*Original Research Article*

# Evaluating the Productivity of some Barely Genotypes under Deficient Water Application in Clayey Soils




## ABSTRACT

This study is intended to identify barely genotypes efficient for water use. For this, a field experiment was conducted at Sakha Research Station. The experimental design was randomize complete block with three replicates during 2018/2019 and 2019/2020 growing seasons. Twenty barely genotypes were grown under two water application treatments ((full irrigation (FI) and water stress (WS)). The values of applied irrigation water were 3430 and 1995 $m^3$/ha under WS and FI, respectively, being lower by 42%, compared to FI amount, average over the two seasons. The interaction between barley genotypes and irrigation water revealed that plant height of line-7, spike length and number of grains/spike of line-6, number of spikes/$m^2$ of Giza133, and grain and biological yields of line-5 were the least affected by WS, compared with their values under FI. The highest values of WUE under WS were found for line-6 and line-11, which also attained the highest WP Line-8 and line-13, expressed the highest value of mean productivity, geometric mean productivity and stress tolerance indices. Furthermore, line-7 had the highest value of stress susceptibility index. Thus, based on WUE, WP and drought tolerance indices, it could be concluded that line-6, line-7, line-8, line-11 and line-13 have the ability to withstand water stress and could be selected for breeding programs for water use efficiency.


**Key word:** *Barely genotypes, Water stress, water use efficiency, water productivity, drought tolerance indices.*

## 1. INTRODUCTION

Barley (Hordeum vulgare L.) ranked fourth in important in cereal after wheat, rice and maize. In Egypt barely is one of the most important crops used in animal feed as well as by human for its nutritional value against degenerative diseases including diabetes, obesity, and colon inflammation. This is due to its rich dietary fibers, i.e., β-glucan composition, high source of phosphorus and potassium [1]. It is also a good source of starch, minerals, vitamins, and protein [2]. Barely is considered as a resilient crop characterized by having tolerance to drought [3] due to a more extensive root systems and its early development that permits drought escape [4].Nevertheless, drought stress could have negative effects on barely, which is dependent on the exposed growth stage. Early drought could reduce seed germination, and seedling emergence [5], as well as seedling growth [6]. Whereas, drought stress occurs during flowering reduces pollination and grain filling [7], which negatively affects two important components of barely grain yield, namely the number of grain per spike and grain weight [8] and consequently it negatively affect final yield of barley [9].Plant breeding programs in Egypt have been successful in producing new barley cultivars having a high degree of drought tolerance under both mild and severe stress conditions. This suggests better description of crop biodiversity in order to understand their response to drought, as well as identify the physiological mechanisms that contribute in increasing its productivity [10]. [11] Reported that, study the effect of genotype and the interaction between genotype and environment are important in selection of stable genotypes. [12] Reported that drought significantly affected most of the studied morpho-physiological traits resulting in strong decreases in yield and the studied traits. In addition to genotypes with the highest 1000-grain weight, and biological yields achieved

higher grain yields under water stress conditions. Several drought tolerance indices have been studied to differentiate between low and high yielding cultivars under stress conditions, namely mean productivity, geometric mean productivity, stress tolerance index and stress susceptibility index. [13] Defined mean productivity as the average stress yield and non-stress yield. [14] and [15] reported that mean productivity index, and geometric mean product index were the most suitable indices in define drought tolerance. [16] Indicated that geometric mean productivity is of interest in the relative performance under various conditions of drought stresses, where its severity can vary under field environment over years. Furthermore, [13] defined stress tolerance index as the differences in yield between the stress (Ys) and non-stress (Yp) environments. Stress tolerance index can be used to identify genotypes that produce high yield under both stress and non-stress conditions [17]. [18] Indicated that stress tolerance index was more effective in identifying high yielding cultivars in both drought-stressed and irrigated cultivars. Another drought stress index was proposed by [19], namely stress susceptibility index (SSI) of the cultivar. Whereas, [20] used another drought index, namely stress susceptibility index (SSI), where it was suggested that higher value SSI than1.0 indicating above-average susceptibility and lower SSI value than 1.0 indicated below-average susceptibility to drought stress. The objectives of this work to identify potentially drought tolerance barely genotypes under water stress irrigation with useful drought tolerance indices for use in the barely breeding program.

## 2. MATERIALS & METHODS

A field experiment was carried out at Sakha Agricultural Research Station, Agricultural Research Center, KafrEl-Sheikh Governorate (Lat. 31° 06' 25.20" N, Long. 30° 56' 26.99" E, elevation above sea level 17 m), Egypt during 2018/19 and 2019/20 growing seasons. For each season, the tested entries were evaluated in two separate irrigation treatments using flood irrigation method. The first treatment included the normal irrigation (three times after planting irrigation + rainfall), while the second treatment included planting irrigation only (water stress) in addition to the amount of rainfed. Average monthly weather data at the experimental site during the two growing seasons were obtained from https://power.larc.nasa.gov/data-access-viewer/.The values of metrological data in 2018/19 and 2019/20 are presented in Table (1). Furthermore, the values of monthly reference evapotranspiration (ETo) was calculated using Penman-Monteith equation, as presented in the United Nations FAO organization by [21] (Table 1). This equation exists in The Basic Irrigation Scheduling model (BISm) [22].

**Table 1.Monthly means of weather data and ETo in 2018/19 and 2019/20 growing seasons in the experimental site.**

| Month | SR | Tmax | Tmin | WS | T dew | RH | Rainfall | ETo |
|---|---|---|---|---|---|---|---|---|
| 2018/19 | | | | | | | | |
| Dec | 9.27 | 19.5 | 13.9 | 2.92 | 9.29 | 75.6 | 22.6 | 2.6 |
| Jan | 11.78 | 18.9 | 12.3 | 3.18 | 3.96 | 67.8 | 34.9 | 2.9 |
| Feb | 14.59 | 19.7 | 14.3 | 2.74 | 6.13 | 72.6 | 15.3 | 3.1 |
| March | 19.11 | 21.7 | 17.6 | 3.08 | 7.26 | 72.2 | 17.3 | 4.3 |
| April | 22.30 | 25.1 | 21.3 | 3.19 | 8.21 | 64.9 | 3.90 | 5.7 |
| 2019/20 | | | | | | | | |
| Dec | 10.22 | 21.4 | 13.4 | 3.16 | 9.04 | 86.4 | 27.9 | 3.0 |
| Jan | 10.49 | 18.4 | 11.8 | 3.09 | 7.99 | 74.7 | 38.4 | 2.3 |
| Feb | 13.59 | 20.4 | 12.7 | 2.65 | 8.27 | 70.6 | 14.3 | 2.7 |
| March | 18.52 | 22.6 | 15.6 | 3.14 | 8.96 | 67.5 | 30.8 | 4.1 |
| April | 23.74 | 26.0 | 18.9 | 2.84 | 10.52 | 62.6 | 0 | 5.2 |

*SR = solar radiation (MJ/m$^2$/day), Tmax, Tmin and Tdew= maximum and minimum and dew point temperatures (°C), respectively, WS = wind speed (m/s), RH= relative humidity (%), rainfall=sum of rainfall (mm/month), ETo = reference evapotranspiration (mm/day).*

Disturbed and undisturbed soil samples were collected from the top 60 cm of soil surface at 15 cm interval. Soil samples were analyzed to determine main chemical and physical soil properties. Chemical analysis was done according to [23].The obtained values are presented in Table 2. According to Natural Resources Conservation Service (NRCS), Oregon State University, USA, the soil at the

experimental site can be classified as saline soil where (EC > 4 dS/m, SAR < 13, ESP < 15% and soil pH < 8.5) [24].

