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ASSESSING DROUGHT TOLERANCE OF SIXTEEN BARLEY GENOTYPES UNDER DIFFERENT IRRIGATION TREATMENTS

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ABSTRACT: Water shortage is one of the most serious challenges in crop production particularly under current climatic change. The study aims to compare the performance of 16 barley genotypes under three irrigation treatments to identify the drought tolerant and sensitive genotypes. In addition, to study the genetic variability and heritability of the major agronomic traits under water deficit and normal irrigation conditions. Two field experiments were carried out at Kafr El-Hamam Research Station, Zagazig, Agricultural Research Center during winter sowing seasons of 2014-2015 and 2015-2016. Three irrigation treatments were used; irrigation once at sowing (T1), twice at sowing and 30 days later (T2) and thrice at sowing, 30 and 60 days after sowing, respectively (T3), using surface irrigation. All investigated traits were affected significantly by irrigation treatments. The genotypes G6, G8, G9, G10, G11, G12, G14 and G15 displayed the highest grain yield and its components at all irrigation treatments. Furthermore, four drought tolerance indices were calculated based on grain yield under stress and non-stress conditions, *i.e.*, mean productivity (MP), geometric mean productivity (GMP), stress tolerance index (STI) and yield index (YI). It was found that G10 exhibited the highest values in the four indices followed by G14, G9, G8 and G13. On the other hand, the lowest value was presented by G4 followed by G1, G7 and G3. The cluster analysis classified the genotypes based on the tolerance indices into four groups. The first group (A) presented G10, which had the highest tolerance indices and it was considered as highly drought tolerant genotype. Moreover, group B presented G8, G9, G11 and G14 had relatively high values of tolerance indices. Otherwise, group C which presented ten genotypes had intermediate values of the estimated indices. While, group D displayed G4 which had the lowest value and it was considered drought-sensitive genotype. The highest phenotypic (PCV) and genotypic (GCV) coefficient of variation values were assigned for number of spikes/m^2, grain number/spike and 1000-grain weight. The difference between PCV and GCV values was very low for days to heading and days to maturity and was intermediate for biological, grain, straw yields and plant height while it was relatively high for number of spikes/m^2, grain number/spike and 1000-grain weight. The heritability in broad sense was very high for each of days to heading, days to maturity, plant height and 1000-grain weight and was moderately high for the remaining traits under both conditions.

Key words: Barley genotypes, yield and yield components, irrigation treatments, drought tolerance indices, cluster analysis, genotypic and phenotypic coefficients of variation.

INTRODUCTION

Barley (*Hordeum vulgare* L.) is an important cereal crop worldwide and it is one of the first domesticated and cultivated cereals (**Yang *et al.*, 2017**). It ranks fourth in cereal acreage and production after wheat, maize and rice (**FAOSTAT, 2018**). It displays higher tolerance to adverse environmental conditions compared to other cereal crops (**Cossani *et al.*, 2012;**

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Ghotbi-Ravandi *et al.*, 2014). Consequently, it is commonly grown in marginal areas and lands suffering water shortage and salinity. In Egypt, it is mostly grown in rainfed regions in the North West coastal region and in North Sinai. Its cultivated area has been decreased gradually in the Nile valley, principally in the regions are suitable for sowing other strategic crops as wheat. Otherwise, its area increased in the newly reclaimed lands under different irrigation systems (**Noaman, 2008**).

Barley cultivated area in Egypt was 96000 faddan during the 1980s, while it became more than 184680 faddan in 2016, furthermore, the total production in 2016 was 120100 tonnes (**FAOSTAT, 2018**). It is principally used for animal and poultry feeding, in addition to malt and some uses in the pharmaceutical industry (**Biel and Jacyno, 2013**). Furthermore, it contains 3 to 7% β-glucan, which is very important dietary fiber that has health benefits (**Oscarsson *et al.*, 1996**). For that reason, recently there is an increasing interest for human consumption due to its nutritional and healthy values especially hull-less barley as an ideal type for achieving this goal (**Setotaw *et al.*, 2010; Biel and Jacyno, 2013**).

Global population is increasing while water resources for crop production are decreasing (**Dozier et *al.*, 2017; Arshadi *et al.*, 2018**). Limited irrigation water is one of the major stresses that reducing crop production and quality in agricultural systems (**Fahad *et al.*, 2017**). Furthermost, the importance of drought has become more serious with increasing climate change and global warming (**Gammans *et al.*, 2017**). The increase of air temperature and the decrease of rainfall caused heat stress and drought in many areas, especially in arid and semi-arid regions (**Khan *et al.*, 2015**). Egypt suffers from severe water deficit in recent years, facing water shortage amounted about 7 billion cubic meters annually and this may increase in the near future due to the effect of Ethiopian Renaissance Dam (**Osman *et al.*, 2016**). For that reason, using genotypes that use water more efficiently is crucial to reduce the agricultural water consumption.

Barley germplasm provides very fruitful source of genes and rich sources of genetic variation for improving drought tolerance (**Wang *et al.*, 2015; Al-Abdallat *et al.*, 2017**). The genotypes exhibit different ability to produce acceptable yield under water deficit conditions. Accordingly, it is essential to screen the genetic potentiality of these genotypes under different water regimes (**Abdel-Moneam *et al.*, 2014; El-Shawy *et al.*, 2017; Mansour *et al.*, 2017**). Additionally, evaluation the performance of barley genotypes under stress as well as favorable conditions is important at the beginning of breeding programs to identify suitable genotypes for environments, which helps in improving crop productivity.

The drought has different impacts over barley growing stages; in general, during the reproductive development stage drought is a key factor affecting spike number/square meter (**Garcia del Moral *et al.*, 2005**). During spikelet initiation, drought leads to reduce grain set and grain number/spikelet, while during grain filling period it leads to reduce individual grain weight (**Samarah *et al.*, 2009**). Moreover, drought in the beginning of grain filling has negative effects on grain weight and grain yield more than during late grain filling period (**Garcia del Moral *et al.*, 2003**).

