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# RESPONSE OF SOME EXOTIC BREAD WHEAT GENOTYPES TO REDUCED IRRIGATION IN NORTH DELTA REGION OF EGYPT

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## ABSTRACT

***Water deficit is one of the most constraints to wheat production in Egypt and worldwide. Therefore, sixteen exotic lines and two local cultivars of bread wheat were evaluated under normal (five irrigation) and water deficit stress (the planting irrigation only) conditions during 2017/18 and 2018/19 growing seasons at Sakha Agricultural Research Station. The current study aimed to enhance the breeding program with lines tolerant to water deficit stress. The two seasons and two water treatments showed sufficient genetic variability among the studied genotypes. Most studied traits showed higher values in the second season compared to the first one. All mean values of the studied traits decreased under water deficit stress. High values of grain and biological yields, number of spikes m$^{-2}$, grain filling period and rate were the most contributors to water deficit stress tolerance. line 1, line 16, line 15 and line 11 had high yielding ability and relative tolerance under water deficit stress. Misr 1 and Giza 171 cultivars were proved to be suitable cultivars under reduced irrigation. The exotics line 3, line 5 and line 9 could be used to enhance wheat breeding program for water deficit stress tolerance.***

Key words: ***Triticum aestivum L., Water deficit stress, Stress tolerance index, ICARDA.***

## INTRODUCTION

Wheat is among the most important cereal crops in Egypt due to its use in food and feed. Water shortage, nutrient deficiency and salinity are the major global limitation to wheat production (Mujeeb-Kazi *et al* 2019). Water deficit stress results from infrequent rains, poor irrigation and water scarcity in irrigated agriculture (Ouda *et al* 2020). The water deficit stress has been reported to reduce number of days to maturity, grain and biological yield and yield components in wheat (Farhat 2015, Hamza *et al* 2018, Seleiman and Abdel-Aal 2018 Abd El-Kreem *et al* 2019, Abd El-Hamid *et al* 2019 and 2020 and Henian *et al* 2020).

To cope with water shortage and save the irrigated area, different choices are available. One of these choices is development of high yield cultivars with stable performance under limited water environments (Mkhabela *et al* 2019, Liwani *et al* 2018 and Thungo *et al* 2019). International Center for Agricultural Research in the Dry Areas (ICARDA) and Egyptian wheat breeding programs pay considerable attention to develop high yielding and widely adapted genotypes with resistance/tolerance to the major biotic and abiotic constraints (Tadesse *et al* 2019). Several stress indices have been proposed to screen genotypes for water stress tolerance. Water stress susceptibility index (Fischer and Maurer 1978) is commonly used in earlier studies to detect tolerant genotypes for water deficit stress (Farhat, 2015 and Abd El-Kreem *et al* 2019 and Henian *et al* 2020).

The relationship between stress tolerant indices and other traits in wheat were studied to detect the most important contributors to water stress tolerance (Hamza *et al* (2018), Farooq *et al* 2020 and Mdluli *et al* 2020). Consequently, the aim of this study was to identify some tolerant exotic bread wheat lines to water deficit stress for use in future breeding programs.

## MATERIALS AND METHODS

One hundred and thirty-three bread wheat lines (*Triticum aestivum* L) had been selected during a training visit to ICARDA's research station at Marchouch agriculture research near Rabat, Morocco in 2014. These lines were screened against rusts during 2015/2016 growing season on Sakha Agricultural Research Station Farm (Egypt; 38°52′N 65°48′E). Sixteen lines were resistant to wheat rusts and selected to be evaluated under water stress conditions together with the Egyptian cultivars Misr 1 and Giza 171 as local checks. Names, pedigree and selection history of the studied genotypes are listed in Table 1.

The genotypes were evaluated in each water treatment separately using randomized complete block design with four replications. Each plot consisted of two rows with 2.5 m long and 30 cm apart. Combined analysis across the two seasons and across the two water treatments was performed after testing the homogeneity of errors according to Levene (1960). Seasons were considered random, while water treatments and genotypes were considered fixed. Spearman rank correlation was done using GenStat 18 software (Payne *et al* 2017).

Sowing date was $28^{th}$ and $23^{rd}$, November during 2017/18 and 2018/19 wheat growing seasons, respectively. The studied genotypes were evaluated in two separate irrigation regime experiments using flood irrigation method. The first regime included the planting irrigation and the next four irrigations (normal), while the second one included only the planting irrigation (reduced irrigation). According to Sakha meteorological station, average minimum temperature was 15.4 and 12.6 $^{0}$C, while average maximum temperature was 27.8 and 25.8 $^{0}$C in 2017/18 and 2018/19 seasons, respectively. Average of relative humidity was 62.7 and 68.7 % in the first and second season, respectively. All cultural practices, except for irrigation were applied according to the recommendations of Wheat

Research Department for Delta region in Egypt. The previous crop was maize in the two seasons.

**Table 1. Name, pedigree and selection history of the studied wheat genotypes.**

| Name | Pedigree | Selection history |
|---|---|---|
| Line 1 | ATTILA 50Y//ATTILA/BCN/3/ STAR'S'/KAUZ'S' | AISBW05-0006-2AP-0AP-0AP-2AP -0SD |
| Line 2 | P1.861/RDWG/4/SERI.1B//KAUZ/HEVO/3/AMAD | AISBW05-0041-3AP-0AP-0AP-2AP -0SD |
| Line 3 | KAUZ'S'/SERI/3/TEVEE'S'//CROW/VEE'S' | ICW05-0443-3AP-0AP-0AP-3AP -0SD |
| Line 4 | SERI.1B//KAUZ/HEVO/3/AMAD/4/PFAU/MILAN | ICW06-00151-9AP-0AP -04 SD |
| Line 5 | SERI.1B//KAUZ/HEVO/3/AMAD/4/PFAU/MILAN | ICW06-00151-8AP-0AP -02 SD |
| Line 6 | SERI.1B//KAUZ/HEVO/3/AMAD/4/PFAU/MILAN | ICW06-00151-9AP-0AP -02 SD |
| Line 7 | ATTILA*2/PBW65//PFAU/MILAN | ICW05-0450-8AP-0AP-0AP-2AP -0SD |
| Line 8 | SERI.1B//KAUZ/HEVO/3/AMAD/4/PFAU/MILAN | ICW06-00151-8AP-0AP -03 SD |
| Line 9 | VEE/PJN//2*KAUZ/3/SHUHA-4/FOW-2 | ICW06-00166-10AP-0AP -1 SD |
| Line 10 | P1.861/RDWG//PBW343/3/MUNIA/ALTAR 84// AMSEL | ICW06-50323-3AP-0AP-0AP -06 SD |
| Line 11 | PFAU/MILAN | CMSS92Y02937S-91Y-05M-010Y-010Y-9M-0Y-5Y-0B-0AP |
| Line 12 | KAUZ//ALTAR 84/AOS/3/TNMU/MILAN/4/MILAN// PSN/BOW | ICW06-50377-5AP-0AP-0AP -02 SD |
| Line 13 | FLAG-1 | CMSW94WM00188S-0300M-0100Y-0100M-13Y-10M-0Y-0AP |
| Line 14 | CHAM-4/MUBASHIIR-9 | ICW06-00411-1AP-0AP -03 SD |
| Line 15 | OPATA/RAYON//KAUZ/3/2*MILAN/DUCULA | ICW06-50333-2AP-0AP-0AP -04 SD |
| Line 16 | TRACHA-2/SHUHA-3//MILAN/PASTOR/4/ WEAVER// VEE/PJN/3/ MILAN | ICW06-50364-2AP-0AP-0AP -07 SD |
| Misr 1 | OASIS / SKAUZ // 4*BCN /3/ 2*PASTOR | CMSS00Y01881T-050M-030Y-030M-030WGY-33M-0Y-0S |
| Giza 171 | SAKHA 93 / GEMMEIZA 9 | S.6-1GZ-4GZ-1GZ-2GZ-0S |

Water quantity of the planting irrigation was about 495 and 500 $m^3$ $fed^{-1}$ in the first and second seasons, respectively, while the total of the remaining four irrigations was about 1320 $m^3$ $fed^{-1}$ and 1380 $m^3$ $fed^{-1}$ for the normal treatment in the first and second season, respectively. In addition, rainfall reached 78.34 and 73.10 mm and were equal to 329.03 $m^3$ $fed^{-1}$ and 307.02 $m^3$ $fed^{-1}$ in the first and second season, respectively. Each experiment was surrounded by 5 m border to minimize the lateral movement of irrigation water. Location of experiments was close to main drainage canal. Values of water table levels were recorded at intervals through irrigation procedures.

The studied traits were number of days to heading (DH) and maturity (DM), grain filling period (GFP) and grain filling rate (GFR, g $day^{-1}$ $m^{-2}$), plant height (PH, cm), number of spikes $m^{-2}$ (SM), number of kernels $spike^{-1}$ (KS), 1000-kernel weight (KW, g), total biological yield (TY, kg $m^{-2}$), grain yield (GY, kg $m^{-2}$) and harvest index (HI). Stress susceptibility index (SSI) was calculated according to Fischer and Maurer (1978).

## RESULTS AND DISCUSION

The level of water table was deeper than 175 cm after 60 days from sowing under the reduced irrigation treatment in the two seasons. While, it reached the same depth after 145 days from sowing under the normal irrigation treatment.

