ASSESSMENT OF WATER STRESS TOLERANCE IN TWENTY BARLEY GENOTYPES UNDER FIELD CONDITIONS

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Abstract

To evaluate some barley (*Hordeum Vulgare* L.) varieties and sixteen breeding lines for high yield potential and stable performance under two irrigation treatments (non-stressed and stressed), days to maturity, plant height, spike length, number of spike m-2 and water use efficiency and seed indices such as 1000-grain weight, number of grains per spike, grain yield, biological yield in addition to seven stress tolerance indices were evaluated (STI, YI, YSI, MP, GMP, Yr, DSI)* during two successive seasons 2009/10 and 2010/11 at Sakha Res. Station. All the studied characteristics were significantly affected by water stress in both growing seasons. There were significant differences for all the seven indices among the genotypes. Grain yield under normal condition (Yp) was highly significantly correlated with grain yields under stressed (Ys) conditions. Correlation analysis between drought tolerance indices and yield components showed that grain yield under irrigated condition was positively correlated with MP, STI, GMP and YI. While, yield under stress condition (Ys) was positively correlated with YSI, MP, STI, GMP and YI and negatively correlated with Yr and DSI. Genotypes were significantly different for their yield under stress and non-stress conditions . L4 and L8 had the heaviest grains and the highest values of WUE under both conditions compared with Giza 126 (check variety), as well as possessed high values of MP, YSI, STI, GMP and YI and DSI less than one, and low values of Yr, revealing that these genotypes were more tolerant to water stress and more desirable genotypes for both stress and non-stress conditions.

Keywords: Barley, water stress, drought tolerance indexes,

*Abbreviations: STI – stress tolerance index, YI – yield index, YSI – yield stability index, MP – mean productivity, GMP – geometrical mean productivity, Yr yield reduction ratio, DSI – stress susceptibility index. Ys – grain yield under drought condition, Yp – grain yield under normal condition, WUE – water use efficiency.

INTRODUCTION

Drought is a major abiotic stress that severely affects barley production worldwide. Therefore, research on crop management practices that enhances drought tolerance and plant growth when water supply is limited has become increasingly essential. Barley germplasm is a treasure trove of useful genes and provides rich sources of genetic variation for crop improvement.

The ability of a cultivar to produce high and satisfactory yield over a wide range of stress and non-stress environments is very important. Finlay (1968) believed that stability over environments and yield potential are more or less independent of each other. Blum (1979) suggested that one method of breeding for increased performance under water stressed conditions might be to breed for superior yield under optimum conditions on the assumption that the best lines would also perform well under sub optimum conditions. Sojka *et al.* (1981), pointed out that a high yield base line that allows a cultivar to do well over a range of environments does not imply drought resistance. They defined drought tolerance as the ability to minimize yield loss in the absence of soil water availability. The ideal situation would be to have a highly stable genotype with high yield potential (Finlay & Wilkinson, 1963, Smith, 1982).

The combination of high yield stability and high relative yield under drought has been proposed as useful selection criterion for characterizing genotypic performance under varying degree of water stress (Pinter *et al.,* 1990). Ahmad *et al.* (1999) found combination of drought susceptibility index (measure of yield stability) *vs.* relative yield useful in identifying genotypes with yield potential and relatively stable yield performance under different moisture environments. The objective of the present study, therefore, was to screen barley genotypes with high yield potential and stability under water stress conditions.

MATERIALS AND METHODS

Twenty barley genotypes (2 lines from ICARDA, 14 breeding lines and three local varieties i.e. Giza 121, Giza 126 and Giza 132 and Beacher Introduced from USA, named Giza118) were chosen for the study based on their reputed differences in yield performance under normal and stress conditions (Table4). Experiments were conducted at the Experimental Farm of Sakha Agricultural Research Station, (ARC), Egypt, during the two successive seasons 2009/10 and 2010/11.

Soil samples were randomly taken from the experimental area at a depth of 0 to 30 cm from soil surface before barley sowing. The soil properties are shown in Table 1. Water application was monitored via a water meter as shown in Table 2.

Table 1.Soil analysis of the Experimental Field at Sakha Agricultural Research Station at 2009/10 and 2010/11 Seasons.

Determination	Sand %	Silt %	Clay %	Texture	pH	E.C(ds/m)
2009/10	13.74	24.91	61.35	Clay	7.9	2.1
2010/11	15.53	23.95	60.52	Clay	8.2	2.9

Table 2. Amount of supplied water in m3fed.-1 at different barley critical growth stages, rainfall amount and total water supplied at 2009/10 and 2010/11 Seasons.

Irrigation Treatment	Growth Season	Growth Stages			Irrigation			
		Sowing	Tillering	Booting	Water (m^3)	Rainfall (mm)	Rainfall (m^3 $fed.^{-1}$)	Total (m^3 $fed.^{-1}$)
Irrigated	2009/10	550	350	450	1350	28	117.6	1667.6
	2010/11	500	325	450	1275	120	504	1779
Stressed	2009/10	550	-	-	550	28	117.6	817.6
	2010/11	500	-	-	500	120	504	1004

In the first season, the maximum temperature was high and the relative humidity and rainfall were low compared with the second season (table 3).

Table 3. Maximum, minimum temperature, average relative humidity and rainfall during the growing seasons of barley crop at Sakha Agricultural Research Station, (ARC), Egypt.

Month	Temperature °(C) 2009/10		Temperature °(C) 2010/11		Relative humidity (%)		Rainfall (mm)	
	Max.	Min.	Max.	Min.	2009/10	2010/11	2009/10	2010/11
Dec.	22.72	8.92	16.82	14.75	66.44	80.94	5.80	44.95
Jan.	21.77	7.77	14.73	12.49	71.48	87.74	0.00	28.21
Feb.	23.38	9.19	15.81	13.32	65.11	79.00	22.20	22.40
Mar.	23.92	9.18	18.24	15.09	62.09	77.97	0.00	13.95
Apr.	28.77	11.76	23.40	18.08	68.62	66.77	0.00	10.50

Twenty barley genotypes (*Hordeum vulgare,* L.), were used and their names, pedigrees and origin are presented in Table 4.

