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Assessment of Barley Genotypes to Drought Tolerance Under Different Levels of Irrigation

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Abstract

Water deficit is one of the major abiotic stresses that severely effects on barley production, it will increase frequency with climate changes. Thus, main objective from this work was to evaluate eighteen barley genotypes differed in their genetic makeup under three water irrigation levels i.e., 800, 1100 and 1400 (m^3/fad.) as severe stress, moderate stress and adequate water supply, respectively in two growing seasons, in newly reclaimed sandy soil of South El-Qantara Shark, Ismailia, Egypt. The analysis of variance for days to 50% heading, days to maturity, plant height, flag leaf area, chlorophyll content, proline content, peduncle length, spike length, number of tillers/m^2, number of spikes/m^2, No. of sterile spikelets/spike and grain yield showed highly significant differences among genotypes at six environments. The average of grain yield over all environments varied from 10.69 (Giza 126) to 15.07 ard./fad. (Line 6). The general mean for all genotypes of grain yield tended to decrease from 14.15, 12.24 to 10.51 ard./fad. in the 1st season and from 15.0, 13.1 to 10.98 ard./fad. for the 2nd season for normal water supply, moderate and severe stresses, respectively. Line 4, Line 5, Line 6, Line 9 and Line 10 had the highest values for grain yield under six environments. Therefore, these barley genotypes are more tolerant to water stress. Based on STI and DI indices, Line 4, Line 5, Line 6, Line 8, Line 9, line 10 and Line 11 were tolerant to drought and had the highest STI and DI indices under both severe and moderate stress treatments. Biological yield, straw yield and grain yield had positive and significantly correlated with spike length, awn length, No. of tillers/m^2, No. of spikes/m^2 and No. of grains/spike. According path analysis, the No. of spikes/m^2, No. of grains/spike and weight of grains/spike were considered the major yield components, indicated that the barley breeder should take into account under normal irrigation and water deficit for developing high yielding genotypes.

Keywords: Barley; Genotypes; Water stress; Heritability; Drought indices

Introduction

Barley (*Hordeum vulgare* L.) is predominant to be the most drought tolerant of the small grain cereal crops and is a major crop in Middle East and North Africa countries. In Egypt, barley is the main cereal crop grown after wheat in winter season on a large scale in the newly reclaimed land, in the low rainfall northern coastal area (100 - 200 mm annual rainfall) and in regions affected by salinity or where fresh water supplies are limited resource. It is grown in both rain fed and irrigated conditions, though in the more favourable irrigated soils of the Nile Valley barley gives way to more valuable crops. The total area to worldwide in 2016 reached about 46.9 million hectares gave total production 141.3 million tons with average 3.01 tons/ha. Meanwhile, in Egypt, the total area was about 77. 6 thousand hectares gave total production 120.1 thousand tons with average 1.55 tons/ha (FAOSTAT, 2018). In newly reclaimed sandy soils fertilization and irrigation and their interaction are the most important factors for increasing grain yield production [5,16]. Drought is the main yield-limiting factor in Mediterranean region, therefore significant areas are watered, while the irrigation water is limited [10,29]. Selection of drought tolerance barley genotypes through agronomic and physiological traits are suitable indicators to increase crop yield in breeding program, and it is major goal of plant breeder nowadays.

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Abiotic stresses including water stress can significantly decrease crop yields and limit the latitudes and soils on which commercially essential species can be cultivated [19]. The seriousness of drought stress depends on its timing, duration and intensity [18]. Drought stress tolerance is a complex inherited trait controlled by several genetic loci and is often confounded by changes in plants phenology [21,26]. Water deficit happens when water potentials in the rhizosphere are sufficiently negative to decrease water availability to sub- optimal levels for crop growth and development [16]. The combination of continued impact of drought and high temperature impairs the photosynthesis during the day-time and increases the surface temperatures in the night, which in turn increase the photo respiratory losses and thus the productivity [10].

Nowadays the agricultural activities used 75 % of global water consumption and irrigation consumes over 90% of water account in many developing countries, thus water shortages may threaten sustainable crop farming [42], more by 2050 the shortage of water are expected to affect 67% of the world's population. Consequently, the convergence of population growth and variable climate is expected to threaten food security on a worldwide scale. Lobell *et al.* (2011) reported that, climate–yield predictions are well captured on global major crops through simulations. These important crops are in need of adaptation investments to avoid catastrophic productivity losses and to meet the food demand of a fast human population growth rate.

Drought stress decreases grain yield of barley genotypes through negative affecting the yield components *i.e.* No. of plants/unit area, No. of spikes and grains per plant or unit area and 1000-kernel weight, which are determined at different stages of plant development [24,39]. Early flowering barely genotypes were better performance as reflected in higher yield compared with late flowering genotypes [4]. A number of researchers have reported that drought tolerant genotypes perform high productivity under both well-watered and drought environments (Sharafi *et al.,* 2011) [24] and can be used as parents in breeding programmes for improvement of drought tolerance in other barley cultivars [11,24]. Selection of different cereal crops genotypes under drought stress conditions is one of the main tasks of plant breeders for exploiting the genetic variations to improve the stress- tolerant cultivars [5,6,26,39].

The objectives of the present study were to evaluate response of eighteen barely genotypes under different water supply levels over two years at newly reclaimed sandy soils. Estimate the genetic variation, heritability and expected genetic advance as well as correlation and path analysis for various traits under study.

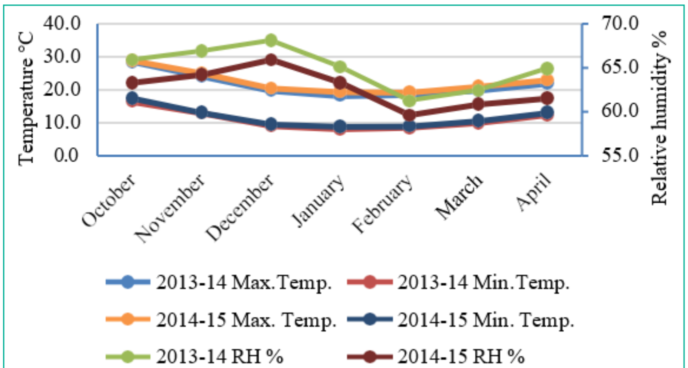

Figure 1: Relative humidity and minimum and maximum temperatures in El-Qantara Shark during the 2013/2014 and 2014/2015 winter barley growing seasons.

Materials and Methods

Barley Genotypes and Experimental Design

Thirteen promising strains (Line1 to Line13) and five local and introduced varieties *i.e.*, Giza 123, Giza 126, Giza 2000, Rihane 3 and California mariout were selected from barley program breeding, ARC, based on their tolerance to drought stress. Three separate trials were grown side by side with 12m apart on all sides, in the South El-Qantara Shark Agric. Res. Station, Barley Research Department, Field Crops Research Institute; Agricultural Research Center, Ismailia governorate condition, during two winter seasons; 2013/2014 and 2014/2015. Water irrigation quantities were adjusted by a water counter, sprinkler irrigation system was used. The experimental layout was a factorial randomized complete block design with three replications. In each environment, the plot area was 6 m^2 included 10 rows, 3 m long and 20 cm apart. Seeds of the eighteen tested barley genotypes were hand drilled at sowing rate of 50 kg grains/fad., for all tested barley genotypes. Sowing date was on the first week of December in the two seasons. Recommended N, P and K fertilizers were added at the rate 60, 150 and 50 unit fad^{-1}, as ammonium nitrate (33.5% N), calcium super phosphate (15.5% P2O5) and potassium sulphate (48% K2O), respectively. All other cultural practices for barley were applied as local recommendations in the region. The soil of the experimentation site was sandy texture.

