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Response of Hull-less Barley Genotypes for High Yield Potential and Stability as Affected by Different Water Stress Conditions

[1]M.A. Abdel-Moneam, [1]M.S. Sultan, [2]A.A. Eid and [2]Sally E. El-Wakeel
[1]Department of Agronomy, Faculty of Agriculture, Mansoura University, Monsoura, Egypt
[2]Department of Barley, Field Crops Research Institute, Agriculture Research Ceter, Giza, Egypt

Corresponding Author: M.A. Abdel-Moneam, Department of Agronomy, Faculty of Agriculture, Mansoura University, Monsoura, Egypt

ABSTRACT

The experiment was conducted to evaluate ten hull-less barley (*Hordeum vulgare* L.) genotypes (line-1 to line-7, Giza 129, Giza 130 and Giza 131) for high yield potential and stable performance under two irrigation treatments (normal and stress). Plant height, spike length, spikes No. m^{-2}, grains number/spike, 1000-grain weight, biological yield/plot and grain yield/plot were evaluated during two successive seasons 2010/2011 and 2011/2012 at Sakha Agricultural Research Station (ARC), Egypt. Results revealed that negative significant effects observed for water stress in both growing seasons. Line-3, line-4 and Giza 130 which had the highest biological yield and grain yield especially under stress condiotion. Drought Susceptibility Index (DSI) over both conditions indicated that line-2, line-7, Giza 130 and Giza 131 were tolerant for most traits, indicating the importance of these parents in this regard. The correlation analysis showed that highly significant positive correlations between yield components and grain yield under the two conditions were detected.

Key words: Barley, water stress, drought susceptibility index, simple correlation coefficient

INTRODUCTION

Drought is a major abiotic stress that severely affects barley production worldwide.Therefore, research into crop management practices that enhance drought tolerance and plant growth when water supply is limited has become increasingly essential. Barley germplasm is a treasure trove of useful genes and provide 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. Blum (1979) suggested that one method of breeding for increasing 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. 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 and Wilkinson, 1963; Smith, 1982). Therefore the experiments were undertaken to screen out the hull-less barley genotypes with high yield potential and stability under water stress conditions.

MATERIALS AND METHODS

Ten hull-less barley genotypes (7 lines and three local varieties i.e., (Giza 129, 130 and131)) were chosen for the study based on their reputed differences in yield performance under

Table 1: Name and pedigree of 10 barley genotypes

Pedigree	Genotypes
CONGONA/3/ATACO/BERMEJO//HIGO/4/PETUNIA 1	Line-1
LIGNEE640/P1382798//DC-B/3/MOLA/4/ LION/ 10/ CLN-B/7/S.P-B/LIGNEE640/6/S.P-B/5/GLORIA-BAR /4/ SOTOL//2762/BC-B/3/ 11012.2 /TERN-B//H272/8/ FALCON-BAR/9/ LION/11/PETUNIA 1	Line-2
CLN-B/80.5138//GLORIA-BAR/COPAL/3/CERRAJA	Line-3
CONGONA/3/ATACO/ACHIRA//HIGO/7/ZARZA/5/GLORIA-BAR/4/SOTOL//2762/BC-B/3/ 11012.2/ TERN-B//H272/6/SEN	Line-4
PETUNIA 2	Line-5
ALANDA//LIGNEE527//ARAR/3/BF891M-653	Line-6
BF891M-597	Line-7
Local variety	Giza 129
Local variety	Giza 130
Local variety	Giza 131

Table 2: Maximum, minimum temperature and rainfall during the growing seasons of barley at sakha agricultural research station (ARC), Egypt

	Temperature (°C)					
	2010/2011		2011/2012		Rainfall (mm)	
Month	Maximum	Minimum	Maximum	Minimum	2010/2011	2011/2012
December	16.82	14.75	20.2	6.4	33.6	14.59
Januar	14.73	12.49	18.2	8.4	12.8	33.47
February	15.81	13.32	17.5	9.6	63.8	32.74
March	18.24	15.09	20.5	12.3	119.0	31.95
April	23.40	18.08	27.1	17.1	137.2	0.00

normal and stress conditions (Table 1). Experiments were conducted at the experimental farm of Sakha Agricultural Research Station, (ARC), Egypt, during the two successive seasons 2010/2011 and 2011/2012.

In the second season, the maximum temperature was high and rainfalls were low compared with the first season (Table 2).