**Table 2**: **Chemical soil properties of the experimental site before cultivation.**

| Soil depth (cm) | pH | EC dS/m | Soil SAR | Soil ESP (%) | Soluble cations (meq $L^{-1}$) | | | | Soluble anions (meq $L^{-1}$) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | $Na^{+}$ | $Ca^{++}$ | $Mg^{++}$ | $K^{+}$ | $HCO_3$ | $Cl^{-}$ | $SO_4$ |
| 0-15 | 7.93 | 4.89 | 10.92 | 12.93 | 33.30 | 7.80 | 10.80 | 0.90 | 4.50 | 25.00 | 23.30 |
| 15-30 | 8.21 | 5.26 | 11.32 | 13.37 | 35.80 | 8.40 | 11.60 | 0.90 | 5.00 | 26.60 | 25.00 |
| 30-45 | 8.20 | 5.35 | 11.41 | 13.47 | 36.43 | 8.75 | 11.80 | 1.00 | 4.83 | 27.27 | 25.49 |
| 45-60 | 8.46 | 5.91 | 12.00 | 14.12 | 40.20 | 9.50 | 13.00 | 1.20 | 5.50 | 30.20 | 28.10 |
| Mean | - | 5.35 | 11.41 | 13.47 | 36.43 | 8.61 | 11.80 | 1.00 | 4.96 | 27.27 | 25.47 |

*Note that: EC = ∑Cations * 10 = ∑Anions * 10*

Particle size distribution was determined according to [25], and soil moisture constants in the experimental site were determined according to [26] and bulk density was calculated according to [27] (Table 3).

**Table 3**.**Soil physical properties and soil moisture constants of the experimental site before cultivation.**

| Soil depth (cm) | Particle size distribution (%) | | | Texture | Field capacity (%) | Wilting point (%) | Available water (%) | Bulk density ($mg/m^3$) |
|---|---|---|---|---|---|---|---|---|
| | Sand | Silt | Clay | | | | | |
| 0-15 | 16.3 | 33.2 | 50.5 | Clayey | 42.80 | 22.86 | 19.94 | 1.18 |
| 15-30 | 14.4 | 33.9 | 51.7 | Clayey | 39.29 | 21.30 | 17.99 | 1.27 |
| 30-45 | 12.8 | 34.3 | 52.9 | Clayey | 38.00 | 20.21 | 17.79 | 1.32 |
| 45-60 | 13.5 | 34.8 | 51.7 | Clayey | 38.00 | 20.21 | 17.79 | 1.32 |

### 2.1. Plant materials and the experimental design

In randomized complete block design with three replicates, twenty barley genotypes were grown under two water application treatments (full irrigation and water stress). The planting date was December $10^{th}$ in both growing seasons. Each genotype was sown in six rows of 3.5 m in length, and 20 cm among rows. The pedigree of the twenty barley genotypes is presented in Table (4).

**Table 4**.**Name and pedigree of the studied twenty barely genotypes.**

| No | Genotypes | Pedigree |
|---|---|---|
| 1 | Giza 123 | Giza117/FAO 86 |
| 2 | Giza 133 | Carbo/Gustoe |
| 3 | Line-1 | Giza 121//ENCINO/TOCTE |
| 4 | Line-2 | Giza 121//ENCINO/TOCTE |
| 5 | Line-3 | Giza 121/7/Alanda/5/Aths/4/Pro/TolI//Cer*2/TolI/3/5106/6/ AwBlack/Aths// Arar/3/9Cr279-07/Roho |
| 6 | Line-4 | Giza 123/4/Acsad 1180 /3/ Mari / Aths *2 // M-Att-73-337-1 |
| 7 | Line-5 | Giza 125//ENCINO/TOCTE |
| 8 | Line-6 | Giza 126/6/Lignee527/NK1272//JLB70-63/5/ BKFMaguelone1604/3/Apro// Sv.02109/ Mari/4/Giza119 |
| 9 | Line-7 | C .C 89/4/Acsad 1180 /3/ Mari / Aths *2 // M-Att-73-337-1 |
| 10 | Line-8 | Rihane-03//Lignee527NK1272/5/Arizona5908/Aths//Avt/attiki /3/s.t/ Barley/4/Aths/ Lignee640/6/Giza 126 |
| 11 | Line-9 | Rihane-03//Lignee527NK1272/5/Arizona5908/Aths//Avt/ attiki/3/ s.t/ Barley/4/Aths/ Lignee 640/6/Alanda//Lignee 527/ Arar /5/Ager // Api / CM67/3/Cel/WI2269//Ore/4/Hamra-01 |
| 12 | Line-10 | Lignee527/NK1272/6/Cita'S'/4/Apm/Rl//Manker/3/Maswi/Bon/5/Copal'S'+Aths/Lignee |

| | | |
|---|---|---|
| | | 686 /5/Apm/RL/4/Api/EB489-8-2-15-4//por/ U.Sask1766/3/Cel/CI |
| 13 | Line-11 | Giza 121/4/Arar//Hr/Nopal/3/Alanda -01/Alanda-01 |
| 14 | Line-12 | M64 - 76 / Bon // Jo / York /3/ M5/Galt // As 46 /4/Hj 34 - 80 / Astrix /5/ NK 1272/7/ Alanda/5/ Aths/4/Pro/Toll//Cer*2 /Toll/3/ 5106/6/Baca'S'/3/AC253 //CI08887/CI05761 |
| 15 | Line-13 | Giza 2000/4/CalMr/3/Alanda//Lignee527/Arar |
| 16 | Line-14 | ACSAD 1182/4/ Arr/ ESP // Alger/ Ceres 362-1-1/3/ WI /5/Alanda/Hamra//Alanda-01 |
| 17 | Line-15 | Giza 126/4/Acsad 1180 /3/ Mari / Aths *2 // M-Att-73-337-1 |
| 18 | Line-16 | U.Sask.1766/Api//Cel/3/Weeah/4/Giza121/Pue |
| 19 | Line-17 | Panniy/Salmas/5/Baca"s"/3/AC253//CI08887/CI05761/4/JLB70-01 |
| 20 | Line-18 | CABUYA/ESMERALDA |

The effects of two irrigation treatments on the barley genotypes were studied. Full irrigation (FI) treatment, where 120% ETo was timely applied with the total of (four irrigation + rainfall) and, water stress treatment (WS), where plants were exposed only to rainfall except for application of sowing irrigation. Seven agro-morphological parameters for barley were measured: plant height (cm), spike length (SL) (cm), number of grain/spike (No. G/spk), number of spike/$m^2$ (No. spk/$m^2$), 1000-grain weight (g), grain yield (ton/ha), and biological yield (ton/ha). Harvest was done on April 30$^{th}$ in both growing seasons.

