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# EVALUATION OF SOME BREAD WHEAT GENOTYPES UNDER HEAT STRESS CONDITIONS IN UPPER EGYPT

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## ABSTRACT

***The experiment was conducted during the three successive seasons, i.e. 2015/16 to 2017/18 at El-Matanaa, Agricultural Research Station, Agricultural Research Center, Egypt, to assess heat tolerance of 12 bread wheat genotypes under nine environments (three sowing dates with three years). The experiment was grown in a randomized complete block design (RCBD) with three replications in each environment. The objectives of this investigation were to estimate stability parameters indices of yield and its components of bread wheat genotypes under heat stress in Upper Egypt conditions to identify the most tolerant genotypes to these conditions and to evaluate their performance and stability. Wheat genotypes showed different responses to environments. Delaying sowing date reduced days to heading, no. of spikes m$^{-2}$, no. of kernels spike$^{-1}$, 1000-kernel weight and grain yield in the second and third planting dates across the three seasons by an average of (10.24 &18.00), (24.48 & 48.80), (21.97 & 51.22), (21.61& 37.75) and (24.39 & 41.99%), respectively, compared with the recommended sowing date. The joint regression analysis of variance for the studied traits showed highly significant mean squares due to environment + genotype × environment interactions revealing that genotypes considerably interacted with the environmental conditions. The mean squares due to G × E (linear) were found to be significant for all studied characters, which reveals genetic variability among genotypes for linear response to varying environments. Stability parameters (bi and S$^2$d) revealed that seven genotypes were stable for days to heading, eight for number of spikes/m$^2$, four for number of kernels/spike and three for 1000-kernel weight. Six out of the twelve studied genotypes, i.e., Giza 171, Misr 2, Gemmeiza 11, Line #8, Line #10 and Line #11 showed non-significant deviation from regression and their regression coefficient values were close to unity which is classified as stable genotypes for grain yield. Three genotypes had grain yield higher than the grand mean (Giza 171, Misr 2 and Line #10) and could be considered the most stable genotypes. The genotypes Misr 2, Gemmeiza 11 and Line #12 showed heat Susceptibility Index less than one and were considered tolerant to heat stress.***

Key words: ***Wheat genotypes, Heat stress, Performance, G ×E, Stability parameters, Heat susceptibility index (HIS).***

## INTRODUCTION

Wheat is the most important cereal crop in Egypt as a major source of nourishment. Increasing production per unit area appears to be one of the important factors for narrowing the gap between wheat production and consumption. In Egypt, wheat crop is considered as the essential strategic cereal crop for thousands of years. Egypt wheat yield annual consumption is about 14 million ton, while the annual local production is about 9.00 million ton in 2016 (F.A.O. Statistic Year Book 2016).Therefore, the task of breeder is to screen out genotypes planted at different environments to enable selection of those genotypes, which are suitable for wider range of environments.

Wheat breeders have recently emphasized the planting of varieties at their optimum times for maximum yield production. For late planting, earliness in flowering and maturity was considered a desirable characteristic. Hence a study of genotype x environment interaction can lead to successful evaluation of wheat cultivars for stability in yield performance across environments. Stable genotypes have the same reactions across the environments. Most favorable stability occurs with high yield or performance Björnsson (2002). Increasing genetic gains in yield is possible in part from narrowing the adaptation of cultivars, thus maximizing yield in particular areas by exploiting genotype × environment interaction (G × E). G × E is of major importance, because it provides information about the effect of different environments on cultivar performance and has a key role for assessment of performance stability of the breeding materials Bose *et al* (2014).

The measure of the relative performance of varieties under different environments provides information on stability pattern of these varieties. Statistical methods are available for estimating phenotypic stability as proposed by Eberhart and Russell (1966). Ahmad *et al* (1996) found that linear and non-liner components of genotype X environment interaction were significant, indicating genetic differences among genotype for their response to varying environments. Significant differences among families x years in spring wheat were detected by Yang and Baker (1991). Abd-El-Ghani *et al* (1994) stated that regression analysis as well as grain yield *per se* could be useful tool for identifying high yielding thermo-tolerant genotypes. Eberhart and Russell (1966) suggested that regression coefficient ($b_i$) and deviation from regression coefficient ($S^2d$) might predict stable genotype. The genotypes are grouped according to the size of their regression coefficients, less than, equal to, or greater than one and according to the size of the variance of the regression deviations (equal to or different from zero). Those genotypes with regression coefficients greater than one would be more adapted to favorable growth conditions, while those with regression coefficients less than one would be adapted to unfavorable environmental conditions, and those with regression coefficients equal to one would have an average adaptation to all environments. Thus, a genotype with unit regression coefficient ($b_{i\,=}$ 1) and deviation not significantly different from zero ($S^2d = 0$) is said to be the most stable genotype. Many investigators have assessed the phenotypic stability of yield performance in wheat genotypes, Tawfelis (2006), Al-Otayk (2010), Arian *et al* (2011) and El-Ameen (2012). Akherdiew *et al* (2000).

Terminal heat stress is a major resistance environmental factor in many population areas. The main purposes of this study were to examine grain yield stability and to characterize the stability of 12 bread wheat genotypes grown under three sowing dates across three years in Upper Egypt conditions to identify the most stable genotypes under these conditions.

## MATERIALS AND METHODS

Twelve genotypes of bread wheat (*Triticum aestivum* L.) were evaluated under nine environments. The nine environments were the combinations of three sowing dates, i.e., 25th November (recommended sowing date), 20th December (moderate late sowing date) and 10th January (late sowing date) and three seasons, i.e**.** 2015/16 to 17/2018 at El-Matanaa Agricultural Research Station, Agricultural Research Center, Egypt. Twelve wheat genotypes from diverse origin including 6 commercial cultivars and 6 Introduced genotypes were used in this study are presented in Table (1).