Giza 131 was the most drought tolerant variety. So, this variety used as check comparing with the other genotypes. Seeds of barley were hand drilled at the recommended sowing rate in Egypt (50 kg fed.). Each genotype was sown in six rows of 3.5 m, with 20 cm between rows. Two separated experiments were laid out in Randomized Complete Blocks Design (RCBD) with three replications. The first experiment was irrigated three times after planting irrigation (normal condition). While, the second experiment was given planting irrigation only (drought stress condition). Sowing was done in 15th of December in both experiments. The preceding crop was cotton in both the seasons.

Plant height (cm), spike length (cm), spikes number m^{-2}, grains number $spike^{-1}$, 1000-grain weight (g), biological yield $plot^{-1}$ (g) and grain yield $plot^{-1}$ (g) were studied.

Drought Susceptibility Index (SDI) were calculated according to Fischer and Maurer (1978) as follows:

$$DSI = (1\text{-}Yd/Yw)/D$$

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) mean higher stress sensitivity.

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

RESULTS AND DISCUSSIONS

In both seasons, a tallest plant was achieved when plants were grown under the well-watered treatment compared with those plants grown under the stress treatments (Table 3). Giza 131 was the tallest genotype followed by Giza 130 and line-2 in both treatments and both seasons and combined. While, line-5 was the shortest in both treatments and both seasons. Line-3 was least affected as a result of water stress, while line-5 was the most affected genotype. The reduction percentage ranged from 6.93, 0.00 and 3.62% in line-3 to 15.84, 16.84 and 16.33% in line-5 in first, second seasons and combined, respectively. These results are agreed with those of Samarah *et al.* (2009) and Vaezi *et al.* (2010).

As shown in Table (4), irrigated treatment had higher spike length than the stressed treatment. spike length (9.77, 8.91 and 9.34 cm in the first, second growing seasons and combined, respectively) was exhibited the highest value under irrigated treatment and corresponding the

Table 3: Effect of irrigation treatments on different barley genotypes and interaction between barley genotypes and irrigation treatments for plant height

	Plant height (cm)		
	Effect of irrigation treatments		
Treatment	2010/2011	2011/2012	Comb.
Normal	120.17	114.14	117.155
Stress	106.56	99.06	102.810
Reduce (%)	11.33	13.21	12.240
F test	**	**	**

	Interaction											
	Means			2010/2011			2011/2012			Comb.		
Genotypes	2010/2011	2011/2012	Comb.	Normal	Stress	Reduce (%)	Normal	Stress	Reduce (%)	Normal	Stress	Reduce (%)
Line-1	111.50	105.28	108.39	118.00	105.00	11.02	112.22	98.33	12.38	115.11	101.67	11.68
Line-2	117.50	113.17	115.34	126.11	108.89	13.65	121.89	104.44	14.32	124.00	106.67	13.98
Line-3	108.33	99.00	103.67	112.22	104.44	6.93	102.44	102.44	0.00	107.33	103.44	3.62
Line-4	111.39	105.28	108.34	117.78	105.00	10.85	113.89	96.67	15.12	115.84	100.84	12.95
Line-5	103.33	96.67	100.00	112.22	94.44	15.84	105.56	87.78	16.84	108.89	91.11	16.33
Line-6	111.94	103.89	107.92	116.67	107.22	8.10	108.89	98.89	9.18	112.78	103.06	8.62
Line-7	110.28	100.83	105.56	117.22	103.33	11.85	109.44	92.22	15.73	113.33	97.78	13.73
Giza 129	115.67	110.83	113.25	123.56	107.78	12.77	118.33	103.33	12.68	120.95	105.56	12.72
Giza 130	121.44	113.61	117.53	128.44	114.44	10.90	122.22	105.00	14.09	125.33	109.72	12.46
Giza 131	122.22	117.44	119.83	129.44	115.00	11.16	126.56	108.33	14.40	128.00	111.67	12.76
F test	**		**		**		**		**		**	
LSD 0.01	3.09		3.17		2.15		4.37		4.49		3.05	

Table 4: Effect of irrigation treatments on different barley genotypes and interaction between barley genotypes and irrigation treatments for spike length

	Spike length (cm)		
	Effect of irrigation treatments		
Treatment	2010/2011	2011/2012	Comb.
Irrigated	9.77	8.91	9.34
Stressed	7.68	6.57	7.13
Reduce%	21.39	26.26	23.72
F test	**	**	**