Drought tolerance is defined as the ability of a genotype to produce acceptable yield under limited water better than the other genotypes (**Ramirez and Kelly, 1998**). Whereas, drought sensitivity is the reduction in yield of the genotypes under drought stress (**Blum, 1988**). There are many drought tolerance indices can be used for identifying genotypes based on grain yield under stress and non-stress conditions, as mean productivity (MP), geometric mean productivity (GMP), and yield index (YI), (**Hossain *et al.*, 1990; Fernandez, 1992; Gavuzzi *et al.*, 1997**). Therefore, screening genotypic performance under water stress and favorable conditions is proposed as useful selection criterion to evaluate yield stability under stress and non-stress environments (**Pinter *et al.*, 1990; Mardeh *et al.*, 2006**).

This study aims to compare the performance of 16 barley genotypes (14 advanced lines and 2 commercial varieties) under three irrigation treatments to identify suitable genotypes for drought stress as well as favorable conditions.

Also, to study the genetic variability and heritability for major agronomic traits under water deficit and normal irrigation conditions, which could contribute in improving of barley productivity under favourable and unfavourable conditions.

MATERIALS AND METHODS

Description of Experimental Site

Two field experiments were carried out at Kafr El-Hamam Research Station, Zagazig, Agricultural Research Center (30°58' N and 31°50' E), Egypt, during winter sowing seasons of 2014-2015 and 2015-2016. Trials were sown on 25 and 29 November in the two seasons, respectively. Based on the soil analysis of experimental site (depth of 0-30 cm), it is characterized as clay loam and the other physical and chemical characteristics are presented in Table 1. Meteorological data (averages of minimum and maximum temperatures and total rainfall) was recorded at station close to the experimental site are presented in Table 2.

Plant Material and Experimental Design

Sixteen six-row barley genotypes including two Egyptian check verities [Giza 123 (G1) and Giza 134 (G2)] and fourteen breeding lines (G3 to G16) were evaluated under three irrigation treatments. The evaluated genotypes are presented in Table 3. Spilt-plot design was used, where the irrigation treatments were laid out in main plots and genotypes were occupied the sub-plots randomly, in three replications. The irrigation treatments were separated by 6-m away from each other, including two field canals. Each plot consisted of fifteen rows 20 cm apart, 3.5 m long. Calcium Superphosphate (15.5% P_2O_5) and Ammonium nitrate (33% N) fertilizers were applied at the recommended rates; 15.5 kg P_2O_5/fad and 45 kg N/fad. The other agronomic practices including, pest, disease and weed control were applied as recommended for barley production in the region.

Irrigation Treatments

Three irrigation treatments were used *e.g.* irrigation once at sowing (T1), twice at sowing and 30 days later (T2) and thrice at sowing, 30 and 60 days after sowing, respectively (T3), using surface irrigation.

Data recorded

Days to heading were recorded as the number of days from sowing date up to spikes emergence on most of plants (more than 50% of spikes were fully headed) in each plot. Days to maturity were scored as the number of days from sowing to physiological maturity, when 50% of the peduncles were ripe and showed complete loss of green color. Plant height (cm) was measured at maturity stage as the distance from the base of the plant to the tip of the spike, excluding owns. Number of spikes was counted in 0.5 m^2 at maturity stage. Five spikes were taken randomly from the five middle rows of each sub plot to measure grain number/spike, 1000-grain weight (g) and grain weight/spike (g). Grain yield (kg/fad.) and biological yield (kg/fad.) were measured from square meter and converted to kilograms/faddan. Straw yield (kg/fad.) was estimated as the difference between biological and grain yields.

Data analysis

The analysis of variance (ANOVA) was applied to test the significance of genotype (G), irrigation treatments (T), and the interaction effect for all studied traits. Least significant difference (LSD) values were calculated at the 5% probability level (**Steel *et al.*, 1997**). In addition, drought tolerance indices were calculated using the following parameters:

$$\text{Mean productivity MP} = \frac{Ys+Yp}{2}$$

(**Hossain *et al.*, 1990**)

$$\text{Geometric mean productivity GMP} = \sqrt{(Ys \times Yp)}$$

(**Fernandez, 1992**)

$$\text{Stress tolerance index STI} = \frac{Ys \times Yp}{(\bar{y}\ p)^2}$$

(**Fernandez, 1992**)

$$\text{Yield index YI} = \frac{Ys}{\bar{y}s}$$ (**Gavuzzi *et al.*, 1997**)

Where Ys is the grain yield of each genotype under water deficit conditions, Yp is the grain yield of each genotype under normal irrigation, $\bar{Y}s$ is average of all genotypes under water

Table 1. Physical and chemical properties of the experimental soil

Characteristic	Value
Soil particles distribution	
Sand (%)	15.6
Silt (%)	38.9
Clay (%)	45.5
Soil texture	Clay loam
Field capacity (FC, %)	30.5
Calcium carbonate ($CaCO_3$, g kg^{-1})	9.0
Organic matter (g kg^{-1})	3.4
pH (1: 2.5 soil-water suspension)	7.95
Electrical conductivity EC (dsm^{-1})	1.32
Soluble cations and anions (mmolc L^{-1}) *	
Calcium (Ca^{++})	5.67
Magnesium (Mg^{++})	2.70
Sodium (Na^{+})	2.90
Potassium(K^{+})	1.93
Carbonate ($CO_3^{=}$)	-
Bicarbonate (HCO_3^{-})	4.90
Chlorine (Cl^{-})	2.87
Sulphate ($SO_4^{=}$)	3.43
Available nutrient (mg kg^{-1} soil)	
Nitrogen (N)	45.6
Phosphorus (P)	12.0
Potassium (K)	245

* Soil water extract 1: 5

Table 2. Average of minimum and maximum temperatures and total rainfall during the two growing seasons in the experimental site