**Table 1. Name, pedigree and origin of the twelve bread wheat genotypes used in this study.**

| Ent. No. | Entry name | Pedigree | Origin |
|---|---|---|---|
| 1 | Shandaweel 1 | SITE//MO/4/NAC/TH.AC//3*PVN/3/MIRLO/BUC. | EGYPT |
| 2 | Giza 171 | Sakha 93/Gemmeiza 9 | EGYPT |
| 3 | Misr 2 | SKAUZ/BAV92. | EGYPT |
| 4 | Sids 14 | Bow"s"/Vee"s"//Bow"s"/TSI/3/Bani Sweef 1. | EGYPT |
| 5 | Gemmeiza 11 | B0W"S"/KVZ"S"//7C/SERI82/3/GIZA168/SAKHA61.GM7892 | EGYPT |
| 6 | Gemmeiza 12 | OTUS/3/SARA/THB//VEE | EGYPT |
| 7 | Line #7 | PRL/2*PASTOR | CIMMYT |
| 8 | Line #8 | MUNAL #1 | CIMMYT |
| 9 | Line #9 | KACHU//KIRITATI/2*TRCH | CIMMYT |
| 10 | Line #10 | MUU/FRNCLN | CIMMYT |
| 11 | Line #11 | CHIBIA//PRLII/CM65531/3FISCAL/4/DANPHE #1/5/CHIBA | CIMMYT |
| 12 | Line #12 | ND643/2*WBLL1//2*KACHU | CIMMYT |

### Layout and experimental design

The experiment was grown in a randomized complete block (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 practices of wheat production were followed throughout the growing seasons. Data were recorded on days to 50% heading, number of spikes m$^{-2}$ (Sm), number of kernels spike$^{-1}$, 1000-kernel weight (g), grain yield (ton h$^{-1}$), one ton = 1000 kg and one hectare = 10000 m$^{2}$.

### Meteorological Data

The monthly mean temperature differed from season to another and the means of maximum and minimum temperature during three growing seasons are summarized in Table (2).

**Table 2. The average, minimum and maximum temperature during growing three seasons at El-Mattana Station.**

| Months | 2015/2016 | | 2016/2017 | | 2017/2018 | |
|---|---|---|---|---|---|---|
| | Max | Min | Max | Min | Max | Min |
| November | 28.47 | 14.53 | 30.06 | 15.32 | 28.09 | 13.32 |
| December | 23.56 | 9.13 | 21.88 | 8.15 | 26.33 | 11.21 |
| January | 22.26 | 7.48 | 23.47 | 7.36 | 22.14 | 7.15 |
| February | 26.59 | 10.64 | 23.55 | 8.28 | 29.11 | 12.05 |
| March | 30.42 | 14.58 | 28.71 | 12.94 | 33.70 | 16.92 |
| April | 36.67 | 18.90 | 35.75 | 18.22 | 41.67 | 30.00 |

## Statistical analysis

### A) Data analysis

Analysis of variance (ANOVA) was calculated for environment one factor and combined over sowing dates and years following Gomes and Gomez (1984). Least significant difference (LSD) was used for comparing means.

### B) Stability analysis

Stability parameters for grain yield and yield components of the 12 genotypes were calculated according to the model of Eberhart and Russell (1966).

### C) Heat susceptibility index (HSI)

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 of Fisher and Muarer (1978). This is expressed as S= (1-YD/ YP)/ D, where 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

### Environment-genotype variations and G×E interactions

Combined analysis of variance for the twelve genotypes evaluated under nine divergent environments are given in Table (3**).** The differences between years and dates were highly significant for all studied characters**,** indicating wide range in climatic conditions factors prevailing during the growing seasons.

Also, the mean square of genotypes found to be highly significant for all studied traits. These variations among genotypes might partially reflect their different genetic backgrounds. Moreover, the interaction of year X dates (Y X D) was highly significant for all characters**,** indicating the different influences of climatic conditions on sowing date **(**Table 3**).** Otherwise, interaction between years X genotypes (Y X G) was found to be highly significant for all studied characters except number of spikes m$^{-2}$**.** The analysis revealed highly significant differences between genotypes X dates (G X D), interaction for all studied traits.

**Table 3. Mean squares from the combined of variance for traits studied of the 12 genotypes tested in favorable and stress environments.**

| SOV | df | Mean squares (M.S) | | | | |
|---|---|---|---|---|---|---|
| | | Days to heading | Number of spikes/m2 | Number of kernels/spike | 1000-Kernel weight (g) | Grain yield (ton/ha) |
| Year (Y) | 2 | 844.46** | 31395.79** | 1876.49** | 941.24** | 68.05** |
| Error a | 4 | 6.97 | 615.57 | 2.85 | 0.33 | 0.31 |
| Dates (D) | 2 | 5637.74** | 1361821.76** | 39001.86** | 6033.66** | 204.37** |
| YXD | 4 | 205.80** | 2360.51** | 193.53** | 1.23 | 5.13** |
| Error b | 12 | 11.73 | 414.34 | 14.14 | 11.02 | 0.26 |
| Genotypes(G) | 11 | 156.94** | 11264.69** | 1011.22** | 174.23** | 8.45** |
| Y X G | 22 | 1.34** | 1431.45 | 8.93** | 2.39** | 0.04 |
| D X G | 22 | 2.07** | 1897.27** | 32.85** | 7.53** | 0.24** |
| Y X D X G | 44 | 1.01** | 1875.15** | 6.15** | 1.71* | 0.08* |
| Pooled error | 198 | 0.619 | 953.32 | 3.79 | 1.12 | 0.05 |

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

These results indicated that genotypes interacted differently with the dates which indicated differential response of the different genotypes to heat stress. Accordingly, there were a differential response among genotypes to sowing dates and years. Similar results were obtained by Al-Otayk (2010). Singh and Narayanan (2000) reported that, if G × E interaction is found to be significant, the stability analysis can be carried out. The combined analysis of variance showed that interaction between years x dates x genotypes was significant or highly significant for all studied characters. Similar results were obtained by Mohiy (2016) and Abdelkader and Abdel-Latif (2017).Mean performance.