	Interaction											
	Means			2010/2011			2011/2012			Comb.		
Genotypes	2010/2011	2011/2012	Comb.	Normal	Stress	Reduce (%)	Normal	Stress	Reduce (%)	Normal	Stress	Reduce (%)
Line-1	8.72	8.06	8.39	10.11	7.33	27.50	9.78	6.33	35.28	9.95	6.83	31.32
Line-2	9.11	8.06	8.59	10.00	8.22	17.80	9.00	7.11	21.00	9.50	7.67	19.32
Line-3	8.06	7.00	7.53	9.22	6.89	25.27	7.89	6.11	22.56	8.56	6.50	24.02
Line-4	7.89	6.78	7.34	9.00	6.78	24.67	7.67	5.89	23.21	8.34	6.34	24.00
Line-5	7.72	6.94	7.33	8.78	6.67	24.03	7.89	6.00	23.95	8.34	6.34	24.00
Line-6	8.28	7.56	7.92	9.67	6.89	28.75	8.78	6.33	27.90	9.23	6.61	28.35
Line-7	9.22	7.78	8.50	9.89	8.56	13.45	8.89	6.67	24.97	9.39	7.62	18.90
Giza 129	9.00	8.39	8.70	10.44	7.56	27.59	9.78	7.00	28.43	10.11	7.28	27.99
Giza 130	9.39	7.94	8.67	10.22	8.56	16.24	9.44	6.44	31.78	9.83	7.50	23.70
Giza 131	9.83	8.89	9.36	10.33	9.33	9.68	10.00	7.78	22.20	10.17	8.56	15.84
F test	**		**		**		**		**		**	
LSD 0.01	0.29		0.4		0.33		0.76		0.56		0.47	

lowest values obtained from the stressed treatment (7.68, 6.57 and 7.13 cm) in the first, second growing seasons and combined, respectively. The reduction percentage was 21.39, 26.26 and 23.72% in the first, second growing seasons and combined, respectively. These results are in agreement with those obtained by Farhat (2005) and Samarah *et al*. (2009).

For means of the ten barley genotypes, results showed highly significant differences existed between barley genotypes. Giza 131 gave the highest values for spike length under both seasons compared to the other genotypes, followed by Giza 130, line-7 and line-2 in the first season, while, Giza 130, line-7 and line-2 in the second season and Giza 129, Giza 130 and line-2 in combined.

Highly significant interaction between barley genotypes and irrigation treatments was found, where Giza 131 gave the highest values for spike length compared to the other genotypes under both treatments which gave the smallest reduction percentage, while line-6 gave the highest reduction percentage in first season and line-1 gave the highest reduction percentage in second season and combined. These results are in harmony with those of Refay (2010), Zare *et al*. (2011) and Amini *et al*. (2012).

Regarding to the influence of irrigation treatments on this trait, the data clearly show that spikes number m^{-2} was highly significant affected by irrigation treatments at both growing seasons. The irrigated treatment recorded the highest number of spike m^{-2} (426.67, 327.33 and 377.00 spikes in m^2 in the first, second growing seasons and combined, respectively (Table 5). The severe drought stress treatment decreased spike number compared with the well-watered treatment in

Table 5: Effect of irrigation treatments on different barley genotypes and interaction between barley genotypes and irrigation treatments for No. of spikes m^{-2}

Treatment	Spikes No. m^{-2} – Effect of irrigation treatments: 2010/2011	2011/2012	Comb.
Irrigated	426.67	327.33	377.00
Stressed	352.00	277.00	314.50
Reduce (%)	17.50	15.38	16.58
F test	**	**	**