Water Supply Treatments

All plots received a total amount of water 800 m^3/fad (severe stress), 1100 m^3/fad (moderate stress), and 1400 m^3/fad (optimum or normal water supply). This amount was given into 2 irrigations/week with 20, 27, and 34 m^3 for each irrigation from seedling stage until heading stage and then 30, 37, and 44 m^3 from heading stage to maturity stage under severe, moderate, and optimum water supply, respectively. The three water treatments received an equal number of irrigations. The water used in irrigation was mixed from El-Salam Canal and water wells.

Studied Traits

The following characters were recorded: Days to 50% Heading (DH), Days to Maturity (DM), Plant Height (PH), Flag Leaf Area (FLA), Chlorophyll Content (CC), Proline Content in Leaves (PCL), Peduncle Length (PL), Spike Length (SL), Awn Length (AL), Total number of Tillers/m^2 (TNT), Number of Non-productive Tillers/m^2 (NNT), Number of Spikes/m^2 (NS), Number of sterile Spikelets/spike (NSS), Number of Grains/spike (NG), Weight of Grains/spike (WG), 1000 grain weight (TGW), Biological Yield (BY), Straw Yield (SY), Grain Yield (GY), and Harvest Index (HI %)

Statistical Analyses

The analysis of variance for each water irrigation treatment was processed and combined analyses for six environments was applied after testing the homogeneity of error variance according to Barttlet test. Differences among barley genotypes means were tested using a revised L.S.D. test at the 0.05 level according to Steel *et al.* [38]. The phenotypic correlation coefficient was used for the studied traits of the barley genotypes at three water treatments over two seasons following Snedecor [37]. Path coefficient analysis was estimated as outlined by Dewey and Lu [15].

Drought Tolerance Measures

The following drought tolerance indices including, Drought

Sensitivity Index (DSI) suggested by Fischer and Maurer (1978), Stress tolerance index (STI) purposed by Fernandez [20], Drought tolerance Index (DI) according to Lan (1998) and Yield Reduction Ratio (RR) was reported by Golestani and Assad [23] were calculated using the below formula, SSI = [1 – (Ys / Yp)] / SI, where, SI (stress intensity) = 1 – ($\bar{Y}$ s / $\bar{Y}$ p); STI = (Ys ×Yp)/($\bar{Y}$ p^2); DI = (Ys×(Ys/Yp))/$\bar{Y}$ s ; and YRR = 1 – ($\bar{Y}$ s / $\bar{Y}$ p) Where**,** Ys and Yp represent yield in stress and non- stress conditions respectively. Also, $\bar{Y}$ s and $\bar{Y}$ p are mean yield in stress and non-stress conditions, respectively, for all genotypes.

Phenotypic and Genotypic Coefficients Analysis

Genotypic and phenotypic mean squares (σ^2 g and σ^2Ph) were estimated by method of Singh and Chaundhary [35]. The genotypic and phenotypic coefficient of variations (G.C.V. % and P.C.V. %) were estimated according to Burton and Johnson *et al.* [12,28]. Broad sense heritability was described by Robinson *et al.* [31] and Allard *et al.* [7]. Genetic Advance (GA) was estimated according to the method given by Johnson *et al.* [28]. A PC Microsoft Excel program, SPSS ® and SAS 9.2 (2008) ® Computer programs for Windows were used for the statistical analysis.

Results and Discussion

Mean Performance

Generally, the analyses of variance revealed significant differences for all studied traits among the eighteen barley genotypes in both 1st and 2nd seasons of three irrigation levels. Severe and moderate water stress levels were significantly reduced all studied traits except proline content, No. of non- productive tillers/m^2, No. of sterile spikelets/spike and harvest index for all barley genotypes than normal water supply treatment.

Earliness Characters

The results in Table 1 indicated that, the irrigation stresses caused a reduction in days to 50% heading in the 1st season by an average of 11.3% and 2.9%, but in the 2nd season by an average of 10.7% and 3.5% under severe and moderate irrigation levels, respectively, compared with the 3rd level (normal). As well as for days to maturity reduction percentage were 12.6% and 3.2% in the 1st season and 12.4% and 2.4% in the 2nd season under 1st and 2nd water regimes, respectively, compared with the 3rd level (optimum). The barley genotypes Line 3 and Giza 123 followed by California mariout exhibited the earliest values for days to 50% heading and maturity under all water regimes across two seasons. These results are in harmony with those of Akgün and EL-Shawy *et al.* [3,17]. Moreover, Samarah [32] observed that severe drought-stressed plants were shorter duration of grain filling than well-watered plants. Thus, earliness is the most efficient drought escape mechanism, particularly when the crop is grown in a stress environment [13].

Chlorophyll Content

Chlorophyll content which was used as the main indicator for drought stress induced leaf senescence was measured by Konica Minolta SPAD-502 plus readings, which gives a value for leaf colour. The highest values were registered by Line 2, Line 10 and Line 9 in two seasons under normal water supply; Line 12, Line 10 and Line 1 in both seasons under moderate as well as Line 12, Line 10 and Line 5 in both seasons under severe stress (Table 2). Leaf chlorophyll content decreased with drought stresses. Thus, decrease percentages were 4.49% and 2.72% in the 1st season and 4.5% in the 2nd season under severe and moderate irrigation levels respectively compared with normal water supply. Overall, Line 10, Line 12 and Line 2 had the heights values for leaf chlorophyll content at six environments. These results are in agreement with those obtained by Hasanuzzaman *et al.* and EL-Shawy *et al.* Megahad *et al.* (2018) [17,25].

Proline Content

For proline content, Table 2 showed that the highest values under severe stress were recorded by Line 8 (6.36), Line 12 (6.30), Line 6 (6.21), Line 7 (6.03), Line 4 (5.82) and Rihane 3 (5.68) in 1st season and Rihane 3 (7.31), Line 7 (6.67), Line 8 (6.02), Line 13 (6.03) and Giza 2000 (6.00) in 2nd season. Moreover, all these genotypes had also the highest values under moderate stress. While for normal water supply the barley genotypes Giza 123, Line 7, Line 11, Line 12 and Giza 2000 in 1st

Table 1: Mean performance of earliness characters for 18 barley genotypes under six environments.

	Days to 50% heading						Days to 50% Maturity					
	1st Y			2nd Y			1st Y			2nd Y		
Genotype	**S**	**M**	**N**	**S**	**M**	**N**	**S**	**M**	**N**	**S**	**M**	**N**
California mariout	75.7	82.0	83.0	78.7	83.0	86.3	111.0	122.0	125.0	114.0	125.0	128.3
Line 1	91.7	99.0	102.7	93.0	102.7	106.0	125.3	139.7	144.7	128.3	144.7	148.0
Line 2	74.3	88.3	93.3	77.3	93.3	96.7	109.7	128.3	135.3	113.0	135.3	138.7
Line 3	72.3	79.3	81.3	76.0	81.3	84.7	107.7	120.7	124.0	110.7	123.3	126.7
Giza 123	72.7	79.3	81.0	75.7	81.0	84.3	108.0	119.3	123.0	111.0	123.0	127.0
Line 4	86.7	89.7	92.7	89.7	92.7	96.0	122.0	130.7	134.7	125.0	134.7	138.0
Line 5	87.3	93.0	94.3	90.3	94.3	97.0	122.7	133.0	136.3	125.7	136.3	137.7
Line 6	83.3	91.7	93.7	86.3	93.3	96.3	118.7	131.7	135.0	121.7	135.0	138.3
Line 7	77.3	87.0	90.7	81.3	89.3	92.7	112.7	127.0	131.3	115.7	131.3	134.7
Line 8	76.7	86.3	87.7	79.7	87.7	91.0	111.7	126.3	129.7	115.0	128.0	133.0
Line 9	76.7	84.7	86.3	79.7	86.3	89.7	112.0	125.3	129.3	116.0	128.3	131.7
Line 10	82.0	89.7	92.3	86.7	92.3	95.7	119.0	129.7	134.3	122.0	134.3	137.7
Line 11	79.7	89.0	89.7	82.7	89.7	93.0	115.0	129.0	131.7	118.0	133.0	135.0
Line 12	87.3	84.0	92.7	90.3	92.7	95.0	122.7	128.3	134.7	125.7	134.7	136.3
Line 13	73.3	84.7	87.3	77.3	88.0	90.7	110.0	124.7	130.3	112.0	129.7	132.7
Rihane 3	82.0	89.7	93.0	85.0	92.3	95.7	117.3	129.7	134.3	120.3	134.3	137.7
Giza 2000	86.0	95.7	97.7	89.7	97.7	100.0	121.3	135.7	139.7	124.3	139.7	143.0
Giza 126	86.3	94.7	96.3	89.3	94.0	99.7	122.7	134.7	138.3	124.7	136.0	141.7
Mean	80.6	88.2	90.9	83.8	90.6	93.9	116.1	128.6	132.9	119.1	132.6	135.9
Reduction %	11.3	2.9		10.7	3.5		12.6	3.2		12.4	2.4	
L.S.D.'0.05 (G)	2.2	3.2	2.0	2.3	2.3	2.1	2.4	2.3	2.0	2.3	2.9	2.2
L.S.D. 0.05												
	Years (Y) =0.35			**G x Y = 1.47**			**Years (Y) = 0.36**			**G x Y = 1.53**		
	Y x I =0.42			**G x I = 1.80**			**Y x I = 0.44**			**G x I = 1.88**		
	Irrigation (I) = 0.60			**G x Y x I = 2.55**			**Irrigation (I) = 0.63**			**G x Y x I = 2.652.65**		