## 2.2. Water relations

### 2.2.1. Amount of applied irrigation water

The depth of applied irrigation water (AIW) to the experimental plots was calculated according to the following equation:

$$AIW = \frac{120\%\ ETo XI}{Ea}$$

Where: AIW = depth of applied irrigation water (mm), ETo=reference evapotranspiration (mm/day), I = irrigation interval (days), Ea = application efficiency (fraction) = 0.6 for surface system at the site.

### 2.2.2. Effective rainfall (Re)

The depth of effective rainfall during growing season was calculated according the relation suggested by the U.S. Bureau of Reclamation [28] giving as follows:

$$Peff = Ptot(125 - 0.2Ptot)/125 \quad for\ Ptot < 250mm\ and$$
$$Peff = 125 + 0.1Ptot \quad for\ Ptot > 250mm$$

Where:

Peff = effective rainfall (mm), and Ptot = total rainfall (mm).

### 2.2.3. Water consumptive use (WCU)

Crop water use was estimated by the method of soil moisture depletion according to [29] as follows:

$$WCU = \sum_{i=1}^{i=4} \frac{\theta 2 - \theta 1}{100} \times Bdxd$$

Where: WCU= water consumptive use or crop evapotranspiration (mm), i= number of soil layer, θ2 = soil moisture content after irrigation, (%, by mass), θ1 = soil moisture content just before irrigation (%, by mass),Bd= soil bulk density (g/$cm^3$), d= depth of soil layer (mm).

### 2.2.4. Water use efficiency (WUE)

Water use efficiency for each barley genotype was calculated according to [30] as:

$$WUE = \frac{Barley yield\ (kg/ha)}{WCU\ (m3/ha)}$$

### 2.2.5. Crop water productivity (WP)

Water productivity is defined as crop yield per unit of applied irrigation water, which determines the efficient use of applied irrigation water and is given as follows [31]:

$$WP = \frac{Barleyyield\ (kg/ha)}{Appliedirrigationwater\ (m3/ha)}$$

### 2.2.6. Drought tolerance indices

To assess the tolerance of the studied barely genotypes to water stress, five drought tolerance indices were calculated using the following equations presented in Table (5).

**Table 5. Stress tolerance indices used for the evaluation of barley genotypes to water tolerance.**

| No. | Stress tolerance indices | Equation | Reference |
|---|---|---|---|
| 1 | Mean productivity | MP = (Ys + Yp)/2 | Bouslama & chapaugh [32] |
| 2 | Geometric mea productivity | GMP =√Ys × Yp | Sio-Se Mardeh et al. [18] |
| 3 | Tolerance index | TOL= Yp – Ys | Rosielle & Hamblin [13] |
| 4 | Stress tolerance index | STI = *Yp × Ys/Y¯p2* | Fernandez [17] |
| 5 | Stress susceptibility index | SSI = *(1 – Ys/Yp)/ (1 – Y¯s/Y¯p)* | Fischer & Maurer [19] |

*Where: Ys and Yp are the yields of genotypes under stress and non-stress conditions, respectively, Y¯s and Y¯p are the mean yields of all genotypes under stress and non-stress conditions, respectively.*

### 2.3. Statistical analysis

The experimental design was randomize complete block with three replicates and data was collected for morphological traits and, yield for the two seasons. All data were statistically analyzed by analysis of variance (ANOVA) published by [33]. Means of the treatments were compared by the least significant difference (LSD) at 5% level of significance as developed by [34]. Combined analysis across the two irrigation treatments in the two seasons was performed when the assumption of errors homogeneity cannot be rejected according to [35].

## 3. RESULTS & DISCUSSIONS

### 3.1. Applied irrigation water

The results in Table (6) indicated that the values of applied irrigation water under full irrigation were 3364 and 3495 $m^3$/ha in the first and second season, respectively and being 1902 and 2087 $m^3$/ha for water stress treatments in the first and second season, respectively. Furthermore, the applied irrigation amount under full irrigation was higher by 44 and 40% than the applied water under water stress treatment. This provide highly stressful environment for barley genotypes to test their ability to withstand water deficiency. The results also showed that water stress treatment was lower in the second season, compared to the first season, due to differences in weather elements between the two seasons.

**Table 6. Applied irrigation amounts ($m^3$/ha) under full irrigation and water stress treatments to barely genotypes in the two seasons.**

| Amount of water | Full irrigation ($m^3$/ha) | | Water stress ($m^3$/ha) | | |
|---|---|---|---|---|---|
| | First season | Second season | Irrigation + rainfall | First season | Second season |
| Sowing irrigation | 962 | 973 | Sowing irrigation | 962 | 973 |
| 1st Irrigation | 488 | 459 | Rainfall (December) | 226 | 279 |
| 2nd Irrigation | 471 | 438 | Rainfall (January) | 349 | 384 |
| 3rd Irrigation | 502 | 512 | Rainfall (February) | 153 | 143 |
| Total amount of rainfall | 940 | 1114 | Rainfall (March) | 173 | 308 |
| - | - | - | Rainfall (April) | 39 | 0 |
| Total | 3364 | 3495 | Total | 1902 | 2087 |

### 3.2. The analysis of variance for the studied traits

Combined analysis of variance for the studied traits is presented in Table (7). Significant effects of seasons(S), irrigation treatments (T) and genotypes (G) ($p < 0.05$ or 0.01) were observed for all the

studied traits. The mean square of irrigation treatments explained most of the total variations for all performance in 2018/19 and 2019/20 growing seasons. Mean squares due to seasons, irrigation treatments and genotypes interaction were significant for all characters, except the interaction between S and T for plant height and number of spike/$m^2$, interaction between T and G for plant height, spike length and number of grains/spike, and interaction between S, T and G for plant height, spike length, number of grains/spike and 1000-grain weight. This suggests the importance of the evaluation of genotypes under low amount of irrigation in order to identify the best genetic makeup under low irrigation amount. Similar results were obtained by [36].

Significant variations were detected due to interactions between genotypes and irrigation treatments for all performances. The variations due to genotypes were higher than those of interactions between genotypes and irrigation treatments. The significance of genotypes variances for all performances under all conditions reflects the presence of sufficient genetic variability between these genotypes and provides the basis for genetic gain [37]. Moreover, the significance of the interactions is a result of the different abilities of genotypes to adjust their performances to the low applied irrigation amounts and seasons, suggesting the importance of genotypes evaluation under different irrigation treatments to identify its tolerance to low application of water.

