

Effect of water deficit on productivity of some barley (*Hordeum vulgare* L.) genotypes

ABSTRACT

Two field experiments were laid out during 2019/2020 and 2020/2021 growing seasons at Sakha region, Kafr El-Sheikh Governorate, Egypt to evaluate the productivity and stress tolerance of ten barely genotypes under full irrigation and water stress conditions. Eight traits for barley were measured: days to maturity, plant height, spike length, number of grains/spike, number of spikes/m², 1000-grain weight, biological yield and grain yield. Also, stress susceptibility index (SSI) was calculated. Results showed that, all the studied traits were decreased under water stress conditions. Mean squares due to seasons, water treatments, genotypes and their interactions were significant or highly significant for most studied traits. From the results, Giza 133 and Line 3 were the earliest genotypes in maturity. Line 4 under normal irrigation and Giza 2000 and Line 5 under stress gave the highest values of grain yield and most of its components. From SSI data, Giza 124, Giza 126, Giza 2000, Line 3 and Line 5 considered as the most tolerant genotypes where it had values less than the unity. so, it can be used in improving barley productivity under water stress condition.

Key words: Barley, water deficit, tolerance index, yield potential.

1. Introduction

Barley (*Hordeum vulgare* L.) considered as one of the most valuable cereal grain crops is cultivated all over the world. Barley has a good adaptation to water stress, and it can be surveyed as a genetic model plant to illustrate drought resistance mechanisms [1], [2]. Barley possesses some special properties that enable it to adapt desirably into different unsuitable environmental conditions compared to other crops. The phenomenon of diminishing barley yields under limited water supply situations is well known [3], therefore, drought stress reduces barley grain yield by negatively affecting the yield components which are determined at various plant development stages [4], [5]. Drought stress is a significant abiotic factor that can diminish photosynthesis efficiency by reducing leaf expansion, hence, causing premature leaf senescence and lower food production. Many papers on crop breeding for drought environments have been recently published [6], [7], [8]. Drought factor is responsible for the greatest amounts of destruction to agricultural products among all other environmental stresses [9], [10], [11]. Only the effect of genotype and the interaction between genotype and environment are important in selection of stable genotypes, both genotype effect and the interaction of genotype and environment should be examined [12]. The objective of this study was to evaluate the productivity and stress tolerance of ten barely genotypes under full irrigation and water stress conditions and select barley genotypes that have considerable stress tolerance which can be used in barley improvement.

2. MATERIALS AND METHODS

Present study was conducted in Sakha region, Kafr El-Sheikh Governorate (Lat. 31° 06' 25.20" N, Long. 30° 56' 26.99" E, elevation above sea level 17 m), Egypt during 2019/2020 and 2020/2021 growing seasons. For each season, the tested genotypes were evaluated in two separate irrigation treatments using flood irrigation method. The first treatment involved the normal irrigation (two times after planting irrigation), while the second one included planting irrigation only (water stress) in addition to the amount of rainfed. All other cultural practices were

applied according to the recommendations of the barley department for the region. The values of metrological data in 2019/2020 and 2020/2021 are presented in Table (1).

Table 1: Monthly means of air temperature (AT °C), relative humidity (RH %) and rainfall (mm/month) in winter seasons 2019/2020 and 2020/2021 at Sakha region.

Month	At °C 2019/20		At °C 2020/21		RH%		Rainfed (mm)	
	Max.*	Min.**	Max.	Min.	2019/20	2020/21	2019/20	2020/21
December	21.4	13.4	22.9	13.7	86.4	87.70	27.9	18.78
January	18.4	11.8	21.0	13.5	74.7	86.70	38.4	14.65
February	20.4	12.7	21.5	12.4	70.6	87.50	14.3	51.40
March	22.6	15.6	22.3	13.8	67.5	81.06	30.8	25.40
April	26.0	18.9	27.5	19.4	62.6	74.30	-	-

* Max = maximum temperature, ** Min = minimum temperature

2.1. Plant materials, experimental design and data recorded.

In randomized complete block design with four replicates, ten barley genotypes differed in their reaction to water stress were grown. The planting date was December 5th in both growing seasons. Each genotype was sown in plot area 4.2m². The pedigree of the ten barley genotypes is presented in Table (2). Eight traits for barley were measured: days to maturity (Number of days from sowing to 50% yellow stage of maturity for all plants/plot), plant height (ten plants were taken at random from each sub plot and measured in cm. from the soil surface to the top of the spike of the main tiller), spike length (ten spikes were selected by random and their lengths were measured, then average was calculated to express mean spike length in cm.), number of grains/spike (average number of grains in ten randomly chosen spikes were estimated), number of spikes/m² (estimated by counting all spikes per square meter), 1000-grain weight (A random sample of 1000-grains was taken from each plot and weighted), biological yield (was recorded from all harvested plants/plot and converted to ton/fedan) and grain yield (was recorded from the grains of harvested plants/plot after threshing and then converted to ardab/fedan) [ardab= 120kg and feddan= 4200m²]. Harvest was done on first of May in both growing seasons.