	Interaction											
	Means			2010/2011			2011/2012			Comb.		
Genotypes	2010/2011	2011/2012	Comb.	Normal	Stress	Reduce (%)	Normal	Stress	Reduce (%)	Normal	Stress	Reduce (%)
Line-1	378.33	306.67	342.50	411.67	345.00	16.20	360.00	253.33	29.63	385.84	299.17	22.46
Line-2	385.00	333.33	359.17	420.00	350.00	16.67	336.67	330.00	1.98	378.34	340.00	10.13
Line-3	416.67	325.00	370.84	458.33	375.00	18.18	333.33	316.67	5.00	395.83	345.84	12.63
Line-4	346.67	253.33	300.00	385.00	308.33	19.91	273.33	233.33	14.63	329.17	270.83	17.72
Line-5	418.33	321.67	370.00	448.33	388.33	13.38	323.33	320.00	1.03	385.83	354.17	8.21
Line-6	405.83	303.33	354.58	438.33	373.33	14.83	348.33	258.33	25.84	393.33	315.83	19.70
Line-7	400.00	295.00	347.50	450.00	350.00	22.22	323.33	266.67	17.52	386.67	308.34	20.26
Giza 129	390.00	307.50	348.75	446.67	333.33	25.37	348.33	266.67	23.44	397.50	300.00	24.53
Giza 130	370.83	300.00	335.42	383.33	358.33	6.52	330.00	270.00	18.18	356.67	314.17	11.92
Giza 131	381.67	275.83	328.75	425.00	338.33	20.39	296.67	255.00	14.05	360.84	296.67	17.78
F test	**		**		**		*		Ns		*	
LSD 0.01	30.67		47.94		28.07		32.39		--		29.93	

both growing seasons. Such response may be attributing to lack of water absorbed and reduction in photosynthetic efficiency under insufficient water condition. Moreover, the reduction in assimilates translocated to new developing tillers might owe much the death of the new tillers and depressed the number of spikes primordial. These results are confirmed by Samarah *et al.* (2009) and Vaezi *et al.* (2010).

There were significant differences in spikes No. m^{-2} among genotypes in both growing seasons and combined. Line-3 and line-5 gave the highest values for spikes number compared to Giza 131 in both seasons and combined, while line-2 gave the highest values in the second growing season. Line-4 was the lowest genotypes in spikes No. m^{-2} in both growing seasons and combined.

There were a significant interaction between irrigation treatments and genotypes for spike number in the first growing season and combined. The reduction percentage ranged from 6.52% in Giza 130 to 25.37% in Giza 129 in the first season, from 1.03% in line-5 to 29.63% in line-1 in the second season and from 8.21% in line-5 to 24.53% in Giza 129 in combined data. These results are in agreement with those obtained by Mamnouie *et al.* (2006). But the interaction between barley genotypes and irrigation treatments was insignificant in the second growing season, where many other researchers found similar result such as, Refay (2010), Mollah and Paul (2011), Zare *et al.* (2011) and Amini *et al.* (2012).

Concerning response of grains number/spike to irrigation treatments, the results presented in Table 6, indicated that grains number per spike was significantly affected by irrigation treatments. This trend hold true in both growing seasons and combined data. It could be noticed that, the

Table 6: Effect of irrigation treatments on different barley genotypes and interaction between barley genotypes and irrigation treatments for grains number/spike

	Grains No. spike^{-1}		
	Effect of irrigation treatments		
Treatment	2010/2011	2011/2012	Comb.
Irrigated	76.80	69.33	73.065
Stressed	70.80	58.00	64.40
Reduce (%)	7.81	16.34	11.86
F test	**	**	**

	Interaction											
	Means			2010/2011			2011/2012			Comb.		
Genotypes	2010/11	2011/12	Comb.	Normal	Stress	Reduce (%)	Normal	Stress	Reduce (%)	Normal	Stress	Reduce (%)
Line-1	80.00	70.67	75.34	82.00	78.00	4.88	73.33	68.00	7.27	77.67	73.00	6.01
Line-2	80.33	70.67	75.50	82.67	78.00	5.65	75.33	66.00	12.39	79.00	72.00	8.86
Line-3	74.00	61.33	67.67	76.00	72.00	5.56	66.67	56.00	16.00	71.34	46.00	10.27
Line-4	66.33	57.33	61.83	68.67	64.00	6.80	60.67	54.00	10.99	64.67	59.00	8.77
Line-5	62.33	53.67	58.00	66.67	58.00	13.00	59.33	48.00	19.10	63.00	53.00	15.87
Line-6	68.33	59.33	63.83	74.67	62.00	16.97	66.67	52.00	22.00	70.67	57.00	19.34
Line-7	77.00	63.33	70.17	80.00	74.00	7.50	68.67	58.00	15.54	74.34	66.00	11.21
Giza 129	72.67	61.67	67.17	79.33	66.00	16.80	73.33	50.00	31.82	76.33	58.00	24.01
Giza 130	77.33	67.33	72.33	78.67	76.00	3.39	72.67	62.00	14.68	75.67	69.00	8.81
Giza 131	79.67	71.33	75.50	83.33	76.00	8.80	76.67	66.00	13.92	80.00	71.00	11.25
F test	**		**		**		**		**		**	
LSD 0.01	4.45		4.38		3.05		6.29		6.2		4.32	

exposure of plants to water shortage at any developmental growth stages decreased significantly number of grains per spike. Water stress at various stages, especially before anthesis, can reduce the number of head spikes and number of grains per spike.