Table 4. Name, pedigree and origin of twenty barley genotypes.

genotypes	Name\Cross	Origin
Giza 126	BaladiBahteem/SD729-por12762-Bc	Egypt
Giza 132	Rihane-05//As46/Aths*2" Aths/ Lignee686	Egypt
Beacher	Introduced to Egypt from USA and named Giza-118	USA
Giza 121	Baladi16/Gem	Egypt
Line 1	Giza 117/3/ACSAD 618//Aths/Lignee 686	Egypt
Line 2	Giza 117/4/Kenya Research/Belle//As46/Aths*2/3/Arar/19-3//WI2294	Egypt
Line 3	Ssn/Bda//Arar/3/Arabayan-01//CI07117-9/Deir Alla 106	ICARDA
Line 4	ACSAD1182/4/Arr/Esp//Alger/Ceres362-1-1/3/WI/5/ACSAD1180/3/Mari/ Aths*2//M-Att-73-337-1	Egypt
Line 5	Giza 117/4/Kenya Research/Belle//As46/Aths*2/3/Arar/19-3//WI2294	Egypt
Line 6	ACSAD1182/Harmal-02/Salmas/4/Lignee527/NK1272/3/Nacha2//Lignee 640/ Harma-01	Egypt
Line 7	HOR 1657/4/GLORIA-BAR/COME-B//LIGNEE 640/.../5/G2000	Egypt
Line 8	Lignee 527/Chn-01/Gustoe/5/Alanda-01/4/WI2291/3/Api/CM67//L2966-69	ICARDA
Line 9	Alanda//Lignee527/Arar/5/Ager//Api/CM67/3/Cel/WI2269//Ore/4/Hamra-1/6/ Lignee527/NK 1272/3/Nacha 2//Lignee 640/Harma-01	Egypt
Line 10	Giza 119/3/ESCOBA/BRB2//ALELI	Egypt
Line 11	Giza 119/4/TOCTE//CEN-B/2*CALI92/3/MARCO/SEN//CARDO	Egypt
Line 12	Giza 125/3/ACSAD 618//Aths/Lignee 686	Egypt
Line 13	CC 89/Saico	Egypt
Line 14	ACSAD1182/Harmal-02/Salmas/5/ACSAD1182/4/Arr/Esp//Alger/Ceres362-1-1/3/WI	Egypt
Line 15	ACSAD 1182/Harmal-02/Salmas/3/Saico	Egypt
Line 16	ACSAD1182/Harmal-02/Salmas/5/ACSAD1182/4/Arr/Esp//Alger/Ceres362-1-1/3/WI	Egypt

Giza 126 was the most drought tolerant variety. So, this variety was used as check compared with the other genotypes. Seeds were hand drilled at the recommended sowing rate of barley in the irrigated land in Egypt (50 kg fed.$^{-1}$). Each genotype was sown in six rows of 3.5 m, spaced with 20 cm among rows. This experiment was laid out in a RCBD design with four replications. The first irrigation treatment was irrigated twice after sowing irrigation (normal condition), while, the second was given planting irrigation only (drought stress condition). Sowing was done in 15th of November in both seasons. The preceding crop was cotton in the two seasons.

Phenological traits such as days to maturity, plant height, spike length, and spikes number m^{-2} and seed indices such as 1000-grain weight, number of grains per spike, grain yield, biological yield and drought tolerance indices were calculated using the following:-

Mean productivity (MP) $= \frac{Ys + Yp}{2}$ (Hossain *et al.*, 1990).

Stress tolerance index (STI) $= \frac{Yp + Ys}{\bar{Y}p^2}$ (Fernandez, 1992).

Geometrical mean productivity $(GMP) = (Yp \times Ys)^{0.5}$ (Fernandez, 1992).

Yield index (YI) $= \frac{Ys}{\bar{Y}s}$ (Gavuzzi *et al.*, 1997, Lin *et al.*, 1986).

Yield stability index (YSI) $= \frac{Ys}{Yp}$ (Bouslama and Schapaugh, 1984).

Yield reduction ratio (Yr) $= 1 - \frac{Ys}{Yp}$ (Golestani and Assad,1998).

Where Ys is the yield of genotype under stress, Yp is the yield of genotype under irrigated condition, $\bar{Y}s$ s and $\bar{Y}p$ are the mean yields of all genotypes under stress and non-stress conditions, respectively.

Stress susceptibility index (DSI) = (1-Yd/Yw)/D (Fischer & Maurer, 1978).

Where Yd = mean yield under drought, Yw = mean yield under normal condition, and D = environmental stress intensity = 1-(mean yield of all genotypes under drought/mean yield of all genotypes under irrigated conditions). Lower stress susceptibility index than unity (DSI <1) is synonymous to high stress tolerance, while high stress susceptibility index (DSI >1) means higher stress sensitivity.

Water use efficiency (WUE) $= \frac{\text{Grain yield in kg}}{\text{Growth irrigation water applied in } m^3}$

(Michael, 1978).

Estimates of the simple phenotypic correlation coefficients (r) among all traits for the entry means were calculated according to Kearsey and Pooni (1996).

RESULTS AND DISCUSSION

Effect of irrigation treatments

The results in Table (5) indicated that all studied characteristic were significantly affected by water stress in both growing seasons, except for water use efficiency. The results showed that the stress resulted in higher value for water use efficiency, compared with the normal irrigation. These results are in agreement with those reported by Mohamed (2001), Bayoumi (2004), Moursi (2003), Mohamed (2004), Farhat (2005) and El-Shawy (2008).

Table 5. Effect of irrigation treatments on barley characteristics in both growing seasons.