Table 2. Name and pedigree of the studied ten barely genotypes.

Genotypes	Pedigree \ Name
Giza 124	Giza 117/Bahteem 52// Giza 118/FAO 86
Giza 126	Baladi Bahteem/SD729-por12762-Bc
Giza 133	Carbo/Gustoe
Giza 134	Alanda-01/4/WI2291/3/Api/CM67//L2966-69
Giza 2000	Cr366-13-1/Giza121
Line 1	Rihane-03//Lignee527NK1272/5/Arizona5908/Aths//Avt/attiki/3/s.t/ Barley/4/Aths/ Lignee640/6/Giza 126
Line 2	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
Line 3	Giza 2000/4/CalMr/3/Alanda//Lignee527/Arar
Line 4	U.Sask.1766/Api//Cel/3/Weeah/4/Giza121/Pue
Line 5	Panniy/Salmas/5/Baca"s"/3/AC253//CI08887/CI05761/4/JLB70-01

Stress susceptibility index (SSI) was estimated according to [13] as: $SSI = (1 - Y_d/Y_p)/D$. Where: Y_d = mean yield under stress, Y_p = mean yield under normal irrigation = potential yield, D = stress stress intensity = $1 - (\text{mean } Y_d \text{ of all genotypes} / \text{mean } Y_p \text{ of all genotypes})$. The analysis of variance was performed according to RCBD. Combined analysis across the two water treatments in the two seasons was performed when the assumption of errors homogeneity cannot be rejected [14]. Means of genotypes were compared using LSD at 0.05 probability level [15].

2.2. Applied irrigation water

The results in Table (3) indicated that the values of applied irrigation water under full irrigation were 1264.88 and 1325.97 m³/feddan in the first and second season, respectively and it were 862.88 and 889.97m³/feddan for water stress treatments in the first and second season, respectively. Furthermore, the applied irrigation amount under full irrigation was higher by 31.78 and 82.88% than the applied water under water stress treatment in the first and second season, respectively, which provide highly stressful environment for barley genotypes to test their ability to withstand water deficiency.

Table (3): Amount of applied water (m³/feddan) under full irrigation and water stress treatments to barely genotypes in the two growing seasons.

Supplied water	2019/2020		2020/2021	
	Normal	Stress	Normal	Stress
Planting irrigation	395.00	395.00	427.00	427.00
First irrigation	208.00	-	211.00	-
Second irrigation	194.00	-	225.00	-
Total irrigation	797.00	-	863.00	-
Rainfall	467.88	467.88	462.97	462.97
Total of water	1264.88	862.88	1325.97	889.97

Feddan = 4200m²

3. RESULTS:

3.1. Analysis of variance:

Table 4 show means of seasons, water treatments and their interaction across all studied genotypes. Means of studied genotypes for all traits were significantly higher in 2020/2021 compared to 2019/2020. Averaging across the 10 entries, the water stress conditions reduced all studied traits.

3.2. Mean performance:

Averaging across the two seasons and water treatments are shown in Table 4. Days to maturity varied from 126.6 days in Giza 133 to 133.3 days in Line 2. From these results, using Giza 133 in breeding program as a source for earliness would be more effective.

In addition, plant height estimates were in the range of 106.1 cm in line 3 and 114.5 cm in Giza 126. Regarding spike length, Giza 134 showed the highest values (9.5cm), while Giza 133 showed the lowest values (6.2cm). Number of grains/spike estimates were in the range of 53.1 in line 3 and 69.2 in Giza 134. Besides, the lowest and highest No. of spikes/m² (379.8 and 450.4 spikes) were detected by Line 1 and Line 5, respectively. Also, the range of 1000-grain weight varied from 48.2 g in Line 3 to 57.6 g in Giza 2000. For biological yield, the data varied from 5.32 ton/feddan for Line 1 to 7.06 ton/feddan for Line 4. Moreover, the highest grain yield was observed by Line 4 (17.54 ardab/feddan), while the lowest value was obtained by Line 1 (14.13 ardab/feddan). From the previous results, the genotypes which showed desirable data could be used for improving barley crop.