	2014-2015			2015-2016		
	T_{min}	T_{max}	Rain. (mm)	T_{min}	T_{max}	Rain. (mm)
November	13.3	25.4	12.0	14.4	26.0	9.3
December	10.3	22.7	10.0	9.6	20.6	13.2
January	7.1	18.9	27.3	6.8	18.2	22.3
February	7.7	20.3	33.5	9.2	24.0	26.5
March	10.7	25.5	8.6	11.3	26.2	10.6
April	11.7	28.5	6.1	14.4	33.1	0.0
May	16.8	34.1	0.0	17.4	34.3	0.0

Table 3. Code, origin and pedigree of the used barley genotypes

Code	Genotype	Pedigree	Origin	Year of release
G1	Giza 123	Giza 117 / FAO 86	Egypt	1988
G2	Giza 134	Alando-01/4/W12291/3/Api/CM67//L2966-69	ICARDA	2011
G3	Line 1	Giza 117 /6/Lignee527//Bahtim/DL7 1/3/Api/CM67/ /Mzq/5/ Ager/ Api/CM67/3/Cel/WI2269//Ore/4/Hamra-01	Egypt	-
G4	Line 2	Giza 117 /6/Lignee527//Bahtim/DL7 1/3/Api/CM67 //Mzq/5/ Ager// Api /CM67 /3/Cel/WI2269 //Ore/4/Hamra-01	Egypt	-
G5	Line 3	Giza 119 /7/Alando-01/5/Ci01021/4/CM67/U.Sask. 1800//Pro/ CM67/3/ DL/70/6/Alando/Hamra	Egypt	-
G6	Line 4	C .C 89 /6/Cen/Bglo'S'/5/Baca'S'/3/AC253// CI05761/ 4/Mari/ Aths*2//M-Att-73-337-1	ICARDA	-
G7	Line 5	C .C 89 /6/Cen/Bglo'S'/5/Baca'S'/3/AC253//CI05761/ 4/Mari/ Aths*2//M-Att-73-337-1	ICARDA	-
G8	Line 6	Giza 117/7/Giza 121/CI06248/4/Apm/B65//11012-/3/ Api/CM67//Ds/Apro/5/Srs-04/6/Can/Bgla"S"	Egypt	-
G9	Line 7	Giza 121/6/Lignee527//Bahtim/DL71/3/Api/CM67// Mzq/5/ Ager//Api/CM67/3/Cel/WI2269//Ore/4/Hamra-01	Egypt	-
G10	Line 8	Giza 125/5/Alanda-01/4/WI2291/3/Api/CM67//L2966-69	Egypt	-
G11	Line 9	Lignee 527/NK 1272/4/Lignee 527//Bahtim/ DL71/3/ Api/CM67/Mzq/5/Arar/Rhn-03	Egypt	-
G12	Line 10	Rihane- 03 //Giza 2000	Egypt	-
G13	Line 11	Rihane- 03/California Mariout	Egypt	-
G14	Line 12	ACSAD 1182/ACSAD952//Deir Alla	ICARDA	-
G15	Line 13	ACSAD 1164/3/Mari/Aths*2//M-Att-73-337-1/7/GIZA121/ CI06248/4/Apm/B65//11012-2/3/Api/ CM67//Ds/Apro/5/Srs-04/6/Can/Bgla"S"	Egypt	-
G16	Line 14	Aths/Lignee 686/5/ACSAD618/5/M9878/CARDO// QUUINA/3/ CHAMICO/4/CIRU	ICARDA	-

deficit conditions and $\bar{Y}p$ is average of all genotypes under normal irrigation. Cluster analysis based on tolerance indices using squared Euclidian distance were performed using the statistical software SPSS version 16.0 (**SPSS Inc., 2007**).

Variance components included phenotypic (σ^2P) and genotypic (σ^2G) components were estimated according to **Kwon and Torrie (1964)** based on combined data of the two growing seasons. Genotypic (GCV) and phenotypic (PCV) coefficients of variation was estimated according to **Burton and Devane (1953)**.

RESULTS AND DISCUSSION

Analysis of Variance

The combined analysis of variance for irrigation treatments, genotypes, years and their interactions is presented in Table 4. Highly significant differences were detected among genotypes as well as between irrigation treatments for all investigated traits. Which provides evidence for presence of genetic variability in the studied genotypes and treatments. Moreover, the mean squares magnitude of irrigation and genotypes exhibited that the evaluated traits were more

Table 4. Mean squares of studied traits for 16 barley genotypes under irrigation treatments over two growing seasons

SV	d.f	DH	DM	PH	NS/m^2	GNS	1000GW	SY	BY	GY
Irrigation (I)	2	697.3**	3289.3*	31960**	456700**	2126**	54.74*	124661723**	163900000**	2702004**
Genotype (G)	15	50.9**	49.4**	1223**	13350**	118.1**	176.3**	2605179**	4294000**	772444**
Year (Y)	1	1280**	493.3*	17750**	158400**	1273**	1497.5**	4309654**	27410000**	9979699**
I×G	30	0.016^{NS}	0.07^{NS}	140.3**	3450**	51.57**	26.75*	156039**	62620**	47151**
I×Y	2	0.415**	5287.1**	142.6**	1955**	3.145**	0.569*	623980**	576600**	5935^{NS}
G×Y	15	0.03**	0.09^{NS}	5.3**	57.14**	0.1747**	0.901**	11700^{NS}	10470**	11533^{NS}
I×G×Y	30	0.001^{NS}	0.05^{NS}	0.76**	14.76^{NS}	0.076^{NS}	0.178^{NS}	9025^{NS}	220.3^{NS}	8814^{NS}

NS: Not significant, * $P < 0.05$, ** $P < 0.01$

DH (Days to heading), DM (Days to maturity), PH (Plant height), SY (Straw yield/fad., kg), BY (Biological yield/fad., kg), NS/m^2 (N. of spikes/m^2), GNS (grain number/spike), 1000GW (1000 grain weight, g), GY (Grain yield/fad., kg).

affected by irrigation than genotypes except 1000-grain weight. The interaction between irrigation and genotypes had a smaller magnitude than the main effect of irrigation and genotypes but it was significant for all traits under investigation, except days to heading and days to maturity. This significant interaction reveals to the genotypes performed differently under different irrigation treatments. Nevertheless, the significant difference between the two years due to weather conditions (Table 1) the three ways interaction between irrigation, genotypes and years was not significant for most studied traits. These results are in consonance with **Abd El-Raouf *et al.* (2012); Khokhar *et al.* (2012); Abdel-Moneam *et al.* (2014); Subhani *et al.* (2015); El-Denary and El-Shawy (2016); Mansour *et al.* (2017); Mariey and Khedr (2017) and El-Hashash and Agwa (2018).** Since, they found significant differences between barley genotypes, irrigation treatments and their interaction.