Characteristic	Days to maturity (days)			Plant height (cm)			Spike length (cm)		
Treatment	2009/10	2010/11	Comb.	2009/10	2010/11	Comb.	2009/10	2010/11	Comb.
Irrigated	119.13	128.16	123.65	103.08	115.44	109.26	7.07	7.94	7.50
Stressed	115.71	122.81	119.26	96.55	111.41	103.98	6.36	7.44	6.90
LSD 0.05	0.33	0.88	0.47	0.90	1.50	0.87	0.12	0.21	0.12
Characteristic	Spikes number m^{-2}			Grains number per spike			1000-grain weight (g)		
Treatment	2009/10	2010/11	Comb.	2009/10	2010/11	Comb.	2009/10	2010/11	Comb.
Irrigated	434.73	482.58	458.65	56.05	61.04	58.54	52.05	53.60	52.82
Stressed	333.82	378.44	356.13	49.14	57.23	53.18	48.77	50.04	49.41
LSD 0.05	6.30	12.79	7.05	0.78	1.48	0.83	0.43	0.85	0.47
Characteristic	Biological yield (kg $fed.^{-1}$)			Grain yield (kg $fed.^{-1}$)			Water Use Efficiency (WUE)		
Treatment	2009/10	2010/11	Comb.	2009/10	2010/11	Comb.	2009/10	2010/11	Comb.
Irrigated	9100	11550	10325	3150	4143	3647	1.89	2.33	2.12
Stressed	5394	6199	5796	1999	2639	2319	2.54	2.63	2.55
LSD 0.05	174	379	211	77	152	85	0.05	0.15	0.08

Effect of barley genotypes

The results in Table (6) showed that all the twenty studied genotypes differ significantly in days to maturity, plant height and spike length in both seasons. The days required for maturity were not similar in the two years of study due to the difference in water applied (rainfall and irrigation water). The difference between the earliest genotype (Beacher variety) and the latest L3 genotype for days to maturity was 6 days in first season, and between the earliest L4 genotype, and the latest L3 genotype was 8 days in second season for days to maturity. The results showed that the genotypes under stress condition were earlier than irrigated condition which received less water than the later ones. All genotypes were earlier than Giza126, except Giza132, L3, L8 and L10 which needed longer time to reach maturity in both seasons.

Table 6 . Comparison among barley genotype means of days to maturity, plant height and spike length in both growing seasons.

Characteristic	Days to maturity (days)			Plant height (cm)			Spike length (cm)		
Genotype	2009/10	2010/11	Comb.	2009/10	2010/11	Comb.	2009/10	2010/11	Comb.
Giza 126	119.02	128.00	123.51	99.18	109.38	104.28	6.88	7.63	7.25
Giza 132	120.42	129.75	125.09	103.38	121.50	112.44	7.87	8.25	8.06
Beacher	115.48	123.25	119.36	84.65	97.63	91.14	5.92	7.13	6.52
Giza 121	117.28	124.63	120.95	101.90	113.38	107.64	7.53	8.88	8.20
L 1	116.95	124.88	120.91	98.41	109.00	103.71	6.50	7.38	6.94
L 2	116.69	124.38	120.53	97.85	114.88	106.36	6.29	7.25	6.77
L 3	121.62	131.75	126.69	104.04	119.00	111.52	6.38	6.50	6.44
L 4	115.58	123.00	119.29	100.52	117.38	108.95	6.15	7.50	6.83
L 5	116.42	124.00	120.21	102.02	120.50	111.26	6.50	7.63	7.06
L 6	116.82	124.63	120.72	101.69	117.88	109.78	7.05	8.88	7.96
L 7	117.11	125.38	121.24	106.06	120.13	113.09	6.98	8.13	7.55
L 8	121.13	129.25	125.19	100.23	115.50	107.86	7.54	8.63	8.08
L 9	115.75	123.00	119.38	102.40	115.25	108.83	6.62	7.63	7.12
L 10	119.59	128.00	123.79	93.88	104.63	99.25	7.38	9.00	8.19
L 11	117.36	125.88	121.62	104.70	120.00	112.35	6.59	8.13	7.36
L 12	115.98	123.25	119.61	98.95	113.75	106.35	6.30	7.25	6.77
L 13	116.82	125.25	121.03	100.69	114.25	107.47	7.00	8.00	7.50
L 14	115.85	123.63	119.74	98.83	109.88	104.35	6.23	7.25	6.74
L 15	115.98	124.50	120.24	95.13	103.25	99.19	5.88	5.75	5.81
L 16	116.56	123.38	119.97	101.75	111.38	106.56	6.73	7.00	6.86
LSD 0.05	1.05	2.79	1.50	2.86	4.73	2.76	0.37	0.66	0.37
CV %	0.90	2.25	1.77	2.89	4.22	3.72	5.58	8.65	7.47

With respect to plant height, the results showed that most genotypes were taller than Giza 126, especially Giza132, L3, L7 and L11. While, Beacher, L10 and L15 genotypes were the shortest in both treatments and both seasons (Table 6). Giza 132, Giza 121, L7, L8, L10, L11 and L13 had highest value for spike length compared with Giza 126 in both seasons (Table 6).

The highest values of spikes number m^{-2} compared to Giza 126 as check variety were obtained by Giza 132, Giza121, L4, L6, L8, L10, L13 and L16 in both seasons (Table 7). For grains number per spike, Giza132, L3, L8, L9 and L10 had higher values compared with Giza126 in both seasons (Table 7). For 1000-grain weight, most genotypes had higher values compared with Giza126 in both seasons, especially

Giza121, L7, L15 and L16. On the other hand, Giza132, Beacher, L8 and L10 had lowest values in both seasons (Table 7). With regard to biological yield, Giza132, L4 and L8 showed the superiority compared to Giza 126 in both treatments and both seasons (Table 8). L4, L5, L6, L8 and L11 gave the highest values for grain yield and water use efficiency compared to Giza 126 in both seasons (Table 8).

Table 7. Comparison among barley genotype means of spikes number m-2, grains number per spike and 1000-grain weight in both growing seasons.