**Analysis of variance**

The results of Levene test proved homogeneity of separate error variances for all the studied traits that allow to performe the combined analysis. The analysis of variance across the seasons and water treatments for the studied traits is presented in Tables (2 and 3).

The variances due to seasons, water treatments and genotypes were significant (p value < 0.05 or 0.01) for all traits. Selection of the germplasm containing genotypic differences for water stress tolerance is the first step in breeding for this purpose (Sallam *et al* 2019).

The observed significant differences among genotypes for the studied traits indicated that the genotypes under study could be used as a source of genetic diversity for breeding for water stress tolerance (Mwadzingeni *et al* 2016).

**Table 2. Analysis of variance for the number of days to heading and maturity, grain filling period and rate and plant height across the seasons, water treatments and genotypes.**

| SOV | df | DH | DM | GFP | GFR | PH |
|---|---|---|---|---|---|---|
| Season (S) | 1 | 12116.06** | 15356.28** | 191.75** | 3935.08** | 42656.34** |
| Water stress (W) | 1 | 1404.5** | 2695** | 208.42** | 915.72** | 4012.59** |
| S x W | 1 | 37.56* | 116.28** | 21.67 | 331.16** | 1148** |
| Reps/W/S = Error (a) | 12 | 4.040 | 5.660 | 6.140 | 1.890 | 82.610 |
| Genotypes (G) | 17 | 83.83** | 20.23** | 45.41** | 30.4** | 240.47** |
| S x G | 17 | 21.66** | 10.3** | 7.8** | 5.54** | 29.68* |
| W x G | 17 | 4.38* | 5.19* | 4.87 | 9.88** | 10.2 |
| S x W x G | 17 | 3.35 | 2.58 | 4 | 5.31** | 10.69 |
| Pooled error b | 204 | 2.310 | 2.690 | 3.090 | 1.510 | 16.490 |
| Total | 287 | | | | | |
| CV % | | 0.49 | 1.13 | 3.99 | 7.02 | 4.28 |

*** and ** = significant at 0.05 and 0.01 probability level, respectively, DH = number of days to heading, DM = number of days to maturity, GFP = grain filling period, GFR = grain filling rate and PH = plant height.**

**Table 3. Analysis of variance for grain yield and its components, total yield and harvest index across the seasons, water stress conditions and studied wheat genotypes.**

| SOV | df | SM | KW | KS | GY | TY | HI |
|---|---|---|---|---|---|---|---|
| Season (S) | 1 | 980777.93** | 30.74* | 9700.16** | 9.07** | 71.4** | 0.059** |
| Water stress (W) | 1 | 493907.56** | 268.29** | 1063.6** | 2.48** | 11.06** | 0.021** |
| S x W | 1 | 123891.36** | 0.94 | 84.39** | 0.61** | 4.55** | 0.004 |
| Reps/W/S = Error (a) | 12 | 5804.500 | 6.030 | 6.740 | 0.005 | 0.037 | 0.001 |
| Genotypes (G) | 17 | 32817.83** | 109.81** | 576.82** | 0.076** | 0.22** | 0.009** |
| S x G | 17 | 11311.1** | 0.95 | 229.11** | 0.014** | 0.101** | 0.003** |
| W x G | 17 | 4865.57 | 5.91** | 19.61** | 0.016** | 0.095** | 0.001 |
| S x W x G | 17 | 2593.97 | 0.75 | 17.97** | 0.008** | 0.061** | 0.001 |
| Pooled error b | 204 | 2983.040 | 2.320 | 6.910 | 0.002 | 0.012 | 0.001 |
| Total | 287 | | | | | | |
| CV% | | 10.83 | 3.84 | 4.26 | 6.15 | 5.67 | 7.70 |

*** and ** = significant at 0.05 and 0.01 probability level, respectively, SM = number of spikes m$^{-2}$, KS = number of kernels spike$^{-1}$, KW = 1000-kernel weight, GY = grain yield, TY = total yield and HI = harvest index.**

The variance due to interaction of seasons was significant for all traits, except for season x water treatment for GFP, KW and HI, season x genotype for KW, water treatment x genotype for GFP, PH, SM and HI, and season x water treatment x genotype for DH, DM, GFP, PH, SM, KW and HI. Similar results were obtained by Farhat (2015), Hamza *et al* (2018), Seleiman and Abdel-Aal (2018), Abd El-Hamid *et al* (2019) and Abd El-Kreem *et al* (2019).

**Effect of genotypes**

The means performance of the studied traits across seasons and water treatments are presented in Table 4. Number of days to heading ranged from 89.6 days (line 12) to 97.9 days (line 7). In addition, number of days to maturity varied from 136.5 days (line 14) to 140.4 days (line 7). Also, the grain filling period differed from 41.1 days (line 3) to 47.2 days (line 12). The lowest value of grain filling rate was recorded by line 5 and line 9 (15.5 g m$^{-2}$ day$^{-1}$), while the highest value was recorded by line 1 (21.1 g m$^{-2}$ day$^{-1}$). The values of plant height ranged from 84.7 cm (line 12) to 101.3 cm (line 6). Besides, the number of spikes m$^{-2}$ were in the range of 414.6 spikes (line 6) to 583.1 spikes (line 13).

**Table 4. Means performance of the studied traits as of the studied genotypes across seasons and water treatments.**

| Name | DH | DM | GFP | GFR | PH | SM2 | KW | KS | GY | TY | HI |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Line 1 | 100.0 | 145.8 | 45.8 | 21.1 | 96.3 | 527.1 | 45.4 | 64.4 | 0.966 | 2.269 | 0.43 |
| Line 2 | 100.8 | 145.1 | 44.3 | 17.9 | 93.4 | 466.3 | 40.0 | 65.3 | 0.799 | 1.746 | 0.46 |
| Line 3 | 105.2 | 146.3 | 41.1 | 17.9 | 97.5 | 530.4 | 39.0 | 63.5 | 0.742 | 1.961 | 0.38 |
| Line 4 | 104.9 | 146.6 | 41.6 | 16.3 | 98.4 | 466.5 | 39.1 | 54.4 | 0.679 | 1.793 | 0.38 |
| Line 5 | 102.1 | 146.3 | 44.2 | 15.5 | 96.9 | 468.3 | 37.0 | 65.4 | 0.685 | 1.831 | 0.39 |
| Line 6 | 102.6 | 146.4 | 43.8 | 17.8 | 101.3 | 414.6 | 41.5 | 64.5 | 0.781 | 1.861 | 0.43 |
| Line 7 | 105.4 | 147.9 | 42.6 | 16.8 | 95.6 | 550.6 | 38.2 | 75.0 | 0.719 | 1.839 | 0.39 |
| Line 8 | 101.9 | 146.4 | 44.5 | 16.9 | 95.9 | 439.8 | 39.3 | 63.1 | 0.752 | 1.834 | 0.41 |
| Line 9 | 99.7 | 146.8 | 47.1 | 15.5 | 90.3 | 488.5 | 37.3 | 58.3 | 0.737 | 1.866 | 0.40 |
| Line 10 | 102.2 | 144.4 | 42.3 | 17.2 | 95.3 | 522.9 | 40.8 | 63.5 | 0.726 | 1.952 | 0.38 |
| Line 11 | 101.1 | 145.3 | 44.2 | 18.0 | 98.1 | 539.6 | 38.3 | 67.7 | 0.801 | 1.967 | 0.41 |
| Line 12 | 97.1 | 144.3 | 47.2 | 15.8 | 84.7 | 550.6 | 38.3 | 52.6 | 0.748 | 1.881 | 0.40 |
| Line 13 | 104.8 | 146.9 | 42.2 | 16.9 | 96.3 | 583.1 | 38.6 | 52.2 | 0.713 | 1.800 | 0.40 |
| Line 14 | 99.6 | 144.0 | 44.4 | 17.0 | 90.0 | 514.2 | 37.8 | 62.7 | 0.760 | 1.923 | 0.40 |
| Line 15 | 101.4 | 145.3 | 43.9 | 18.5 | 94.1 | 501.5 | 38.2 | 59.2 | 0.815 | 1.915 | 0.43 |
| Line 16 | 98.9 | 144.3 | 45.3 | 18.6 | 91.3 | 526.3 | 38.9 | 61.1 | 0.850 | 2.048 | 0.42 |
| Misr 1 | 100.6 | 144.3 | 43.7 | 19.0 | 94.4 | 538.5 | 38.1 | 52.4 | 0.834 | 1.934 | 0.43 |
| Giza 171 | 101.4 | 145.9 | 44.6 | 18.3 | 98.1 | 447.9 | 46.8 | 66.0 | 0.820 | 1.853 | 0.45 |
| Mean | 101.7 | 145.7 | 44.0 | 17.5 | 94.9 | 504.3 | 39.6 | 61.7 | 0.774 | 1.904 | 0.41 |
| $LSD_{0.05}$ | 1.06 | 1.14 | 1.22 | 0.86 | 2.83 | 38.07 | 1.06 | 1.83 | 0.03 | 0.08 | 0.02 |

**DH = number of days to heading, DM = days to maturity, GFP = grain filling period (days), GFR = grain filling rate (g day$^{-1}$ m$^{-2}$), PH = plant height (cm), SM = number of spikes m$^{-2}$, KS = number of kernels spike$^{-1}$, KW = 1000-kernel weight (g), GY = grain yield (kg m$^{-2}$), TY = total yield (kg m$^{-2}$) and HI = harvest index.**

The lowest 1000-kernel weight was obtained from line 5 (37.0 g), while the highest weight was obtained from Giza 171 (46.8 g). The number of kernels spike$^{-1}$ varied from 52.2 (line 13) to 75.0 kernels (line 7).