Table 4: Effect of seasons, irrigation treatments, genotypes and their interaction on all studied traits over seasons and irrigation treatments.

Treatments	Days to maturity (day)	Plant height (cm)	Spike length (cm)	Number of grains/spike	Number of spikes /m²	1000 grain weight (g)	Biological yield (ton/ feddan)	Grain yield (ardab/ feddan)
Seasons (S)	**	**	**	**	**	**	**	NS
2019/2020	127.90	108.10	8.10	61.60	415.00	51.80	6.17	16.00
2020/2021	129.60	110.80	8.20	62.60	429.60	53.10	6.26	15.99
Irrigation treatments (I)	**	**	**	**	**	**	**	**
Normal	130.70	114.00	8.50	62.90	440.90	53.10	6.39	15.55
Water stress	125.00	104.40	7.40	56.50	456.20	53.10	5.62	14.36
Genotypes (G)	**	**	**	**	**	**	**	**
Giza 124	127.90	109.20	8.00	59.70	448.50	53.10	6.01	14.95
Giza 126	128.80	114.50	7.80	58.60	415.30	49.40	5.88	15.00
Giza 133	126.60	101.60	6.20	61.10	401.80	53.90	6.21	16.23
Giza 134	129.50	110.00	9.50	69.20	433.10	54.10	6.42	16.80
Giza 2000	128.00	109.00	7.80	58.70	427.60	57.60	6.79	17.53
Line-1	128.30	110.50	8.20	61.10	379.80	49.70	5.32	14.13
Line-2	133.30	109.20	9.20	67.40	391.10	52.30	5.43	14.22
Line-3	127.30	106.10	6.90	53.10	435.30	48.20	6.24	16.38
Line-4	130.50	113.30	9.00	65.70	440.40	55.00	7.06	17.54
Line-5	127.70	111.10	9.10	66.70	450.40	51.30	6.81	17.17
Mean of genotypes	128.80	109.40	8.20	62.10	422.30	52.50	6.22	15.99
LSD0.05	1.11	5.67	0.50	3.01	12.65	1.79	0.15	0.92
S x G	**	**	**	**	**	**	**	**
I x G	**	**	**	**	**	**	**	**
S x I x G	**	*	**	**	**	*	**	**

* and ** indicate respectively differences at $p \leq 0.05$ and $p \leq 0.01$ probability level, N.S. indicates not significant difference.

3.3. The effect of season and barley genotypes interaction:

Table 5 show means of all studied traits across the water treatments and seasons. Values of number of days to maturity ranged from 125.4 and 127.8 days in Giza 133 to 132.3 and 134.2 days in Line 2 in the first and second seasons, respectively. Plant height estimates varied from 101.6 and 101.5 cm in Giza 133 at the first and second season, respectively to 116.6 in Line 4 at the first season and 117.1 cm in Giza 126 at the second season. For spike length, values ranged from 6.2 cm in Giza 133 to 9.3 and 9.7 cm in Giza 134 in the first and second seasons, respectively. Values of No. of grains/spike varied from 52.2 and 54.0 grains in Line 3 to 68.0 and 70.4 grains in Giza 134 in the first season and second seasons, respectively. Besides, number of spikes/m² were in the range of 375.0 and 384.6 spikes in Line 1 and 447.2 in Line 5 and 459.5 spikes in Line 2 in the first and second seasons, correspondingly. In addition, the lowest 1000-grain weight was 47.6 g and 48.9 in Line 3 and the highest values were 57.7 and 57.6 g in Giza 2000 in the first and second season, respectively. For biological yield, values ranged from 5.17 and 5.47 ton in Line 1 to 7.01 and 7.11 ton in Line 4 in the first and second seasons, respectively. The highest grain yields were 18.02 ardab for Line 4 and 17.26 ardab for Giza 2000, while the lowest values were 13.88 and 14.38 ardab for Line 1 in the first season and second season, respectively.