### Days to 50% heading

The performance of the studied genotypes in the nine environments are presented in Table (4). The average number of days to heading across all environments ranged from 68.65 days for Line # 7 to 76.09 days for Sids 14 with an average of 71.65 days. These results indicated that genotypes Gemmeiza 11, Line # 7 and Line # 12 are earlier in heading than the grand mean across all environments under Upper Egypt conditions. Saini *et al* (1986) reported significant shortening of the period of ear growth when the crop is sown at late time and its flowering period shortened considerably because the time of flowering stage and the atmospheric temperature start to rising up.

It is clear that, late planting date reduced number of days to heading in the second and third planting dates by an average of 10.24 and 18.00 %, respectively, compared to the optimum planting date. These findings are also in agreement with the results obtained by Abdel-Shafi *et al* (1999), El-Morshidy *et al* (2001) and Tawfelis *et al* (2010). Salous (2007) reported that late planting reduced days to heading by 4.32 % across all genotypes when compared with recommended date.

**Table 4. Average number of days to heading and number of spikes m$^{-2}$ for the twelve bread wheat genotypes under three planting dates in the three seasons and across all seasons.**

| Genotypes | Days to heading | | | Average across all | Reduction% | | Number of spikes/m$^2$ | | | Average across all | Reduction% | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $D_1$ | $D_2$ | $D_3$ | | $D_1$-$D_2$/$D_1$ | $D_1$-$D_3$/$D_1$ | $D_1$ | $D_2$ | $D_3$ | | $D_1$-$D_2$/$D_1$ | $D_1$-$D_3$/$D_1$ |
| Shandaweel 1 | 77.83 | 69.44 | 63.56 | 70.28 | 10.78 | 18.34 | 481.56 | 363.22 | 259.67 | 368.15 | 24.57 | 46.08 |
| Giza 171 | 81.06 | 72.33 | 66.11 | 73.17 | 10.76 | 18.44 | 458.67 | 362.67 | 219.78 | 347.04 | 20.93 | 52.08 |
| Misr 2 | 81.94 | 73.78 | 67.89 | 74.54 | 9.97 | 17.15 | 495.33 | 374.67 | 272.22 | 380.74 | 24.36 | 45.04 |
| Sids 14 | 83.06 | 74.89 | 70.33 | 76.09 | 9.83 | 15.32 | 474.22 | 364.33 | 237.00 | 358.52 | 23.17 | 50.02 |
| Gemmeiza 11 | 76.28 | 68.11 | 62.44 | 68.94 | 10.71 | 18.14 | 414.78 | 320.11 | 218.11 | 317.67 | 22.82 | 47.41 |
| Gemmeiza 12 | 78.06 | 70.11 | 63.22 | 70.46 | 10.18 | 19.00 | 488.34 | 362.67 | 240.56 | 363.85 | 25.73 | 50.74 |
| Line #7 | 75.94 | 67.56 | 62.44 | 68.65 | 11.05 | 17.78 | 448.45 | 320.11 | 201.78 | 323.45 | 28.62 | 55.01 |
| Line #8 | 78.50 | 71.44 | 64.56 | 71.50 | 8.99 | 17.76 | 457.22 | 334.44 | 235.00 | 342.22 | 26.85 | 48.60 |
| Line #9 | 79.83 | 72.33 | 65.44 | 72.54 | 9.39 | 18.02 | 389.55 | 339.33 | 223.22 | 317.37 | 12.89 | 42.70 |
| Line #10 | 77.83 | 70.33 | 63.56 | 70.57 | 9.64 | 18.34 | 472.78 | 341.78 | 246.89 | 353.81 | 27.71 | 47.78 |
| Line #11 | 81.50 | 73.44 | 67.00 | 73.98 | 9.88 | 17.79 | 456.33 | 335.44 | 228.78 | 340.19 | 26.49 | 49.87 |
| Line #12 | 77.33 | 68.22 | 61.78 | 69.11 | 11.78 | 20.11 | 485.33 | 352.00 | 244.56 | 360.63 | 27.47 | 49.61 |
| Average | 79.10 | 71.00 | 64.86 | 71.65 | 10.24 | 18.00 | 460.21 | 347.56 | 235.63 | 347.80 | 24.48 | 48.80 |
| LSD 0.05 | | | | | | | | | | | | |
| Year (Y) | | | | 0.997 | | | | | | 9.37 | | |
| Dates (D) | | | | 1.016 | | | | | | 6.03 | | |
| Y*D | | | | 1.760 | | | | | | 10.45 | | |
| Genotypes | | | | 0.419 | | | | | | 16.47 | | |
| Y*G | | | | 0.727 | | | | | | n.s | | |
| D*G | | | | 0.726 | | | | | | 28.27 | | |
| Y*D*G | | | | 1.259 | | | | | | 49.39 | | |

**D1= first planting date, D2=second planting date, D3= third planting date**

## Number of spikes m$^{-2}$

The combined average for number of spikes m$^{-2}$ across all environments ranged from 317.37 spikes m$^{-2}$ for Line# 9 to 380.74 spikes m$^{-2}$ for Misr 2 with an average of 347.80 spikes m$^{-2}$ These results indicated that Misr 2, Gemmeiza 12, Shandaweel 1, Sids 14, Line #12 and Line #10 had the highest number of spikes m$^{-2}$ compared with the grand mean across all environments under Upper Egypt conditions (Table 4). This might be due to the high efficiency of plants to convert solar energy to chemical energy, which increased number of spikes m$^{-2}$ with sowing on 25th Nov. than the other tested sowing dates. These results are in harmony with those obtained by Nasim *et al* (2006) and Alisial *et al* (2010).

The reduction in number of spikes m$^{-2}$ in the second and third planting dates in the three seasons was by an average of 24.48 and 48.80 % respectively, compared to the optimum planting date. Furthermore, the results clearly showed that delaying sowing decreased number of spikes m$^{-2}$ under terminal heat stress in Upper Egypt.

Therefore, the number of spikes per square meter was affected due to the heat stress imposed on late period of life span. These results suggest that the reduction of spike number may be due to failure of fertilization process or the high mortality rate of young spikes because of the heat stress. Similar results were obtained by Tawfelis, (2006), Seleem (2007) and Mohiy (2016). Moreover, Tawfelis *et al* (2010) reported that late planting reduced no. of spikes m$^{-2}$ by 10.96%.