S: Severe Stress; M: Moderate stress; N: Normal water supply

Table 2: Mean performance chlorophyll of content and proline content for 18 barley genotypes under six environments.

	Chlorophyll content						Proline content (µ mol/g f.wt.)					
	1st Y			2nd Y			1st Y			2nd Y		
Genotype	S	M	N	S	M	N	S	M	N	S	M	N
California mariout	45.23	44.48	39.56	53.90	53.91	47.17	4.22	4.20	3.02	4.66	4.32	2.38
Line 1	38.73	52.02	52.54	46.20	46.18	62.65	4.50	4.44	3.84	4.71	4.54	2.91
Line 2	46.77	45.74	61.33	55.77	55.79	73.13	4.45	4.40	4.38	5.10	4.43	3.27
Line 3	42.37	47.41	36.95	50.53	50.54	44.05	4.90	4.79	4.08	5.12	4.94	3.26
Giza 123	39.07	45.53	45.11	46.57	46.55	53.79	5.46	5.14	4.99	5.45	5.18	4.14
Line 4	38.20	46.16	47.41	45.57	45.55	56.53	5.82	5.36	4.10	5.77	5.69	2.66
Line 5	50.43	47.20	50.19	60.17	60.15	61.15	5.22	4.31	4.04	5.11	5.15	4.36
Line 6	47.43	48.46	41.59	56.53	56.53	44.18	6.21	5.72	4.09	5.72	4.11	4.94
Line 7	48.37	36.63	43.40	57.67	57.66	55.29	6.03	5.73	4.57	6.67	5.99	5.22
Line 8	38.20	37.37	48.51	45.57	45.55	59.03	6.36	4.51	4.08	6.02	5.88	3.46
Line 9	49.53	48.67	52.72	59.03	59.03	64.65	4.86	4.63	3.84	5.78	4.69	2.91
Line 10	51.60	57.04	58.21	61.53	61.53	71.64	4.80	4.61	4.31	5.66	4.79	3.49
Line 11	47.83	46.26	50.73	57.00	57.03	55.29	4.83	4.88	4.80	5.38	4.96	3.03
Line 12	57.23	58.19	47.94	68.27	68.27	58.03	6.30	5.22	4.71	5.92	4.91	3.15
Line 13	42.07	37.99	48.46	50.17	50.17	57.66	5.39	5.23	4.35	6.03	4.73	4.31
Rihane 3	49.40	47.31	47.57	58.90	58.91	56.28	5.68	5.28	4.30	7.31	5.22	3.57
Giza 2000	47.93	48.46	46.13	57.20	57.16	54.41	5.39	4.46	4.48	6.00	5.40	3.25
Giza 126	46.37	47.20	47.30	55.30	55.29	57.33	4.57	4.34	4.10	4.91	4.90	2.75
Mean	45.93	46.79	48.09	54.77	54.77	57.35	5.28	4.85	4.23	5.63	4.99	3.50
Reduction %	4.49	2.72		4.50	4.50		-24.85	-14.69		-60.69	-42.49	
L.S.D.'0.05 (G)	0.33	0.36	5.26	0.37	0.36	0.45	0.26	0.19	0.10	0.08	0.11	0.08
L.S.D. 0.05												
Years (Y) = 0.29				G x Y = 1.25			Years (Y) = 0.02			G x Y = 0.10		
Y x I = 0.36				G x I = 1.53			Y x I = 0.03			G x I = 0.12		
Irrigation (I) = 0.51				G x Y x I = 2.17			Irrigation (I)= 0.04			G x Y x I = 0.16		

S: Severe stress; M: Moderate stress; N: Normal water supply

Table 3: Mean performance of grain yield and harvest index for 18 barley genotypes under six environments.

	Grain yield (ardab/fad.)						Harvest index %					
	1st Y			2nd Y			1st Y			2nd Y		
Genotype	S	M	N	S	M	N	S	M	N	S	M	N
California mariout	8.69	10.54	11.97	9.16	11.19	13.01	33.60	30.75	32.40	37.20	38.76	31.23
Line 1	9.45	11.52	13.37	9.92	12.30	13.94	35.44	35.02	32.33	37.46	34.66	30.62
Line 2	10.17	11.13	12.98	10.50	12.10	13.70	37.42	31.51	33.15	42.99	35.83	30.70
Line 3	10.62	12.04	13.79	11.03	12.69	14.54	37.32	32.67	32.02	41.69	34.51	31.93
Giza 123	9.97	11.69	14.05	10.26	12.36	14.74	35.45	32.53	32.18	42.24	38.80	37.05
Line 4	12.54	14.56	16.45	13.01	13.01	17.03	36.01	37.90	34.62	38.07	32.13	35.41
Line 5	13.07	14.41	16.37	13.65	15.27	17.06	35.84	34.19	35.27	42.02	39.97	42.40
Line 6	12.89	14.61	16.63	13.58	15.47	17.23	37.51	36.48	34.49	42.76	36.17	32.88
Line 7	10.74	12.45	14.74	11.20	12.94	15.42	37.74	33.86	33.42	39.31	31.91	35.31
Line 8	11.26	12.72	14.60	11.61	13.59	15.48	37.79	33.07	33.63	42.44	34.11	32.78
Line 9	12.31	14.51	16.21	12.66	15.53	16.86	36.77	35.25	33.56	41.70	34.35	35.92
Line 10	11.32	13.65	15.52	11.83	14.48	16.17	36.06	33.36	33.89	33.79	31.43	32.78
Line 11	11.03	12.38	13.65	11.61	14.28	14.62	39.93	35.02	32.05	41.94	36.28	32.80
Line 12	10.50	11.43	13.22	11.05	12.17	14.06	34.41	29.25	33.12	38.61	31.75	32.71
Line 13	8.69	10.36	12.59	9.19	12.27	15.79	32.23	30.15	32.87	36.62	36.36	39.22
Rihane 3	9.34	11.71	13.71	9.80	12.71	14.23	33.79	30.42	32.31	35.30	32.57	30.86
Giza 2000	8.48	10.28	12.29	9.04	12.29	12.96	31.87	31.72	31.29	41.97	42.83	34.20
Giza 126	8.17	10.41	12.48	8.58	11.25	13.25	31.17	30.19	31.48	38.52	37.81	33.49
Mean	10.51	12.24	14.15	10.98	13.10	15.00	35.58	32.96	33.00	39.70	35.57	34.02
Reduction %	25.67	13.44		26.82	12.67		-7.79	0.12		-16.71	-4.56	
L.S.D.'0.05 (G)	0.87	1.61	1.69	0.88	2.57	1.53	3.16	3.23	1.63	5.13	4.16	3.40
L.S.D. 0.05												
	Years (Y) = 0.21			G x Y = 0.89			Years (Y) = 0.5			G x Y = 2.14		
	Y x I = 0.26			G x I = 1.09			Y x I = 0.62			G x I = 2.62		
	Irrigation (I) = 0.36			G x Y x I = 1.54			Irrigation (I) = 0.87			G x Y x I = 3.70		

S: Severe stress; M: Moderate stress; N: Normal water supply

season and Line 7, Line 5, Line 6 and Line 13 in 2nd season were registered the highest values.