The reduction percentage was 7.81, 16.34 and 11.86% in the first, second growing seasons and combined, respectively. According to Ceccarelli (1987), water deficit during the early stage of plant development induces a reduction in spikelets primordia, while water deficit late in the plant development increases death of the flower and the entire spikelet. The number of grains per spike fertility depends on water availability during the early vegetative phase and during shooting stage. If water deficit occurs after the flowering stage, it induces a decrease of grain weight and thus its yield. The results are supported with obtained by Farhat (2005), Samarah *et al.* (2009) and Vaezi *et al.* (2010).

The differences among genotypes were highly significant in both growing seasons, indicating that overall differences between two irrigation treatments. Giza131, line-1 and line-2 produced highest number of grains per spike, in both growing seasons and combined, while, line-5 gave the lowest value compared to Giza 131 in both growing seasons and combined data.

Regarding the interaction effect between genotypes and irrigation treatments, highly significant interactions were observed in both seasons. These results indicated that, the behavior of genotypes affected by changing environments. The reduction percentage ranged from 3.39% in Giza 130-16.97% in line-6 in the first season, from 7.27% in line-1 to 31.82% in Giza 129 in the second season and from 6.01% in line-1 to 24.01% in Giza 129 in combined data. These results are in agreement with those obtained by Samarah *et al.* (2009), Refay (2010) and Zare *et al.* (2011).

Table 7: Effect of irrigation treatments on different barley genotypes and interaction between barley genotypes and irrigation treatments for 1000-grain weight

	1000-grain weight (g)		
	Effect of irrigation treatments		
Treatment	2010/2011	2011/2012	Comb.
Irrigated	41.51	38.575	40.0425
Stressed	37.18	34.690	35.9350
Reduce (%)	10.43	10.070	10.2600
F test	**	**	**

	Interaction											
	Means			2010/2011			2011/2012			Comb.		
Genotypes	2010/2011	2011/2012	Comb.	Normal	Stress	Reduce (%)	Normal	Stress	Reduce (%)	Normal	Stress	Reduce (%)
Line-1	41.82	39.14	40.48	43.88	39.75	9.41	41.20	37.08	10.00	42.54	38.42	9.70
Line-2	36.73	33.80	35.27	39.05	34.4	11.91	35.37	32.23	8.00	37.21	33.32	10.47
Line-3	37.5	36.28	36.89	40.87	34.13	16.49	37.77	34.78	7.92	39.32	34.46	12.37
Line-4	42.88	39.93	41.41	44.42	41.35	6.91	42.55	37.32	12.29	43.49	39.34	9.54
Line-5	43.14	41.38	42.26	43.83	42.45	3.15	42.53	40.23	5.41	43.18	41.34	4.26
Line-6	42.06	39.15	40.61	44.68	39.43	11.75	41.33	36.97	10.55	43.01	38.20	11.17
Line-7	31.8	29.48	30.64	34.82	28.78	17.35	31.72	27.25	14.09	33.27	28.02	15.80
Giza 129	36.85	33.79	35.32	39.27	34.43	12.32	37.42	30.17	19.37	38.35	32.30	15.76
Giza 130	40.13	37.66	38.90	40.93	39.32	3.93	38.57	36.75	4.72	39.75	38.04	4.31
Giza 131	40.53	35.71	38.12	43.35	37.7	13.03	37.3	34.12	8.53	40.33	35.91	10.95
F test	**		**		**		**		**		**	
LSD 0.01	1.39		1.20		0.89		1.97		1.7		1.25	

Results in Table 7 show that, 1000-grain weight was significantly affected by irrigation treatments. Generally, it could be noticed that, this reduction might be attributed to that water deficits during the vegetative, flowering and grain filling stages which reduce available assimilate for grain filling and re-translocation of stored assimilates to grains which in turn cause a reduction in grain size. Drought stress is known to reduce 1000-grain weight by shortening the grain-filling period. These results are in agreement with those obtained by Samarah *et al.* (2009) and Vaezi *et al.* (2010).