### Number of kernels spike$^{-1}$

The average number of kernels spike$^{-1}$ under D1, D2 and D3 across all the three seasons were 73.95, 57.70 and 36.07. Data are presented in Table (5). Mean number of kernels spike$^{-1}$ of the twelve genotypes across the three sowing dates during the three years ranged from 46.63 for Line # 7 to 66.70 for Misr 2 with an average of 55.91 in the across all genotypes. These results indicated that genotypes Misr 2, Shandaweel 1, Giza 171, Sids 14, Gemmeiza 12, Line # 10 and Line # 12 have high number of kernels spike$^{-1}$ compared with the grand mean across all environments under Upper Egypt conditions.

**Table 5. Average number of kernels spike$^{-1}$, 1000-kernel weight and grain yield for the twelve bread wheat genotypes under three planting dates in the three seasons and across all seasons.**

| Genotypes | Number of kernels spike$^{-1}$ | | | Average across all | Reduction % | | 1000-Kernel weight (gm) | | | Average across all | Reduction % | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $D_1$ | $D_2$ | $D_3$ | | $D_2$-$D_1$/$D_1$ | $D_3$-$D_1$/$D_1$ | $D_1$ | $D_2$ | $D_3$ | | $D_2$-$D_1$/$D_1$ | $D_3$-$D_1$/$D_1$ |
| Shandaweel 1 | 81.67 | 63.78 | 44.89 | 63.45 | 21.91 | 45.03 | 40.95 | 32.45 | 26.93 | 33.44 | 20.75 | 34.24 |
| Giza 171 | 77.33 | 60.78 | 37.89 | 58.67 | 21.41 | 51.00 | 37.76 | 29.62 | 24.93 | 30.77 | 21.54 | 33.97 |
| Misr 2 | 86.00 | 67.33 | 46.78 | 66.70 | 21.71 | 45.61 | 42.68 | 33.58 | 28.48 | 34.91 | 21.31 | 33.27 |
| Sids 14 | 78.56 | 60.33 | 38.22 | 59.04 | 23.20 | 51.35 | 38.69 | 31.02 | 25.40 | 31.70 | 19.83 | 34.36 |
| Gemmeiza 11 | 67.11 | 50.33 | 25.45 | 47.63 | 25.00 | 62.08 | 43.52 | 34.80 | 30.33 | 36.22 | 20.04 | 30.30 |
| Gemmeiza 12 | 74.00 | 61.44 | 39.33 | 58.26 | 16.96 | 46.84 | 38.28 | 31.93 | 24.36 | 31.52 | 16.60 | 36.37 |
| Line #7 | 65.22 | 49.11 | 25.56 | 46.63 | 24.70 | 60.82 | 36.44 | 27.22 | 19.59 | 27.75 | 25.32 | 46.25 |
| Line #8 | 72.00 | 58.44 | 33.89 | 54.78 | 18.82 | 52.93 | 39.28 | 30.95 | 22.38 | 30.87 | 21.20 | 43.02 |
| Line #9 | 70.33 | 47.22 | 30.56 | 49.37 | 32.86 | 56.55 | 36.31 | 28.46 | 20.99 | 28.59 | 21.62 | 42.19 |
| Line #10 | 73.67 | 57.89 | 37.11 | 56.22 | 21.42 | 49.62 | 40.21 | 31.14 | 24.12 | 31.82 | 22.54 | 40.02 |
| Line #11 | 67.56 | 55.89 | 33.44 | 52.30 | 17.27 | 50.50 | 37.83 | 27.35 | 21.64 | 28.94 | 27.70 | 42.80 |
| Line #12 | 74.00 | 59.89 | 39.78 | 57.89 | 19.07 | 46.25 | 41.65 | 32.74 | 25.69 | 33.36 | 21.39 | 38.31 |
| Average | 73.95 | 57.70 | 36.07 | 55.91 | 21.97 | 51.22 | 39.47 | 30.94 | 24.57 | 31.66 | 21.61 | 37.75 |
| LSD 0.05 | | | | | | | | | | | | |
| Year (Y) | | | | 0.64 | | | | | | 0.22 | | |
| Dates (D) | | | | 1.11 | | | | | | 0.98 | | |
| Y*D | | | | 1.93 | | | | | | 1.70 | | |
| Genotypes (G) | | | | 1.04 | | | | | | 0.56 | | |
| Y*G | | | | 1.80 | | | | | | 0.98 | | |
| D*G | | | | 1.77 | | | | | | 0.97 | | |
| Y*D*G | | | | 3.12 | | | | | | 1.63 | | |

**Table 5. Cont.**

| Genotypes | Grain yield (ton ha$^{-1}$) | | | Average over all | Reduction% | |
|---|---|---|---|---|---|---|
| | D$_1$ | D$_2$ | D$_3$ | | D$_2$-D$_1$/D$_1$ | D$_3$-D$_1$/D$_1$ |
| **Shandaweel 1** | **7.37** | **5.65** | **4.20** | **5.74** | **23.29** | **43.04** |
| **Giza 171** | **6.59** | **5.09** | **3.92** | **5.20** | **22.76** | **40.54** |
| **Misr 2** | **7.62** | **6.09** | **4.63** | **6.11** | **20.17** | **39.21** |
| **Sids 14** | **6.62** | **5.27** | **3.96** | **5.28** | **20.29** | **40.18** |
| **Gemmeiza 11** | **6.07** | **4.75** | **3.64** | **4.82** | **21.75** | **39.95** |
| **Gemmeiza 12** | **6.87** | **5.40** | **3.98** | **5.42** | **21.44** | **42.11** |
| **Line #7** | **5.67** | **4.11** | **3.24** | **4.34** | **27.43** | **42.90** |
| **Line #8** | **6.34** | **4.55** | **3.55** | **4.81** | **28.21** | **44.02** |
| **Line #9** | **6.32** | **4.27** | **3.34** | **4.64** | **32.46** | **47.18** |
| **Line #10** | **6.69** | **4.99** | **3.76** | **5.15** | **25.45** | **43.89** |
| **Line #11** | **5.57** | **3.92** | **3.00** | **4.16** | **29.65** | **46.23** |
| **Line #12** | **6.55** | **5.09** | **4.21** | **5.28** | **22.20** | **35.76** |
| **Average** | **6.52** | **4.93** | **3.78** | **5.08** | **24.39** | **41.99** |
| **LSD 0.05** | | | | | | |
| **Year (Y)** | | | | **0.209** | | |
| **Dates (D)** | | | | **0.151** | | |
| **Y*D** | | | | **0.261** | | |
| **Genotypes (G)** | | | | **0.124** | | |
| **Y*G** | | | | **n.s** | | |
| **D*G** | | | | **0.216** | | |
| **Y*D*G** | | | | **0.373** | | |