Moreover, the grain yield ranged from 0.679 kg $m^{-2}$ (line 4) to 0.966 kg $m^{-2}$ (line 1). The total biological yield varied from 1.746 kg $m^{-2}$ in line 2 to 2.269 kg $m^{-2}$ in line 1. In addition, the harvest index ranged from 0.38 in line 3, line 4 and line 10 to 0.46 in line 2.

**Effect of genotype x season interaction**

Sallam *et al* (2019) reported that selection for water stress tolerance should be done in more than one year in the target environments, because water stress tolerance usually has low heritability. The mean of the studied traits across the two water treatments in the two seasons are shown in Tables (5 and 6).

**Table 5. Means performance of number of days to heading and maturity, grain filling period and rate and plant height of studied genotypes in 2017/18 and 2018/19 seasons.**

| Name | DH | | DM | | GFP | | GFR | | PH | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 2017/18 | 2018/19 | 2017/18 | 2018/19 | 2017/18 | 2018/19 | 2017/18 | 2018/19 | 2017/18 | 2018/19 |
| Line 1 | 92.1 | 107.9 | 137.9 | 153.8 | 45.8 | 45.9 | 18.8 | 23.4 | 84.4 | 108.1 |
| Line 2 | 94.8 | 106.8 | 138.0 | 152.1 | 43.3 | 45.4 | 13.8 | 22.0 | 79.4 | 107.5 |
| Line 3 | 100.6 | 109.8 | 140.0 | 152.6 | 39.4 | 42.9 | 14.4 | 21.4 | 85.6 | 109.4 |
| Line 4 | 97.4 | 112.5 | 138.8 | 154.4 | 41.4 | 41.9 | 12.8 | 19.8 | 87.5 | 109.4 |
| Line 5 | 95.3 | 108.9 | 139.4 | 153.1 | 44.1 | 44.3 | 11.7 | 19.3 | 85.0 | 108.8 |
| Line 6 | 95.3 | 110.0 | 139.0 | 153.9 | 43.8 | 43.9 | 12.8 | 22.8 | 87.5 | 115.0 |
| Line 7 | 99.0 | 111.8 | 141.4 | 154.5 | 42.4 | 42.8 | 13.2 | 20.4 | 83.1 | 108.1 |
| Line 8 | 95.4 | 108.5 | 139.8 | 153.1 | 44.4 | 44.6 | 12.9 | 20.8 | 83.8 | 108.1 |
| Line 9 | 94.5 | 104.9 | 139.8 | 153.9 | 45.3 | 49.0 | 12.5 | 18.6 | 76.9 | 103.8 |
| Line 10 | 95.4 | 109.0 | 137.4 | 151.5 | 42.0 | 42.5 | 13.6 | 20.7 | 85.0 | 105.6 |
| Line 11 | 95.4 | 106.9 | 138.0 | 152.6 | 42.6 | 45.8 | 14.1 | 21.9 | 86.3 | 110.0 |
| Line 12 | 90.1 | 104.1 | 136.9 | 151.8 | 46.8 | 47.6 | 11.1 | 20.5 | 70.0 | 99.4 |
| Line 13 | 95.6 | 113.9 | 137.6 | 156.3 | 42.0 | 42.4 | 13.7 | 20.2 | 82.5 | 110.0 |
| Line 14 | 94.5 | 104.8 | 137.4 | 150.6 | 42.9 | 45.9 | 13.6 | 20.4 | 76.9 | 103.1 |
| Line 15 | 95.3 | 107.6 | 138.3 | 152.4 | 43.0 | 44.8 | 14.7 | 22.3 | 83.1 | 105.0 |
| Line 16 | 94.3 | 103.6 | 138.0 | 150.5 | 43.8 | 46.9 | 14.8 | 22.4 | 80.6 | 101.9 |
| Misr 1 | 93.9 | 107.4 | 136.4 | 152.3 | 42.5 | 44.9 | 15.1 | 22.8 | 83.8 | 105.0 |
| Giza 171 | 94.4 | 108.4 | 137.3 | 154.6 | 42.9 | 46.3 | 14.6 | 21.9 | 87.5 | 108.8 |
| Mean | 95.2 | 108.1 | 138.4 | 153.0 | 43.2 | 44.9 | 13.8 | 21.2 | 82.7 | 107.0 |
| $LSD_{0.05}$ | 1.51 | 1.51 | 1.67 | 1.59 | 1.64 | 1.84 | 1.08 | 1.34 | 3.27 | 4.66 |

**DH = number of days to heading, DM = number of days to maturity, GFP = grain filling period (days), GFR = grain filling rate (g $day^{-1}$ $m^{-2}$) and PH = plant height (cm).**

**Table 6. Means performance of grain yield and its components, total biological yield and harvest index traits of studied genotypes in 2017/18 and 2018/19 seasons.**

| Name | SM | | KW | | KS | | GY | | TY | | HI | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2017/18 | 2018/19 | 2017/18 | 2018/19 | 2017/18 | 2018/19 | 2017/18 | 2018/19 | 2017/18 | 2018/19 | 2017/18 | 2018/19 |
| Line 1 | 427.5 | 626.7 | 45.0 | 45.8 | 64.5 | 64.4 | 0.860 | 1.072 | 1.825 | 2.713 | 0.47 | 0.39 |
| Line 2 | 374.2 | 558.3 | 39.8 | 40.2 | 63.1 | 67.5 | 0.599 | 1.000 | 1.282 | 2.209 | 0.47 | 0.45 |
| Line 3 | 504.2 | 556.7 | 38.5 | 39.6 | 63.6 | 63.4 | 0.567 | 0.917 | 1.469 | 2.453 | 0.39 | 0.37 |
| Line 4 | 421.7 | 511.3 | 39.0 | 39.2 | 51.0 | 57.8 | 0.531 | 0.827 | 1.402 | 2.183 | 0.38 | 0.38 |
| Line 5 | 364.2 | 572.5 | 36.8 | 37.2 | 55.9 | 74.8 | 0.516 | 0.853 | 1.173 | 2.489 | 0.44 | 0.34 |
| Line 6 | 337.5 | 491.7 | 40.6 | 42.4 | 56.8 | 72.2 | 0.561 | 1.001 | 1.229 | 2.494 | 0.46 | 0.40 |
| Line 7 | 528.3 | 572.9 | 38.0 | 38.4 | 62.3 | 87.7 | 0.563 | 0.874 | 1.365 | 2.313 | 0.41 | 0.38 |
| Line 8 | 392.9 | 486.7 | 38.9 | 39.6 | 55.6 | 70.6 | 0.573 | 0.931 | 1.342 | 2.326 | 0.43 | 0.40 |
| Line 9 | 421.7 | 555.4 | 37.0 | 37.7 | 53.3 | 63.4 | 0.564 | 0.910 | 1.413 | 2.319 | 0.40 | 0.39 |
| Line 10 | 473.3 | 572.5 | 40.5 | 41.1 | 56.0 | 70.9 | 0.572 | 0.881 | 1.446 | 2.458 | 0.40 | 0.36 |
| Line 11 | 453.8 | 625.4 | 38.1 | 38.5 | 61.5 | 73.8 | 0.600 | 1.002 | 1.378 | 2.556 | 0.44 | 0.39 |
| Line 12 | 482.5 | 618.8 | 37.5 | 39.1 | 49.4 | 55.8 | 0.520 | 0.976 | 1.276 | 2.485 | 0.41 | 0.39 |
| Line 13 | 551.7 | 614.6 | 38.4 | 38.7 | 46.1 | 58.3 | 0.573 | 0.854 | 1.426 | 2.174 | 0.40 | 0.39 |
| Line 14 | 481.7 | 546.7 | 37.6 | 38.0 | 58.3 | 67.2 | 0.584 | 0.937 | 1.466 | 2.381 | 0.40 | 0.39 |
| Line 15 | 432.5 | 570.4 | 37.5 | 38.9 | 49.3 | 69.1 | 0.629 | 1.000 | 1.465 | 2.365 | 0.43 | 0.42 |
| Line 16 | 455.8 | 596.7 | 38.7 | 39.0 | 55.6 | 66.7 | 0.649 | 1.050 | 1.496 | 2.600 | 0.43 | 0.40 |
| Misr 1 | 510.0 | 567.1 | 37.9 | 38.3 | 50.8 | 54.0 | 0.643 | 1.025 | 1.496 | 2.373 | 0.43 | 0.43 |
| Giza 171 | 412.9 | 482.9 | 46.7 | 46.9 | 53.8 | 78.2 | 0.627 | 1.014 | 1.363 | 2.344 | 0.46 | 0.43 |
| Mean | 445.9 | 562.6 | 39.3 | 39.9 | 55.9 | 67.5 | 0.6 | 1.0 | 1.406 | 2.402 | 0.42 | 0.40 |
| $LSD_{0.05}$ | 48.80 | 59.04 | 1.55 | 1.46 | 2.29 | 2.88 | 0.04 | 0.05 | 0.10 | 0.11 | 0.03 | 0.03 |

**PH = plant height (cm), SM = number of spikes $m^{-2}$, KS = number of kernels $spike^{-1}$, KW = 1000-kernel weight (g), GY = grain yield (kg $m^{-2}$), TY = total yield (kg $m^{-2}$) and HI = harvest index.**

The average values for all traits were significantly higher in 2018/19 season compared to 2017/18 season (Tables 2, 3 and 5), except for HI, confirming the seasonal changes effects. The high values of the studied traits may be due to the lower temperature and higher relative humidity in the second season compared to the first one.