Line-5 was the heaviest genotype in 1000-grain weight followed by line-4, line-6 and line-1 in both seasons and combined data. While, line-7 was the lowest in 1000-grain weight in both seasons and combined. The reduction percentage ranged from 3.15-17.35% in first season, 4.26-15.80% in line-5 and line-7 in combined data, respectively and ranged from 4.72% in Giza 130 to 19.37% in Giza 129 in second season.

Results show highly significant differences among irrigation treatments in both seasons, where the irrigated treatment out yielded the stressed treatment (Table 8). The reduction percentages were 10.32, 18.7 and 14.26% at the first season, the second and combined data, respectively. These results are confirmed by Bayoumi (2004) and Refay (2010). Biological yield differences were related to low plant height and tiller numbers; grain yield differences were caused by a reduction in spikes plant^{-1} and grains spike^{-1}. Genotypes Giza131 and line-3 produced the highest values, while line-2 and line-7 were the lowest genotypes in both seasons and their combined data for biological yield plot^{-1}.

Table 8: Effect of irrigation treatments on different barley genotypes and interaction between barley genotypes and irrigation treatments for biological yield

	Biological yield plot^{-1} (g)		
	Effect of irrigation treatments		
Treatment	2010/2011	2011/2012	Comb.
Irrigated	5460.00	4840.00	5150.000
Stressed	4896.67	3935.00	4415.835
Reduce (%)	10.32	18.70	14.26
F test	**	**	**

	Interaction											
	Means			2010/11			2011/12			Comb.		
Genotypes	2010/2011	2011/2012	Comb.	Normal	Stress	Reduce (%)	Normal	Stress	Reduce (%)	Normal	Stress	Reduce (%)
Line-1	5183.33	4533.33	4858.33	5833.30	4533.33	22.29	5166.67	3900.00	24.52	5500.00	4216.67	23.33
Line-2	4483.33	3916.67	4200.00	4600.00	4366.67	5.07	4166.67	3666.67	12.00	4383.34	4016.67	8.36
Line-3	5833.33	4750.00	5291.67	6233.30	5433.33	12.83	5200.00	4300.00	17.31	5716.67	4866.67	14.87
Line-4	5233.33	4300.00	4766.67	5533.30	4933.33	10.84	4966.67	3633.33	26.85	5250.00	4283.33	18.41
Line-5	4900.00	4116.67	4508.34	5366.70	4433.33	17.39	4633.33	3600.00	22.30	5000.00	4016.67	19.67
Line-6	5316.67	4716.67	5016.67	5333.33	5300.00	0.63	5066.67	4366.67	13.82	5200.61	4773.34	8.22
Line-7	4516.67	3816.67	4166.67	4866.70	4166.67	14.38	4400.00	3233.33	26.52	4633.34	3700.00	20.14
Giza 129	5116.67	4450.00	4783.34	5166.70	5066.67	1.94	4766.67	4133.33	13.29	4966.67	4600.00	7.38
Giza 130	5516.67	4475.00	4995.84	5633.30	5400.00	4.14	4866.67	4083.33	16.10	5250.00	4741.67	9.68
Giza 131	5683.33	4800.00	5241.67	6066.70	5300.00	12.64	5166.67	4433.33	14.19	5616.67	4866.67	13.35
F test	**		**		**		**		*		**	
$LSD_{0.01}$	456.09		357.56		283.86		645.01		377.52		401.44	

Regarding the interaction effect between genotypes and irrigation treatments, significant and highly significant interactions were observed in both seasons and their combined data. These results indicated that, the behavior of genotypes affected by changing environments. The reduction percentage ranged from 0.63% in line-6 to 22.29% in line-1 in the first season, from 12.0% in line-2 to 26.85% in line-4 in the second season and from 7.38 in Giza 129 to 23.33% in line-1 in combined data for biological yield plot^{-1} (Table 8).