**D1= first planting date, D2=second planting date, D3= third planting date**

It is clear that late planting dates caused a reduction in number of kernels/spike in the second (D2) and third (D3) planting dates by an average of 21.97% and 51.22 %, respectively as compared with the optimum (D1) planting date. The lower number of kernels spike$^{-1}$ in all genotypes was observed at late sowing might be due to high temperature during the reproductive phase which can cause pollen sterility and adverse effects on floral organs, consequently, decreased number of grain per spike (Prasad *et al* 2008). Similar results were also reported by Seleem (2007), Mohiy (2016).

### 1000-kernel weight (g)

The performance of the studied genotypes in the nine environments for 1000-kernel weight is presented in Table (5). The average of 1000-kernel weight across all environments (31.66 g) ranged from 27.75 for Line # 7 to 36.22 for Gemmeiza 11. Six genotypes (Shandaweel 1, Misr 2, Sids 14, Gemmeiza 11, Line #10, and Line #12) have high 1000 kernel weight average comparing to the grand mean across all environments under Upper Egypt conditions.

**Table 6. The joint regression analysis of variance for the characters studied.**

| SOV | df | Mean squares (M.S.) | | | | |
|---|---|---|---|---|---|---|
| | | Days to heading | Number of spikes/m2 | Number of kernels/spike | 1000-KW | Grain yield |
| Environment | 8 | 1707.68** | 349481.30** | 10316.46** | 1744.43** | 70.66** |
| Genotypes | 11 | 156.71** | 11264.61** | 1011.13** | 174.27** | 8.44** |
| Env. + G x Env. | 96 | 285.86** | 10248.67** | 290.69** | 49.47** | 11.88** |
| a- Env.(linear) | 1 | 13661.44** | 2795850.0** | 82531.70** | 13955.48** | 565.31** |
| b- G x Env. (linear) | 11 | 2.40** | 1957.29* | 28.62** | 7.25** | 0.27** |
| c- pooled dev. | 84 | 1.11** | 1597.76** | 10.41** | 2.55** | 0.08** |
| Pooled error | 198 | 0.619 | 953.32 | 3.79 | 1.12 | 0.05 |

*** $p < 0.05$, ** $p < 0.01$.**

The reduction 1000-kernel weight in the second and third planting dates at the three seasons was by an average of 21.61 and 37.75% respectively, compared to the optimum planting date. This may be due to high temperatures affecting the grain maturity which resulted in shrinked kernels. The results, showed similar trend with that obtained by Menshawy (2007) who reported that high reduction in kernel weight under late planting; it could be fully accounted by the reduction in grain filling period. Tawfelis *et al* (2010) reported that delaying sowing date reduced 1000-kernel weight by 5.27 and 10.80% in the second and third planting dates, respectively.

### Grain yield (ton/ha)

The averages of grain yield ton/ha under D1, D2 and D3 were 6.65, 4.93 and 3.78 ton ha$^{-1}$. Across the three years are presented in Table (5). The twelve genotypes across all environments during the three years ranged from 4.11 ton ha$^{-1}$ for genotype Line #11 to 6.11 ton ha$^{-1}$ for genotype Misr 2 with an average of 5.08 ton ha$^{-1}$ across all genotypes. The results indicated that genotypes Shandaweel 1, Giza 171, Misr 2, Sids 14, Gemmeiza 12, Line #10 and Line #12 have high grain yield ton ha$^{-1}$ compared with the grand mean across all environments under Upper Egypt conditions.

Late planting caused a reduction in grain yield in the second and third planting dates by an average of 24.39 and 41.99%, respectively, compared to the optimum planting date. These results indicated that delayed sowing decreased grain yield. This may be due to the high temperature during delay sowing, which shortened the period of grain filling and resulted in reduce development of grain and ultimately decreasing the grain yield (Guilioni *et al* 2003). The delay in heading date under late sowing may be attributed to grains which could be affected by the high temperature specially during this period. Tawfelis (2006) found significant variation in yield and yield components among wheat genotypes under favorable and late planting. Seeding earlier and later reduces yield potential. Wheat yield declined by 30 to 40% when seeding was delayed from early September to late October in SW Saskatchewan as obtained by (McLeod *et al* 1992). Delayed planting of wheat from first October to first December in Kansas (USA) decreased grain yield by 18% per month as reported by (Witt 1996). Similar results were reported by Salous (2007), Mohiy (2016) and Abdelkader and Abdel-Latif (2017).

**Joint regression analysis**

The joint regression analysis of variance for the studied characters is presented in Table (6). The variances among wheat genotypes and environments were highly significant for all the studied traits, indicating the presence of wide variability among the genotypes as well as environments and reflecting the differential response of genotypes in various environments. Furthermore, all mean squares of Env. + (G × Env.) interaction indicates that the genotypes considerably interacted with the nine environmental conditions.