Leaf proline content increased under drought stresses for all barley genotypes. Thus, increase percentages were 24.85% and 14.69% in the 1st season and 60.69% and 42.49% in the 2nd season under severe and moderate irrigation levels respectively compared with normal water supply. Generally, Line 7, Rihane 3, Giza 123, Line 12, Line 6 and Line 8 had the highest values for proline content under six environments. The proline is accumulated along with several abiotic stresses, such as drought stress and it has been defined as an osmoprotectant [14]. The role of amino acid proline accumulation is still controversially discussed as it is designated to role as antioxidant, a radical scavenger, and is involved in seed development and in the regulation of apoptosis [30,40].

Grain Yield (ard./fad.)

In the 1st season, maximum grain yield were 13.07 (line 5), 14.61 (Line 6) and 16.63 ard./fad. (Line 6) under severe stress, moderate stress and normal water supply, respectively, whereas minimum grain yield were 8.17 (Giza 126), 10.28 (Giza 2000) and 11.97 (California mariout) under severe stress, moderate stress and normal water supply, respectively (Table 3). Furthermore, in 2nd season, grain yield varied from 8.58 (Giza 126) to 13.65 (Line 5) under severe stress; from 11.19 (California mariout) to 15.53 (Line 9) under moderate stress and from 12.96 (Giza 2000) to 17.23 (Line 6) under normal water supply.

The reduction percentage for grain yield was 25.67% and 13.44% in the 1st season and 26.82% and 12.67% in the 2nd season under severe and moderate irrigation levels, respectively compared with normal water supply. To clarify, Line 4, Line 5, Line 6, Line 9 and Line 10 had the highest values for grain yield under six environments. Therefore, these barley genotypes are more tolerant to water stress, and exhibited relative stability from environment to another. These results are in line with those obtained by Singh *et al.* and Megahad *et al.* (2018) [36]. Moreover, severe and moderate drought stresses reduced biological and grain yield by reducing the No. of tillers, spikes, grains/plant and individual grain weight [1,26].

Harvest index %

The mean values of harvest index are shown in Table 3. In the 1st season, maximum harvest index were 39.93% (line 11), 36.48% (Line 6) and 35.27**%** (Line 5) under severe stress, moderate stress and normal water supply, respectively. Furthermore, in 2nd season, harvest index varied from 33.79 (Line 10) to 42.99% (Line 2) under severe stress; from 31.43 (Line 10) to 42.83% (Giza 2000) under moderate stress and from 30.62 (Line 1) to 42.40% (Line 5) under normal water supply. To clarify, Giza 123, Line 5, Line 6, Line 9 and Line 11 had the highest values for harvest index under six environments. Therefore, these barley genotypes are more tolerant to water stress, and exhibited relative stability from environment to another. These results are in line with those obtained by Yazdanseta *et al.* [43].

Generally, the mean values of grain yield and other traits were severely decreased at the first (severe stress) and second (moderate) irrigation levels when compared with the third level (normal water supply). In other words, the drought stress caused reduction in mean performance of barley genotypes for earliness characters (shorter life cycle for plants than normal water supply); shorter plant height; narrow flag leaf area; lower chlorophyll content; shorter peduncle length; shorter spike length; shorter awn length; lower yield and its components than normal water supply. In contrast, drought stress presented increase proline content, No. of non-productive tillers/m^2, No. of sterile spikelets/spike and harvest index than normal water supply. These results are in agreement with those obtained by Al- Ajlouni *et al.*, Megahad *et al.* (2018) and Moustafa [4,29]. Moreover, Elakhdar et al. [16] found that the drought-stressed plants had shorter duration of grain filling than well-watered plants and reduced grain yield by reducing the No. of tillers, spikes and grains per plant and individual grain weight.

Drought Indices

The Drought Sensitivity Index (DSI), Stress Tolerance Index (STI) and Drought Tolerance Index (DI) values were calculated for determining the stress tolerance of barley genotypes based on minimization of grain yield losses at water deficit compared to normal water supply (Table 4). Analysis of variance for drought indices under sever and moderate stresses exhibited significant differences of 18 barley genotypes for grain yield trait.

The mean of DSI values varied from 0.71 to 1.40, and from 0.34 to 1.57 in response to severe and moderate stresses, respectively. The barley genotypes showing DSI values close to zero or less than one or showing a negative value are more tolerant to drought stress, while those with values close to one or above 1.0 are susceptible to drought stress. Thus, under severe stress treatment the following barley genotypes, i.e., Line 11, Line 12, Line 5, Line 2, Line 6, Line 3, Line 4, Line 8 and Line 9 had the most desirable DSI values to drought resistance (0.71, 0.77, 0.77, 0.81, 0.83, 0.88, 0.91, 0.93 and 0.93, respectively). Whereas, under moderate stress treatment the most desirable values were obtained from the genotypes, i.e., Line 11 (0.34), Line 9 (0.67), Giza 2000 (0.70), Line 10 (0.79), Line 5 (0.87) and Line 6 (0.88), were relatively tolerant to water stress. However, the barley genotypes, i.e., Line 13, Giza 126, Giza 123 and California mariout were highly susceptible to drought under both severe and moderate stress treatments.

Table 4: The mean performance of 18 barley genotypes for Drought Sensitivity Index (DSI), Stress Tolerance Index (STI) and Drought tolerance Index (DI) for grain yield under severe and moderate stresses.

	Severe stress			Moderate stress		
Genotype	DSI	STI	DI	DSI	STI	DI
California mariout	1.08	0.52	0.59	1.04	0.64	0.75
Line 1	1.10	0.62	0.64	0.98	0.77	0.82
Line 2	0.81	0.65	0.75	1.06	0.74	0.80
Line 3	0.88	0.72	0.77	1.00	0.83	0.85
Giza 123	1.12	0.69	0.66	1.30	0.82	0.79
Line 4	0.91	1.01	0.91	1.42	1.09	0.90
Line 5	0.77	1.05	0.99	0.87	1.17	1.04
Line 6	0.83	1.05	0.96	0.88	1.20	1.06
Line 7	1.04	0.78	0.74	1.30	0.90	0.85
Line 8	0.93	0.81	0.81	0.88	0.93	0.91
Line 9	0.93	0.97	0.88	0.67	1.17	1.08
Line 10	1.02	0.86	0.79	0.79	1.05	0.99
Line 11	0.71	0.75	0.85	0.34	0.89	1.00
Line 12	0.77	0.69	0.81	1.04	0.76	0.81
Line 13	1.40	0.60	0.53	1.57	0.76	0.71
Rihane 3	1.21	0.63	0.62	0.98	0.81	0.84
Giza 2000	1.17	0.52	0.57	0.70	0.67	0.80
Giza 126	1.31	0.51	0.51	1.20	0.66	0.72
L.S.D.' 0.05	**0.40**	**0.11**	**0.15**	**0.70**	**0.20**	**0.18**

The mean STI values ranged from 0.51 to 1.05, and from 0.64 to 1.17, while DI values varied from 0.51 to 0.99, and from 0.71 to 1.08 under severe and moderate stresses, respectively. The low values of STI and DI (<1.0) are show sensitivity to drought stress. Therefore, high values of STI and DI (≥1.0) are important to select high-yielding barley genotypes under drought conditions. Based on these two indices, Line 4, Line 5, Line 6, Line 8, Line 9, line 10 and Line 11 were tolerant to drought and had the highest STI and DI indices under both severe and moderate stress treatments, indicating that the same trend of DSI. Similar findings were reported by Megahad *et al.* (2018) and Elakhdar *et al.* and Ferioun *et al.* [16,19] they noted a wide range of response to drought stress in barley genotypes.