Similar results were obtained by Darwish *et al* (2017), Farhat *et al* (2019) and Abd El-Hamid *et al* (2020). They reported that the high temperature during grain filling period may cause a reduction in grain growth and a shorter period for normal grain growth.

Number of days to heading ranged from 80.1 days (line 12) and 98.6 days (line 16) to 90.6 days (line 3) and 108.9 days (line 13) in the first and second season, respectively. The lowest number of days to maturity was 136.4 days (Misr 1) and 150.5 days (line 16), while the highest values were 141.4 days (line 7) and 156.3 days (line 13 in the first and second season, respectively. The grain filling period ranged from 39.4 days in line 3 and 41.9 days in line 4 to 46.8 in line 12 and 49.0 days in line 9 in the first and second season, respectively. Furthermore, the lowest values of grain filling rate were recorded by line 12 (11.1 g $m^{-2}$ $day^{-1}$) and line 9 (18.6 g $m^{-2}$ $day^{-1}$), while the highest values were recorded by line 1 (18.8 and 23.4 g $m^{-2}$ $day^{-1}$) in the first and second season, respectively. The plant height was in the range from 70.0 and 99.4 cm in line 12 to 87.5 in line 4, line 6 and Giza 171 and 115.0 cm in line 6 in the first and second season, respectively. Besides, the number of spikes $m^{-2}$ ranged from 337.5 spikes in line 6 and 482.9 spikes in Giza 171 to 551.7 spikes in line 13 and 626.7 spikes in line 1 in the first and second season, respectively. In addition, the lowest and highest values of 1000-kernel weight were 36.8 and 37.2 g in line 5 and 46.7 and 46.9 g in Giza 171 in the first and second season, respectively. The number of kernels $spike^{-1}$ varied from 46.1 kernels in line 13 and 54.0 kernels in Misr 1 to 64.5 kernels in line 1 and 87.7 kernels in line 7 in the first and second season, respectively. The lowest grain yield was shown by to line 5 (0.516 kg $m^{-2}$) and line 4 (0.827 kg $m^{-2}$), while the highest values were obtained by line 1 (0.860 and 1.072 kg $m^{-2}$) in the first and second season, respectively. The total biological yield had values ranging from 1.173 kg $m^{-2}$ (line 5) and 2.1774 kg $m^{-2}$ (line 13) to 1.860 and 2.713 kg $m^{-2}$ (line 1) in the first and second seasons, respectively. Additionally, the harvest index ranged from 0.38 (line 3) and 0.34 (line 5) to 0.47 (line 1 and line 2) and 0.45 (line 2) in the first and second seasons, respectively.

**Effect of water genotype x treatment interaction**

Means of the studied traits across the two seasons for the two water treatments are presented in Table (7 and 8). The means of all studied traits decreased under water stress. Number of days to heading ranged from 92.4 and 86.9 days for line 12 to 100.5 days in line 4 and 96.4 days in line 7 under normal and water stress, respectively.

**Table 7. Means performance of the studied genotypes for number of days to heading and maturity, grain filling period and rate and plant height under normal (N) and water stress (S) conditions.**

| Name | DH | | DM | | GFP | | GFR | | PH | |
|---|---|---|---|---|---|---|---|---|---|---|
| | N | S | N | S | N | S | N | S | N | S |
| Line 1 | 102.0 | 98.0 | 148.8 | 142.9 | 46.8 | 44.9 | 22.7 | 19.4 | 101.3 | 91.3 |
| Line 2 | 102.8 | 98.8 | 147.8 | 142.4 | 45.0 | 43.6 | 19.9 | 15.9 | 96.9 | 90.0 |
| Line 3 | 106.9 | 103.5 | 149.3 | 143.4 | 42.4 | 39.9 | 18.6 | 17.3 | 101.3 | 93.8 |
| Line 4 | 108.0 | 101.9 | 149.9 | 143.3 | 41.9 | 41.4 | 19.9 | 12.7 | 102.5 | 94.4 |
| Line 5 | 103.9 | 100.3 | 149.0 | 143.5 | 45.1 | 43.3 | 16.2 | 14.9 | 100.6 | 93.1 |
| Line 6 | 105.6 | 99.6 | 149.8 | 143.1 | 44.1 | 43.5 | 20.0 | 15.6 | 105.6 | 96.9 |
| Line 7 | 106.9 | 103.9 | 150.6 | 145.3 | 43.8 | 41.4 | 19.5 | 14.2 | 100.0 | 91.3 |
| Line 8 | 104.3 | 99.6 | 149.5 | 143.4 | 45.3 | 43.8 | 19.7 | 14.1 | 100.0 | 91.9 |
| Line 9 | 101.8 | 97.6 | 149.4 | 144.3 | 47.6 | 46.6 | 16.4 | 14.7 | 95.0 | 85.6 |
| Line 10 | 104.6 | 99.8 | 147.3 | 141.6 | 42.6 | 41.9 | 19.5 | 14.8 | 97.5 | 93.1 |
| Line 11 | 102.6 | 99.6 | 148.1 | 142.5 | 45.5 | 42.9 | 19.3 | 16.6 | 101.3 | 95.0 |
| Line 12 | 99.9 | 94.4 | 147.5 | 141.1 | 47.6 | 46.8 | 17.1 | 14.5 | 87.5 | 81.9 |
| Line 13 | 107.6 | 101.9 | 150.0 | 143.9 | 42.4 | 42.0 | 18.8 | 15.0 | 101.3 | 91.3 |
| Line 14 | 102.4 | 96.9 | 148.6 | 139.4 | 46.3 | 42.5 | 19.4 | 14.6 | 93.1 | 86.9 |
| Line 15 | 104.0 | 98.9 | 148.9 | 141.8 | 44.9 | 42.9 | 20.0 | 16.9 | 97.5 | 90.6 |
| Line 16 | 100.8 | 97.1 | 148.3 | 140.3 | 47.5 | 43.1 | 19.7 | 17.5 | 95.0 | 87.5 |
| Misr 1 | 102.6 | 98.6 | 146.9 | 141.8 | 44.3 | 43.1 | 20.3 | 17.6 | 98.1 | 90.6 |
| Giza 171 | 103.0 | 99.8 | 148.1 | 143.8 | 45.1 | 44.0 | 19.9 | 16.6 | 100.6 | 95.6 |
| Mean | 103.9 | 99.4 | 148.8 | 142.6 | 44.9 | 43.2 | 19.3 | 15.7 | 98.6 | 91.1 |
| $LSD_{0.05}$ | 1.35 | 1.65 | 1.56 | 1.69 | 1.59 | 1.89 | 1.21 | 1.23 | 4.16 | 3.89 |

**DH = number of days to heading, DM = number of days to maturity, GFP = grain filling period (days), GFR = grain filling rate (g day$^{-1}$ m$^{-2}$) and PH = plant height (cm).**

**Table 8. The mean performance of the studied genotypes for grain yield and its components, total yield and harvest index under normal (N) and water stress (S) conditions.**

| Name | SM | | KW | | KS | | GY | | TY | | HI | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | N | S | N | S | N | S | N | S | N | S | N | S |
| Line 1 | 585.8 | 468.3 | 45.8 | 44.9 | 67.8 | 61.0 | 1.059 | 0.873 | 2.469 | 2.069 | 0.44 | 0.43 |
| Line 2 | 515.0 | 417.5 | 42.6 | 37.4 | 67.9 | 62.7 | 0.901 | 0.698 | 1.938 | 1.554 | 0.47 | 0.45 |
| Line 3 | 539.2 | 521.7 | 40.0 | 38.1 | 64.1 | 62.9 | 0.789 | 0.695 | 2.056 | 1.866 | 0.39 | 0.37 |
| Line 4 | 509.6 | 423.3 | 40.1 | 38.1 | 55.4 | 53.5 | 0.831 | 0.526 | 2.146 | 1.440 | 0.39 | 0.37 |
| Line 5 | 510.8 | 425.8 | 37.7 | 36.4 | 67.5 | 63.2 | 0.729 | 0.640 | 1.925 | 1.736 | 0.40 | 0.39 |
| Line 6 | 447.1 | 382.1 | 43.5 | 39.5 | 66.8 | 62.2 | 0.882 | 0.679 | 2.079 | 1.644 | 0.44 | 0.42 |
| Line 7 | 579.6 | 521.7 | 38.9 | 37.5 | 79.1 | 70.9 | 0.848 | 0.589 | 2.130 | 1.547 | 0.41 | 0.38 |
| Line 8 | 496.7 | 382.9 | 40.9 | 37.6 | 64.1 | 62.1 | 0.888 | 0.616 | 2.133 | 1.534 | 0.42 | 0.40 |
| Line 9 | 502.1 | 475.0 | 37.8 | 36.9 | 58.8 | 57.9 | 0.786 | 0.688 | 1.959 | 1.772 | 0.40 | 0.39 |
| Line 10 | 593.3 | 452.5 | 41.4 | 40.2 | 66.1 | 60.8 | 0.834 | 0.619 | 2.206 | 1.698 | 0.39 | 0.37 |
| Line 11 | 579.2 | 500.0 | 39.4 | 37.3 | 70.7 | 64.6 | 0.888 | 0.714 | 2.122 | 1.813 | 0.43 | 0.40 |
| Line 12 | 586.7 | 514.6 | 38.8 | 37.8 | 54.2 | 51.0 | 0.819 | 0.677 | 2.021 | 1.741 | 0.41 | 0.39 |
| Line 13 | 618.8 | 547.5 | 40.0 | 37.1 | 53.1 | 51.3 | 0.798 | 0.629 | 1.977 | 1.623 | 0.41 | 0.39 |
| Line 14 | 552.9 | 475.4 | 38.4 | 37.3 | 63.7 | 61.7 | 0.897 | 0.623 | 2.215 | 1.632 | 0.41 | 0.38 |
| Line 15 | 564.6 | 438.3 | 39.2 | 37.2 | 61.2 | 57.2 | 0.903 | 0.726 | 2.104 | 1.725 | 0.43 | 0.42 |
| Line 16 | 556.7 | 495.8 | 39.6 | 38.1 | 61.9 | 60.3 | 0.937 | 0.762 | 2.242 | 1.854 | 0.42 | 0.42 |
| Misr 1 | 608.3 | 468.8 | 38.2 | 37.9 | 53.9 | 50.8 | 0.903 | 0.765 | 2.048 | 1.821 | 0.44 | 0.42 |
| Giza 171 | 475.8 | 420.0 | 47.7 | 45.9 | 69.4 | 62.6 | 0.905 | 0.735 | 2.029 | 1.677 | 0.45 | 0.44 |
| Mean | 545.7 | 462.8 | 40.6 | 38.6 | 63.7 | 59.8 | 0.867 | 0.681 | 2.100 | 1.708 | 0.42 | 0.40 |
| $LSD_{0.05}$ | 53.91 | 54.42 | 1.51 | 1.51 | 2.88 | 2.30 | 0.05 | 0.05 | 0.10 | 0.12 | 0.03 | 0.03 |