In fact, Env. + (G × Env.) ss interaction for each character is only a makeup of the two parts; Env. and G × Env ss of the same character. Env. ss is completely represented by Env. (Linear) in which its mean square was highly significant for the studied characters, indicating differences among environments and their influences would remarkably be reflected on the studied characters. Also, the partition of G × Env ss interaction of the studied traits into its two components; i.e., regression ss G× Env (Iinear) ss and deviations from regression pooled deviations, demonstrated that GxE (linear) ss was significant for all studied characters, indicating the presence of genetic differences among genotypes for their regression on the environmental index. Therefore, it could be proceeded in the stability analysis (Eberhart and Russell 1966). The significance of pooled deviation mean squares for all studied characters, except, number of spike $m^{-2}$ suggests that performance of different genotypes were significantly fluctuated from their respective linear path of response to environments. These findings are in agreement with those obtained by Al-Otayk (2010), Arian *et al* (2011), El-Ameen (2012), Hassan *et al* (2013), Abd El-Shafi *et al* (2014) and Mohiy (2016). Kaya *et al* (2002) reported that there were significant differences among wheat genotypes as well as GE in yield and yield components.

**Estimated stability parameters**

It is important to report that plant breeders in executing selection programs would prefer to select genotypes with high average performance and most stable across various environments. For each genotype, the values of mean performance across environments (X), the stability regression coefficient (bi) and deviation from regression ($S^2di$) for each genotype and for all studied traits are presented in Table (7).

**Table 7. Stability parameters for studied characters of twelve bread wheat genotypes under nine environments**

| Genotypes | Days to heading | | | Number of spikes $m^{-2}$ | | | Number of kernels $spike^{-1}$ | | | 1000-Kernel weight (g) | | | Grain yield (ton $ha^{-1}$) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Mean | bi | $S^2d$ | Mean | bi | $S^2d$ | Mean | bi | $S^2d$ | Mean | bi | $S^2d$ | Mean | bi | $S^2d$ |
| Shandaweel 1 | 70.28 | 0.976 | 0.96 | 368.15 | 0.988 | 621.0 | 63.45 | 0.955 | 9.80* | 33.44 | 0.954 | 1.66 | 5.74 | 1.109** | 0.114* |
| Giza 171 | 73.17 | 1.038 | 1.11 | 347.04 | 1.060 | 993.3 | 58.67 | 1.032 | 2.90 | 30.77 | 0.903 | 2.74 | 5.20 | 0.979 | 0.024 |
| Misr 2 | 74.54 | 1.007 | 0.58 | 380.74 | 0.993 | 1040.4 | 66.70 | 1.034 | 4.91 | 34.91 | 0.959 | 1.44 | 6.11 | 1.070 | 0.072 |
| Sids 14 | 76.09 | 0.938 | 2.71** | 358.52 | 1.046 | 1788.8 | 59.04 | 1.065 | 6.11 | 31.70 | 0.909* | 1.05 | 5.28 | 0.991 | 0.117* |
| Gemmeiza 11 | 68.94 | 0.979 | 0.37 | 317.67 | 0.876** | 186.6 | 47.63 | 1.106* | 8.23* | 36.22 | 0.936 | 3.57** | 4.82 | 0.917 | 0.059 |
| Gemmeiza 12 | 70.46 | 1.032 | 1.39* | 363.85 | 1.089 | 386.1 | 58.26 | 0.938 | 14.38* | 31.52 | 0.918 | 5.54** | 5.42 | 1.054* | 0.122* |
| Line #7 | 68.65 | 0.932* | 1.01 | 323.45 | 1.078 | 6654.5** | 46.63 | 1.045 | 6.01 | 27.75 | 1.111* | 1.48 | 4.34 | 0.888* | 0.043 |
| Line #8 | 71.50 | 0.964 | 0.90 | 342.22 | 1.003 | 680.1 | 54.78 | 1.015 | 8.25* | 30.87 | 1.119* | 2.77* | 4.81 | 1.009 | 0.059 |
| Line #9 | 72.54 | 1.006 | 0.53 | 317.37 | 0.773 | 3398.6** | 49.37 | 1.029 | 34.61** | 28.59 | 1.029 | 3.09* | 4.64 | 1.074** | 0.129* |
| Line #10 | 70.57 | 1.006 | 2.39** | 353.81 | 1.006 | 1021.6 | 56.22 | 0.973 | 9.17* | 31.82 | 1.047 | 2.12 | 5.15 | 1.070 | 0.050 |
| Line #11 | 73.98 | 1.026 | 0.42 | 340.19 | 1.019 | 2008.4* | 52.30 | 0.91 | 15.36** | 28.94 | 1.061 | 4.44** | 4.16 | 0.930 | 0.040 |
| Line #12 | 69.11 | 1.096* | 1.01 | 360.63 | 1.070 | 393.3 | 57.89 | 0.90** | 5.24 | 33.36 | 1.055* | 0.66 | 5.28 | 0.910* | 0.176** |
| Average | 71.65 | | | 347.80 | | | 55.91 | | | 31.66 | | | 5.08 | | |
| LSD 0.05 | 0.419 | | | 16.47 | | | 1.04 | | | 0.56 | | | 0.124 | | |

***, ** Significantly different from unity for (bi) and from zero for ($S^2d$) at the 0.05 and 0.01 probability levels, respectively.**

According to the definition of Eberhart and Russell (1966), a stable genotype is one with a high mean performance, unit regression coefficient (bi=1) and deviation from regression equal to zero ($S^2di = 0$).

### Days to 50% heading

Data in Table (7), indicated that seven genotypes were stable due to their bi's and $S^2di$'s did not differ significantly from a unit and the zero, respectively. The genotypes Shandaweel 1, Gemmeiza 11 and Line #8 are considered specifically adapted to the unfavorable environments because the regression coefficients were less than 1 (bi<1), while Giza 171, Misr 2, Line #9 and Line #11 were adapted to favorable environment (bi>1). Sids 14, Gemmeiza 12 and Line #10 were considered as genotypes with poor stability. This significant deviation from regression for heading date was also attributed by Joppa *et al* (1971). These results are in harmony with those obtained by Kheiralla and Ismail (1995) and Mohamed and Said (2014). Tawfelis *et al* (2010) found that ten genotypes were stable due to their bi's and $S^2di$'s did not differ from a unit and the zero, respectively.