It is clear from the above results; the main goal of barley breeding program is improvement of drought stress tolerance that represents a major goal for the plant breeders and for the sustainable agriculture in the future. Necessity of developing sustainable agriculture in arid situation in the times of global climate changes exhibited complexity of this task. Furthermore, stresses can be caused by abiotic and biotic factors, which may influence to the strategy of barley breeding and selection of

Table 5: Variance components of earliness characters for 18 barley genotypes at six environments as well as the combined across environments.

Trait	Days of 50% heading						Days of maturity					
	1st Y			2nd Y			1st Y			2nd Y		
Variance components	**S**	**M**	**N**	**S**	**M**	**N**	**S**	**M**	**N**	**S**	**M**	**N**
G.C.V.%	7.44	6.06	6.25	6.85	6.08	5.9	5.02	4.06	4.14	4.84	4.16	4.04
P.C.V.%	7.66	6.49	6.43	7.09	6.32	6.1	5.21	4.23	4.27	5.01	4.41	4.18
Tb	94.29	87.06	94.45	93.2	92.38	93.58	92.57	91.84	94.07	93.1	89.04	93.2
Genetic Advance (GA)	11.9	10.17	11.27	11.32	10.83	10.95	11.47	10.24	10.93	11.38	10.68	10.85
GA as % of Mean (GAM)	14.88	11.65	12.51	13.62	12.03	11.75	9.94	8.01	8.27	9.61	8.1	8.03
	Chlorophyll content						**Proline content**					
G.C.V.%	11.46	12.2	11.72	11.46	11.47	13.58	12.63	9.87	10.32	11.91	10.34	22.13
P.C.V.%	11.47	12.21	13.59	11.47	11.48	13.59	13.05	10.2	10.43	11.94	10.44	22.18
Tb	99.82	99.81	74.38	99.84	99.85	99.85	93.64	93.68	97.88	99.35	98.11	99.56
Genetic Advance (GA)	10.8	11.71	10.05	12.88	12.89	16.08	1.34	0.97	0.89	1.38	1.05	1.62
GA as % of Mean (GAM)	23.59	25.1	20.82	23.6	23.61	27.95	25.18	19.69	21.03	24.45	21.11	45.5
	Grain yield (ard./fad.)						**Harvest index %**					
G.C.V.%	13.91	11.4	9.84	13.58	8.42	8.75	5.78	6.37	2.86	5.61	8.06	8.51
P.C.V.%	14.94	13.82	12.14	14.57	13.23	10.64	7.75	8.66	4.11	9.6	10.79	10.42
Tb	86.72	68.14	65.69	86.87	40.56	67.66	55.55	54.21	48.51	34.12	55.78	66.65
Genetic Advance (GA)	2.88	2.42	2.36	2.93	1.47	2.26	3.2	3.21	1.36	2.68	4.34	4.87
GA as % of Mean (GAM)	26.69	19.39	16.43	26.08	11.05	14.83	8.87	9.67	4.11	6.75	12.4	14.31

S: Severe stress; M: Moderate stress; N: Normal water supply

wide adopted genotypes or selection for specific (unfavorable or favorable) condition.

Estimates of Variance Components for Grain Yield

Variance components for earliness characters, chlorophyll content, proline content, grain yield and harvest index of 18 barley genotypes at six environments are shown in Table. In general, from previously table, the results indicated that the Phenotypic Coefficient of Variation (PCV) values were relatively greater than Genotypic Coefficient of Variation (GCV) values for all traits.

Earliness Characters

The GCV values for days to 50% heading were varied from 5.9 % for normal water supply in 2nd season to 7.44% for severe stress in 1st season and 15.05% for combined analyses. Similarly, the PCV values for this trait were ranged between 6.10 % for normal water supply in 2nd season and 7.66% for severe stress in 1st season and 15.15% for combined analyses (Table 5). Correspondingly, days to maturity had similar trend as days to 50% heading, the GCV values were varied from 4.04 % for normal water supply in 2nd season to 5.02% for severe stress in 1st season and 10.31% for combined analyses. Likewise, the PCV values were varied from 4.18% for normal water supply in 2nd season and 5.21% for severe stress in 1st season and 10.39% for combined analyses (Table 5). Additionally, the GCV values were near to PCV values for earliness characters, demonstrating high contribution of genotypic effect for phenotypic expression of earliness characters. The results in Table (5) showed that high broad sense heritability estimates (>90) coupled with moderate (10–20%) and low (>10) Genetic Advance in percentage of Mean (GAM) were obtained for days to 50% heading and days to maturity respectively under six environments, representing wide scope for improvement through of plant selection of these characters. These results are in line with those obtained by Arshadi *et al.* and Gadissa *et al*. [9,22].

Chlorophyll Content

The GCV values were varied from 11.46% for severe stress in 1st and 2nd seasons to 13.58% for normal water supply in 2nd season. Correspondingly, the PCV values were varied from 11.47% for severe stress in two seasons to 13.59% under normal water supply in two seasons (Table 5). The results displayed that the moderate and close GCV and PCV values under all environments, indicated narrow range of genotypic variability coupled with less influence of environment for the expression of chlorophyll content. Heritability in broad scenes for chlorophyll content was greater than 80% and along with high GAM (> 20%) for all environments except severe stress in 1st season (Tb = 74.38%), indicating the predominance of additive gene action and improving of this trait could be done through selection. Similar results were stated by Wehner et al. and Iannucci *et al.* [27,40].

Proline Content

The GCV values were varied for proline content from 9.87% for moderate stress in 1st season to 22.13% for normal water supply in 2nd season. Correspondingly, the PCV values were ranged between 10.20% for moderate stress in 1st season and 22.18% for normal water supply in 2nd season (Table 5). The results displayed that the moderate and close GCV and PCV values under all environments, indicated narrow range of genotypic variability coupled with less influence of environment for the expression of proline content. Heritability in broad scenes for proline content was greater than 90% and along with high GAM (> 20%) at six environments, indicating improving of proline content could be done through selection. These results were in harmony with those of Naresh *et al.* [30].

Grain Yield (ard./fad.)

The PCV values for grain yield were relatively greater than GCV, however, GCV values under six environments as well as combined analyses were near to PCV. Moreover, the GCV values were varied from 8.42% under moderate stress to 13.91% under severe stress in 1st season. Whereas, the PCV values were ranged between 10.64% under normal water supply in 2nd season and 14.94% under severe stress environment in 2nd season (Table 5).

Table 6: Simple correlation coefficients as calculated over two seasons of 18 barley genotypes for all studied traits under severe stress.