Mean Performance

Days to heading was significantly affected by irrigation treatments, it ranged between 80 days at T1 to 92.0 days at T3. The genotypes; G4, G12, G10 and G3 exhibited the earliest heading, while genotypes G14, G13, G8 and G6 displayed the latest heading under the three treatments (Fig.1, A). Likewise, days to maturity was significantly differed between irrigation treatments, it varied between 106.8 days at T1 to 129.4 days at T3. The earliest maturity was assigned for genotypes G4, G12 and G10 while, the latest maturity was observed for G14, G13 and G6 under the three treatments (Fig.1, B). All genotypes showed significant differences among irrigation treatments. Furthermore, it is interest to note that the early heading genotypes were also early maturing in most cases, as well, analogous manner observed for the late ones. The genotypes displayed early heading and maturity under water deficit compared with well-irrigated conditions. Therefore, earliness could be considered as an escape strategy and resilient adaptation under drought stress (**Shavrukov *et al.*, 2017**).

Under water deficit, the genotypes presented short vegetative growth stage compared to the well irrigated. Plant height was depressed significantly due to decreasing of the amount of irrigation water applied, it decreased from 151.7 cm at T3 to 79.6 cm at T1. The shortest plants were assigned for G13 and G11 genotypes while the tallest plants were shown by G1, G2 and G5 under the three treatments (Fig.1, C).

Number of spikes/m^2 was significantly differed in response to irrigation treatments. It varied between 268 at T1 to 442 spikes/m^2 at T3. The genotypes; G8, G11, G16 and G7 displayed

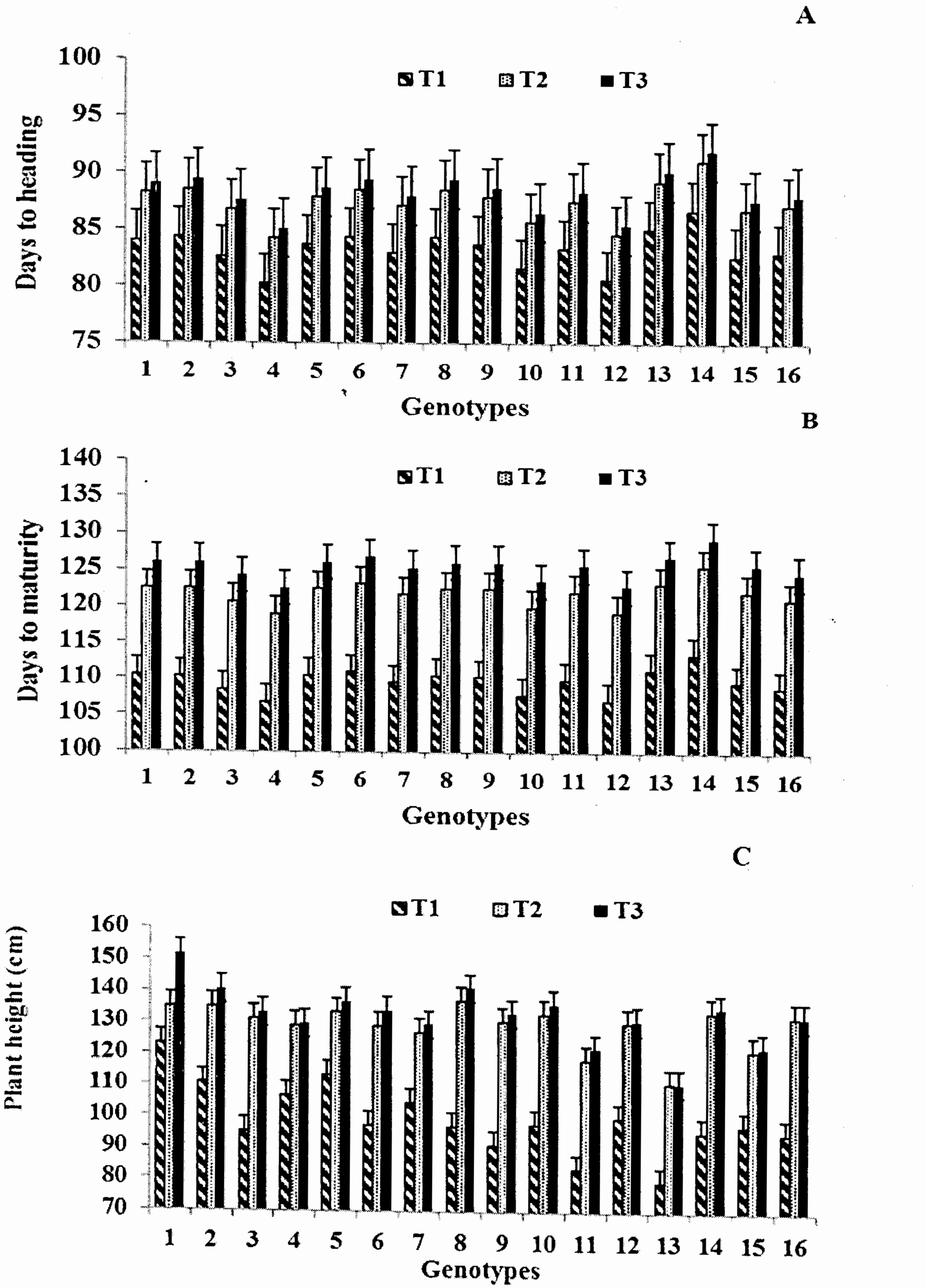

Fig. 1. Impact of irrigation treatments on days to heading (A), days to maturity (B) and plant height (C) for the 16 barley genotypes