As drought stress severity increased, grain yield decreased for all genotypes in both seasons (Table 9). The percentage of reduction in grain yield plot^{-1} by the severe drought stress treatment were 1.32, 10.46 and 5.60% in the first, the second season and combined analysis, respectively. Average yields in irrigated treatment varied from 1785-2023 kg and in the stressed treatment, they varied from 1598.33-1996.67 kg in the second and first seasons, respectively. Under both water stress and irrigated conditions, line-3 revealed the highest grain yield for two years and combined. On the other hand, line-7 was the lowest, These results agreed with Santos *et al.* (2008), Samarah *et al.* (2009), Refay (2010) and Vaezi *et al.* (2010).

The grain yield under stress environments is dependent up on stress susceptibility yield potential. The susceptibility of a plant genotype to stress in the product of many physiological and morphological traits for which effective selection criteria have not yet been developed (Fischer and Maurer, 1978). Therefore, grain yield and attributes remain as major selection criteria for improved adaptation to stress environments in many breeding programs.

Table 9: Effect of irrigation treatments on different barley genotypes and interaction between barley genotypes and irrigation treatments for grain yield

Treatment	Grain yield (g) — Effect of irrigation treatments 2010/2011	2011/2012	Comb.
Irrigated	2023.33	1785.00	1904.165
Stressed	1996.67	1598.33	1797.50
Reduce (%)	1.32	10.46	5.60
F test	ns	**	**

	Interaction											
	Means			2010/2011			2011/2012			Comb.		
Genotypes	2010/11	2011/12	Comb.	Normal	Stress	Reduce (%)	Normal	Stress	Reduce (%)	Normal	Stress	Reduce (%)
Line-1	2041.67	1825.00	1933.34	2216.70	1866.70	15.79	1966.67	1683.33	14.41	2091.67	1775.00	15.14
Line-2	1775.00	1483.33	1629.17	1800.00	1750.00	2.78	1516.67	1450.00	4.40	1658.34	1600.00	3.52
Line-3	2258.33	1900.00	2079.17	2350.00	2166.70	7.80	2000.00	1800.00	10.00	2175.00	1983.34	8.81
Line-4	2133.33	1766.67	1950.00	2216.70	2050.00	7.52	1966.67	1566.67	20.34	2091.67	1808.34	13.55
Line-5	1925.00	1558.33	1741.67	2016.70	1833.30	9.09	1783.33	1333.33	25.23	1900.00	1583.33	16.67
Line-6	2125.00	1750.00	1937.50	2250.00	2000.00	11.11	1783.33	1716.67	3.74	2016.67	1858.34	7.85
Line-7	1633.33	1350.00	1491.67	1666.00	1600.70	3.92	1416.67	1283.33	9.41	1541.34	1442.00	6.44
Giza 129	1950.00	1608.33	1779.17	2100.00	1800.00	14.29	1616.67	1600.00	1.03	1858.34	1700.00	8.52
Giza 130	2200.00	1841.67	2020.84	2250.00	2150.00	4.44	1950.00	1733.33	11.11	2100.00	1941.67	7.54
Giza 131	2058.33	1833.33	1945.83	2083.30	2033.30	2.40	1850.00	1816.67	1.80	1966.67	1925.00	2.12
F test	**		**		**		**		**		**	
LSD 0.01	124.67		137.4		90.48		176.31		194.33		127.95	

As a result of water stress condition, the average of grain yield for these genotypes decreased. Several authors reported that, drought stress reduced photosynthesis and translocation rates and increased respiration which reduced available assimilates for grain filling and finally decreased grain yield (El-Naggar, 2010; Zare *et al*., 2011).

Highly significant interactions were observed in both seasons and combined and between genotypes and irrigation treatments. These results indicated that, the behavior of genotypes affected by changing environments. The reduction percentage ranged from 2.4% in Giza 131 to 15.79% in line-1 in the first season, from 1.03% in Giza 129-25.23% in line-5 in the second season and from 2.12% in Giza 131 to 16.67% in line-5 in combined analysis.

A drought Susceptibility Index (SI) which provides a measure of stress resistance based on minimization of yield loss under stress as compared to optimum conditions, rather than on yield level under stress, has been used to characterize the relative drought tolerance of wheat genotypes (Fischer and Maurer, 1978). This index was used to estimate the relative stress loss because it accounted for variation in yield potential and stress intensity. Lower stress susceptibility index than unity (SI<1) is synonymous to high stress tolerance, while high stress Susceptibility Index (SI>1) mean higher stress sensitivity.

