
Gemmeiza 9	14.68	10.63	0.93
El-Nelin	13.72	9.73	0.98
Debeira	15.12	9.98	1.14
HD2501	13.65	10.22	0.85
Grand mean	14.28	10.03	1.00

Fisher and Wood, (1979) concluded that *HSI* was used to estimate stress injury. Low stress susceptibility (HSI < 1) is synonymous with higher stress tolerance. Results in (Table 8) indicated that the values of *HSI* over all three years ranged from 0.85 for HD 2501 to 1.14 for genotype Debeira. The genotypes Line # 3 , Line # 7, Line # 8 Gemmeiza 9 , El-Nelin and HD

2501 produced low heat susceptibility index (0.91, 0.93, 0.98, 0.93 0.98 and 0.85) and straw yields of 9.93, 10.18, 10.11, 10.63, 9.73 and 10.22 t/ha for the six genotypes, respectively. A superior genotypes for heat tolerance would give the least values of heat susceptibility index (HSI < 1) and high straw yield under heat stress. Therefore, these genotypes could be considered as promising genotypes in breading wheat program for heat stress.

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الاختلافات الوراثية في تحمل قمح الخبز للإجهاد الحراري تحت ظروف منطقة مصر العليا

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أجري هذا البحث في محطة البحوث الزراعية بشندويل – مركز البحوث الزراعية – مصر خلال المواسم الزراعية الثلاثة 2004/ 2005 ، 2005/ 2006 ،2006/ 2007 وكان الهدف من الدراسة تقييم بعض التراكيب الوراثية لقمح الخبز تحت ثلاثة مواعيد زراعة وكذلك تأثير الزراعة المتأخرة والتعرض للحرارة علي بعض الصفات المورفولوجية ومحصول القش وأيضاً التفاعل بين التركيب الوراثي والبيئة وتحليل الثبات ومعامل الحساسية للحرارة.

أستخدم في التجربة 12 تركيبا وراثيا من قمح الخبز بينهما اختلافات وراثية واسعة بعضها أصناف محلية وأخري مستوردة، زرعت هذه الأصناف والسلالات في ثلاثة مواعيد زراعية، الموصي به (25 نوفمبر)، المتأخر (10 ، 25 ديسمبر) خلال الثلاث مواسم، باستخدام تصميم قطاعات كاملة العشوائية مع ثلاثة مكررات في كل ميعاد زراعة.

وقد تمت دراسة عدد الأيام من الزراعة حتى النضج الفسيولوجي ، طول النبات، طول حامل السنبلة، مساحة ورقة العلم ومحصول القش طن/هكتار. وقد أظهرت النتائج استجابات مختلفة للتراكيب الوراثية من بيئة إلي أخري. كما أدت الزراعة في ميعاد متأخر إلي نقص في عدد الأيام من الزراعة حتى النضج الفسيولوجي ، طول النبات، طول حامل السنبلة ، مساحة ورقة العلم ومحصول القش طن/هكتار في الميعاد الثاني والثالث بمقـــــدار (6.63 ، 14.00٪) و (3.85و 10.33٪) و (6.85 و 20.21٪) و (14.45 و 23.59٪) و (17.37 و 29.76٪) بالمقارنة بالزراعة في الميعاد الأول علي الترتيب. تشير هذه النتائج إلى أن التراكيب الوراثية تباينت في استجابتها للظروف البيئية مما يوضح أهمية تقييم التراكيب الوراثية تحت بيئات مختلفة بغرض تحديد أفضل التراكيب الوراثية لهذه البيئات.

أظهر تحليل تباين الانحدار فروقا عالية المعنوية بين التراكيب الوراثية لكل الصفات المدروسة. علاوة على ذلك كان لمكون التفاعل بين البيئة والصنف x البيئة تأثيرا عالى المعنوية في الصفات تحت الدراسة وكان لمكون (الصنف x البيئة) تأثير عالي المعنوية لكل الصفات عدا طول حامل السنبلة ، وكان الجزء المتبقي عالي المعنوية لكل الصفات المدروسة.

أكدت النتائج ضرورة استخدام كل من متوسط أداء التركيب الوراثي ومقياس الثبات الخاصة به معا للتوصية باستخدام أي تركيب وراثي في بيئات مختلفة.

و أظهرت النتائج أيضا أن معامل الحساسية للحرارة لمحصول القش بين ميعاد الزراعة الموصى به والميعاد المتأخر جداً إلي أنه توجد ستة تراكيب وراثية هي سلالة رقم 3، سلالة رقم7 ، سلالة رقم 8 ، جميزة 9 والصنفين المستوردين النيلين و ديبيرا متحملة للحرارة (الزراعة المتأخرة) وأعطت قيمة لمعامل الحساسية للحرارة أقل من الواحد الصحيح وذات محصول قش عالي تحت الزراعة المتأخرة.