the fewest spike number/m^2 at T1, while G7, G4, G6 and G1 showed the fewest number at T2 and T3. On the other hand, G13, G10, G5 and G14 exhibited the uppermost number at T1 and G14, G10 and G15 showed copious number of spikes at T2 and T3 (Fig.2, A). Consonancy, number of grains/spike varied significantly by irrigation treatments. It ranged between 40 at T1 to 59 grains/spike at T3. The genotypes G1, G15 and G5 presented the fewest grain number, while G6 presented the highest value under the three treatments (Fig. 2, B). Likewise, 1000 grain weight significantly decreased under water deficiency, and the genotypes exhibited different performances. It varied between 28 at T1 to 43 g at T3. The lightest 1000-grain weight was assigned for G13, G3 and G4 genotypes at T1 and T2 while G3, G4 and G16 had the lightest grain index at T3. Whereas, the genotypes; G1, G11, G8 and G7 exhibited the heaviest 1000-grain weight under the three treatments (Fig. 2, C).

Biological yield was significantly affected by water limitation, it ranged between 4037 at T1 to 7941 kg/fad., at T3. The genotypes; G4, G2, G8 and G1 presented the lowest biological yield, while G6, G11, G12, G10 and G13 gave the highest ones under the three treatments (Fig. 3, A). Correspondingly, straw yield varied significantly by irrigation treatments. It varied between 2226 at T1 to 5517 kg/fad., at T3. The genotypes; G2, G8, and G4 presented the lowest values at the three treatments while G6, G11and G13 genotypes produced the highest straw yield under the three treatments (Fig. 3, B). Finally, grain yield significantly decreased due to water deficiency, it ranged between 1629 at T1 to 3041 kg/fad., at T3. G4 exhibited the lowest grain yield while G10 displayed the highest one under the three treatments (Fig. 3, C).

Generally, difference between irrigation treatments T2 and T3 was largely varied for all investigated traits. Particularly the genotypes; G1, G2, G4, G6, G12 and G14 did not present significant difference in their grain yield and its components between T2 and T3. Thereupon, these genotypes could be grown with just twice irrigations, as any increase in the amount of irrigation did not produce further significant increase in grain yield. Other researchers reported the difference between barley genotypes in their response to different irrigation treatments as **Samarah *et al.* (2009), Abd El-Raouf *et al.* (2012), Khokhar *et al.* (2012), Abdel-Moneam *et al.* (2014), Pecio and Wach (2015), Subhani *et al.* (2015), El-Denary and El-Shawy (2016), Mansour *et al.* (2017), Mariey and Khedr (2017) and Soleimani *et al.* (2017).**

Drought Tolerance Indices and Cluster Analysis

Using different drought tolerance indices to identify the tolerant and sensitive genotypes is more useful and accurate assessment of yield performance and drought resistance (**Nouri *et al.*, 2011**). Tolerance indices; MP, GMP, STI and YI were calculated based on grain yield under water deficit and normal irrigation conditions (Table 5). The highest indices were observed for genotype G10 followed by G14, G9, G8 and G13, herby, these genotypes are more tolerant to drought stress. While the lowest values were registered by G4 followed by G1, G7 and G3, therefore they could be considered as sensitive ones. Additionally, cluster analysis was estimated based on the tolerance indices. It classified the genotypes into four groups A, B, C and D with 1, 4, 10 and 1 genotypes, respectively (Fig. 4). In this analysis, group A presented G10, which had the highest tolerance indices. Therefore, it is considered highly drought tolerant genotype, and the most desirable genotype for both conditions. Followed by group B (G8, G9, G11 and G14) had high values (drought-tolerant genotypes). Additionally, group C presented 10 genotypes which had intermediate indices values. This group was divided into two sub-groups, included 3 and 7 genotypes. The seven genotypes (G5, G16, G6, G12, G2, G15 and G13) presented higher values of tolerance indices than the three genotypes (G3, G7 and G1), therefore, they are considered more tolerant. On the other hand, group D displayed G4 which had the lowest value, subsequently; it is considered drought-sensitive genotype. These results are consistent with the findings of **Nazari and Pakniyat (2010), Sharafi *et al.* (2011); Zare (2012); Subhani *et al.* (2015) Mansour *et al.* (2017), Soleimani *et al.* (2017), Mariey and Khedr (2017) and El-Hashash and Agwa (2018).**