Characteristic	Spikes number m^{-2}			Grains number per spike			1000-grain weight (g)		
Genotype	2009/10	2010/11	Comb.	2009/10	2010/11	Comb.	2009/10	2010/11	Comb.
Giza 126	387.44	413.13	400.28	55.64	61.88	58.76	48.43	49.61	49.02
Giza 132	398.87	449.17	424.02	61.05	65.53	63.29	45.91	47.18	46.55
Beacher	370.37	399.17	384.77	49.44	52.04	50.74	46.39	47.98	47.19
Giza 121	400.14	454.38	427.26	51.85	57.66	54.76	53.07	57.43	55.25
L 1	370.41	402.29	386.35	47.50	57.46	52.48	50.82	50.68	50.75
L 2	382.74	419.38	401.06	50.36	58.99	54.68	51.62	53.12	52.37
L 3	380.34	447.29	413.82	56.84	62.96	59.90	41.01	42.86	41.94
L 4	399.23	473.54	436.39	51.78	57.48	54.63	50.15	51.04	50.60
L 5	363.70	422.08	392.89	51.14	54.50	52.82	52.13	53.24	52.69
L 6	414.42	446.88	430.65	47.98	55.72	51.85	52.56	54.02	53.29
L 7	364.86	429.17	397.02	49.82	56.67	53.24	58.58	61.19	59.89
L 8	399.93	441.88	420.90	58.31	65.48	61.90	41.92	42.76	42.34
L 9	365.34	440.83	403.09	55.46	63.86	59.66	50.85	50.46	50.66
L 10	411.25	461.88	436.56	58.91	66.68	62.79	39.48	41.29	40.39
L 11	358.48	404.58	381.53	52.47	59.53	56.00	54.78	56.15	55.46
L 12	360.60	414.58	387.59	51.29	56.08	53.69	52.00	51.77	51.89
L 13	432.00	467.29	449.64	49.08	57.74	53.41	51.73	53.45	52.59
L 14	382.04	412.29	397.17	48.14	54.63	51.38	53.77	56.63	55.20
L 15	343.86	375.42	359.64	54.73	62.72	58.72	58.82	60.70	59.76
L 16	399.38	435.00	417.19	50.05	55.14	52.59	54.22	54.75	54.49
LSD 0.05	19.92	40.46	22.31	2.48	4.67	2.64	1.37	2.69	1.50
CV %	5.23	9.49	7.86	4.76	7.98	6.78	2.24	5.24	4.22

Table 8. Comparison among barley genotype means of biological yield, grain yield and water use efficiency in both growing seasons.

Characteristic	Biological yield (kg fed.$^{-1}$)			Grain yield (kg fed.$^{-1}$)			Water Use Efficiency		
Genotype	2009/10	2010/11	Comb.	2009/10	2010/11	Comb.	2009/10	2010/11	Comb.
Giza 126	7607	9225	8416	2682	3519	3100	2.16	2.53	2.35
Giza 132	8102	10300	9201	2671	3513	3092	2.15	2.52	2.35
Beacher	6755	7975	7365	2447	3069	2758	1.97	2.21	2.09
Giza 121	7354	8925	8139	2640	3488	3064	2.12	2.51	2.33
L 1	6426	7950	7188	2361	3194	2777	1.90	2.30	2.11
L 2	7015	8275	7645	2617	3613	3115	2.11	2.60	2.37
L 3	7236	9275	8256	2285	3094	2689	1.84	2.22	2.04
L 4	8159	10163	9161	3018	4250	3634	2.43	3.05	2.76
L 5	7459	9638	8548	2687	3625	3156	2.16	2.61	2.40
L 6	7512	9350	8431	2768	3744	3256	2.23	2.69	2.47
L 7	7190	8900	8045	2341	3106	2723	1.88	2.23	2.07
L 8	7928	9988	8958	2812	3725	3268	2.26	2.68	2.48
L 9	7053	9038	8045	2570	3381	2976	2.07	2.43	2.26
L 10	6419	7700	7060	2275	2963	2619	1.83	2.13	1.99
L 11	7234	9275	8255	2794	3725	3259	2.25	2.68	2.47
L 12	6440	7425	6932	2473	3125	2799	1.99	2.25	2.13
L 13	7130	8438	7784	2502	3163	2832	2.01	2.27	2.15
L 14	7152	8738	7945	2479	3206	2842	2.00	2.30	2.16
L 15	7140	8738	7939	2514	3356	2935	2.02	2.41	2.23
L 16	7627	8175	7901	2556	2963	2759	2.06	2.13	2.09
LSD 0.05	550	1198	666	243	482	269	0.16	0.46	0.25
CV %	7.66	13.63	11.87	9.54	14.36	12.94	9.24	19.02	16.99

Effect of the interaction between barley genotypes and irrigation treatment.

In the first season, significant interaction between barley genotypes and irrigation treatments was found in most characteristics (Tables 9, 10, 11, 12 and 13), while, for days to maturity, biological yield, grain yield and water use efficiency were not significant. On the other hand, the interaction was significant just for grain number per spike and 1000-grain weight in second season. The significance of interaction for most characteristics in the first season may be due to the maximum high temperature and the low relative humidity and rainfall compared with the second season (Table 3).

Table 9. Effect of the interaction between barley genotypes and irrigation treatments on days to maturity and plant height in both growing seasons.