3.4. The effect of irrigation treatments and barley genotypes interaction:

The means of all studied traits combined over the two seasons for the same water treatment are exhibited in Tables 6. Number of days to maturity ranged from 130.0 and 123.2 days in Giza 133 to 136.3 and 130.1 days in Line 2 under normal and water stress conditions, respectively. Plant height estimates varied from 104.6 and 98.5 cm in Giza 133 to 121.1 and 113.8 cm in Line 4 and Giza 126 under normal and water stress conditions, respectively. Concerning spike length estimates, values varied from 6.8 and 5.5 cm in Giza 133 to 9.9 cm in Line 2 and 9.2 cm in Giza 134 under normal and water stress conditions, respectively. The number of grains/spike varied between 55.3 to 51.0 grains in Line 3 to 71.6 in Line 2 and 67.5 grains in Giza 134 under normal and water deficit conditions, respectively. Besides, the number of spikes/m² went in the range from 395.7 and 363.8 spikes in Line 1 to 669.6 spikes in Line 3 and 440.9 spikes in Giza 124 under normal and water stress conditions, respectively. The lowest grain weights were 49.7 and 46.6 g in Line 3, while the highest values were 58.0 and 56.3 g in Giza 2000 under normal and water stress conditions, respectively. For biological yield, values ranged from 5.7 and 5.94 ton in Line 1 to 7.43 and 6.99 ton in Line 4 under normal and water stress conditions, respectively. The lowest values of grain yield were 15.39 ardab in Line 2 and 12.37 ardab for Line 1, while the highest values were 19.17 ardab in Line 4 and 16.73 ardab for Giza 2000 under normal and water stress conditions, respectively.

3.5. The effect of season, irrigation treatments and barley genotypes interaction:

The mean performance of all the studied traits of the interaction seasons, water treatments and barley genotypes are presented in Tables 7 and 8. The earlier genotype was belonged to Giza 133 under normal irrigation in the first season and under stress condition in the two seasons and to Line 3 under normal irrigation in the second season. While the highest numbers were recorded for Line 2 in the first and second season under normal and water stress conditions. For plant height, the shortest genotypes were Giza 133 under normal irrigation in the two seasons, Line 2 under stress in the first season and Line 3 in the second season, while tallest genotypes were Line 4 under normal and water stress conditions in the first season, Line 5 under normal irrigation and Giza 2000 under stress in the second season. For spike length and number of grains/spike, the highest values recorded for Giza 134 under normal irrigation in the first season and under stress condition in the two seasons and for Line 2 under normal irrigation in the second season. Moreover, the highest number of spikes/m² detected by Line 3 under normal irrigation in the first and second seasons and under stress condition in the second season and by Line 5 under stress condition in the first season. Besides, the highest grain weight was obtained by Giza 2000 under all conditions. Additionally, the highest value of biological yield was obtained by Line 4 under all conditions. At the same time, the highest values of grain yield were detected by Line 4 under normal irrigation in the two seasons, Giza 2000 in the first season and Line 5 in the second season under stress condition, respectively.

Table 5. Mean performance of interaction between seasons and barley genotypes for the all studied traits combined over water treatments.

Genotype	Days to maturity (day)		Plant height (cm)		Spike length (cm)		Number of grains/spike		Number of spikes/m ²		1000 grain weight (g)		Biological yield (ton/feddan)		Grain yield (ardab/feddan)	
	S ₁	S ₂	S ₁	S ₂	S ₁	S ₂	S ₁	S ₂	S ₁	S ₂	S ₁	S ₂	S ₁	S ₂	S ₁	S ₂
Giza 124	126.50	129.20	106.00	112.40	8.10	7.90	60.30	59.10	440.80	456.20	51.20	54.90	5.97	6.04	14.51	15.40
Giza 126	127.50	130.10	111.90	117.10	7.90	7.60	59.60	57.60	409.30	421.30	49.30	49.40	5.87	5.88	15.01	14.99
Giza 133	125.40	127.80	101.60	101.50	6.20	6.20	61.10	61.10	392.50	411.20	51.60	56.30	6.26	6.17	16.54	15.91
Giza 134	129.20	129.80	108.60	111.40	9.30	9.70	68.00	70.40	426.80	439.30	53.20	55.00	6.40	6.44	16.68	16.93
Giza 2000	127.20	128.90	105.30	112.70	7.70	7.90	57.90	59.40	416.70	438.50	57.70	57.60	6.80	6.79	17.80	17.26
Line-1	127.80	128.80	106.80	114.20	7.80	8.50	58.90	63.30	375.00	384.60	49.40	50.10	5.17	5.47	13.88	14.38
Line-2	132.30	134.20	105.70	112.80	9.20	9.30	66.90	67.90	392.00	390.10	51.90	52.60	5.35	5.50	13.91	14.54
Line-3	127.00	127.90	109.00	103.30	6.70	7.00	52.20	54.00	411.20	459.50	47.60	48.90	6.16	6.32	16.19	16.56
Line-4	130.10	131.00	116.60	109.90	8.90	9.00	65.40	66.00	438.50	442.20	54.90	55.20	7.01	7.11	18.02	17.05
Line-5	126.60	128.80	109.20	113.00	9.00	9.20	66.10	67.20	447.20	453.50	51.30	51.20	6.74	6.88	17.47	16.86
LSD0.05	0.79		4.01		0.35		2.13		8.94		1.27		0.11		0.65	

S₁ and S₂= first and second season, respectively. Ardab = 120kg , Feddan= 4200m²

Table 6. Mean performance of interaction between irrigation treatments and barley genotypes for all studied traits combined over seasons.