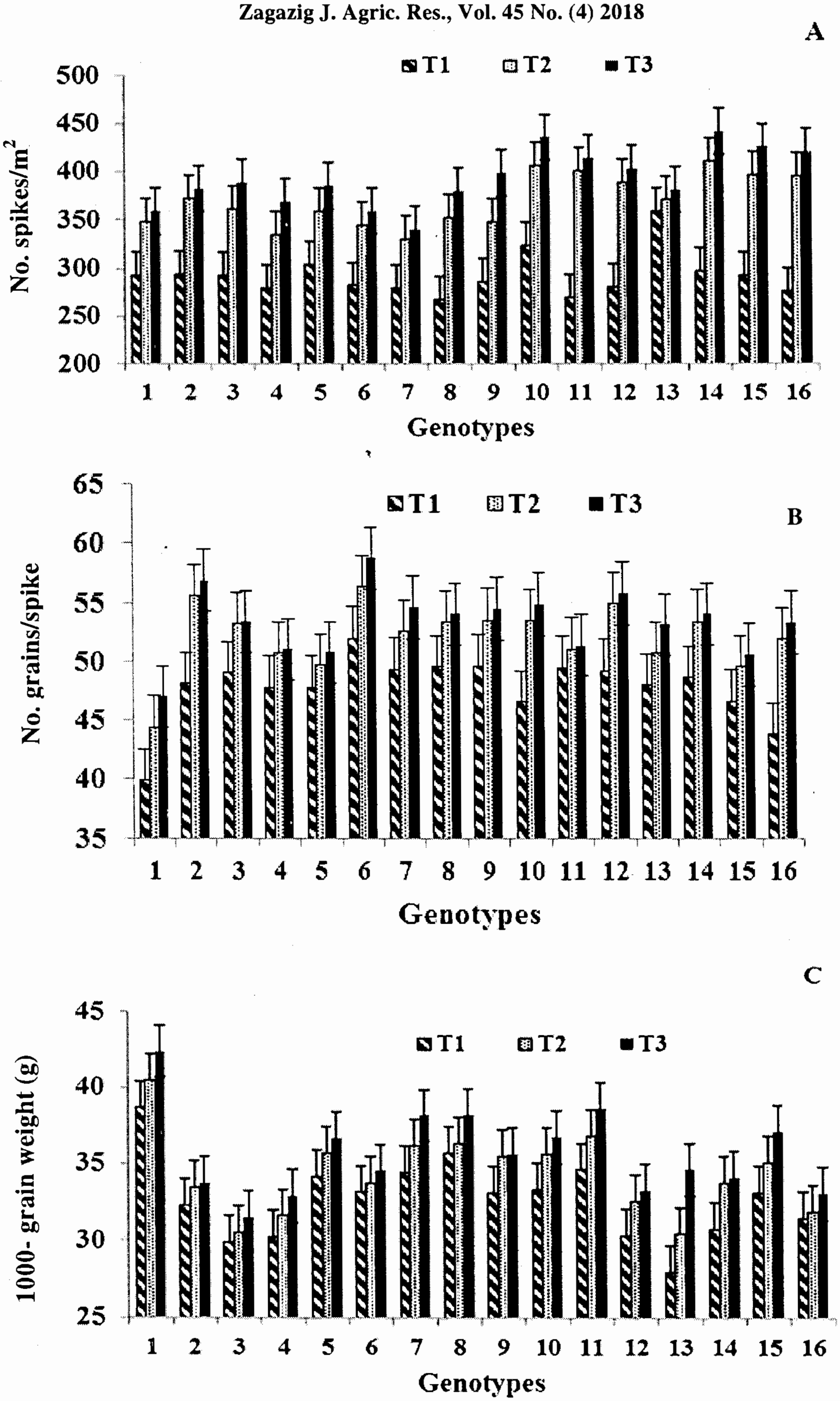

Fig. 2. Impact of irrigation treatments on number of spikes/m^2 (A), number of grains/spike (B) and 1000-grain weight (g) (C) for the 16 barley genotypes

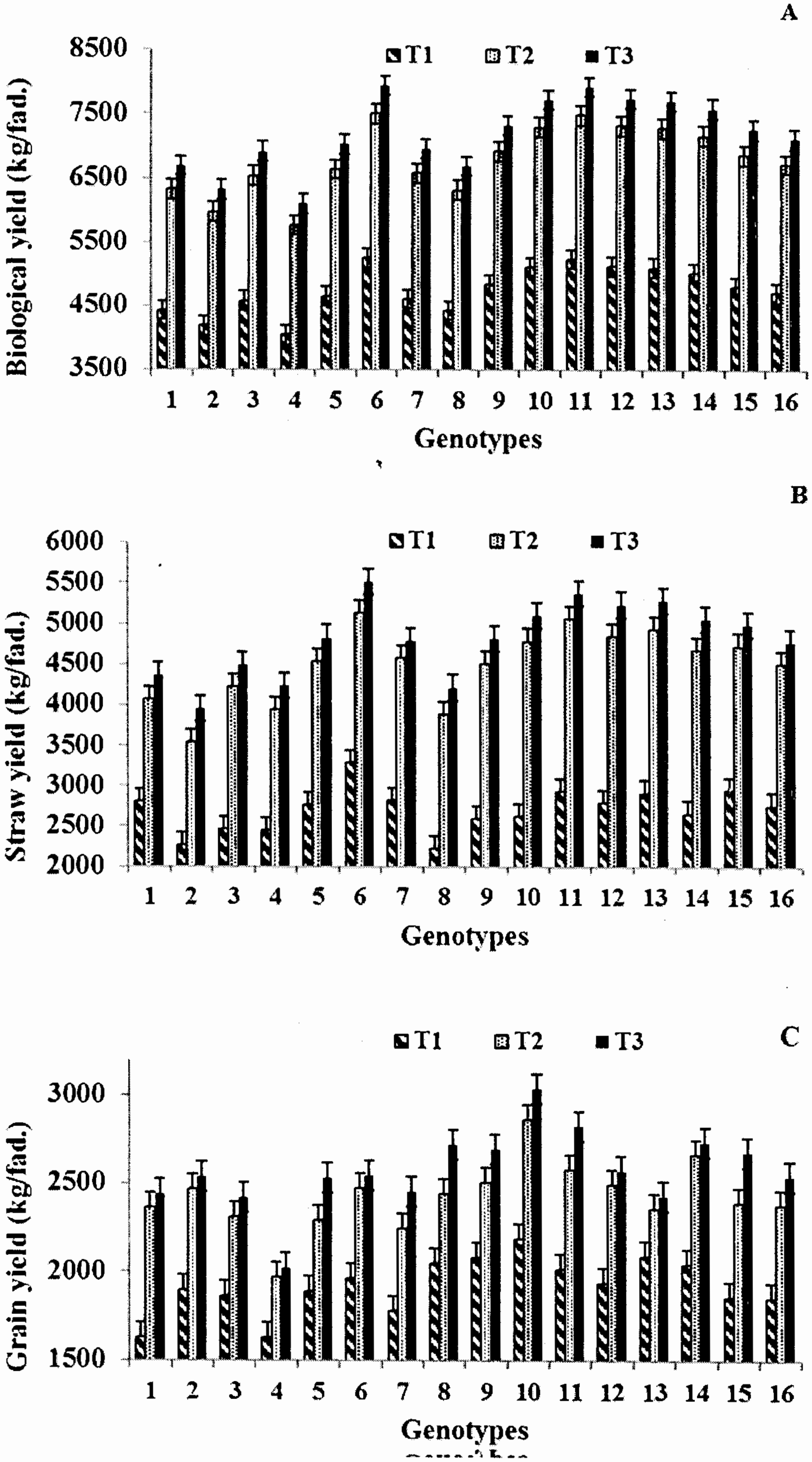

Fig. 3. Impact of irrigation treatments on biological yield (A), straw yield (B) and grain yield (C) for the 16 barley genotypes