**Table 7.Analysis of variance for the studied traits under irrigation treatments for the studied genotypes.**

| SOV | df | Plant height(cm) | Spike length (cm) | No of grains/spike | No. of spikes/$m^2$ | 1000-grain weight (g) | Grain yield (ton/ha) | Biological yield (ton/ha) |
|---|---|---|---|---|---|---|---|---|
| Season (S) | 1 | 1220.95** | 9.16** | 329.77** | 8807.61** | 65.29** | 5.29** | 101.75** |
| Treatments (T) | 1 | 11818.87** | 59.23** | 2132.44** | 183465.49** | 187.63** | 25.88** | 262.56** |
| S x T | 1 | 15.91 | 1.29** | 46.42** | 154.18 | 2.38** | 0.4** | 4.8** |
| Reps/S/T = Error (a) | 8 | 21.23 | 0.06 | 1.16 | 102.75 | 0.10 | 0.01 | 0.08 |
| Genotypes (G) | 19 | 544.72** | 12.9** | 464.54** | 31774.36** | 27.67** | 3.84** | 37.7** |
| S x G | 19 | 41.89* | 0.44* | 15.91* | 426.7** | 1.7** | 0.15** | 2.2** |
| T x G | 19 | 26.99 | 0.26 | 9.39 | 2309.47** | 3.87** | 0.22** | 3.38** |
| S x T x G | 19 | 17.99 | 0.2 | 7.26 | 357.79* | 0.59 | 0.08** | 1.17** |
| Pooled error b | 152 | 24.52 | 0.26 | 9.47 | 190.16 | 0.41 | 0.04 | 0.23 |
| CV% | | 4.57 | 6.27 | 5.05 | 3.21 | 1.26 | 3.73 | 3.01 |

### 3.3. The effect of the interaction between seasons, irrigation treatments and genotypes

Due to insignificant values for the S x T x G interaction for plant height, spike length, number of grains/spike and 1000-grain weight (table 7), the results will be discussed as S x G interaction for these traits. Results in Table (8) showed that, the highest values were obtained for plant height from line-12 at first and second season (115.5 and 117.91 cm, respectively), for spike length from line-8 in the first season and line-13 in the second season (9.15 and 10.0 cm, respectively), for number of grains/spike from line-8 in the first season and line-13 in the second season (66.90 and 71.99 grain, respectively) and for 1000-grain weight from line-14 in the first season and line-6 in the second season (53.07 and 53.59 g, respectively).

**Table 8.Mean performance of plant height, spike length, number of grains/spike and 1000-grain weight as affected by interactions among seasons and genotypes.**

| Genotypes | Plant height (cm) | | Spike length (cm) | | No of grains/ spike | | 1000 grain weight (g) | |
|---|---|---|---|---|---|---|---|---|
| | 1st | 2nd | 1st | 2nd | 1st | 2nd | 1st | 2nd |
| Giza 123 | 99.50 | 106.60 | 7.77 | 8.12 | 58.60 | 60.72 | 49.43 | 50.51 |
| Giza 133 | 88.50 | 92.15 | 6.15 | 6.36 | 48.90 | 50.17 | 51.00 | 51.34 |
| Line-1 | 112.83 | 113.43 | 7.98 | 8.84 | 59.90 | 65.06 | 51.01 | 51.68 |
| Line-2 | 105.83 | 109.80 | 7.78 | 8.29 | 58.70 | 61.73 | 50.56 | 50.76 |
| Line-3 | 105.83 | 110.40 | 8.55 | 8.61 | 63.30 | 63.63 | 49.90 | 51.30 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Line-4 | 111.67 | 115.56 | 7.82 | 8.55 | 58.90 | 63.29 | 48.03 | 49.52 |
| Line-5 | 110.00 | 114.41 | 7.93 | 9.16 | 59.60 | 66.94 | 52.29 | 52.94 |
| Line-6 | 108.17 | 116.54 | 9.02 | 8.68 | 66.10 | 64.09 | 53.01 | 53.59 |
| Line-7 | 100.00 | 107.87 | 6.28 | 6.45 | 49.70 | 50.72 | 50.52 | 51.52 |
| Line-8 | 109.83 | 115.41 | 9.15 | 9.31 | 66.90 | 67.86 | 50.94 | 52.40 |
| Line-9 | 116.00 | 116.45 | 9.00 | 9.09 | 66.00 | 66.53 | 49.48 | 50.74 |
| Line-10 | 92.00 | 96.62 | 6.70 | 7.01 | 52.20 | 54.04 | 45.91 | 48.46 |
| Line-11 | 104.83 | 121.50 | 9.07 | 9.36 | 66.42 | 68.15 | 51.53 | 51.47 |
| Line-12 | 115.50 | 117.91 | 8.48 | 8.62 | 62.90 | 63.73 | 49.55 | 51.10 |
| Line-13 | 111.17 | 113.70 | 8.95 | 10.00 | 65.70 | 71.99 | 51.51 | 52.30 |
| Line-14 | 102.67 | 108.76 | 5.78 | 6.68 | 46.70 | 52.07 | 53.07 | 53.43 |
| Line-15 | 107.33 | 109.45 | 7.12 | 7.22 | 54.70 | 55.35 | 49.10 | 50.33 |
| Line-16 | 109.50 | 110.18 | 9.02 | 9.20 | 66.10 | 67.22 | 47.17 | 49.99 |
| Line-17 | 104.83 | 104.98 | 8.63 | 9.01 | 63.80 | 66.04 | 50.57 | 51.94 |
| Line-18 | 105.83 | 110.36 | 7.98 | 8.43 | 59.90 | 62.58 | 51.36 | 51.45 |
| Mean | 106.09 | 110.60 | 7.96 | 8.35 | 59.75 | 62.10 | 50.30 | 51.34 |
| LSD0.05 | 5.35 | 6.01 | 0.60 | 0.58 | 3.62 | 3.46 | 0.81 | 0.65 |
| LSD0.05 S x G | 5.68 | | 0.59 | | 3.54 | | 0.73 | |

With respect to number of spikes/$m^2$, Table (9) indicated that, under full irrigation, the highest values were found for line-6, namely 566.00 and 573.96 in first and second season, respectively. While the lowest values were found for line-7, namely 364.00 and 372.76, in first and second season respectively. The highest values under water stress treatment were found for line-11, i.e. 517.33 and 526.85 in first and second season, respectively. While the lowest values were found for line-7, i.e. 302.67 and 310.41 in the first and second season, respectively.

With respect to grain yield, Table (9) indicated that, under full irrigation, the highest values were found for line-6 and line-13, namely 6.51 and 6.85 ton/ha in first and second season, respectively. While the lowest values were found for line-2, namely 4.53 and 4.73 ton/ha, in first and second season, respectively. The highest values under water stress treatment were found for line 6, i.e. 5.79 and 6.42 ton/ha in the first and second season, respectively. While, the lowest values were found for line-7 and line-2, i.e. 3.87 and 4.25 ton/ha in the first and second season, respectively.