Characters	HD	MD	PH	FLA	CC	PC	PL	SL	AL	NT	NNT	NS	NSS	NG	WG	TGW	BY	SY	GY
HD	1																		
MD	0.99**	1																	
PH	0.27	0.30	1																
FLA	0.44*	0.44*	0.27	1															
CC	0.16	0.19	0.42	0.35	1														
PC	0.03	0.03	0.35	-0.01	-0.17	1													
PL	0.09	0.07	0.02	0.34	-0.10	0.17	1												
SL	0.11	0.12	0.31	-0.34	0.18	0.08	-0.08	1											
AL	0.03	0.04	0.36	-0.32	-0.10	0.26	-0.02	0.44*	1										
NT	-0.14	-0.14	0.04	-0.60**	0.07	0.00	-0.39	0.61**	0.59**	1									
NNT	-0.09	-0.10	-0.28	0.40	-0.41	-0.05	0.45*	-0.47*	-0.24	-0.58**	1								
NS	-0.12	-0.12	0.08	-0.61**	0.12	0.01	-0.42	0.62**	0.57**	0.99**	-0.66**	1							
NSS	-0.16	-0.16	-0.07	0.35	-0.04	0.08	0.51*	-0.31	-0.48*	-0.68**	0.68**	-0.71**	1						
NG	0.14	0.16	0.62**	-0.02	0.31	0.53*	-0.05	0.60**	0.70**	0.40	-0.34	0.41	-0.33	1					
WG	0.04	0.02	0.22	-0.16	-0.41	0.29	0.54*	0.10	0.10	-0.13	0.24	-0.15	0.32	-0.11	1				
TGW	0.13	0.10	-0.57**	-0.13	-0.57**	-0.29	0.03	-0.34	-0.16	0.02	0.11	0.00	-0.25	-0.59**	0.16	1			
BY	0.29	0.30	0.38	-0.42	0.15	0.29	-0.24	0.71**	0.68**	0.75**	-0.66**	0.77**	-0.63**	0.68**	0.05	-0.15	1		
SY	0.37	0.40	0.40	-0.36	0.17	0.30	-0.22	0.62**	0.61**	0.58**	-0.68**	0.62**	-0.56**	0.63**	0.07	-0.17	0.96**	1	
GY	0.12	0.13	0.29	-0.46*	0.09	0.23	-0.24	0.74**	0.68**	0.88**	-0.55**	0.88**	-0.63**	0.65**	0.03	-0.11	0.92**	0.77**	1
HI	-0.31	-0.32	-0.04	-0.27	-0.05	0.01	-0.06	0.38	0.27	0.63**	-0.03	0.58**	-0.25	0.24	-0.04	0.00	0.21	-0.07	0.58**

HD: Days to 50% Heading; MD: Days to Maturity; PH: Plant Height; FLA: Flag Leaf Area; CC: Chlorophyll CONTENT; PC: Proline Content; PL: Peduncle Length; SL: Spike Length; AL: Awn Length; NT: No. of Tillers/m²; NNT: No. of Non-productive Tillers/m²; NS: No. of Spikes/m²; NSS: No. of Sterile Spikelets/spike; NG: No. of grains/spike; WG: Weight of Grains/spike; TGW:1000-Grain Weight; BY: Biological Yield; SY: Straw Yield; GY: Grain Yield and HI: Harvest Index %.
*, ** Significant at 0.05 and 0.01 levels of probability, respectively.

Table 7: Simple correlation coefficients as calculated over two seasons of 18 barley genotypes for all studied traits under normal water supply.

Characters	HD	MD	PH	FLA	CC	PC	PL	SL	AL	NT	NNT	NS	NSS	NG	WG	TGW	BY	SY	GY
HD	1																		
MD	0.99**	1																	
PH	0.45	0.43	1																
FLA	0.22	0.24	0.08	1															
CC	0.18	0.16	0.21	-0.06	1														
PC	-0.04	-0.07	0.29	-0.07	0.15	1													
PL	-0.28	-0.27	0.23	0.05	0.07	0.16	1												
SL	0.12	0.10	0.29	-0.57*	0.21	0.23	-0.12	1											
AL	-0.01	-0.01	0.29	0.43	0.37	-0.12	0.25	-0.17	1										
NT	0.02	0.00	0.23	-0.64**	0.11	0.41	0.17	0.79**	-0.25	1									
NNT	-0.30	-0.30	-0.62**	0.14	0.06	0.01	-0.02	-0.46	-0.08	-0.33	1								
NS	0.05	0.03	0.25	-0.63**	0.10	0.45	0.14	0.78**	-0.27	0.99**	-0.35	1							
NSS	0.20	0.21	0.20	0.63**	0.02	-0.14	0.13	-0.65**	0.30	-0.77**	0.12	-0.76**	1						
NG	-0.04	-0.05	0.47	-0.25	0.43	0.05	0.45	0.59**	0.31	0.59**	-0.34	0.55*	-0.31	1					
WG	-0.08	-0.07	-0.06	-0.34	-0.13	-0.11	0.37	0.31	-0.39	0.34	-0.31	0.31	-0.26	0.33	1				
TGW	-0.13	-0.11	-0.38	0.39	-0.20	-0.04	0.05	-0.50*	0.05	-0.66**	0.22	-0.66**	0.46	-0.52*	-0.05	1			
BY	0.02	0.00	0.04	-0.59**	0.00	0.13	-0.01	0.80**	-0.34	0.81**	-0.32	0.79**	-0.63**	0.51*	0.27	-0.42	1		
SY	0.06	0.05	-0.03	-0.41	-0.01	0.03	-0.08	0.66**	-0.32	0.61**	-0.18	0.60**	-0.45	0.42	0.10	-0.29	0.95**	1	
GY	-0.05	-0.06	0.17	-0.74**	0.01	0.32	0.12	0.83**	-0.33	0.94**	-0.46	0.93**	-0.74**	0.52*	0.47	-0.53*	0.85**	0.63**	1
HI	-0.11	-0.12	0.26	-0.55*	0.03	0.42	0.23	0.40	-0.11	0.59**	-0.40	0.60**	-0.48	0.22	0.46	-0.37	0.15	-0.18	0.64**

HD: Days to 50% Heading; MD: Days to Maturity; PH: Plant Height; FLA: Flag Leaf Area; CC: Chlorophyll Content; PC: Proline Content; PL: Peduncle Length; SL: Spike Length; AL: Awn Length; NT: No. of Tillers/m²; NNT: No. of Non-productive Tillers/m² NS: No. of Spikes/m²; NSS: No. of Sterile Spikelets/spike; NG: No. of Grains/spike; WG: Weight of Grains/spike; TGW:1000-Grain Weight; BY: Biological Yield; SY: Straw Yield; GY: Grain Yield and HI: Harvest Index %.
*, ** Significant at 0.05 and 0.01 levels of probability, respectively.

Table 8: Direct (Diagonal) and indirect effects of yield components on grain yield of 18 barley genotypes across two seasons under water treatments.

Traits	Water regime	No. of spikes/m^2	No. of grains/ spike	Weight of grains/ spike	1000 grain weight (gm)	Harvest index %	Correlation with yield
No. of spikes/m^2	S	0.663	0.185	-0.023	0.000	0.054	0.880
	N	0.905	0.012	0.050	-0.071	0.035	0.932
No. of grains/ spike	S	0.269	0.456	-0.016	-0.085	0.022	0.650
	N	0.492	0.022	0.053	-0.056	0.013	0.516
Weight of grains/ spike	S	-0.100	-0.047	0.154	0.025	-0.004	0.027
	N	0.278	0.007	0.161	-0.006	0.027	0.470
1000 grain weight (gm)	S	0.001	-0.270	0.027	0.143	0.000	-0.105
	N	-0.598	-0.011	-0.009	0.108	-0.022	-0.529
Harvest index %	S	0.387	0.107	-0.006	0.000	0.092	0.579
	N	0.545	0.005	0.074	-0.040	0.058	0.645
Residual	S	0.280					
	N	0.299					

S: Severe stress; N= Normal water supply

Heritability values for grain yield were moderate under moderate stress and normal water supply environments in both two seasons and high under severe stress in both two seasons. Heritability values varied from 40.56% to 86.87% under moderate and severe stresses in 2nd season, respectively and 92.90% for combined analyses. Similarly, the GAM values were moderate under moderate stress and normal water supply environments in both seasons and high under severe stress in both seasons. GAM varied from 11.05% under moderate stress in 2nd season to 26.69% under severe stress in 1st season. Accordingly, grain yield was controlled by a number of genetic and environmental factors. These results were in harmony with those of Yadav *et al.*, Arshadi *et al.* and Moustafa [9,29,41].