Table 5. Drought tolerance indices for 16 barley genotypes under water deficit and normal irrigation conditions (averaged over the two growing seasons)

Genotype	Ys	Yp	MP	GMP	STI	YI
G1	1628	2498	2063	2017	0.60	0.85
G2	1895	2589	2242	2215	0.73	0.99
G3	1862	2420	2141	2123	0.67	0.97
G4	1629	2069	1849	1836	0.50	0.85
G5	1891	2529	2210	2187	0.71	0.98
G6	1964	2570	2267	2246	0.75	1.02
G7	1780	2449	2115	2088	0.65	0.93
G8	2048	2721	2384	2361	0.83	1.07
G9	2079	2690	2385	2365	0.83	1.08
G10	2184	3041	2613	2578	0.99	1.14
G11	2014	2825	2420	2385	0.84	1.05
G12	1936	2605	2270	2246	0.75	1.01
G13	2089	2466	2278	2270	0.76	1.09
G14	2038	2855	2447	2412	0.86	1.06
G15	1860	2676	2268	2231	0.74	0.97
G16	1854	2536	2195	2168	0.70	0.96

Yp: Grain yield under normal irrigation, Ys: Grain yield under drought stress, MP: Mean productivity, GMP: Geometric mean productivity, STI: Stress tolerance index, YI: Yield index.

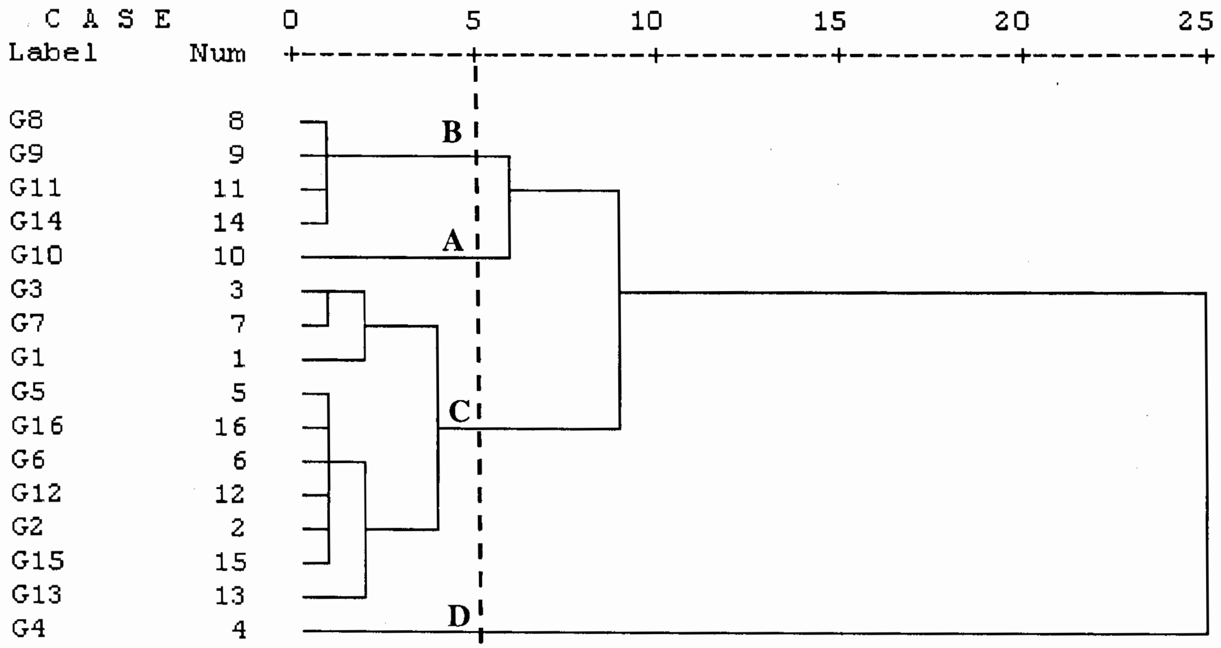

Fig. 4. **Dendogram of the phenotypic distances among 16 barley genotypes under water deficit and normal irrigation conditions based on grain yield and the drought tolerant indices. With cutting dendrogram obtained from Ward method in distance five, the genotypes were classified into four groups A (highly drought-tolerant, one genotype), B (drought-tolerant, 4 genotypes), C (moderate drought-tolerant, 10 genotypes were divided into two sub-groups, 3 and 7 genotypes) and D (drought-sensitive, one genotype)**

Genetic Variability and Heritability

Phenotypic (PCV) and genotypic (GCV) coefficient of variation for investigated traits under water deficit and normal irrigation conditions are presented in Table 6. The highest PCV and GCV values were assigned for number of spikes/m^2, grain number/spike and 1000-grain weight. In general, PCV values were higher than GCV ones for all studied traits under both conditions. Notwithstanding, the differences between PCV and GCV values were small. This difference was very low for days to heading and days to maturity, intermediate for biological yield, grain yield, straw yield and plant height while it was relatively high for number of spikes/m^2, grain number/spike and 1000 grain weight. The low differences revealed to small environmental effect for the expression of most traits. Which indicated that the selection could be effective based on these traits and their phenotypic expression would be a good indication of genotypic potential. On the other hand, heritability in broad sense can be divided into; low (less than 40%), intermediate (40-60%), moderately high (60-80%) and very high heritability (more than 80%), (**Hailu *et al.*, 2016**). Based on this classification, days to heading, days to maturity, plant height and 1000-grain weight displayed very high heritability in the broad sense and the remaining traits presented moderately high heritability under both conditions. High heritability values indicates to high response to selection for the investigated traits. These results are in line with those found by **Al-Tabbal and Al-Fraihat (2011), Dyulgerova and Valcheva (2014), Hailu *et al.* (2016), Shrimali *et al.* (2017) and Arshadi *et al.* (2018)**.