Genotype	Days to maturity (day)		Plant height (cm)		Spike length (cm)		Number of grains/spike		Number of spikes/m ²		1000 grain weight (g)		Biological yield (ton/feddan)		Grain yield (ardab/feddan)	
	N	S	N	S	N	S	N	S	N	S	N	S	N	S	N	S
Giza 124	130.70	125.00	114.00	104.40	8.50	7.40	62.90	56.50	456.20	440.90	53.10	53.10	6.39	5.62	15.55	14.36
Giza 126	132.60	124.90	115.20	113.80	8.30	7.30	61.50	55.70	398.60	432.10	49.80	48.90	6.15	5.61	15.78	14.25
Giza 133	130.00	123.20	104.60	98.50	6.80	5.50	64.90	57.30	405.90	397.80	54.90	53.00	6.52	5.90	17.31	15.15
Giza 134	133.00	126.00	114.30	105.70	9.80	9.20	70.90	67.50	462.00	404.10	55.20	53.00	6.89	5.94	18.52	15.09
Giza 2000	131.90	124.10	115.30	102.70	8.00	7.50	60.10	57.20	414.20	441.00	58.00	56.30	6.95	6.64	18.34	16.73
Line-1	129.80	126.80	118.80	102.20	8.70	7.60	64.40	57.80	395.70	363.80	51.10	48.40	5.70	4.94	15.89	12.37
Line-2	136.30	130.10	119.80	98.60	9.90	8.50	71.60	63.20	417.30	364.80	53.30	51.30	5.79	5.07	15.39	13.06
Line-3	129.70	124.90	113.20	99.10	7.20	6.50	55.30	51.00	469.60	401.00	49.70	46.60	6.52	5.96	17.34	15.41
Line-4	132.50	128.60	121.10	105.50	9.50	8.40	69.20	62.20	462.60	418.10	56.20	53.80	7.43	6.69	19.17	15.90
Line-5	130.80	124.50	120.70	101.50	9.60	8.60	69.80	63.50	467.00	433.70	52.20	50.30	7.08	6.53	17.70	16.63
LSD0.05	0.93		5.88		0.45		2.68		15.16		0.61		0.14		0.70	

N and S= Normal and Stress condition, respectively. Ardab = 120kg , Feddan= 4200m²

Table 7. The mean performance of days to maturity, plant height, spike length and number of grains/spike as affected by interactions among seasons, irrigation treatments and genotypes.

Genotypes	Days to maturity (day)				Plant height (cm)				Spike length (cm)				Number of grains/spike			
	S ₁		S ₂		S ₁		S ₂		S ₁		S ₂		S ₁		S ₂	
	N	S	N	S	N	S	N	S	N	S	N	S	N	S	N	S
Giza 124	128.77	124.18	132.67	125.83	111.10	100.91	116.80	107.91	8.80	7.30	8.17	7.53	64.80	55.80	61.00	57.20
Giza 126	129.93	126.07	131.33	129.81	112.21	107.55	118.13	106.07	8.63	7.23	7.87	7.33	63.80	55.40	59.20	56.00
Giza 133	127.40	123.41	132.67	123.01	106.36	96.91	109.88	100.18	7.20	5.17	6.43	5.93	67.22	55.00	62.60	59.55
Giza 134	132.60	125.74	133.33	126.24	113.60	103.67	114.95	107.80	9.70	8.97	9.93	9.53	70.20	65.80	71.60	69.15
Giza 2000	130.17	127.16	133.67	128.10	119.98	110.67	120.63	114.70	7.83	7.47	8.20	7.60	59.00	56.80	61.20	57.60
Line-1	129.47	126.07	130.11	127.45	113.64	100.00	124.00	104.32	8.43	7.20	9.04	8.05	62.60	55.20	66.26	60.32
Line-2	135.84	128.80	136.73	131.71	115.65	95.67	124.05	101.57	9.67	8.63	10.20	8.42	70.00	63.80	73.18	62.55
Line-3	128.55	125.37	130.76	128.41	113.45	104.49	112.98	93.64	7.00	6.40	7.42	6.59	54.00	50.40	56.52	51.55
Line-4	132.12	128.00	132.89	129.11	122.15	111.07	120.00	99.90	9.54	8.27	9.54	8.47	69.24	61.60	69.24	62.85
Line-5	129.88	123.33	131.81	125.74	116.33	102.00	124.98	100.98	9.37	8.67	9.89	8.51	68.20	64.00	71.36	63.08
LSD0.05	1.11				5.67				0.50				3.01			