Characteristic	Spike length (cm)						Spikes number m^{-2}					
Genotype	2009/10		2010/11		Comb.		2009/10		2010/11		Comb.	
	Irrigated	Stressed	Irrigated	Stressed	Irrigated	Stressed	Irrigated	Stressed	Irrigated	Stressed	Irrigated	Stressed
Giza 126	7.00	6.75	7.75	7.50	7.38	7.13	430.08	344.80	470.00	356.25	450.04	350.53
Giza 132	8.70	7.04	8.75	7.75	8.73	7.40	444.90	352.85	533.33	365.00	489.12	358.92
Beacher	6.30	5.54	7.25	7.00	6.78	6.27	411.98	328.76	453.33	345.00	432.65	336.88
Giza 121	7.80	7.25	9.25	8.50	8.53	7.88	437.68	362.60	495.00	413.75	466.34	388.18
L 1	6.88	6.13	7.50	7.25	7.19	6.69	413.63	327.20	463.33	341.25	438.48	334.22
L 2	6.58	6.00	7.25	7.25	6.91	6.63	418.18	347.31	470.00	368.75	444.09	358.03
L 3	6.63	6.13	6.75	6.25	6.69	6.19	440.90	319.78	538.33	356.25	489.62	338.02
L 4	6.68	5.63	7.75	7.25	7.21	6.44	445.10	353.37	513.33	433.75	479.22	393.56
L 5	6.88	6.13	7.75	7.50	7.31	6.81	415.40	312.01	486.67	357.50	451.03	334.75
L 6	7.43	6.67	9.25	8.50	8.34	7.58	489.13	339.71	510.00	383.75	499.56	361.73
L 7	7.43	6.54	8.50	7.75	7.96	7.15	394.70	335.03	458.33	400.00	426.52	367.51
L 8	7.95	7.13	9.00	8.25	8.48	7.69	461.60	338.25	485.00	398.75	473.30	368.50
L 9	6.95	6.29	8.00	7.25	7.48	6.77	429.68	301.00	481.67	400.00	455.67	350.50
L 10	7.63	7.13	9.25	8.75	8.44	7.94	442.25	380.26	475.00	448.75	458.63	414.50
L 11	6.93	6.25	8.50	7.75	7.71	7.00	447.10	269.87	476.67	332.50	461.88	301.18
L 12	6.43	6.17	7.50	7.00	6.96	6.58	428.30	292.91	456.67	372.50	442.48	332.70
L 13	7.80	6.21	8.25	7.75	8.03	6.98	490.33	373.67	513.33	421.25	501.83	397.46
L 14	6.43	6.04	7.50	7.00	6.96	6.52	441.18	322.91	473.33	351.25	457.25	337.08
L 15	6.18	5.58	6.00	5.50	6.09	5.54	379.98	307.75	408.33	342.50	394.15	325.13
L 16	6.83	6.63	7.00	7.00	6.91	6.81	432.45	366.32	490.00	380.00	461.23	373.16
LSD 0.05	0.52		ns		ns		28.18		ns		31.54	
CV %	5.58		8.65		7.47		5.23		9.49		7.86	

Table 10. Effect of the interaction between barley genotypes and irrigation treatments on spike length and spikes number m-2in both growing seasons.

Characteristic	Spike length (cm)						Spikes number m^{-2}					
Genotype	2009/10		2010/11		Comb.		2009/10		2010/11		Comb.	
	Irrigated	Stressed	Irrigated	Stressed	Irrigated	Stressed	Irrigated	Stressed	Irrigated	Stressed	Irrigated	Stressed
Giza 126	7.00	6.75	7.75	7.50	7.38	7.13	430.08	344.80	470.00	356.25	450.04	350.53
Giza 132	8.70	7.04	8.75	7.75	8.73	7.40	444.90	352.85	533.33	365.00	489.12	358.92
Beacher	6.30	5.54	7.25	7.00	6.78	6.27	411.98	328.76	453.33	345.00	432.65	336.88
Giza 121	7.80	7.25	9.25	8.50	8.53	7.88	437.68	362.60	495.00	413.75	466.34	388.18
L 1	6.88	6.13	7.50	7.25	7.19	6.69	413.63	327.20	463.33	341.25	438.48	334.22
L 2	6.58	6.00	7.25	7.25	6.91	6.63	418.18	347.31	470.00	368.75	444.09	358.03
L 3	6.63	6.13	6.75	6.25	6.69	6.19	440.90	319.78	538.33	356.25	489.62	338.02
L 4	6.68	5.63	7.75	7.25	7.21	6.44	445.10	353.37	513.33	433.75	479.22	393.56
L 5	6.88	6.13	7.75	7.50	7.31	6.81	415.40	312.01	486.67	357.50	451.03	334.75
L 6	7.43	6.67	9.25	8.50	8.34	7.58	489.13	339.71	510.00	383.75	499.56	361.73
L 7	7.43	6.54	8.50	7.75	7.96	7.15	394.70	335.03	458.33	400.00	426.52	367.51
L 8	7.95	7.13	9.00	8.25	8.48	7.69	461.60	338.25	485.00	398.75	473.30	368.50
L 9	6.95	6.29	8.00	7.25	7.48	6.77	429.68	301.00	481.67	400.00	455.67	350.50
L 10	7.63	7.13	9.25	8.75	8.44	7.94	442.25	380.26	475.00	448.75	458.63	414.50
L 11	6.93	6.25	8.50	7.75	7.71	7.00	447.10	269.87	476.67	332.50	461.88	301.18
L 12	6.43	6.17	7.50	7.00	6.96	6.58	428.30	292.91	456.67	372.50	442.48	332.70
L 13	7.80	6.21	8.25	7.75	8.03	6.98	490.33	373.67	513.33	421.25	501.83	397.46
L 14	6.43	6.04	7.50	7.00	6.96	6.52	441.18	322.91	473.33	351.25	457.25	337.08
L 15	6.18	5.58	6.00	5.50	6.09	5.54	379.98	307.75	408.33	342.50	394.15	325.13
L 16	6.83	6.63	7.00	7.00	6.91	6.81	432.45	366.32	490.00	380.00	461.23	373.16
LSD 0.05	0.52		ns		ns		28.18		ns		31.54	
CV %	5.58		8.65		7.47		5.23		9.49		7.86	

Table 11. Effect of the interaction between barley genotypes and irrigation treatments on grains number per spike and 1000-grain weight in both growing seasons.