Data in Table 10 indicated that, line-1, line-3 and line-6 for plant height, line-2, line-7 and Giza 131 for spike length, line-2, line-3, line-5 and Giza 130 for spikes No. m^{-2}, all genotypes except line-5, line-6 and Giza 129 for grains number/spike, line-1, line-4, line-5 and Giza 130 for

Table 10: Susceptibility index for the ten hull-less barley genotypes based on all studied traits

	Plant height	Spike length	Spikes No. m^{-2}	Grains No. $spike^{-1}$	1000-grain weight	Biological yield	Grain yield
Line-1	0.98	1.32	1.35	0.51	0.94	1.64	1.65
Line-2	1.17	0.81	0.61	0.75	1.02	0.59	0.38
Line-3	0.30	1.01	0.76	0.41	1.20	1.04	0.96
Line-4	1.08	1.01	1.07	0.74	0.93	1.29	1.47
Line-5	1.37	1.01	0.49	1.34	0.42	1.38	1.81
Line-6	0.72	1.20	1.19	1.63	1.09	0.45	0.85
Line-7	1.15	0.79	1.22	0.95	1.54	1.41	0.70
Giza 129	1.06	1.18	1.48	2.02	1.54	0.52	0.93
Giza 130	1.04	1.00	0.72	0.74	0.42	0.68	0.82
Giza 131	1.07	0.67	1.07	0.95	1.07	0.94	0.23

Table 11: Simple correlation coefficients among the studied traits of hulless barley genotype under normal and water stress conditions

		Plant height	Spike length	Spikes m^{-2}	Grains/spike	1000 grain weight	Biology yield
Spike length	Normal	0.722**	1				
	Stress	0.765**	1				
Spikes m^{-2}	Normal	0.216	0.523**	1			
	Stress	0.374**	0.454**	1			
Grains $spike^{-1}$	Normal	0.691**	0.862**	0.568**	1		
	Stress	0.099	-0.086	0.296*	1		
1000 grain weight	Normal	-0.035	-0.027	0.291*	-0.092	1	
	Stress	0.709**	0.717**	0.527**	0.044	1	
Biology yield	Normal	0.060	0.263*	0.521**	0.233	0.603**	1
	Stress	0.695**	0.537**	0.595**	0.378**	0.535**	1
Grain yield	Normal	0.078	0.117	0.357**	0.104	0.737**	0.889**
	Stress	0.700**	0.416**	0.556**	0.429**	0.558**	0.942**

*,**Significant at 0.05 and 0.01 levels of probability, respectively

1000-grain weight, line-2, line-6, Giza 129, Giza 130 and Giza 131 for biological yield and all genotypes except line-1, line-4 and line-5 for grain yield possessed DSI less than one, revealing that these parents were more resistance to water stress for these traits. These results agreed with those obtained by Farhat (2005), Amer (2010) and Amer *et al.* (2011).

Correlation coefficient is important in plant breeding where it measures the degree of association between two or more characters. The correlation coefficients among the studied characters of hull-less barley genotypes under the two conditions are shown in Table 11.

Highly significant positive correlation coefficient were found between plant height and each of spike length under both conditions, grains No. $spike^{-1}$ under normal, spikes No. m^{-2}, 1000-grain weight, biological yield and grain yield under stress condition.

Highly significant positive correlations were found between spike length and each of spikes No. m^{-2} and biological yield under the two conditions, grains No. $spike^{-1}$ under normal, 1000-grain weight and grain yield under water stress. Also significant or highly significant positive correlation was detected between spikes No. m^{-2} and each of grains No. $spike^{-1}$, 1000-grain weight, biological yield and grain yield under the two conditions. Highly significant positive correlations were found between grains No. $spike^{-1}$ and each of biological yield and grain yield under water stress. Highly significant positive correlations were found between 1000-grain weight and each of biological yield and grain yield under the two conditions. Highly significant positive correlations were found among biological yield and grain yield under the two conditions. These results are in agreement with those obtained by Singh *et al.* (1998), Singh (1999), Yadav *et al.* (2003) and Vaezi *et al.* (2010).

CONCLUSION

It can be concluded that water stress had negative significant effects in both growing seasons. Line-3, line-4 and Giza 130 had the highest biological yield and grain yield especially under stress condiotion. line-2, line-7, Giza 130 and Giza 131 were tolerant for water stress condition for most traits, indicating the importance of these parents in this regard. Highly significant positive correlations were detected between yield components and grain yield under the both conditions.

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