**Table 9.Mean performance of number of spikes/$m^2$, grain and biological yield as affected by interactions among seasons, irrigation treatments and genotypes.**

| Genotypes | No. of spikes/$m^2$ | | | | Grain yield (ton/ha) | | | | Biological yield (ton/ha) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2018/2019 | | 2019/2020 | | 2018/2019 | | 2019/2020 | | 2018/2019 | | 2019/2020 | |
| | FI | WS | FI | WS | FI | WS | FI | WS | FI | WS | FI | WS |
| Giza 123 | 412.67 | 384.00 | 423.63 | 390.39 | 4.84 | 4.35 | 4.99 | 4.73 | 14.31 | 12.75 | 15.42 | 15.04 |
| Giza 133 | 428.00 | 410.00 | 427.15 | 420.00 | 5.10 | 4.46 | 5.36 | 4.86 | 15.70 | 13.54 | 15.95 | 14.19 |
| Line-1 | 478.33 | 428.00 | 484.21 | 437.84 | 5.63 | 4.35 | 5.96 | 4.98 | 18.63 | 12.75 | 19.66 | 15.71 |
| Line-2 | 421.33 | 398.00 | 437.97 | 400.21 | 4.53 | 4.10 | 4.73 | 4.25 | 13.79 | 13.33 | 16.24 | 14.12 |
| Line-3 | 529.33 | 482.00 | 528.81 | 476.29 | 6.25 | 5.44 | 6.85 | 5.55 | 18.54 | 15.88 | 19.70 | 17.80 |
| Line-4 | 377.33 | 362.67 | 394.81 | 364.96 | 4.75 | 3.96 | 4.76 | 4.39 | 13.94 | 11.33 | 14.66 | 13.65 |
| Line-5 | 426.33 | 364.00 | 474.88 | 374.92 | 5.36 | 4.85 | 5.53 | 5.50 | 16.06 | 14.42 | 17.18 | 16.48 |
| Line-6 | 566.00 | 480.00 | 573.96 | 494.73 | 6.51 | 5.79 | 6.71 | 6.42 | 19.88 | 18.38 | 21.22 | 19.90 |
| Line-7 | 346.00 | 302.67 | 372.76 | 310.41 | 4.78 | 3.87 | 5.39 | 5.06 | 13.73 | 11.08 | 15.39 | 13.99 |
| Line-8 | 411.33 | 362.67 | 413.35 | 366.88 | 4.72 | 4.04 | 5.04 | 4.54 | 13.67 | 11.83 | 14.87 | 13.94 |
| Line-9 | 388.00 | 351.33 | 391.28 | 374.83 | 4.75 | 4.54 | 5.04 | 4.53 | 15.56 | 14.25 | 14.71 | 13.93 |
| Line-10 | 492.00 | 354.67 | 508.19 | 447.43 | 5.08 | 4.67 | 5.36 | 4.79 | 15.73 | 14.42 | 16.87 | 16.02 |
| Line-11 | 548.00 | 517.33 | 551.55 | 526.85 | 6.41 | 5.72 | 6.60 | 6.24 | 19.35 | 18.04 | 20.48 | 18.46 |
| Line-12 | 482.00 | 445.33 | 494.25 | 452.22 | 5.53 | 4.94 | 5.40 | 4.76 | 16.75 | 14.58 | 17.76 | 13.97 |
| Line-13 | 476.67 | 372.00 | 477.93 | 386.49 | 6.09 | 4.68 | 6.09 | 5.24 | 17.56 | 13.17 | 17.33 | 16.17 |
| Line-14 | 442.00 | 332.00 | 454.25 | 355.43 | 5.28 | 4.75 | 5.35 | 4.73 | 15.73 | 13.50 | 17.21 | 14.07 |
| Line-15 | 422.00 | 361.33 | 433.32 | 372.17 | 4.64 | 4.08 | 5.03 | 4.73 | 13.90 | 12.17 | 16.50 | 16.14 |
| Line-16 | 470.00 | 411.33 | 474.27 | 426.16 | 5.98 | 4.72 | 6.18 | 5.43 | 19.15 | 14.75 | 19.41 | 15.61 |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Line-17 | 466.67 | 416.00 | 474.27 | 420.21 | 5.90 | 4.87 | 5.89 | 5.14 | 17.56 | 14.00 | 18.61 | 16.92 |
| Line-18 | 465.33 | 376.00 | 468.75 | 387.28 | 5.58 | 4.77 | 5.78 | 4.64 | 16.55 | 14.42 | 17.31 | 14.18 |
| Mean | 452.47 | 395.57 | 462.98 | 409.29 | 5.39 | 4.65 | 5.60 | 5.03 | 16.30 | 13.93 | 17.32 | 15.51 |
| LSD0.05 | 29.52 | 16.49 | 26.08 | 15.96 | 0.32 | 0.23 | 0.32 | 0.38 | 0.91 | 0.83 | 0.53 | 0.83 |
| LSD0.05 S x T x G | 22.25 | | | | 0.31 | | | | 0.77 | | | |

*FI= full irrigation, WS= water stress.*

The results in Table (9) also illustrate that, under full irrigation, the highest values of biological yield were found for line-6, namely 19.88 and 21.22 ton/ha in the first and second season, respectively. While, the lowest values were found for line-8 and line-4, namely 13.67 and 14.66 ton/ha, in the first and second season, respectively. The highest values under water stress treatment were found for line 6, namely 18.38 and 19.90 ton/ha, in the first and second season, respectively. Whereas, the lowest values were found for line-7 and line-4, i.e.11.08 and 13.65 ton/ha, in the first and second season, respectively.

[38] Showed that, both genotype effect and the interaction of genotype and environment must be examined simultaneously. [11] Reported that, study the effect of genotype and the interaction between genotype and environment are important in selection of stable genotypes. [39] Found that water stress caused a reduction in plant height, biological yield and grain yield components. [40] Found that drought stress reduced the grain yield by 37% and straw yield by 18%. [12] Reported that drought significantly affected most of the studied morpho-physiological traits resulting in strong decreases in yield and the studied traits. In addition to genotypes with the most spikes, the highest 1000-grain weight, and biological yields achieved higher grain yields under water stress conditions.

## 3.4. Barley genotypes and water relations

### 3.4.1. Water productivity and water use efficiency

Crop water productivity is a quantitative term used to define the relationship between crop produced and the amount of water involved in crop production [31]. [41] Reported that quantification of crop water productivity help in studying the impact of irrigation scheduling decisions, with regard to water management. The results in Table (10) showed that application of water stress treatment attained the highest water productivity values in both growing seasons due to lower barley yield by 14 and 10% average over all the genotypes in the first and second season, respectively under water stress treatment and lower amount of irrigation water by 44 and 40% in the first and second season, respectively. Similar result was observed by [42], who stated that lower water productivity exited under application of higher levels of irrigation amounts. Furthermore, the results also showed that the highest values of water productivity under water stress treatment were found for line-6 and line-11, where its values were 3.04 and 3.01 kg/m$^3$ in the first season, and were 3.08 and 2.99 kg/m$^3$ in the second season, respectively.