**PH = plant height (cm), SM = number of spikes $m^{-2}$, KS = number of kernels $spike^{-1}$, KW = 1000-kernel weight (g), GY = grain yield (kg $m^{-2}$), TY = total yield (kg $m^{-2}$) and HI = harvest index.**

Also, number of days to maturity ranged from 139.4 days in Misr 1 and 131.9 days in line 14 to 143.1 and 137.8 days in line 7 under normal and water stress, respectively. In addition, the grain filling period ranged from 41.4 days in line 4 and 39.9 days in line 3 to 47.6 (line 9 and line 12) and 46.8 days (line 12) under normal and water stress, respectively. Besides, the lowest values of grain filling rate were exhibited by line 5 (16.2 g $m^{-2}$ $day^{-1}$) and line 4 (12.7 g $m^{-2}$ $day^{-1}$) and the highest values were shown by line 1 (22.7 and 19.4 g $m^{-2}$ $day^{-1}$) under normal and water stress, respectively. The values of plant height varied from 87.5 and 81.9 cm in line 12 to 105.6 and 96.9 cm in line 6 under normal and water stress, respectively. Besides, the number of spikes $m^{-2}$ was in the range from 447.1 and 382.1 spikes in line 5 to 618.8 and 547.5 spikes in line 13 under normal and water stress, respectively. The lowest kernel weight was observed by line 5 (37.7 and 36.4 g), while the highest value was observed by Giza 171 (47.7 g and 45.9 g) under normal and water stress, respectively. Number of kernels $spike^{-1}$ varied from 53.1 kernels in line 13 and 50.8 kernels in Misr 1 to 79.1 and 70.9 kernels in line 7 under normal and water stress, respectively. The lowest values of grain yield were obtained by line 5 (0.729 kg $m^{-2}$) and line 4 (0.526 kg $m^{-2}$), while the highest values were obtained by line 1 (1.059 and 0.873 kg $m^{-}$2) under normal and water stress, respectively.

Mean of total biological yield ranged from 1.925 kg $m^{-2}$ in line 5 and 1.440 kg $m^{-2}$ in line 4 to 2.469 and 2.069 kg $m^{-2}$ in line 1 under normal and water stress, respectively. The harvest index ranged from 0.39 and 0.37 in line 3, line 4 and line 10 to 0.47 in line 2 and 0.45 in line 2 under normal and water stress, respectively. In general, the genotypes that perform well under normal irrigation retain high yield under water stress. These results confirm that reported by Mwadzingeni *et al* (2016). The reduction in number of days to heading and maturity, grain yield and yield components under water stress was also reported in many earlier studies (Farhat, 2015, Hamza *et al* 2018, Seleiman and Abdel-Aal 2018 and Abd El-Kreem *et al* 2019 and Abd El-Hamid *et al* 2019 and 2020).

**Effect of genotype x water treatment x season interaction**

The means of the studied traits in the two water treatments and two seasons are presented in Tables (9, 10 and 11).

**Table 9. Means performance of the studied genotypes for number of days to heading and maturity and grain filling period and rate in the two seasons under the two irrigation regimes.**

| Name | Number of days to heading | | | | Number of days to maturity | | | | Grain filling period (day) | | | | Grain filling rate (g $day^{-1}$ $m^{-2}$) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2017/18 | | 2018/19 | | 2017/18 | | 2018/19 | | 2017/18 | | 2018/19 | | 2017/18 | | 2018/19 | |
| | N | S | N | S | N | S | N | S | N | S | N | S | N | S | N | S |
| Line 1 | 94.5 | 89.8 | 109.5 | 106.3 | 142.0 | 133.8 | 155.5 | 152.0 | 47.5 | 44.0 | 46.0 | 45.8 | 19.4 | 18.3 | 84.5 | 79.8 |
| Line 2 | 96.3 | 93.3 | 109.3 | 104.3 | 140.5 | 135.5 | 155.0 | 149.3 | 44.3 | 42.3 | 45.8 | 45.0 | 14.9 | 12.7 | 86.3 | 83.3 |
| Line 3 | 102.0 | 99.3 | 111.8 | 107.8 | 143.5 | 136.5 | 155.0 | 150.3 | 41.5 | 37.3 | 43.3 | 42.5 | 14.7 | 14.2 | 92.0 | 89.3 |
| Line 4 | 101.0 | 93.8 | 115.0 | 110.0 | 142.8 | 134.8 | 157.0 | 151.8 | 41.8 | 41.0 | 42.0 | 41.8 | 13.9 | 11.8 | 91.0 | 83.8 |
| Line 5 | 98.0 | 92.5 | 109.8 | 108.0 | 142.8 | 136.0 | 155.3 | 151.0 | 44.8 | 43.5 | 45.5 | 43.0 | 12.2 | 11.2 | 88.0 | 82.5 |
| Line 6 | 99.0 | 91.5 | 112.3 | 107.8 | 143.3 | 134.8 | 156.3 | 151.5 | 44.3 | 43.3 | 44.0 | 43.8 | 13.8 | 11.8 | 89.0 | 81.5 |
| Line 7 | 100.8 | 97.3 | 113.0 | 110.5 | 145.0 | 137.8 | 156.3 | 152.8 | 44.3 | 40.5 | 43.3 | 42.3 | 14.2 | 12.3 | 90.8 | 87.3 |
| Line 8 | 97.5 | 93.3 | 111.0 | 106.0 | 143.3 | 136.3 | 155.8 | 150.5 | 45.8 | 43.0 | 44.8 | 44.5 | 14.1 | 11.7 | 87.5 | 83.3 |
| Line 9 | 96.5 | 92.5 | 107.0 | 102.8 | 142.3 | 137.3 | 156.5 | 151.3 | 45.8 | 44.8 | 49.5 | 48.5 | 13.1 | 11.8 | 86.5 | 82.5 |
| Line 10 | 98.5 | 92.3 | 110.8 | 107.3 | 140.8 | 134.0 | 153.8 | 149.3 | 42.3 | 41.8 | 43.0 | 42.0 | 14.6 | 12.6 | 88.5 | 82.3 |
| Line 11 | 97.8 | 93.0 | 107.5 | 106.3 | 141.5 | 134.5 | 154.8 | 150.5 | 43.8 | 41.5 | 47.3 | 44.3 | 14.6 | 13.5 | 87.8 | 83.0 |
| Line 12 | 93.5 | 86.8 | 106.3 | 102.0 | 140.5 | 133.3 | 154.5 | 149.0 | 47.0 | 46.5 | 48.3 | 47.0 | 11.4 | 10.8 | 83.5 | 76.8 |
| Line 13 | 99.0 | 92.3 | 116.3 | 111.5 | 141.3 | 134.0 | 158.8 | 153.8 | 42.3 | 41.8 | 42.5 | 42.3 | 14.7 | 12.7 | 89.0 | 82.3 |
| Line 14 | 97.5 | 91.5 | 107.3 | 102.3 | 143.5 | 131.3 | 153.8 | 147.5 | 46.0 | 39.8 | 46.5 | 45.3 | 14.3 | 12.8 | 87.5 | 81.5 |
| Line 15 | 99.0 | 91.5 | 109.0 | 106.3 | 142.5 | 134.0 | 155.3 | 149.5 | 43.5 | 42.5 | 46.3 | 43.3 | 15.4 | 13.9 | 89.0 | 81.5 |
| Line 16 | 96.0 | 92.5 | 105.5 | 101.8 | 143.0 | 133.0 | 153.5 | 147.5 | 47.0 | 40.5 | 48.0 | 45.8 | 15.0 | 14.7 | 86.0 | 82.5 |
| Misr 1 | 96.3 | 91.5 | 109.0 | 105.8 | 139.5 | 133.3 | 154.3 | 150.3 | 43.3 | 41.8 | 45.3 | 44.5 | 15.5 | 14.8 | 86.3 | 81.5 |
| Giza 171 | 96.3 | 92.5 | 109.8 | 107.0 | 139.8 | 134.8 | 156.5 | 152.8 | 43.5 | 42.3 | 46.8 | 45.8 | 15.3 | 13.9 | 86.3 | 82.5 |
| Mean | 97.7 | 92.6 | 110.0 | 106.3 | 142.1 | 134.7 | 155.4 | 150.6 | 44.3 | 42.1 | 45.4 | 44.3 | 14.5 | 13.1 | 87.7 | 82.6 |
| $LSD_{0.05}$ | 1.9 | 2.4 | 1.9 | 2.4 | 2.2 | 2.6 | 2.3 | 2.3 | 2.3 | 2.4 | 2.3 | 3.0 | 1.6 | 1.5 | 1.9 | 2.4 |