S₁ and S₂ = first and second season, respectively. N and S = Normal and Stress condition, respectively. Ardab = 120kg , Feddan= 4200m²

Table 8. The mean performance of number of spikes/m², 1000 grain weight, biological yield and grain yield as affected by interactions among seasons, irrigation treatments and genotypes.

Genotypes	Number of spikes/m ²				1000 grain weight (g)				Biological yield (ton/feddan)				Grain yield (ardab/feddan)			
	S ₁		S ₂		S ₁		S ₂		S ₁		S ₂		S ₁		S ₂	
	N	S	N	S	N	S	N	S	N	S	N	S	N	S	N	S
Giza 124	438.33	413.33	443.37	429.13	52.51	49.92	56.60	53.18	6.36	5.58	6.42	5.66	14.80	14.22	16.30	14.50
Giza 126	421.00	399.67	442.18	400.50	49.60	48.93	50.07	48.82	6.10	5.64	6.19	5.57	15.56	14.46	16.00	14.99
Giza 133	400.00	385.00	411.81	410.54	52.28	50.93	56.60	55.98	6.61	5.91	6.43	5.90	17.71	15.38	16.92	14.91
Giza 134	463.70	390.00	460.26	418.25	54.23	52.20	56.27	53.79	6.80	6.00	6.99	5.89	18.27	15.08	18.76	15.10
Giza 2000	421.67	411.67	460.78	446.29	58.93	56.42	58.97	57.19	6.97	6.61	6.92	6.66	18.66	16.95	18.01	16.50
Line-1	387.33	362.67	404.15	364.96	50.85	47.87	51.32	48.84	5.48	4.87	5.93	5.01	14.90	12.85	16.89	11.88
Line-2	421.33	362.67	413.35	366.88	53.13	50.75	53.48	51.80	5.66	5.04	5.92	5.09	15.04	12.79	15.74	13.33
Line-3	467.67	354.67	471.52	447.43	49.51	45.59	50.11	47.70	6.39	5.93	6.65	5.99	17.28	15.10	17.40	15.72
Line-4	460.93	416.00	464.27	420.21	56.04	53.67	56.44	53.99	7.41	6.62	7.46	6.75	19.17	16.87	19.17	14.94
Line-5	463.00	431.33	470.93	436.16	52.11	50.58	52.35	50.11	7.03	6.44	7.13	6.63	18.29	16.65	17.10	16.62
LSD0.05	12.65				1.79				0.15				0.92			

S₁ and S₂ = first and second season, respectively. N and S = Normal and Stress condition, respectively. Ardab = 120kg , Feddan= 4200m²

3.6. Stress susceptibility index (SSI):

Stress susceptibility index (SSI) was calculated using the grain yield under normal irrigation and water stress conditions (Table 9). The SSI values represent tolerance, moderate tolerance or sensitivity and sensitivity if they were less than, equal or near to and above unity, respectively. Averaging the mean of SSI values across the two seasons, Giza 124, Giza 126, Giza 2000, Line 3 and Line 5 considered as the most tolerant genotypes where it had values less than the unity. Giza 133 considered as moderately tolerant, while Line 2 and Line 4 considered as moderately susceptible where it had values around the unity. On the other hand, Line 1 considered as the most susceptible genotype where it had value higher than the unity.

Table 9. Estimates of stress susceptibility index (SSI) based on grain yield for the studied genotypes in the two growing seasons.