Characteristic	Grains number per spike						1000-grain weight (g)					
Genotype	2009/10		2010/11		Comb.		2009/10		2010/11		Comb.	
	Irrigated	Stressed	Irrigated	Stressed	Irrigated	Stressed	Irrigated	Stressed	Irrigated	Stressed	Irrigated	Stressed
Giza 126	57.10	54.18	61.27	62.50	59.18	58.34	49.10	47.77	50.09	49.14	49.59	48.45
Giza 132	63.13	58.98	67.47	63.60	65.30	61.29	47.23	44.59	48.20	46.16	47.71	45.38
Beacher	55.38	43.51	54.33	49.75	54.85	46.63	49.18	43.60	51.64	44.33	50.41	43.96
Giza 121	54.00	49.71	56.47	58.85	55.23	54.28	54.08	52.06	57.61	57.26	55.84	54.66
L 1	53.48	41.53	61.47	53.45	57.47	47.49	53.48	48.16	55.33	46.04	54.40	47.10
L 2	56.18	44.55	61.73	56.25	58.95	50.40	52.50	50.75	53.50	52.75	53.00	51.75
L 3	58.73	54.96	67.27	58.65	63.00	56.80	42.55	39.47	43.33	42.40	42.94	40.93
L 4	52.60	50.95	54.20	60.75	53.40	55.85	51.80	48.49	52.58	49.51	52.19	49.00
L 5	55.23	47.05	58.00	51.00	56.61	49.03	53.00	51.27	54.69	51.79	53.84	51.53
L 6	51.38	44.59	61.33	50.10	56.35	47.35	55.83	49.29	59.23	48.81	57.53	49.05
L 7	54.08	45.56	60.53	52.80	57.30	49.18	60.38	56.79	62.89	59.50	61.63	58.14
L 8	61.48	55.15	64.67	66.30	63.07	60.73	42.38	41.46	43.04	42.48	42.71	41.97
L 9	58.60	52.32	67.42	60.30	63.01	56.31	53.38	48.33	54.86	46.07	54.12	47.20
L 10	62.18	55.64	68.40	64.95	65.29	60.30	41.33	37.64	42.70	39.88	42.01	38.76
L 11	55.48	49.46	61.00	58.05	58.24	53.75	56.80	52.76	57.64	54.66	57.22	53.71
L 12	55.20	47.38	60.07	52.10	57.63	49.74	53.48	50.52	52.46	51.08	52.97	50.80
L 13	52.85	45.31	58.93	56.55	55.89	50.93	53.13	50.33	54.86	52.03	53.99	51.18
L 14	52.03	44.26	54.00	55.25	53.01	49.75	54.98	52.56	58.38	54.89	56.68	53.73
L 15	56.90	52.55	62.13	63.30	59.52	57.93	60.88	56.76	62.92	58.48	61.90	57.62
L 16	55.00	45.09	60.13	50.15	57.57	47.62	55.50	52.95	56.01	53.48	55.76	53.22
LSD 0.05	3.50		6.61		3.73		1.94		3.80		2.12	
CV %	4.76		7.98		6.78		2.75		5.24		4.22	

Table 12. Effect of the interaction between barley genotypes and irrigation treatments on biological yield and grain yield in both growing seasons.

Characteristic	Biological yield (kg fed.$^{-1}$)						Grain yield (kg fed.$^{-1}$)					
Genotype	2009/10		2010/11		Comb.		2009/10		2010/11		Comb.	
	Irrigated	Stressed	Irrigated	Stressed	Irrigated	Stressed	Irrigated	Stressed	Irrigated	Stressed	Irrigated	Stressed
Giza 126	9339	5875	12000	6450	10669	6163	3240	2123	4238	2800	3739	2462
Giza 132	10420	5783	14050	6550	12235	6166	3246	2097	4288	2738	3767	2417
Beacher	8468	5042	10200	5750	9334	5396	2911	1984	3638	2500	3274	2242
Giza 121	9107	5600	11600	6250	10354	5925	3204	2075	4200	2775	3702	2425
L 1	8825	4028	11250	4650	10038	4339	3108	1615	4225	2163	3666	1889
L 2	8665	5366	10450	6100	9558	5733	3184	2050	4375	2850	3780	2450
L 3	9283	5189	12500	6050	10892	5620	2883	1687	3963	2225	3423	1956
L 4	9820	6498	12625	7700	11222	7099	3536	2500	4925	3575	4231	3037
L 5	9064	5853	12400	6875	10732	6364	3262	2112	4400	2850	3831	2481
L 6	9367	5658	12000	6700	10683	6179	3409	2128	4613	2875	4011	2501
L 7	9311	5068	11950	5850	10630	5459	2863	1819	3863	2350	3363	2084
L 8	9929	5927	12625	7350	11277	6639	3372	2252	4300	3150	3836	2701
L 9	8546	5560	11200	6875	9873	6217	3000	2140	3888	2875	3444	2507
L 10	8005	4833	9725	5675	8865	5254	2726	1823	3475	2450	3101	2136
L 11	9292	5177	11950	6600	10621	5888	3511	2077	4638	2813	4074	2445
L 12	8104	4776	9750	5100	8927	4938	3152	1795	4025	2225	3588	2010
L 13	9188	5073	11250	5625	10219	5349	3085	1918	3838	2488	3461	2203
L 14	9054	5251	11375	6100	10215	5675	3188	1770	4125	2288	3656	2029
L 15	8868	5413	11350	6125	10109	5769	3052	1975	4063	2650	3557	2313
L 16	9346	5907	10750	5600	10048	5754	3071	2041	3788	2138	3429	2089
LSD 0.05	ns		ns		942		ns		ns		ns	
CV %	7.66		13.63		11.87		9.54		14.36		12.94	

Table 13. Effect of the interaction between barley genotypes and irrigation treatments on water use efficiency in both growing seasons.

Characteristic	Water Use Efficiency					
Genotype	2009/10		2010/11		Comb.	
	Irrigated	Stressed	Irrigated	Stressed	Irrigated	Stressed
Giza 126	1.94	2.60	2.38	2.79	2.17	2.70
Giza 132	1.95	2.56	2.41	2.73	2.19	2.65
Beacher	1.75	2.43	2.04	2.49	1.90	2.46
Giza 121	1.92	2.54	2.36	2.76	2.15	2.66
L 1	1.86	1.98	2.37	2.15	2.13	2.07
L 2	1.91	2.51	2.46	2.84	2.19	2.69
L 3	1.73	2.06	2.23	2.22	1.99	2.15
L 4	2.12	3.06	2.77	3.56	2.46	3.33
L 5	1.96	2.58	2.47	2.84	2.22	2.72
L 6	2.04	2.60	2.59	2.86	2.33	2.75
L 7	1.72	2.22	2.17	2.34	1.95	2.29
L 8	2.02	2.75	2.42	3.14	2.23	2.97
L 9	1.80	2.62	2.19	2.86	2.00	2.75
L 10	1.63	2.23	1.95	2.44	1.80	2.35
L 11	2.11	2.54	2.61	2.80	2.36	2.68
L 12	1.89	2.20	2.26	2.22	2.08	2.21
L 13	1.85	2.35	2.16	2.48	2.01	2.42
L 14	1.91	2.16	2.32	2.28	2.12	2.23
L 15	1.83	2.42	2.28	2.64	2.06	2.54
L 16	1.84	2.50	2.13	2.13	1.99	2.29
LSD 0.05	ns		ns		ns	
CV %	9.24		19.02		16.99	