Harvest Index %

However, GCV values under six environments were near to PCV. Moreover, the GCV values were varied from 2.86% to 8.51% under normal water supply in 1st and 2nd seasons with 9.24% for combined analyses. Whereas, the PCV values were ranged between 4.11% under severe stress in 1st season to 10.79% under moderate stress in 2nd season (Table 5). The results exposed that the GCV and PCV values under six environments were low to moderate, indicated to little or moderate influence of environmental factor for the expression of harvest index from environment to another. Heritability values for harvest index were moderate under all environments in both two seasons. Heritability values varied from 34.12% to 66.65% under severe stress and normal water supply in 2nd season respectively. The GAM values were low under all environments in both two seasons. GAM varied from 4.11% to 14.31% under normal water supply in 1st and 2nd seasons.

It could be concluded that under this study at six different conditions, the characters of days to 50% heading, days to maturity, flag leaf area, chlorophyll content, proline content and No. of spikes/m^2 were controlled by genetic factors. On the other hand, plant height, peduncle length, awn length, No. of tillers / m^2, No. of sterile spikelets / spike, No. of grains / spike, biological yield, straw yield, grain yield and harvest index were controlled by a number of genetic and environmental factors. These results are in agreement with those obtained by Yadav *et al.* and Iannucci *et al.* [27,41].

Correlation Coefficient Analysis

Severe stress: Simple correlations based on the combined data over two seasons were calculated among all possible combinations under severe stress of the all studied traits are listed in Table 6. Days to 50% heading had positive and significant correlations with days to maturity (0.99**) and flag leaf area (0.44*) as well as days to maturity with flag leaf area (0.44*). On the other hand, flag leaf area had negative and significant correlations with No. of tillers/m^2, No. of spikes/m^2 and grain yield.

Positive and significant correlations were detected between No. of tillers/m^2 with spike length and awn length as well as between spike length and awn length (0.44*). Besides peduncle length was positive and significantly correlated to No. of non-productive tillers/m^2 (0.45*), No. of sterile spikelets/spike (0.51*) and weight of grains/spike (0.54*). Furthermore, the correlations between No. of spikes/m^2 and spike length, awn length and No. of tillers/m^2 were positive and significant. Also, No. of grains/spike was positive and high correlated with plant height, proline content, spike length and awn length. In contrast, 1000-grain weight had negative and significant correlations with plant height, chlorophyll content and No. of grains/ spike.

Biological yield, straw yield and grain yield had positive and significantly correlated with spike length, awn length, No. of tillers/m^2, No. of spikes/m^2 and No. of grains/spike. Contrariwise, they exhibited negative correlations with flag leaf area, No. of non-productive tillers/m^2, No. of sterile spikelets/spike and 1000-grain weight.

Strong positive and highly significant correlations were detected between biological yield, straw yield and grain yield together. Likewise harvest index exhibited positive and significant ($P<0.01$) correlation with No. of tillers/m^2, No. of spikes/m^2 and grain yield.

Normal Water Supply

Close correlation between days to 50% heading and days to maturity (0.99**) was observed under normal water supply (Table 7). On the contrary, plant height had negative and significant correlation with No. of non-productive tillers/m^2.

Positive and significant correlations were detected between flag leaf area with No. of sterile spikelets/spike. Inversely, flag leaf area was negative and significantly correlated to spike length, No. of tillers/m^2, No. of spikes/m^2, No. of grains/spike, biological yield, grain yield and harvest index. Likewise, No. of sterile spikelets/spike was negative and significantly correlated with spike length, No. of tillers/m^2 and No. of spikes/m^2. Furthermore, the correlations between spike length with No.

of tillers/m^2, No. of spikes/m^2, No. of grains/spike, biological yield, straw yield and grain yield were positive and significant. Also, No. of grains/spike had positive and high correlated with spike length, No. of tillers/m^2 and No. of spikes/m^2. In contrast, 1000-grain weight had negative and significant correlations with, spike length, No. of tillers/m^2, No. of spikes/m^2 and No. of grains/spike.

Biological yield, straw yield and grain yield had positive and significantly correlated with spike length, No. of tillers/m^2, No. of spikes/m^2 and No. of grains/spike. Contrariwise, they exhibited negative correlations with flag leaf area, No. of non-productive tillers/m^2, No. of sterile spikelets/spike and 1000- grain weight. Strong positive and highly significant correlations were detected between biological yield, straw yield and grain yield together. Likewise harvest index exhibited positive and significant ($P<0.01$) correlation with No. of tillers/m^2, No. of spikes/m^2 and grain yield.

From foregoing correlation results, it can be concluded that, the most barley traits exhibited the same trend under three water treatments over two seasons. Biological yield, straw yield and grain yield had positive and significantly correlated with spike length, awn length, No. of tillers/m^2, No. of spikes/m^2 and No. of grains/spike. Contrariwise, they exhibited negative correlations with flag leaf area, No. of non-productive tillers/m^2, No. of sterile spikelets/spike and 1000-grain weight under three water treatments. High correlations were observed for proline content to SPAD and biomass yield giving hint that proline trait is involved in leaf senescence and drought stress tolerance [40]. Furthermore, Arpali and Yagmur [8] reported that grain yield had significant positive correlation with No. of spike/m^2 and harvest index. The grain yield/plant had positively and significantly associated with spike length, plant height, No. of spikelets/spike and biological yield/plant under normal and drought conditions [34,39].

Path Coefficient Analysis

The results in Table 8 showed that No. of spikes/m^2 had the largest direct effect on barley grain yield under severe stress (0.663), moderate stress (0.64) and normal water supply (0.905) followed by No. of grains/spike (0.456 and 0.565 under severe and moderate stresses, respectively), weight of grains/spike (0.154, 0.126 and 0.161 for severe and moderate stresses and normal water supply, respectively), then 1000-grain weight followed by harvest index under severe stress and normal water supply, indicating the effectiveness of direct selection for No. of spikes/m^2, No. of grains/spike and weight of grains/spike under normal irrigation and water deficit for improvement barley grain yield. While the direct effect of 1000-grain weight and harvest index on barley grain yield were positive but low in magnitude.

Positive indirect effects on barley grain yield under three water regimes were often observed of the No. of spikes/m^2 and No. of grains/spike via each other, likewise harvest index and No. of spikes/m^2. On the other side, weight of grains / spike and 1000-grain weight had negative indirect effect on grain yield via No. of spikes/m^2 and No. of grains / spike, also weight of grains / spike via harvest index.

Generally, the aforementioned results exposed that No. of spikes/m^2, No. of grains/spike and weight of grains/spike were considered the major yield components, indicated that the barley breeder should take into account as the most selection criteria under normal irrigation and water deficit for developing high yielding genotypes at early generations. Shrimali *et al.* [34] reported that biological yield and harvest index had positive direct effect on grain yield of 64 barley genotypes across two locations. Conversely, days to maturity revealed highest negative direct effect on grain yield. Whereas, Ahmad *et al.* [2] showed that 1000-grain weight and hectoliter grain weight revealed the highest direct effects on barely grain yield.

Conclusion

Based on mean performance and drought indices, Line 4, Line 5, Line 6, Line 8, Line 9, line 10 and Line 11 were tolerant to drought and could be used in breeding programs for improvement barely yields under drought stress of new reclaimed sandy soil.