Table (10) also showed that application of water stress treatment resulted in higher values water use efficiency than its values under full irrigation. Five genotypes attained higher water use efficiency values than the rest of the studied genotypes, namely Giza133, line-3, line-5, line-6, and line-11, where the values were > 4.0 kg/m$^3$ in the first season and were > 5.0 kg/m$^3$ in the second season.

**Table 10.Water Productivity and water use efficiency of barley genotypes under full irrigation and water stress treatments in the two growing seasons.**

| Genotypes | Water productivity (kg/m$^3$) | | | | Water use efficiency (kg/m$^3$) | | | |
|---|---|---|---|---|---|---|---|---|
| | First season | Second season | First season | Second season | First season | Second season | First season | Second season |
| | Full irrigation | | Low irrigation | | Full irrigation | | Low irrigation | |
| Giza 123 | 1.44 | 1.43 | 2.29 | 2.27 | 2.16 | 2.33 | 3.95 | 4.94 |
| Giza 133 | 1.52 | 1.53 | 2.34 | 2.33 | 2.28 | 2.50 | 4.05 | 5.07 |
| Line-1 | 1.67 | 1.71 | 2.29 | 2.39 | 2.51 | 2.79 | 3.95 | 5.20 |
| Line-2 | 1.35 | 1.35 | 2.16 | 2.04 | 2.02 | 2.21 | 3.72 | 4.44 |
| Line-3 | 1.86 | 1.96 | 2.86 | 2.66 | 2.79 | 3.20 | 4.94 | 5.79 |
| Line-4 | 1.41 | 1.36 | 2.08 | 2.10 | 2.12 | 2.22 | 3.60 | 4.58 |
| Line-5 | 1.59 | 1.58 | 2.55 | 2.64 | 2.39 | 2.58 | 4.41 | 5.74 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Line-6 | 1.94 | 1.92 | 3.04 | 3.08 | 2.91 | 3.14 | 5.26 | 6.70 |
| Line-7 | 1.42 | 1.54 | 2.03 | 2.42 | 2.13 | 2.52 | 3.51 | 5.28 |
| Line-8 | 1.40 | 1.44 | 2.12 | 2.18 | 2.11 | 2.36 | 3.67 | 4.74 |
| Line-9 | 1.41 | 1.44 | 2.39 | 2.17 | 2.12 | 2.36 | 4.12 | 4.73 |
| Line-10 | 1.51 | 1.53 | 2.46 | 2.30 | 2.27 | 2.50 | 4.24 | 5.00 |
| Line-11 | 1.91 | 1.89 | 3.01 | 2.99 | 2.86 | 3.08 | 5.20 | 6.51 |
| Line-12 | 1.64 | 1.55 | 2.60 | 2.28 | 2.47 | 2.52 | 4.49 | 4.97 |
| Line-13 | 1.81 | 1.74 | 2.46 | 2.51 | 2.72 | 2.85 | 4.25 | 5.47 |
| Line-14 | 1.57 | 1.53 | 2.50 | 2.27 | 2.36 | 2.50 | 4.31 | 4.94 |
| Line-15 | 1.38 | 1.44 | 2.15 | 2.27 | 2.07 | 2.35 | 3.71 | 4.94 |
| Line-16 | 1.78 | 1.77 | 2.48 | 2.60 | 2.67 | 2.89 | 4.29 | 5.67 |
| Line-17 | 1.75 | 1.69 | 2.56 | 2.46 | 2.63 | 2.75 | 4.42 | 5.37 |
| Line-18 | 1.66 | 1.65 | 2.51 | 2.22 | 2.49 | 2.70 | 4.33 | 4.84 |

### 3.4.2. Drought tolerance indices for barley genotypes

Drought tolerance indices for the studied barley genotypes are presented in Table 11. The results indicated that the highest values of MP and GMP indices were found for line-8 and line-13 in the first season, as well as line-5, line-8 and line-13 in the second season, where its values were > 6.0. Similar results were obtained by [43]. However, [44] criticize MP index and pointed out that it is expected to have high value of it under low irrigation water application, thus it cannot be used as a valid indicator to identify the tolerant genotypes.

Based on TOL index, the tolerance genotypes can be identified as line-3, line-15 and line-18 in the first seasons, where they have higher values between 1.26 - 1.42 in the first season, and 1.14 - 1.30 in the second season, compared to the values of the other studied genotypes. Whereas, in the second season, line-5 and line-20 have the highest values, namely 1.30 and 1.14. [45] Indicated that the low value of Ys or high value of Yp leads to an increase in TOL index. Criticism of TOL index was reported by [18] and [46], as they considered it not worthy index to screen drought tolerant genotypes and stated that TOL failed to recognize the best genotypes, because it tends to select low-yielding genotypes.

**Table 11.Drought tolerance indices for the studied barley genotypes under full irrigated and water stress treatments in both growing seasons.**