Water use efficiency (WUE) is often considered an important determinant of yield under stress and even as a component of crop drought tolerance. As well as water utilization efficiency is a useful measure in evaluating irrigation practice, particularly under deficit irrigation technique, where irrigation water is searched. Such measure illustrated the crop performance as irrigation water was applied water that require for crop yield potentiality. L4, L5, L6, L8 and L11 gave the highest values for water use efficiency compared to Giza 126 in both seasons under both conditions (table 13). This finding is confirming the fact that if the crop performance under soil water stress is acceptable, it well be better under available soil moisture condition. These results are in agreement with those reported by Kamel *et al.* (2008) and Ali (2009).

Data in Table 14 showed that the yield was the highest in Giza132, L2, L4, L5, L6, L8 and L11. Also, they showed no reduction in yield compared with Giza126. On the other hand, L10, Beacher, L3 and L7 were the lowest, while, reduction averages in stress condition compared with normal condition were lowest in L9, L10 and Beacher, and the highest reduction was obtained in L1, L11, L14, L12 and L6. The genotypes showed significant differences in grain yield. Grain yield under irrigated condition was adversely correlated with stress condition (Table 17), suggesting that high potential yield under optimal conditions, generally gave the same trend under stress condition for all characteristics at both seasons, this finding is corresponded with those reported by Finlay (1968) and Blum (1979). Thus, indirect selection for a drought-prone environment based on the results of optimum conditions could be efficient.

Table 14. Grain yield status of barley genotypes in drought trail compared to local variety (Giza126) in 2009-2010 and 2010-2011 seasons.

Genotype	Yield (%) of genotypes compared to yield of Giza126		Mean of 2 trials	Difference to Giza126[1]	Average reductions[2]
	N	S			
Giza 126	100	100	100	0.00	1277
Giza 132	101	100	100	-0.27	1349
Beacher	88	89	88	-11.04	1032
Giza 121	99	99	99	-1.18	1277
L 1	98	90	94	-10.41	1778
L 2	101	100	101	0.47	1330
L 3	92	87	89	-13.26	1467
L 4	113	117	115	17.22	1193
L 5	102	102	102	1.80	1350
L 6	107	105	106	5.03	1510
L 7	90	88	89	-12.15	1278
L 8	103	105	104	5.42	1135
L 9	92	96	94	-4.02	937
L 10	83	84	84	-15.54	964
L 11	109	105	107	5.13	1630
L 12	96	90	93	-9.72	1579
L 13	93	91	92	-8.65	1259
L 14	98	92	95	-8.32	1628
L 15	95	95	95	-5.33	1245
L 16	92	89	90	-11.00	1340

[1] Deference of grain yields of 20 genotypes to local variety (Giza126) under both conditions.

[2] Average reduction of grain yield of 20 barley genotypes caused by drought stress (kg fed.$^{-1}$).

Biological yield and grain yield showed highly positive significantly correlated with all studied characters. Highly significant positive correlations were observed between days to maturity and each of plant height, spike length, spike number m^{-2}, grain per spike, biological yield and grain yield. Highly significant positive correlations were observed between plant height, spike number m^{-2} and all studied characteristic, except for water use efficiency was not significant. The correlation coefficients highly significant and positive between spike length and most studied characteristic, except for water use efficiency and 1000-grain weight were not significant (Table 15).

Table 15. Simple correlation coefficients between grain yield and the other studied characteristics overall the two growing seasons.

Characteristic	1	2	3	4	5	6	7	8	9
Days to maturity (1)	1.00								
Plant height (2)	0.70**	1.00							
Spike length (3)	0.57**	0.58**	1.00						
Spike number (4)	0.57**	0.50**	0.52**	1.00					
Grain per spike (5)	0.64**	0.45**	0.47**	0.47**	1.00				
1000-grain weight (6)	-0.02	0.25**	0.00	0.15**	-0.09	1.00			
Biological yield (7)	0.61**	0.54**	0.46**	0.80**	0.51**	0.29**	1.00		
Grain yield (8)	0.59**	0.58**	0.46**	0.77**	0.53**	0.30**	0.90**	1.00	
Water use efficiency (9)	-0.26	0.22	0.14	0.16	-0.05	0.16	0.62**	0.94**	1.00

*: Significant at 5% levels of probability

**: highly Significant at 1% levels of probability

Concerning grain yield, results showed that L4 and L8 had the heaviest grains among other genotypes under both conditions. Also, data in Table16 indicated that all drought tolerance indices for L4 and L8 genotypes possessed high values for MP, YSI, STI, GMP and YI and DSI less than one, and low values of Yr, revealing that these genotypes were more tolerant to water deficient (Table 16).

Genotypes with low DSI values (less than I) can be considered drought tolerant (Bruckner & Frohberg, 1987), because they exhibit smaller yield reductions under water stress compared with normal condition than the mean of all genotypes. However, the low DSI values may not necessarily give a good indication of drought tolerance of genotype. Low DSI values of a variety could be due to lack of yield production under normal conditions rather than an indication of its ability to tolerate water stress.

Table16. Tolerance indices of 20 barley genotypes under stress and non-stress conditions.