References

1. Abu-El-Lail FFB, Hamam KA, Kheiralla KA, El-Hifny MZ. Evaluation of twenty barley genotypes for drought tolerance under sandy clay soil. Egypt. J Agron. 2016; 38: 173– 187.
2. Ahmad J, Vaez B, Aboughadareh AP. Analysis of variability, heritability, and interrelationships among grain yield and related characters in barley advanced lines. Genetika. 2016; 48: 73-85.
3. Akgün N. Genetic variability and correlation studies in yield and yield related characters of barley (Hordeum vulgare L.) genotypes. Selcuk J Agr Food Sci. 2016; 30: 88-95.
4. Al-Ajlouni ZI, Al-Abdallat AM, Al-Ghzawi AA, Ayad JY, Abu Elenein JM, Al-Quraan NA, et al. Impact of pre-anthesis water deficit on yield and yield components in barley (Hordeum vulgare L.) plants grown under controlled conditions. Agronomy. 2016; 6: 1-14.
5. Ali MMA. Stability analysis of bread wheat genotypes under different nitrogen fertilizer levels. J Plant Production Mansoura Univ. 2017; 8: 261-275.
6. Ali MMA, Abdul-Hamid MIE. Yield stability of wheat under some drought and sowing dates environments in different irrigation systems. Zagazig J Agric Res. 2017; 44: 865–886.
7. Allard RW. Principle of plant breeding, John Wiley and Sons, Inc., New York. 1960.
8. Arpali D, Yagmur M. The determination of selection criteria using path analysis in two rowed barley (Hordeum vulgare L. Conv. Distichon). Türk Tarım ve Doğa Bilimleri Dergisi. 2015; 2: 248–255.
9. Arshadi A, Karami E, Sartip A, Zare M. Application of secondary traits in barley for identification of drought tolerant genotypes in multi-environment trials. AJCS. 2018; 12: 157-167.
10. Asadi AA, Mohammadi B, Nazari H, Ahakpaz F. Identification of Drought Tolerant Genotypes in Barley using Quantitative Tolerance Indices. jcb. 2023; 15: 46-59.
11. Behrooz P, Bernousi I, Aharizad S, Ahakpaz F. Investigation of genetic diversity and grouping of barley genotypes based on indices related to grain yield under rain-fed and supplemental irrigation conditions. Journal of Crop Breeding. 2023; 15: 27-37.
12. Burton GW. Quantitative interaction in grasses. In: Proc. 6th Inter. Grassland Congr. 1952; 1: 277–283.
13. Ceccarelli S. Tolerance to climatic stresses. Proceed. 5th Int. Barley Genetic Symposium, Okayama. 1986; 6-12.
14. Delauney AJ, Verma DPS. Proline biosynthesis and osmoregulation in plants. The Plant journal: for cell and molecular biology. 1993; 4: 215–223.

15. Dewey DR, Lu KH. A Correlation and path coefficient analysis of components of crested wheat grass production. Agron J. 1959; 51: 515-518.

16. Elakhdar A, Solanki S, Kubo T, Abed A, Elakhdar I, Khedr R, et al. Barley with improved drought tolerance: Challenges and perspectives. Environmental and Experimental Botany. 2022; 201: 104965.

17. EL-Shawy EE, EL Sabagh A, Mansour M, Barutcular C. Comparative study for drought tolerance and yield stability in different genotypes of barley (Hordeum vulgare L.). Journal of Experimental Biology and Agricultural Sciences. 2017; 5: 151-162.

18. Fatemi F, Kianersi F, Pour-Aboughadareh A, Poczai P, Jadidi O. Overview of identified genomic regions associated with various agronomic and physiological traits in barley under abiotic stresses. Applied Sciences. 2022; 12: 5189.

19. Ferioun M, Srhiouar N, Bouhraoua S, El Ghachtouli NE, Louahlia S. Physiological and biochemical changes in Moroccan barley (Hordeum vulgare L.) cultivars submitted to drought stress. Heliyon. 2023; 9: e13643.

20. Fernandez GCJ. Effective selection criteria for assessing plant stress tolerance. Proceeding of the International Symposium on Adaptation of Vegetables and other Food Crops in Temperature and Water Stress, Shanhua, Taiwan. 1992; 257–270.

21. Fleury D, Jefferies S, Kuchel H, Langridge P. Genetic and genomic tools to improve drought tolerance in wheat. J Exp Bot. 2010; 61: 3211–3222

22. Gadissa F, Gudeta TB. Phenotypic characterization and seed viability test in ex-situ conserved Ethiopian cultivated barley (Hordeum vulgare L.) landraces Gadissa and Gudeta. BMC Plant Biology. 2023; 23: 613.

23. Golestani SA, Assad MT. Evaluation of four screening techniques for drought resistance and their relationship to yield reduction ratio in wheat. Euphytica. 1998; 103: 293–299.

24. Haddadin MF. Assessment of drought tolerant barley varieties under water stress. Int J Agric and Forestry. 2015; 5: 131-137.

25. Hasanuzzaman M, Shabala L, Brodribb TJ, Zhou M, Shabala S. Assessing the suitability of various screening methods as a proxy for drought tolerance in barley. Functional Plant Biology. 2016: 44.

26. Hebbache H, Benkherbache N, Bouchakour M, Mefti M, Bekaddour H. Assessment relationship between agro-morphological traits and grain yield in barley genotypes under drought stress conditions. Cereal Research Communications. 2024; 52: 267–275.

27. Iannucci A, Suriano S, Codianni P. Genetic diversity for agronomic traits and phytochemical compounds in coloured naked barley lines. plants (Basel). 2021; 10: 1575.

28. Johnson HW, Robinson HF, Comstock RW. Estimates of genetic and environment variability in Soybean. Agronomy Journal. 1955; 47: 314–318.

29. Moustafa Ehab SA. Assessment of genetic variations and interrelationships among agronomic traits in advanced breeding barley lines under salinity condition. Egyptian J Desert Res. 2021; 71: 1-22.

30. Naresh K, Sehrawat D, Kumar Y. Assessment of genetic variability for agronomic and biochemical characters in barley (Hordeum Vulgare L.). Forage Res. 2023; 48: 445-452

31. Robinson HF, Comstock PH. Harvey. Estimates of heritability and degree of dominance in corn. Agron J. 1949; 42: 353 – 359.

32. Samarah NH. Effects of drought stress on growth and yield of barley. Agron Sustain Dev. 2005; 25: 145-149.

33. SAS. Statistical analysis system, version 9.2. SAS Institute Inc. Cary, NC, USA. 2008.

34. Shrimali J, Shekhawat AS, Kumari S. Correlation and path analysis studies in barley (Hordeum vulgare L.) genotypes under normal and limited moisture conditions. Int J Curr Microbiol App Sci. 2017; 6: 1850-1856.

35. Singh RK, Chaudhary BD. Biometrical Methods in Quantitative Genetic Analysis. Kalyani Publishers, New Delhi, India. 1979.

36. Singh B, Dhaka AK, Kumar M, Kumar S. Evaluation of drought tolerance indices for selection of barley (Hordeum vulgare L.) cultivars under different levels of irrigation. Int J Curr Microbiol App Sci. 2017; 6: 624-632.

37. Snedecor GW. Statistical Methods. 5th edition. Iowa State University Press, Ames, Iowa, USA. 1956.

38. Steel RGD, Torrie JH, Dickey DA. Principles and Procedures of Statistics: A Biometrical Approach. 3rd Ed. McGraw Hill Book Co. Inc. New York. 1997.

39. Thakur VS, Mishra V, Tamrakar A, Kumar K, Chourasiya KK, Kumar M. Assessment of genetic diversity and yield performance in barley (Hordeum vulgare L.) under rainfed condition. The Pharma Innovation Journal. 2022; 11: 1888-1891.

40. Wehner GG, Balko CC, Enders MM, Humbeck KK, Ordon FF. Identification of genomic regions involved in tolerance to drought stress and drought stress induced leaf senescence in juvenile barley. BMC Plant Biology. 2015; 15: 125.

41. Yadav SK, Singh AK, Pandey P, Singh S. Genetic variability and direct selection criterion for seed yield in segregating generations of barley (Hordeum vulgare L.). American Journal of Plant Sciences. 2015; 6: 1543-1549.

42. Yang S, Vanderbeld B, Wan J, Huang Y. Narrowing down the targets: towards successful genetic engineering of drought tolerant crops. Mol Plant. 2010; 3: 469–490.

43. Yazdanseta S, Haravan EM, Sorkhi B, Mohammadi S. Assessment of yield, yield- related traits and drought tolerance of barley (Hordeum vulgare L.) genotypes. Int J Biosci. 2014; 4: 62-72.