### Number of spikes $m^{-2}$

Results in Table (7) indicated that Shandaweel 1, Misr 2, Sids 14, Gemmeiza 12, Line #10 and Line #12 genotypes showed high mean performance and gave bi and $S^2di$ that did not differ significantly from a unit and the zero, respectively, indicating that these genotypes may be considered as stable for number of spikes $m^{-2}$ when compared with grand mean. The other genotypes were unstable (bi differed significantly from unity and/or $S^2$d was significant from zero). The most desired and stable genotypes can be considered when their regression coefficient equal one (bi=1) with lower values of $S^2$di (Eberhart and Russell 1966). These findings are in agreement with those obtained by Seleem (2007), Tawfelis *et al* (2010) and Mohamed and Said (2014).

**Number of kernels spike$^{-1}$**

Three genotypes; Giza 171, Misr 2 and Sids 14 (Table 7) have high average and insignificant bi and $S^2$d from unity and the zero, respectively, indicating that these genotypes may be considered as stable for such trait. The other genotypes were unstable because bi was significantly different from unity and/or $S^2$d was significantly higher than zero. Giza 171 was stable and performed better in favorable environments (bi>1), while Shandaweel 1 was stable and unfavorable environment (bi<1). Our results are in line with those obtained by Tawfelis *et al* (2010) and Abd El-Rady and Koubisy (2017).

**1000-kernel weight (g)**

Regarding the 1000-kernel weight, results in (Table 7) revealed that three genotypes Shandaweel 1, Misr 2 and Line #10 exhibited insignificant stability parameters from unity and from zero for the regression coefficient (bi) and deviation from regression ($S^2$d), respectively. Additionally, the same genotypes were the most desired genotypes for 1000-kernel weight and showed high mean performance when compared with grand mean beside their stability. These results are in harmony with those obtained by El-Ameen (2012), Mohamed and Said (2014) and Mohiy (2016).

**Grain yield (ton ha$^{-1}$)**

In consideration to the stability parameters bi and $S^2$di, out of the twelve genotypes, six genotypes were stable across all the studied environments; i.e. their bi and $S^2$di were insignificant as presented in Table (7). The other genotypes were unstable (bi was significantly different from unity and /or $S^2$di was significant higher than zero). More than three out of the six genotypes had grain yield above the grand mean. According to ascending orders of yields to these genotypes were Misr 2, Giza 171 and Line #10 (6.11, 5.20 and 5.15 ton ha$^{-1}$), respectively. However, Shandaweel 1 Gemmeiza 12, Line #9 and Line #12 gave reasonable mean yield but had high value of bi and $S^2$di than the remaining genotypes, which makes its performance unpredictable under varying environments and thus it is less stable. The most desired and stable genotypes can be considered when their regression coefficient equal one (bi=1) with lower values of $S^2$di (Eberhart and Russell 1966) accordingly in this study three genotypes Misr 2, Giza 171 and Line #10 were considered as desired and stable for grain yield when compared with grand mean. These results are in line with those obtained by Tawfelis *et al* (2010), Abd El-Shafi *et al* (2014) and Mohiy (2016).

**Heat susceptibility index (HSI)**

Clarke and Townley-Smith (1984) and Fisher and Wood (1979) concluded that HSI was used to estimate stress injury. Low stress susceptibility (HSI < 1) is synonymous with higher stress tolerance. The means of grain yield/plant of the 12 genotypes simultaneously grown under normal (D1) and late sowing (D3) dates are shown in (Table 8), indicated that the values of HSI in the first season ranged from 0.81 to 1.20 for Sids 14 and Line #9 respectively.

**Table 8. The means of grain yield for 12 genotypes under normal (D1) and late sowing (D3) dates with Heat Susceptibility Index (HSI).**

| Genotypes | 2015/2016 | | | 2016/2017 | | | 2017/2018 | | | Over all | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | D1 | D3 | HSI | D1 | D3 | HSI | D1 | D3 | HSI | D1 | D3 | HSI |
| Shandaweel 1 | 7.31 | 5.30 | 0.94 | 8.10 | 4.33 | 1.04 | 6.70 | 2.97 | 1.05 | 7.37 | 4.20 | 1.03 |
| Giza 171 | 6.64 | 4.90 | 0.89 | 7.22 | 4.08 | 0.97 | 5.92 | 2.78 | 1.00 | 6.59 | 3.92 | 0.97 |
| Misr 2 | 7.82 | 5.73 | 0.91 | 8.26 | 4.70 | 0.96 | 6.79 | 3.47 | 0.92 | 7.62 | 4.63 | 0.93 |
| Sids 14 | 6.66 | 5.08 | 0.81 | 7.40 | 4.19 | 0.97 | 5.79 | 2.61 | 1.04 | 6.62 | 3.96 | 0.96 |
| Gemmeiza 11 | 6.33 | 4.52 | 0.97 | 6.83 | 3.83 | 0.98 | 5.05 | 2.58 | 0.92 | 6.07 | 3.64 | 0.95 |
| Gemmeiza 12 | 7.12 | 5.07 | 0.98 | 7.53 | 3.91 | 1.07 | 5.96 | 2.95 | 0.95 | 6.87 | 3.98 | 1.00 |
| Line #7 | 5.79 | 3.87 | 1.13 | 6.30 | 3.56 | 0.97 | 4.92 | 2.29 | 1.01 | 5.67 | 3.24 | 1.02 |
| Line #8 | 6.50 | 4.32 | 1.14 | 7.16 | 3.75 | 1.06 | 5.37 | 2.57 | 0.98 | 6.34 | 3.55 | 1.05 |
| Line #9 | 6.37 | 4.12 | 1.20 | 7.08 | 3.71 | 1.06 | 5.51 | 2.19 | 1.14 | 6.32 | 3.34 | 1.12 |
| Line #10 | 6.84 | 4.84 | 1.00 | 7.40 | 3.72 | 1.11 | 5.84 | 2.70 | 1.01 | 6.69 | 3.76 | 1.05 |
| Line #11 | 5.68 | 3.70 | 1.19 | 6.27 | 3.21 | 1.09 | 4.77 | 2.08 | 1.06 | 5.57 | 3.00 | 1.10 |
| Line #12 | 6.72 | 4.91 | 0.92 | 7.19 | 4.83 | 0.73 | 5.74 | 2.88 | 0.94 | 6.55 | 4.21 | 0.85 |
| Average | 6.65 | 4.70 | 1.00 | 7.23 | 3.98 | 1.00 | 5.70 | 2.67 | 1.00 | 6.52 | 3.78 | 1.00 |