**Table 10. Means performance of the studied genotypes for plant height, number of spikes m$^{-2}$, 1000-kernel weight and number of kernels spike$^{-1}$ as affected by season and water stress.**

| Name | Plant height (cm) | | | | Number of spikes m$^{-2}$ | | | | 1000-kernel weight | | | | Number of kernels spike$^{-1}$ | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2017/18 | | 2018/19 | | 2017/18 | | 2018/19 | | 2017/18 | | 2018/19 | | 2017/18 | | 2018/19 | |
| | N | S | N | S | N | S | N | S | N | S | N | S | N | S | N | S |
| Line 1 | 87.5 | 81.3 | 115.0 | 101.3 | 463.3 | 391.7 | 708.3 | 545.0 | 45.2 | 44.8 | 46.5 | 45.0 | 67.7 | 61.3 | 68.0 | 60.8 |
| Line 2 | 81.3 | 77.5 | 112.5 | 102.5 | 381.7 | 366.7 | 648.3 | 468.3 | 42.5 | 37.1 | 42.7 | 37.8 | 67.5 | 58.8 | 68.3 | 66.6 |
| Line 3 | 87.5 | 83.8 | 115.0 | 103.8 | 508.3 | 500.0 | 570.0 | 543.3 | 39.5 | 37.4 | 40.5 | 38.7 | 64.3 | 63.0 | 64.0 | 62.8 |
| Line 4 | 88.8 | 86.3 | 116.3 | 102.5 | 440.0 | 403.3 | 579.2 | 443.3 | 40.0 | 38.0 | 40.3 | 38.2 | 51.5 | 50.5 | 59.2 | 56.4 |
| Line 5 | 86.3 | 83.8 | 115.0 | 102.5 | 376.7 | 351.7 | 645.0 | 500.0 | 37.6 | 36.1 | 37.8 | 36.6 | 57.6 | 54.3 | 77.5 | 72.2 |
| Line 6 | 90.0 | 85.0 | 121.3 | 108.8 | 360.0 | 315.0 | 534.2 | 449.2 | 41.8 | 39.4 | 45.2 | 39.6 | 60.5 | 53.0 | 73.2 | 71.3 |
| Line 7 | 85.0 | 81.3 | 115.0 | 101.3 | 538.3 | 518.3 | 620.8 | 525.0 | 38.8 | 37.1 | 39.0 | 37.8 | 64.6 | 60.0 | 93.7 | 81.8 |
| Line 8 | 85.0 | 82.5 | 115.0 | 101.3 | 409.2 | 376.7 | 584.2 | 389.2 | 40.4 | 37.4 | 41.5 | 37.8 | 57.5 | 53.8 | 70.8 | 70.5 |
| Line 9 | 80.0 | 73.8 | 110.0 | 97.5 | 428.3 | 415.0 | 575.8 | 535.0 | 37.4 | 36.6 | 38.1 | 37.2 | 53.9 | 52.8 | 63.7 | 63.1 |
| Line 10 | 86.3 | 83.8 | 108.8 | 102.5 | 516.7 | 430.0 | 670.0 | 475.0 | 41.1 | 40.0 | 41.8 | 40.4 | 60.5 | 51.5 | 71.7 | 70.2 |
| Line 11 | 88.8 | 83.8 | 113.8 | 106.3 | 482.5 | 425.0 | 675.8 | 575.0 | 39.2 | 37.1 | 39.5 | 37.5 | 67.0 | 56.0 | 74.4 | 73.2 |
| Line 12 | 71.3 | 68.8 | 103.8 | 95.0 | 513.3 | 451.7 | 660.0 | 577.5 | 38.1 | 37.0 | 39.5 | 38.7 | 51.5 | 47.3 | 56.8 | 54.8 |
| Line 13 | 83.8 | 81.3 | 118.8 | 101.3 | 558.3 | 545.0 | 679.2 | 550.0 | 39.8 | 37.0 | 40.3 | 37.2 | 47.3 | 45.0 | 59.0 | 57.6 |
| Line 14 | 78.8 | 75.0 | 107.5 | 98.8 | 496.7 | 466.7 | 609.2 | 484.2 | 38.1 | 37.1 | 38.6 | 37.4 | 59.3 | 57.3 | 68.2 | 66.1 |
| Line 15 | 85.0 | 81.3 | 110.0 | 100.0 | 453.3 | 411.7 | 675.8 | 465.0 | 38.6 | 36.4 | 39.7 | 38.0 | 52.9 | 45.8 | 69.5 | 68.7 |
| Line 16 | 81.3 | 80.0 | 108.8 | 95.0 | 478.3 | 433.3 | 635.0 | 558.3 | 39.5 | 38.0 | 39.8 | 38.3 | 57.0 | 54.3 | 66.9 | 66.4 |
| Misr 1 | 85.0 | 82.5 | 111.3 | 98.8 | 560.0 | 460.0 | 656.7 | 477.5 | 38.0 | 37.9 | 38.5 | 38.0 | 53.8 | 47.8 | 54.1 | 53.8 |
| Giza 171 | 88.8 | 86.3 | 112.5 | 105.0 | 433.3 | 392.5 | 518.3 | 447.5 | 47.6 | 45.8 | 47.8 | 45.9 | 57.2 | 50.5 | 81.7 | 74.8 |
| Mean | 84.4 | 81.0 | 112.8 | 101.3 | 466.6 | 425.2 | 624.8 | 500.5 | 40.2 | 38.4 | 40.9 | 38.9 | 58.4 | 53.5 | 68.9 | 66.2 |
| $LSD_{0.05}$ | 5.2 | 4.1 | 6.6 | 6.7 | 63.3 | 75.9 | 88.9 | 79.9 | 2.0 | 2.4 | 2.3 | 1.9 | 3.9 | 2.5 | 4.3 | 3.9 |

**Table 11. The mean performance of grain yield, total yield and harvest index as affected by season x water stress x genotype interaction.**

| Name | Grain yield (kg m$^{-2}$) | | | | Total yield (kg m$^{-2}$) | | | | Harvest index | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2017/18 | | 2018/19 | | 2017/18 | | 2018/19 | | 2017/18 | | 2018/19 | |
| | N | S | N | S | N | S | N | S | N | S | N | S |
| Line 1 | 0.918 | 0.803 | 1.201 | 0.943 | 1.938 | 1.713 | 3.000 | 2.425 | 0.48 | 0.47 | 0.40 | 0.39 |
| Line 2 | 0.658 | 0.539 | 1.143 | 0.857 | 1.371 | 1.194 | 2.504 | 1.915 | 0.48 | 0.46 | 0.46 | 0.45 |
| Line 3 | 0.607 | 0.527 | 0.971 | 0.863 | 1.531 | 1.406 | 2.581 | 2.325 | 0.40 | 0.38 | 0.38 | 0.37 |
| Line 4 | 0.580 | 0.481 | 1.082 | 0.571 | 1.488 | 1.317 | 2.804 | 1.563 | 0.39 | 0.37 | 0.39 | 0.37 |
| Line 5 | 0.547 | 0.486 | 0.911 | 0.795 | 1.223 | 1.123 | 2.627 | 2.350 | 0.45 | 0.43 | 0.35 | 0.34 |
| Line 6 | 0.611 | 0.511 | 1.154 | 0.847 | 1.306 | 1.152 | 2.852 | 2.135 | 0.47 | 0.44 | 0.40 | 0.40 |
| Line 7 | 0.626 | 0.499 | 1.070 | 0.679 | 1.452 | 1.277 | 2.808 | 1.818 | 0.43 | 0.39 | 0.38 | 0.37 |
| Line 8 | 0.644 | 0.502 | 1.131 | 0.730 | 1.467 | 1.217 | 2.800 | 1.852 | 0.44 | 0.41 | 0.40 | 0.39 |
| Line 9 | 0.601 | 0.527 | 0.971 | 0.850 | 1.469 | 1.356 | 2.450 | 2.188 | 0.41 | 0.39 | 0.40 | 0.39 |
| Line 10 | 0.618 | 0.527 | 1.051 | 0.711 | 1.508 | 1.383 | 2.903 | 2.013 | 0.41 | 0.38 | 0.36 | 0.35 |
| Line 11 | 0.639 | 0.562 | 1.136 | 0.867 | 1.406 | 1.350 | 2.838 | 2.275 | 0.45 | 0.42 | 0.40 | 0.38 |
| Line 12 | 0.538 | 0.502 | 1.101 | 0.851 | 1.285 | 1.267 | 2.756 | 2.215 | 0.42 | 0.40 | 0.40 | 0.39 |
| Line 13 | 0.619 | 0.528 | 0.977 | 0.730 | 1.479 | 1.373 | 2.475 | 1.873 | 0.42 | 0.39 | 0.40 | 0.39 |
| Line 14 | 0.657 | 0.510 | 1.138 | 0.736 | 1.567 | 1.365 | 2.863 | 1.900 | 0.42 | 0.38 | 0.40 | 0.39 |
| Line 15 | 0.671 | 0.588 | 1.135 | 0.865 | 1.542 | 1.388 | 2.667 | 2.063 | 0.44 | 0.43 | 0.43 | 0.42 |
| Line 16 | 0.704 | 0.595 | 1.170 | 0.930 | 1.608 | 1.383 | 2.875 | 2.325 | 0.44 | 0.43 | 0.41 | 0.40 |
| Misr 1 | 0.669 | 0.617 | 1.138 | 0.913 | 1.500 | 1.492 | 2.596 | 2.150 | 0.45 | 0.42 | 0.44 | 0.43 |
| Giza 171 | 0.666 | 0.588 | 1.145 | 0.882 | 1.433 | 1.292 | 2.625 | 2.063 | 0.47 | 0.46 | 0.44 | 0.43 |
| Mean | 0.643 | 0.549 | 1.090 | 0.812 | 1.476 | 1.336 | 2.724 | 2.080 | 0.44 | 0.41 | 0.40 | 0.39 |
| $LSD_{0.05}$ | 0.058 | 0.054 | 0.073 | 0.082 | 0.14 | 0.16 | 0.14 | 0.17 | 0.05 | 0.05 | 0.04 | 0.04 |