Table 6. Genetic variability parameters for the studied traits in 16 barley genotypes under water deficit (T1) and normal irrigation (T3) conditions

Trait	σ^2g		σ^2p		GCV		PCV		h^2b	
	T1	T3	T1	T3	T1	T3	T1	T3	T1	T3
DH	13.50	13.20	14.77	14.58	4.39	4.10	4.59	4.31	91.40	90.52
DM	8.80	7.90	9.63	9.20	2.48	2.26	2.60	2.44	91.35	85.87
PH	61.80	38.70	77.22	46.23	7.93	4.72	8.86	5.16	80.03	83.70
NS/m^2	1076.57	759.48	1456.50	982.89	11.75	6.79	13.66	7.72	73.91	77.27
GNS	28.55	16.12	39.38	21.11	10.85	6.95	12.74	7.96	72.50	76.36
1000GW	13.16	16.47	16.02	19.77	10.29	11.27	11.35	12.35	82.16	83.31
SY	16935.39	38353.00	22646.91	50266.87	4.81	4.06	5.56	4.65	74.78	76.30
GY	7319.84	4319.84	10745.53	6041.07	4.17	2.77	5.05	3.28	68.12	71.51
BY	12771.35	36735.61	17225.84	46921.07	2.38	2.67	2.76	3.01	74.14	78.29

DH (Days to heading), DM (Days to maturity), PH (Plant height), NS/m^2 (No. of spikes/m^2), GNS (grain number/spike), 1000GW (1000 grain weight, g), SY (Straw yield/fad., kg), GY (Grain yield/fad., kg), BY (Biological yield/fad., kg),.

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تقييم تحمل الجفاف لستة عشر تركيب وراثي من الشعير تحت معاملات ري مختلفة

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يعتبر نقص الماء أحد أخطر التحديات التي تواجه إنتاج المحاصيل خاصة في ظل التغيرات المناخية الحالية، الهدف من هذه الدراسة هو مقارنة سلوك ستة عشر تركيباً وراثياً من الشعير تحت ثلاث معاملات ري لتحديد التراكيب الوراثية المتحملة والحساسة للجفاف، بالإضافة إلى ذلك دراسة التباين الوراثي وكفاءة التوريث للصفات المحصولية تحت ظروف الإجهاد المائي والري الطبيعي، تم إجراء تجربتين حقليتين في محطة بحوث كفر الحمام، الزقازيق، مركز البحوث الزراعية خلال موسمي ٢٠١٤-٢٠١٥ و٢٠١٥-٢٠١٦، تم استخدام ثلاث معاملات ري وهى: الري مرة واحدة عند الزراعة (T1)، الري مرتين عند الزراعة وبعد الزراعة بثلاثين يومًا (T2) والري ثلاث مرات عند الزراعة وبعد الزراعة بثلاثين وستين يوما على التوالي (T3)، وذلك باستخدام الري السطحي، أظهرت النتائج أن جميع الصفات تحت الدراسة تأثرت بشكل كبير بمعاملات الري، وأعطت التراكيب الوراثية: G6 ، G8 ، G9 ، G10 ، G11 ، G12 ، G14 و G15 أعلى إنتاجية ومكونات المحصول تحت جميع معاملات الري، علاوة على ذلك، تم حساب أربعة أدلة تحمل للجفاف على أساس محصول الحبوب تحت ظروف الإجهاد المائي والري الطبيعي وهى MP ، GMP ، STI و YI ، وأظهرت النتائج أن G10 أعطى أعلى القيم في الأربعة أدلة متبوعاً بـ G14 ، G9 ، G8 وG13 ، ومن ناحية أخرى، أعطى G4 أقل القيم متبوعاً بـG1، G7 وG3، وكذلك تم تقسيم التراكيب الوراثية باستخدام التحليل العنقودي على أساس قيم أدلة تحمل الجفاف إلى أربعة مجموعات، المجموعة الأولى (A) كان بها التركيب G10 الذي أعطى أعلى قيم لأدلة تحمل الجفاف ولذلك يمكن اعتباره عالي التحمل للجفاف، بالإضافة إلى المجموعة (B) التى ضمت التراكيب الوراثية G8، G9 ، G11 و G14 التي أعطت قيماً عالية نسبياً لأدلة تحمل الجفاف، والمجموعة (C) التي اشتملت على عشرة تراكيب وراثية لها قيم متوسطة لأدلة تحمل الجفاف، في حين أن المجموعة (D) كان بها G4 الذى أعطى أقل قيم لأدلة تحمل الجفاف ولذلك يمكن اعتباره حساساً للجفاف، وعلاوة على ذلك، تم تقدير معامل الاختلاف الوراثي (GCV) والمظهري (PCV) للصفات المدروسة تحت ظروف الإجهاد المائي والري الطبيعي، وكانت أعلى قيم لمعامل الاختلاف الوراثي والمظهري لعدد السنابل في المتر المربع، وعدد حبوب السنبلة ووزن الألف حبة، وكان الفرق بين قيم معامل الاختلاف الوراثي والمظهري منخفضة جدا لعدد الأيام حتى الطرد وعدد الأيام حتى النضج ومتوسطة للمحصول البيولوجي، محصول القش، محصول الحبوب وارتفاع النبات بينما كان الفرق عالي نسبيا لعدد السنابل في المتر المربع، عدد حبوب السنبلة ووزن الألف حبة، وجاءت تقديرات كفاءة التوريث في المعنى العام عالية جدا لعدد الأيام حتى الطرد، عدد الأيام حتى النضج، ارتفاع النبات ووزن الألف حبة وكانت مرتفعة لباقي الصفات تحت كل الدراسة.

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