| Genotypes | MP | GMP | TOL | STI | SSI | MP | GMP | TOL | STI | SSI |
|---|---|---|---|---|---|---|---|---|---|---|
| | First season | | | | | Second season | | | | |
| Giza 123 | 4.60 | 4.59 | 0.50 | 0.32 | 0.69 | 4.86 | 4.86 | 0.26 | 0.31 | 0.49 |
| Giza 133 | 4.78 | 4.77 | 0.64 | 0.33 | 0.85 | 5.11 | 5.10 | 0.50 | 0.33 | 0.87 |
| Line-1 | 4.99 | 4.95 | 1.27 | 0.34 | 1.53 | 5.47 | 5.45 | 0.98 | 0.35 | 1.53 |
| Line-2 | 4.32 | 4.31 | 0.44 | 0.30 | 0.65 | 4.49 | 4.48 | 0.48 | 0.29 | 0.95 |
| Line-3 | 5.85 | 5.83 | 0.81 | 0.40 | 0.87 | 6.20 | 6.17 | 1.30 | 0.40 | 1.77 |
| Line-4 | 4.36 | 4.34 | 0.79 | 0.30 | 1.12 | 4.58 | 4.57 | 0.37 | 0.29 | 0.72 |
| Line-5 | 5.11 | 5.10 | 0.52 | 0.35 | 0.65 | 5.52 | 5.52 | 0.03 | 0.35 | 0.05 |
| Line-6 | 6.15 | 6.14 | 0.72 | 0.42 | 0.74 | 6.56 | 6.56 | 0.29 | 0.42 | 0.41 |
| Line-7 | 4.32 | 4.30 | 0.91 | 0.30 | 1.29 | 5.23 | 5.22 | 0.33 | 0.33 | 0.57 |
| Line-8 | 4.38 | 4.36 | 0.68 | 0.30 | 0.97 | 4.79 | 4.78 | 0.50 | 0.31 | 0.93 |
| Line-9 | 4.65 | 4.65 | 0.21 | 0.32 | 0.30 | 4.79 | 4.78 | 0.50 | 0.31 | 0.93 |
| Line-10 | 4.88 | 4.87 | 0.42 | 0.33 | 0.56 | 5.08 | 5.07 | 0.57 | 0.32 | 1.00 |
| Line-11 | 6.07 | 6.06 | 0.69 | 0.42 | 0.73 | 6.42 | 6.41 | 0.36 | 0.41 | 0.50 |
| Line-12 | 5.24 | 5.23 | 0.59 | 0.36 | 0.72 | 5.08 | 5.07 | 0.64 | 0.32 | 1.10 |
| Line-13 | 5.39 | 5.34 | 1.42 | 0.37 | 1.57 | 5.67 | 5.65 | 0.84 | 0.36 | 1.29 |
| Line-14 | 5.02 | 5.01 | 0.53 | 0.34 | 0.68 | 5.04 | 5.03 | 0.62 | 0.32 | 1.09 |
| Line-15 | 4.36 | 4.35 | 0.56 | 0.30 | 0.81 | 4.88 | 4.88 | 0.29 | 0.31 | 0.54 |
| Line-16 | 5.35 | 5.31 | 1.26 | 0.37 | 1.42 | 5.80 | 5.79 | 0.74 | 0.37 | 1.12 |
| Line-17 | 5.38 | 5.36 | 1.03 | 0.37 | 1.18 | 5.51 | 5.50 | 0.75 | 0.35 | 1.18 |
| Line-18 | 5.17 | 5.16 | 0.81 | 0.35 | 0.98 | 5.21 | 5.17 | 1.14 | 0.33 | 1.84 |
| Sum | 100.34 | 100.07 | 14.78 | 6.88 | 0.93 | 106.26 | 106.11 | 11.49 | 6.78 | 0.96 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Mean | 5.02 | 5.00 | 0.74 | 0.34 | 0.93 | 5.31 | 5.31 | 0.57 | 0.34 | 0.96 |

*MP= Mean productivity, GMP=Geometric mean productivity, TOL= Tolerance index, SSI= Stress susceptibility index, STI= Stress tolerance index.*

Table 11 also showed that the studied genotypes with high values of MP and GMP indices tends to have higher value of STI index, namely line-8 and line-13 in the first season, as well as line-5, line-8 and line-13 in the second season, where its values were ≥ 0.4. [47] Reported that STI was more useful index to select the proper cultivars under drought stress.

[48] Reported that cultivars with low SSI values were considered as stress tolerant, as they exhibited a lower reduction in grain yield under low applied irrigation water amounts compared to application of full irrigation. The results in Table (11) indicated that line-7 and line-11 in the first season, as well as line-7 and line-8 in the second season showed the least values of SSI index, namely < 1.0. [20] Indicated that SSI value > 1.0 refers to above-average susceptibility, whereas SSI < 1.0 indicates below-average susceptibility to drought stress.

## 4. CONCLUSIONS

In this investigation, we tested twenty barley genotypes for its ability to tolerate imposed water stress by applying sowing irrigation only and the plants continued its growth seasons using rain fall. It was found that line-6 and line-11 could be selected based on their highest water productivity and use efficiency values. Furthermore, based on drought tolerance indices, line-7, line-8, and line-13 have the ability to withstand the imposed water stress and could be selected genotypes with high yield at both environments.

## REFERENCES


1. Kumari, R & Kotecha, M. Pyhsicochemical and nutritional evaluation of Yava (*Hordeumvulgare* Linn.) International Research Journal of Pharmacy;2015;6(1):70–72.
2. Farag, MA, Xiao, J, Abdallah, HM. Nutritional value of barley cereal and better opportunities for its processing as a value-added food: a comprehensive review. Critical Reviews in Food Science and Nutrition; 2020.https://doi.org/10.1080/10408398.2020.1835817\
3. Sánchez-Díaz M, García JL, Antolín MC, Araus JL. Effects of soil drought and atmospheric humidity on yield, gas exchange, and stable carbon isotope composition of barley, Photosynthetica; 2002;40:415–421.
4. Kooyers, NJ. The evolution of drought escape and avoidance in natural herbaceous populations. Plant Sci.;2015;234:155–162. Doi: 10.1016/j.plantsci.2015.02.012.
5. Srivastava, LM. Plant growth and development: hormones and environment. Ann Bot.;2003; 92:846.
6. Hameed A, Goher M, Iqbal N. Evaluation of Seedling Survivability and Growth Response as Selection Criteria for Breeding Drought Tolerance in Wheat. Cereal Res. Commun; 2010;38:193–202. doi: 10.1556/CRC.38.2010.2.5.
7. Ceccarelli, S, Grando, S, Baum, M. Participatory plant breeding in water-limited environments. ExperimentalAgriculture; 2007;43(4):411-435.OI: http://dx.doi.org/10.1017/S0014479707005327.
8. Sallam A, Mourad AMI, Hussain W. Stephen Baenziger P. Genetic variation in drought tolerance at seedling stage and grain yield in low rainfall environments in wheat (*Triticumaestivum* L.) Euphytica;2018; 214:169. doi: 10.1007/s10681-018-2245-9.
9. Al Ajlouni, Z, Al Abdallat, AM, Al Ghzawi, AA, Ayad, JY, Abu Elenein, JM, Al Quraan, NA, Stephen Baenziger, P. Impact of pre-anthesis water deficit on yield and yield components in barley (Hordeumvulgare L.) plants grown under controlled conditions. Agronomy; 2016);6(33):1-14. DOI: http://dx.doi.org/10.3390/agronomy6020033.
10. Ahmadzadeh, A Determining the best indices of drought stress in selected maize lines. M.Sc. Thesis, Tehran University; 1990,Iran.
11. Zargar, M, Romanova, E, Trifonova,A, Shmelkova, E, Kezimana, P. AFLP analysis of genetic diversity in soybean [Glycine max (l.) Me rr.] Cultivars Russian and foreign selection. Agronomy research; 2017; 15(5):2217 -2225.