Seven genotypes showed low value of HIS that was less than one, so these genotypes were considered to be tolerant to heat stress.  In 2016/2017 season, heat susceptibility index (HSI) ranged from 0.73 for Line #12 to 1.11 for Line #10. Six genotypes showed the low value (HSI less than one), so these genotypes were considered to be tolerant to heat stress. In the third season the values of HSI ranged from (0.92 to 1.14) of the genotypes Misr 2, Gemmeiza 11 and Line #9, respectively. The seven genotypes displayed HSI values >1 indicating relative susceptibility to heat stress. Meanwhile, the other genotypes displayed HSI value < 1, indicated, relative tolerance to heat stress. The HSI has sometimes been regarded as providing a measure of genotype yield potential under heat stress conditions (Bruckner and Frogberg 1987). HSI actually provides a measure of yield stability based on yield loss under stress as compared to non stressed condition rather than on yield level under dry conditions (Clark *et al* 1984).

On the other hand, the HSI across all three years ranged from 0.85 for Line #12 to 1.12 for genotype Line #9. The five genotypes Giza 171, Misr 2, Sids 14, Gemmeiza 11, and Line #12 showed low heat susceptibility index (HSI value < 1), which indicated relative resistance to heat stress. In general, the less the difference between grain yield under across all environments the less the value of HIS and the high degree of tolerance. Heat susceptibility index varied greatly from year to year with inconsistent direction. However, the genotypes, Line #12, Sids 14, Misr 2 and Giza 171 were considered to be tolerant to heat stress and could be used in wheat breading programs for heat stress.

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# تقييم بعض التراكيب الوراثية من قمح الخبز تحت ظروف الاجهاد الحرارى فى صعيد مصر

**موسى شوقى سلوس موسى**

قسم بحوث القمح– معهد بحوث المحاصيل الحقلية–مركز البحوث الزراعية –الجيزة

*أجري هذا البحث في محطة البحوث الزراعية بالمطاعنة – مركز البحوث الزراعية –مصر خلال المواسم الزراعية الثلاثة ٢٠١٦/٢٠١٥ ، ٢٠١٧/٢٠١٦ و ٢٠١٨/٢٠١٧ وكان الهدف من الدراسة تقييم أثنى عشر من التراكيب الوراثية لقمح الخبز تحت تسع بيئات (ثلاثة مواعيد زراعة خلال ثلاث مواسم). وقد تم استخدام تصميم القطاعات الكاملة العشوائية في ثلاثة مكررات في كل ميعاد زراعة. وكان الهدف من الدراسة تقييم الاثنى عشر تركيبا وراثيا فى بيئات متباينة ، وتم تقدير معامل الثبات للمحصول ومكوناته للتراكيب الوراثية تحت ظروف الاجهاد الحرارى فى مصر العليا وذلك لتحديد أكثر التراكيب الوراثية تحملا لهذه الظروف وتقييم أدائها واستقرارها. وقد أظهرت النتائج استجابة مختلفة للتراكيب الوراثية من بيئة إلي أخري، كما أدت الزراعة فى ميعاد متأخر الى نقص فى عدد الايام من الزراعة الى التزهير، عدد السنابل /م٢ ، عدد حبوب السنبلة، وزن الالف حبة ومحصول الحبوب فى الميعاد الثانى والثالث بمقدار (١٠,٢٤ ، ١٨,٠٠ %) و (٢٤,٤٨ ، ٤٨,٨٠%) و (٢١,٩٧ ،٥١,٢٢%) و (٢١,٦١ ،٣٧,٧٥%) و (٢٤,٣٩ ،٤١,٩٩ %) بالمقارنة بالزراعة فى الميعاد الامثل على الترتيب. أظهر تحليل الانحدار المشترك للتباين للصفات المدروسة اختلافات عالية المعنوية لمكون البيئة +(التركيب الوراثي ×البيئة ) وهذا يشير إلى أن التركيب الوراثي يتفاعل تفاعلا كبيرا مع الظروف البيئية . كان التفاعل بين التراكيب الوراثية والبيئات (الخطى ) معنوي لكل الصفات المدروسة مما دل على وجود اختلافات معنوية بين التراكيب الوراثية للاستجابة الخطية للبيئات المختلفة .أظهرت مقاييس الثبات أن سبعة تراكيب وراثية لعدد الأيام حتى الطرد، ثمانية لعدد السنابل/م٢، أثنان لعدد الحبوب/السنبلة وأربعة لوزن الألف حبة كانت ثابتة .أظهرت النتائج ستة تراكيب وراثية وهى جيزة١٧١، مصر٢، جميزة ١١، سلالة ٨، سلالة ١٠ وسلالة ١١ من الاثنى عشر تركيب وراثى تحت الدراسة انحرافاً غير معنويا عن خط الانحدار ، وكانت قيم معامل الانحدار لها غير معنوية عن الوحدة لذلك تعتبر هذه التراكيب ثابتة لصفة محصول الحبوب .أعطت ثلاثة من هذه التراكيب (مصر٢، جيزة ١٧١ و سلالة ١٠) محصول حبوب عالى بالمقارنة بالمتوسط العام للسلالات وبالتالي تعتبر هذه التركيب الوراثية الأكثر تأقلما تحت ظروف هذه الدراسة. كما أظهرت التراكيب الوراثية مصر ٢، جميزة ١١ وسلالة ١٢ قيم معامل الحساسية للحرارة أقل من الواحد مما يشير الى قدرة هذه التراكيب على تحمل الحرارة واستخدامها فى برامج التربية والتحسين لتحمل الحرارة.*

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