The earliest genotype for heading was line 12 and line 16, while line 3 and line 13 were the latest ones under the two water treatments in the first and second seasons, respectively. In the same time, Misr 1, line 14 and line

16 were the earliest genotypes in maturity, while line 7 and line 13 were the latest ones under most conditions. Furthermore, line 3 and line 4 had the lowest values of GFP, while line 5, line 12 and line 9 had the highest value under most conditions. Moreover, line 5, line 12, line 9 and line 4 had the lowest value of grain filling rate under most conditions, while line 1 had the highest value under most conditions. For plant height, line 12 was the shortest genotype under all conditions, while Misr 1, line 13, line 1 and line 12 were the tallest genotypes under most conditions. Besides, line 6, Giza 171 and line 8 showed the lowest values of SM, while Misr 1, line 13, line 1 and line 12 had the highest values under most conditions. Additionally, line 5 and line 9 had the lowest weight of kernels under most conditions. By contrast, Giza 171 had the highest weight under all conditions. Moreover, line 13 in the first season and Misr 1 in the second season gave the lowest values of KS, while Lin1, line 3 and line 7 had the highest values under most conditions. In the same time, line 12, line 4 and line 5 had the least grain yield under most conditions, while line 1 was the highest yielding one under all conditions. The lowest values of total biological yield were observed by line 2, line 5 and line 4, while line 1, Misr 1 and line 5 had the highest values under most conditions. In addition, line 3, line 4, line 9 and line 5 gave the least harvest index estimates, while the highest estimates were shown by line 2, line 1 and Misr 1 under most conditions.

**Water stress susceptibility index**

Table (12) shows the water stress susceptibility index (SSI) which was calculted using grain yield in the two seasons. line 3 followed by line 5, line 9, Misr 1, line 12, line 1, line 16, Giza 171, line 11 and line 15 had SSI values lower than unity for the mean of the two seasons, indicating that these genotypes were the most tolerant ones for water stress. On the other hand, above unity SSI was shown by line 4, line 14, line 8, line 7, line 10, line 6 and line 2 as an average of the two seasons, indicating that these genotypes were the most susceptible ones for water stress. Moreover, line 13 had an average value of SSI across the two seasons equal to unity. However, in breeding context, tolerance and susceptibility indices alone are not sufficient, genotypes with high yield performance must be taken into consideration (Thiry *et al* 2016). Therefore, Farhat (2015) was concerned with the superiority of grain yield under the studied stress conditions in addition to the stress susceptibility index. As in Tables (8, 11 and 12), line 1, line 16, line 15 and line 11 in addition to Misr 1 and Giza 171 cultivars combine between high grain yield and water stress tolerance, so could be considered suitable for reduced irrigation conditions.

**Table 12. Estimates of water stress susceptibility index based on grain yield for the studied genotypes in the two seasons.**

| Genotype | 2017/2018 | 2018/2019 | Mean |
|---|---|---|---|
| Line 1 | 0.86 | 0.84 | 0.82 |
| Line 2 | 1.25 | 0.98 | 1.05 |
| Line 3 | 0.91 | 0.44 | 0.56 |
| Line 4 | 1.17 | 1.85 | 1.71 |
| Line 5 | 0.77 | 0.50 | 0.57 |
| Line 6 | 1.12 | 1.04 | 1.07 |
| Line 7 | 1.40 | 1.43 | 1.42 |
| Line 8 | 1.52 | 1.39 | 1.43 |
| Line 9 | 0.85 | 0.49 | 0.58 |
| Line 10 | 1.01 | 1.27 | 1.20 |
| Line 11 | 0.83 | 0.93 | 0.91 |
| Line 12 | 0.45 | 0.89 | 0.81 |
| Line 13 | 1.01 | 0.99 | 0.99 |
| Line 14 | 1.55 | 1.38 | 1.43 |
| Line 15 | 0.86 | 0.94 | 0.91 |
| Line 16 | 1.07 | 0.80 | 0.87 |
| Misr 1 | 0.54 | 0.78 | 0.72 |
| Giza 171 | 0.80 | 0.90 | 0.88 |

**Reduction percentage and correlation coeffeicient**

The means and ranges of reduction % due to water stress for the studied traits are presented in Table (13). The means of reduction were in the positive direction for all studied charcters. The least affected trait by the water stress was plant height in the first season (4.11%) and harvest index in the second season (2.49%). On the ther hand, the most affected trait was grain yield (14.52 and 25.51%) in the first and second season, respectively. The reduction% ranged from 0.24% for 1000-kernel weight and 0.39% for number of kernels spike$^{-1}$ to 22.44 and 47.26% for grain yield in the first and second season, respectively.

**Table 13. Means and ranges of reduction% due to water stress for the studied traits and Spearman correlation coefficient among means of susceptibility index and means of genotypes for the studied traits under normal and water stress conditions across the two seasons.**

| Traits | Reduction% | | | | | | Correlation coefficient with water stress susceptibility index | |
|---|---|---|---|---|---|---|---|---|
| | Mean | | Range | | | | | |
| | | | Minimum | | Maximum | | | |
| | 2017/18 | 2018/19 | 2017/18 | 2018/19 | 2017/18 | 2018/19 | Normal | Water stress |
| Number of days to heading | 5.26 | 3.36 | 2.70 | 1.16 | 7.58 | 4.66 | 0.44** | 0.19 |
| Number of days to maturity | 5.20 | 3.12 | 3.51 | 2.24 | 8.54 | 4.07 | 0.29* | -0.09 |
| Grain filling period | 5.07 | 2.54 | 1.06 | 0.54 | 13.83 | 6.49 | -0.32** | -0.34** |
| Grain filling rate | 9.80 | 23.75 | 2.02 | 7.94 | 16.88 | 47.01 | 0.29* | -0.58** |
| Plant height | 4.11 | 10.16 | 1.54 | 5.75 | 7.81 | 14.74 | 0.10 | 0.18 |
| Number of spikes $m^{-2}$ | 8.86 | 19.90 | 1.64 | 4.68 | 17.86 | 33.38 | -0.12 | -0.30* |
| 1000-kernel weight | 4.52 | 5.00 | 0.24 | 1.30 | 12.63 | 12.46 | 0.35** | 0.10 |
| Number of kernels $spike^{-1}$ | 8.44 | 4.01 | 1.94 | 0.39 | 16.42 | 12.71 | 0.13 | 0.06 |
| Grain yield | 14.52 | 25.51 | 6.59 | 11.20 | 22.44 | 47.26 | 0.16 | -0.62** |
| Total yield | 9.51 | 23.62 | 0.56 | 9.93 | 17.05 | 44.28 | 0.47** | -0.83** |
| Harvest index | 5.54 | 2.49 | 1.24 | 1.36 | 10.33 | 4.93 | 0.01 | -0.18 |

*** and ** = Significant at 0.05 and 0.01 probability level, respectively.**

In this respect, Farhat (2015) reported that SM, BY, GY and KW were the characters that were most affected by reduced irrigation. Moreover, HI, DH, DM and GFR were the least affected characters by reduced irrigation. The range of the reduction due to reduced irrigation ranged from 3.27 % for DH to 41.10 for GY.

The rank correlation was used by several authors in place of Pearson coefficient of correlation because the water stress susceptibility index (SSI) cannot be assumed to be normally distributed (Abebe and Girma 2017, Darwish *et al* 2017 and Morsy *et al* 2020). Spearman correlation coefficients (r) among the mean of water stress susceptibility index and the means of studied traits under normal and water stress for studied genotypes are presented in Table (13). Positive and significant correlation was observed between SI and DH, DM, GFR, KW and TY under normal conditions. In contrast, negative and significant correlation was obtained between SI and GFP, GFR, SM, GY and TY under water stress, indicating that these traits were the most contributors for water stress tolerance. Also, negative and significant correlation was obtained between SI and GFP under normal condition. These results indicate the importance of grain yield under water stress for water stress tolerance and the high yield potential under non-stressed conditions does not necessarily result in high yield under the water stress (Farhat, 2015, Abd El-Kreem *et al* 2019, Karaman, 2019 and Farshadfrar *et al* 2020).