Genotype	2019/2020	2020/2021	Mean
Giza 124	0.34	0.80	0.59
Giza 126	0.62	0.46	0.76
Giza 133	1.15	0.86	0.97
Giza 134	1.53	1.41	1.43
Giza 2000	0.80	0.61	0.68
Line-1	1.21	2.15	1.72
Line-2	1.31	1.11	1.17
Line-3	1.11	0.70	0.86
Line-4	1.05	1.60	1.32
Line-5	0.79	0.20	0.47

4. DISCUSSION:

The significance variances for all characteristics under all conditions reflects the presence of sufficient genetic variability among the genotypes and provides the basis for genetic gain and the adaptation for any breeding program [22]. According to the analysis of variance, the two seasons and two irrigation treatments behaved differently and the studied genotypes had sufficient variability. The tested genotypes responded differently to the water treatments and seasons based on the interactions among the studied factors, allowing for the selection of the most advantageous genotypes. In this regard, evaluation barley genotypes under normal irrigation compared to water stress conditions found to be effective in identifying tolerant genotypes to water deficit [23]. In this respect, significant genetic variability among the studied genotypes under seasons and water treatments were found [5]. The highest values in the second season may be a result of the lowest temperature and higher relative humidity than in the first one. Similar results were obtained by [24], [5]. Results showed that, water deficit reduced all studied traits. These results were confirmed by [20], [25], [26], [5]. The reduction in number of grains/spike may be due to premature abortion of florets [27]. Also, under water stress condition grain weight may be decreased due to a shortage in grain-filling period and hence lower dry matter accumulation, or a reduced rate and duration of starch accumulation in the endosperm [21]. Also, grain yield was decreased under stress condition and this due to the decrease in number of spikes/m² [28], grain weight per spike [21] and grain number per spike [29]. Also, many other researchers observed that the yield and its attributes were decreased under water deficit conditions in different crops [30], [20]. Under stress condition the genotypes that produced low value of SSI are drought stress tolerance because they have lower reduction in productivity. As well as, the genotypes that had SSI value more than 1.0 indicated sensitivity.

5. CONCLUSION

Giza 124, Giza 126, Giza 2000, Line 3 and Line 5 considered as the most tolerant genotypes where it had values less than the unity of SSI. In addition, Giza 2000 and Line 5 were the highest yielding genotypes under stress condition, so it can be used in improving barley productivity under water stress condition.

6. REFERENCES:

1. **Baik, B. K. and S. E. Ullrich (2008).** Barley for Food: Characteristics, Improvement, and Renewed Interest. *Journal of Cereal Science*, 48, 233-242. <http://dx.doi.org/10.1016/j.jcs.2008.02.002>
2. **Arshadi, A., E. Karami, A. Sartip & M. Zare (2018a).** Application of secondary traits in barley for identification of drought tolerant genotypes in multi-environment trials. *Australian journal of crop science* 12(01), 157–167.
3. **Hossain, A., J. A. Teixeira Da Silva, M. V. Lozovskaya, V. P. Zvolinsky & V. I. Mukhortov (2012).** High temperature combined with drought affect rainfed spring wheat and barley in southeastern Russia: Yield, relative performance and heat susceptibility index. *Journal of Plant Breeding and Crop Science* 4(11), 184–196.
4. **Vadez, V. (2014).** Root hydraulics: The forgotten side of roots in drought adaptation. *Field Crops Research* 165, 15–24.
5. **Abo Elenein, Rashad, Mohamed Mansour, Tahany Noreldin, El-Sayed E. El-Shawy and Sally E. Elwakeel (2022).** Evaluating the Productivity of some Barely Genotypes under Deficient Water Application in Clayey Soils. *International J. of Plant & Soil Sci.* 34(13): 51-64.
6. **Fleury, D., S. Jefferies, H. Kuchel & P. Langridge (2010).** Genetic and genomic tools to improve drought tolerance in wheat. *Journal of Experimental Botany* 61, 3211–3222.
7. **Passioura, J.B. & J. F. Angus (2010).** Improving productivity of crops in water-limited environments. In: Sparks D.L. (ed.): *Advances in Agronomy*. Volume 106, Academic Press, Burlington, pp. 37–55.
8. **Kosova, K. (2014).** Breeding for Enhanced Drought Resistance in Barley and Wheat Drought associated Traits, Genetic Resources and their Potential Utilization in Breeding Programs. *Czech J. Genet. Plant Breed.* 50(4), 247–261.
9. **Ceccarelli, S. (2010).** Drought and drought resistance. *Encyclopedia of Biotechnology in Agriculture and Food* 1, 205–207.
10. **Arshadi, A., E. Karami, B. Khateri & P. Rezabakhsh (2016).** Drought stress effects on the grain yield among different barley cultivars. *Genetika* 48, 1087–1100.
11. **Arshadi, A., E. Karami, A. Sartip, M. Zare & P. Rezabakhsh (2018b).** Genotypes performance in relation to drought tolerance in barley using multi-environment trials. *Agronomy research* 16(1), 5–21, doi.org/10.15159/ar.18.004.
12. **Yan, W. & M. S. Kang (2003).** GGE Biplot Analysis: A Graphical Tool for Breeders, Geneticists and Agronomists. 1st Edn., CRC Press LLC., Boca Roton, Florida, pp. 271.
13. **Fischer, R. A. and R. Maurer (1978).** Drought resistance in spring wheat cultivars I. Grain yield responses. *Aust. J. Agric. Res.*, 29:897-912.
14. **Levene, H. (1960).** Levene test for equality of variances. *Contributions to probability and statistics*, 278-292.
15. **Steel R.G.D., J. H. Torrie and D. A. Dicky (1997)** Principles and Procedures of Statistics, A Biometrical Approach. 3rd Edition, McGraw Hill, Inc. Book Co., New York, 352-358.
16. **Soliman, M. A. M., A. M. O. El-Bawab and El-M. A. El-Kholy (2011).** Productivity of some barley cultivars under different methods and amounts of irrigation water. *Int. J. Acad. Res.*, 3 (1): 43-51.