Genotype	GYp	GYs	YSI	YI	GMP	STI	MP	Yr	DSI
Giza 126	3739	2462	0.66	1.06	3034	0.69	3100	0.34	0.95
Giza 132	3767	2417	0.64	1.04	3017	0.68	3092	0.36	1.00
Beacher	3274	2242	0.68	0.97	2709	0.55	2758	0.32	0.88
Giza 121	3702	2425	0.66	1.05	2996	0.67	3064	0.34	0.96
L 1	3666	1889	0.52	0.81	2631	0.52	2777	0.48	1.35
L 2	3780	2450	0.65	1.06	3043	0.70	3115	0.35	0.98
L 3	3423	1956	0.57	0.84	2587	0.50	2689	0.43	1.19
L 4	4231	3037	0.72	1.31	3585	0.97	3634	0.28	0.78
L 5	3831	2481	0.65	1.07	3083	0.71	3156	0.35	0.98
L 6	4011	2501	0.62	1.08	3167	0.75	3256	0.38	1.05
L 7	3363	2084	0.62	0.90	2647	0.53	2723	0.38	1.06
L 8	3836	2701	0.70	1.16	3219	0.78	3268	0.30	0.82
L 9	3444	2507	0.73	1.08	2938	0.65	2976	0.27	0.76
L 10	3101	2136	0.69	0.92	2574	0.50	2619	0.31	0.86
L 11	4074	2445	0.60	1.05	3156	0.75	3259	0.40	1.11
L 12	3588	2010	0.56	0.87	2685	0.54	2799	0.44	1.22
L 13	3461	2203	0.64	0.95	2761	0.57	2832	0.36	1.01
L 14	3656	2029	0.55	0.87	2723	0.56	2842	0.45	1.24
L 15	3557	2313	0.65	1.00	2868	0.62	2935	0.35	0.97
L 16	3429	2089	0.61	0.90	2677	0.54	2759	0.39	1.09
LSD 0.05	408.80	340.01	0.08	0.14	319.84	0.14	317.23	0.08	0.07

Grain yield under normal Yp was highly significantly correlated with grain yields under stressed Ys conditions (Table 17). Correlation analysis between drought indices and yield components showed that grain yield under irrigated and stress conditions was positively correlated with MP, STI, GMP and YI, while, yield under stress condition was positively correlated with YSI, and negatively correlated with Yr and DSI .Furthermore, correlation analysis between the various stress tolerant indices used in this study provides interesting observations. MP, YSI, STI, GMP and YI were positively significantly correlated between each other, as well as showing significant negative correlation with Yr and DSI. These results are in general agreement with those reported by Nazari and H. Pakniyat (2010), Abdi H. *et al.* (2012) and Muhammad *et al.* (2012).

Table 17 Simple correlation coefficients (r) between grain yield under normal Yp, grain yield under stressed Ys conditions and tolerance indices overall the two growing seasons.

Indices	GYp	GYs	YSI	YI	GMP	STI	MP	Yr	DSI
GYp	1.00								
GYs	0.68**	1.00							
YSI	0.03	0.75**	1.00						
YI	0.68**	1.00**	0.75**	1.00					
GMP	0.87**	0.95**	0.51*	0.95**	1.00				
STI	0.87**	0.95**	0.51*	0.95**	1.00**	1.00			
MP	0.92**	0.92**	0.42	0.91**	0.99**	0.99**	1.00		
Yr	-0.03	-0.75**	-1.00**	-0.75**	-0.51*	-0.51*	-0.42	1.00	
DSI	-0.03	-0.75**	-1.00**	-0.75**	-0.51*	-0.52*	-0.43	1.00**	1.00

*: Significant at 0.05 level of probability

**: highly Significant at 0.01 level of probability

CONCLUSION

All the studied characteristics were significantly affected by water stress in both growing seasons. The yield was the highest in Giza132, L2, L4, L5, L6, L8 and L11compared with Giza126 (as a check). Grain yield under normal (Yp) condition was highly significantly correlated with grain yields under stressed Ys conditions. Correlation analysis between drought indices and yield components showed that grain yield under irrigated and stress conditions was positively correlated with MP, STI, GMP and YI. Also, yield under stress condition (Ys) was positively correlated with YSI, and negatively correlated with Yr and DSI. L4 and L8 which had the heaviest grains and the highest values of WUE among the genotypes under both conditions, as well as possessed high values of MP, YSI, STI, GMP and YI and DSI less than one, and low values of Yr, revealing that these genotypes were more tolerant to water stress.

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تقدير تحمل عشرون تركيباً وراثياً من الشعير للإجهاد المائى تحت الظروف الحقلية

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٢. *قسم بحوث الشعير– معهد بحوث المحاصيل الحقلية – مركز البحوث الزراعية*

لتقدير تحمل أربعه أصناف وسته عشر سلالة من الشعير للإجهاد المائى، تم قياس صفات عدد الأيام حتى النضج، ارتفاع النبات، طول السنبلة، عدد السنابل فى المتر المربع، عدد حبوب السنبلة، وزن الألف حبة، محصول الحبوب، المحصول البيولوجي و كفائة الاستهلاك المائى وكذلك تم تقدير سبع دلائل لتحمل الإجهاد (STI، YI، YSI، MP ، GMP، *Yr* و DSI) وذلك فى محطة بحوث سخا فى موسمى ٢٠٠٩/٢٠١٠ ، ٢٠١٠/٢٠١١. وقد تأثرت جميع الصفات المدروسة سلبيا وبشكل كبير نتيجة للإجهاد المائى فى كل من الموسمين. وكان هناك فروقا معنوية بين كل دلائل التحمل بين كل التراكيب الوراثية المستخدمة. وقد وجد ارتباط معنوى موجب بين محصول الحبوب تحت الظروف الطبيعة ومحصول الحبوب تحت الإجهاد المائى ، وكذلك ارتباط معنوى موجب بين محصول الحبوب تحت الظروف الطبيعة و(YI – STI – MP- GMP) فى حين وجد. ارتباط معنوى موجب بين محصول الحبوب تحت ظروف الإجهاد و (YSI - –STI –MP-GMP) YIوارتباط عكسى مع Yr وDSI . وقد أظهرت السلالتان ٤ و ٨ قيما مرتفعة لمحصول الحبوب وكفائة الاستهلاك المائى تحت كل من الظروف الطبيعية وتحت ظروف الإجهاد بالمقارنة بالصنف جيزة ١٢٦(صنف المقارنة)، حيث أعطيتا قيما مرتفعة لــ (YI – MP- GMP – STI – YSI) وكذلك أعطيتا قيما منخفضة لدليل الحساسية DSI ودليل انخفاض المحصول Yr. فكلتا السلالتان تمثلان أكثر التراكيب الوراثية المرغوبة والمتحملة للإجهاد.