## CONCLUSION

It could be concluded that line 1, line 16, line 15 and line 11could be introduced for advanced evaluation on the national level to confirm the present results. Misr 1 and Giza 171 cultivars proved to be suitable cultivars under reduced irrigation. Line 3, line 5 and line 9 could be used to enhance wheat breeding for water stress tolerance. High grain and biological yield, number of spikes m$^{-2}$, grain filling period and rate were the most important selection criteria for screening wheat genotypes for water stress tolerance.

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## REFERENCES

**Abd El-Hamid, E. A. M., M. A. Aglan and Eman Hussein (2019).** Modified method for the analysis of genotype by trait (GT) biplot as a selection criterion in wheat under water stress conditions. Egyptian J. of Agronomy 41 (3): 293-312.

**Abd El-Hamid, E. A. M., M. N. A. El-Hawary, Rania. A. Khedr, and Alaa M. E. A. Shahein (2020).** Evaluation of some bread wheat genotypes under water stress. J. of Plant Production, Mansoura Univ. 11 (2): 167-77.

**Abd El-Kreem Thanaa, H. A., Abdel-Hamid E. A. M. and M. N. A. Elhawary (2019).** Tolerance indices and cluster analysis to evaluate some bread wheat genotypes under water deficit conditions. Alex. J. Agric. Sci. 64 (4): 245-56.

**Abebe, A. and E. Girma (2017).** Historical development and practical application of correlation and path coefficient analysis in agriculture. J. Natural Sciences Research 7 (13): 43-49.

**Darwish, M. A. H., W. M. Fares and Eman M. A. Hussein (2017).** Evaluation of some bread wheat genotypes under saline soil conditions using tolerance indices and multivariate analysis. J. Plant Production, Mansoura Univ. 8 (12): 1383-94.

**Farhat, W. Z. E. (2015).** Response of 21 spring bread wheat genotypes to normal and reduced irrigation in north Delta. J. Plant Production, Mansoura Univ. 6 (6): 943-963.

**Farhat, W. Z. E, Kh. I. Gad and M. A. A. Aglan (2019).** Evaluation of selected promising bread wheat lines in late generations under two sowing dates. Annals of Agric. Sci., Moshtohor 57(4): 1-10.

**Farooq, M. O., K. Muhammad, K. Ihsan, and A. Nisar. (2020).** Phenotypic selection of wheat genotypes for drought stress tolerance. Int. J. Agric. Biol. 23 (3): 509-14.

**Farshadfrar, E., A. Yaghotipoor, S. J. Nezhad, F. Bavandpori, and M. Farshadfar (2020).** Evaluation of genetic variability of durum wheat genotypes based on physiological characteristics in drought conditions using the GGE-biplot Method. Iranian J. Crop Sci. 22(2): 125-139.

**Fischer, R. A. and R. Maurer (1978).** Drought resistance in spring wheat cultivars. I. Grain yield responses. Aust. J. Agric. Res. 29:897-912.

**Hamza Doaa, A., Sanaa I. Milad, M. N. Barakat, A. Ageez and A. I. Nawar (2018).** Evaluation of drought tolerance indices for screening some wheat (*Triticum aestivum* L.) genotypes under drought conditions. Middle East J. Agric. Res. 7 (4): 1234-1244.

**Henian Manal, M., B. R. Bakheit, M. B. M. Ali, M. A. El-Morshidy and A. M. Amro (2020).** Assessment of bread wheat genotypes under normal irrigation and water stress. Assiut J. Agric. Sci. 51(1): 26-26.

**Karaman, M. (2019).** Evaluation of bread wheat genotypes in irrigated and rainfed conditions using biplot analysis. Applied Ecology and Environmental Research 17 (1): 1431-50.

**Levene, H. (1960).** Levene test for equality of variances. Contributions to probability and statistics: 278-292.

**Liwani, U., L. S. Magwaza, N. J. Sithole, A. O. Odindo and T. J. Tsilo (2018).** Physiological responses of irrigated wheat (*Triticum aestivum* L.) genotypes to water stress. Acta Agriculturae Scandinavica, Section B-Soil & Plant Science 68:524-533.

**Mdluli, S. Y., H. Shimelis, and J. Mashilo (2020).** Screening for pre-and post-anthesis drought responses in selected bread wheat (*Triticum aestivum* L.) genotypes. Acta Agriculturae Scandinavica, Section B-Soil & Plant Science 70 (4): 272-84.

**Mkhabela ,S. S., H. Shimelis, A. O. Odindo and J. J. Mashilo (2019).** Response of selected drought tolerant wheat (*Triticum aestivum* L.) genotypes for agronomic traits and biochemical markers under drought-stressed and non-stressed conditions. Acta Agriculturae Scandinavica, Section B-Soil & Plant Science 69(8): 674-689.

**Morsy, A. M., M. A. Aglan and M. Y. ELMasry (2020).** Evaluation of some bread wheat genotypes under normal and saline soil conditions. J. Plant Production, Mansoura Univ. 11(3): 267-74.

**Mujeeb-Kazi, A., R. Munns, A. Rasheed, F. C. Ogbonnaya, N. Ali, P. Hollington, I. Dundas, N. Saeed, R. Wang, P. Rengasamy, M. S. Saddiq, J. L. D. De León, M. Ashraf, and S. Rajaram (2019).** Breeding strategies for structuring salinity tolerance in wheat. Advances in Agronomy 155: 121-187.

**Mwadzingeni, L., H. Shimelis, S. Tesfay, and T. J. Tsilo (2016).** Screening of bread wheat genotypes for drought tolerance using phenotypic and proline analyses. Front Plant Sci. 7: 1276.

**Ouda Samiha, A. H., A. Zohry and T. Noreldin (2020).** Deficit Irrigation: A Remedy for Water Scarcity. First edition, Springer Nature Switzerland AG.

**Payne, R. W., D. A. Murray and S. A. Harding (2017).** An introduction to the GenStat command language. Hemel Hempstead, UK: VSN International.

**Sallam, A., A. M. Alqudah, Mona F. A. Dawood, P. S. Baenziger and A. Börner (2019).** Drought stress tolerance in wheat and barley: advances in physiology, breeding and genetics research. Int. J. Mol. Sci. 20 (13): 3137.

**Seleiman, M. F. and M. S. M. Abdel-Aal (2018).** Response of growth, productivity and quality of some Egyptian wheat cultivars to different irrigation regimes. Egypt. J. Agron. 40 (3): 313-30.

**Tadesse, W., Z. Bishaw, and S. Assefa (2019).** Wheat production and breeding in Sub-Saharan Africa. International J. of Climate Change Strategies and Management 11 (5): 696-715.

**Thiry, A. A., P. N. Chavez Dulanto, M. P. Reynolds and W. J. Davies (2016).** How can we improve crop genotypes to increase stress resilience and productivity in a future climate? A new crop screening method based on productivity and resistance to abiotic stress. J. Exp. Bot. 67: 5593-5603.

**Thungo, Z, H. Shimelis, A. O. Odindo and J. Mashilo (2019).** Genotype by environment interaction of elite heat and drought tolerant bread wheat (*Triticum aestivum* L.) genotypes under non-stressed and drought-stressed conditions. Acta Agriculturae Scandinavica, Section B-Soil & Plant Science 69:725-733.

# استجابة بعض التراكيب الوراثية المستوردة من قمح الخبز لنقص مياه الري في شمال الدلتا في مصر

**مصطفى تاج الدين شهاب الدين و وليد ذكي اليماني فرحات***
قسم بحوث القمح معهد بحوث المحاصيل الحقلية- - مركز البحوث الزراعية مصر

***يُعد نقص المياه أحد أهم معوقات إنتاج القمح في مصر والعالم. وفي ضوء ذلك، تم تقييم ستة عشر سلالة مستوردة وصنفين محليين من قمح الخبز تحت ظروف الري العادي (خمس ريات) والإجهاد المائي (رية الزراعة فقط) خلال موسمي الزراعة 18/2017 و19/2018 في مركز البحوث الزراعية بسخا. وهدفت الدراسة إلى تعزيز برنامج التربية بسلالات تتحمل الإجهاد المائي. وقد أظهر موسما الزراعة ومعاملتا الري اختلافًا في استجابة التراكيب الوراثية المدروسة. وكانت قيم أكثر الصفات المدروسة أعلى في موسم الزراعة الثاني مقارنة بالموسم الأول. وقد تناقصت جميع قيم الصفات المدروسة تحت الإجهاد المائي. وكانت صفات محصول الحبوب العالي، المحصول البيولوجي، عدد السنابل بالمتر المربع وفترة ومعدل امتلاء الحبوب هي الأكثر مساهمةً في تحمل الإجهاد المائي. وقد أظهرت السلالات رقم 1، 16، 15 و11 قدرة إنتاجية عالية لمحصول الحبوب وتحملاً نسبيًا للإجهاد المائي. وأثبتت النتائج أن الصنفين مصر 1 وجيزة 171 مناسبان للزراعة تحت ظروف نقص مياه الري. وكذلك يمكن استخدام السلالات رقم 3، 5 و9 لتحسين القمح لتحمل الإجهاد المائي.***

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