12. Istanbuli,T, Baum, M, Touchan, H, Hamwieh, A. Evaluation of morpho-physiological traits under drought stress conditions in barley (HordeumVulgare L.), Photosynthetica; 2020;58(4):1059-1067. DOI: 10.32615/ps.2020.041
13. Rosielle, AA & Hamblin, J. Theoretical aspects for yield in stress and non-stress environments. Crop Sci; 1981; 21: 943–946.
14. Karami, E, Ghannadha MR, Naghavi MR, Mardi, M. Identifying of drought tolerant cultivars in barley. Iranian J. Agric. Sci.; 2005;37:371- 379.
15. Nazari, L &Pakniyat, H. Assessment of drought tolerance in barley genotypes. J. Appl. Sci. 2010;10: 151-156.
16. Ramirez, P & Kelly, JD. Traits Related to Drought Resistance in Common Bean. Euphytica; 1998;99:127-136. http://dx.doi.org/10.1023/A:1018353200015
17. Fernandez, GCJ. Effective Selection Criteria for Assessing Stress Tolerance, Proc. Int. Symp. Adaptation of Vegetables and Other Food Crops in Temperature and Water Stress, Kuo, C.G., Ed. Tainan; AVRDC Publ.; 1992;257–270; Taiwan:
18. Sio-Semardeh, A, Ahmad, A, Poustini, K, Mohammadi, V. Evaluation of drought resistance indices under various environmental conditions. Field Crops Research; 2006;98:222–229.
19. Fischer, RA & Maurer, R. Drought tolerance in spring wheat cultivars. I: Grain yield response. Australian Journal of Agricultural Research; 1978;29:897–912.
20. Guttieri, MJ, Stark, JC, Brien, K and Souza, E. Relative sensitivity of spring wheat grain yield and quality parameters to moisture deficit. Crop Sci.; 2001; 41:327-335.
21. Allen, RG, Pereira, LS, Raes, D, Smith, M. Crop evapotranspiration —guidelines for computing crop water requirements. FAO Irrigation and drainage paper 56. Food and Agriculture Organization; 1998;Rome. http://www.fao.org/docrep/x0490e/x0490e00.htm
22. Snyder, RL, Orang, M, Bali, K, Eching, S. Basic irrigation scheduling BIS;2004; http://www.waterplan.water.ca.gov/landwateruse/wateruse/Ag/CUP/Californi/Climate_Data_010804.xls
23. Page, ALR, Miller, H & Keeney, DR. Methods of Soil Analysis. Part 2: Chemical and Microbiological Properties. 2nd Edition, Agronomy Monograph, No. 9, ASA, CSSA, and SSSA; 1982; Madison.
24. Horneck, DA, Ellsworth, JW, Hopkins, BG, Sullivan, DM, Stevens, RG. Managing Salt- affected Soils for Crop Production. A Pacific Northwest Extension publication, Oregon State University; 2007.
25. Piper, CS. Soil and Plant Analysis. Inter Science Publication; 1950; New York, Reddy, BVS, Reddy, PS, Bidinger, F.
26. Stackman, WP. Determination of pore size by the air bubbling pressure method. Proceedings of the Wageningen Symposium on water in the unsaturated zone, Netherlands; 1966; UNESCO. 366- 372.
27. Blak, GR & Hartge, KH. Bulk Density," In: A. Klute, et al., Eds., Methods of Soil Analysis, Part I, ASA and SSSA, Madison; 1986;363-375.
28. Smith, M. CROPWAT—A Computer Program for Irrigation Planning and Management; Irrigation and Drainage. Paper 46; Food and Agriculture Organisation: Rome; 1992; Italy.
29. Majumdar, DK. Irrigation Water Management: Principles and Practice. 2nd ed. Prentice-Hall of India; 2002; New Delhi- 110001.487p.
30. Stanhill, G. Water use efficiency. Advances in Agronomy; 1986; 39:53-85.
31. Zhang Cun-Hui. Compound decision theory and empirical Bayes methods: Invited paper. The Annals of Statistics;2003; 31(2):379-390.
32. Bouslama M & Schapaugh, WT. Evaluation of three screening techniques for heat and drought tolerance. Crop Science; 1984;24:933–937.
33. Gomez, KA & Gomez, AA. Statistical procedures for agricultural research, 2nd edition. John Wiley and Sons; 1984; 680. New York.
34. Waller, RA & Duncan, DB. A Bayes Rule for the Symmetric Multiple Comparison Problem, Journal of the American Statistical Association. 1969; 64:1484-1504.
35. Cochran, WG. The distribution of the largest of a set of estimated variances as a fraction of their total. Ann. Eugen; 1941; 11:47-52.
36. Tawfelis, MB. Stability parameters of some bread wheat genotypes (Triticumaestivum L.) in new and old lands under Upper Egypt, Egypt. J. Plant Breed; 2006; 10 (1):223-246.

37. Rajaram, S, M. van Ginkel & Fischer RA. CIMMYT's wheat breeding mega- environments (ME). p. 1101–1106. In Proc. Intl. Wheat Genet.Symp., 8th, Beijing; 2003; China. 1–6 Sept. Agric. Scientech Press; 1994; Beijing, China.
38. Yan, W & Kang, MS. GGE Biplot Analysis: A Graphical Tool for Breeders. Geneticists and Agronomists. 1st Edn., CRC Press LLC., Boca Roton; 2003;271. Florida.
39. Ali, AH &Mansorr, HN. Effect of imposed water stress at certain growth stages on growth and yield of barley grown under different planting pattern. Plant Archives; 2018;18(2):1735-1744.
40. Katerji, N, Mastrorilli, M, van Hoorn, JW, Lahmer, FZ, Hamdy, A, Oweis, T. Durum wheat and barley productivity in saline–drought environments. Europ. J. Agronomy; 2009;31:1–9.
41. FAO. The State of Food Insecurity in the World; 2003. ISBN 92-5-104986-6.
42. Goswami, SB & Sarkar, S. Effect of irrigation on crop water productivity of pointed gourd (Trichosanthesdioica) at varying bed width planting system. Indian Journal of Agricultural Sciences; 2007;77(6):340-343.
43. Almeselmani, M, AL-Rzak Saud, A, Al-Zubi, K, AL- Ghazali, S, Hareri, F, AL-Nassan, M, Ammar, MA, Kanbar, OZ, AL-Naseef, H, AL-Nator, A, AL-Gazawy, A, Teixeira da Silva, JA. Evaluation of physiological traits, yield and yield components at two growth stages in 10 durum wheat lines grown under rainfed conditions in southern Syria. CercetăriAgronomice in Moldova; 2015; 2(162):29-49.
44. Shirazi, A, Bahiraee, A, Ahmadi, E, Nazari, H, Heidari, B, Borjian, S. The Effect of the duration of in vitro maturation (IVM) on parthenogenetic development of ovine oocytes. American Journal of Molecular Biology; 2009; 1:181-191.
45. Zangi, MR. Correlation between drought resistance indices and cotton yield in stress and non-stress conditions. Asian J. of Plant Sci.; 2005;4:106-108.
46. Dorostkar, S, Dadkhodaie, A & Heidari, B. Evaluation of grain yield indices in hexaploid wheat genotypes in response to drought stress. Archives Agro. And Soil Sci. (2014); 61:397-413.
47. Moghaddam, A & Hadizadeh, MH. Response of corn (Zea mays L.) hybrids and their parental lines to drought using different stress tolerance indices. Seed Plant;2002;18(3): 255-272.
48. Winter, SR, Musick, JT, Porter, KB. Evaluation of screening techniques for breeding drought-resistant winter wheat. Crop Sci.; 1988; 28:512- 516.