17. **El-Seidy, E. H. E.; Kh. A. Amer, A. A. El-Gammaal and E. E. ElShawy (2012).** Assessment of water stress tolerance in twenty barley genotypes under field conditions. Egypt J. Agric. Res., 90 (4): 325-345.
18. **El-Denary, M.E. and E.E. El-Shawy (2014).** Molecular and field analysis of some barley genotypes for water stress tolerance. Egyptian Journal of Genetics and Cytology 43 :187-198.
19. **Mansour, M., E. E. El-Shawy and S.I. Abaas (2016).** Genetic improvement of water stress tolerance in some barley genotypes. Egyptian Journal of Plant Breeding 20 :119- 134.
20. **EL-Shawy; E.E, A. EL Sabagh, M. Mansour and C. Barutcular (2017).** A comparative study for drought tolerance and yield stability in different genotypes of barley (*Hordeum vulgare* L.). Journal of Experimental Biology and Agricultural Sciences, 5(2):151-162.
21. **Zhao, W., L. Liu, Q. Shen, J. Yang, X. Han, F. Tian, J. Wu (2020).** Effects of water stress on photosynthesis, yield, and water use efficiency in winter wheat. Water 12(8): 2127.
22. **Rajaram S., H. J. Braun, M. V. Ginkel (1996).** CIMMYT's approach to breed for drought tolerance. Euph. 92: 147-153.
23. **Morsy, S. M., I. S. Elbasyoni, A. M. Abdallah, P. S. Baenziger (2021).** Imposing water deficit on modern and wild wheat collections to identify drought-resilient genotypes. Journal of Agronomy and Crop Science 00: 1-14.
24. **Farhat, W. Z. E., M. T. Shehab-Eldeen and R. A. Khedr (2020).** Agronomic and physiological studies on some exotic and local bread wheat genotypes under saline soil conditions in north delta region. Egypt. J. Plant Breed. 24(2): 465-491.
25. **Sallam, A., A. M. I. Mourad, W. Hussain P. Stephen Baenziger (2018).** Genetic variation in drought tolerance at seedling stage and grain yield in low rainfall environments in wheat (*Triticumaestivum* L.) Euphytica; 214:169. doi: 10.1007/s10681-018-2245-9.
26. **Mansour. M., and Aziza A. Aboulila (2021).** Molecular variability and salinity effects on growth characters and antioxidant enzymes activity in Egyptian barley genotypes. Physiological and Molecular Plant Pathology 116 (2021) 101739.
27. **Dolferus R, N. Powell, X. Ji, R. Ravash, J. Edlington, S. Oliver, J. V. Dongen and B. Shiran (2013).** The physiology of reproductive-stage abiotic stress tolerance in cereals. In: Rout G. R. and A. B. Das eds. Molecular stress physiology of plants. New Delhi, India, Springer: 193-216.
28. **Leilah, A. A. and S. A. Al-Khateeb (2005).** Statistical analysis of wheat yield under drought conditions. J. Arid Environ., 61: 483-496.
29. **Ehdaie, B., G. A. Alloush and J. G. Waines (2008).** Genotypic variation in linear rate of grain growth and contribution of stem reserves to grain yield in wheat. Field Crops Res. 106: 34-43.
30. **Rashwan, E., A. Mousa, A. EL-Sabagh, C. Barutcular (2016).** Yield and Quality Traits of Some Flax Cultivars as Influenced by Different Irrigation Intervals. Journal of Agricultural Science, 8:226-240. DOI:http://dx.doi.org/10.5539/jas.v8n10p226.