STABILITY ANALYSIS OF BARLEY GENOTYPES UNDER DIFFERENT WATER STRESS LEVELS

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ABSTRACT: Water deficit is the main yield-limiting factor in Egypt and overall the world. Thus the main objective from this work was to evaluate eighteen barley genotypes differed in their genetic makeup under six varied environments which are the combination between, two growing seasons (2013/2014 and 2014/2015) and three water irrigation levels (800, 1100 and 1400 m^3/fad.) as severe stress, moderate stress and adequate, respectively in newly reclaimed sandy soil of South El-Qantara Shark, Ismailia, Egypt, for days to 50% heading, flag leaf area, plant height, 1000-grain weight, biological yield and grain yield. The combined analyses of variance and the mean square of joint regression analysis of variance revealed significant differences among genotypes (G), environments (E) and the G × E interaction for all the traits. Environment + Genotype × Environment (E + G × E), mean squares due to environment (linear) and linear interaction (G × E linear) had highly significant effects for all characters. Severe and moderate water stress levels were significantly reduced all studied traits except 1000-grain weight for all barley genotypes than adequate water supply treatment. Grain yield reduced in the 1st year by an average of 25.67% and 13.44% and in the 2nd year by an average of 26.82% and 12.67% under 1st and 2nd irrigation levels, respectively, compared with the 3rd level. Phenotypic stability parameters showed that barely genotypes, Line 9, Rihane 3 and Line 11 were highly adapted to favorable environments for days to 50% heading; Line 6, Line 5 and Giza 2000 for plant height; Giza 126 for flag leaf area; Line 1, Line 11and Rihane 3 for 1000-grain weight; Line 9, Line 7 and Line 2 for biological yield and Line 6, Line 9 and line 10 for grain yield. Genotypic stability parameters indicated that barley genotypes Line 11 and Giza 2000 was highly adapted to favorable environments for days to 50% heading; Line 2 for plant height, 1000-grain weight and biological yield; California mariout, Giza 123, Line 4, Line 6 and Line 7 for grain yield. The additive main effects and multiplicative interaction (AMMI) analysis of variance showed highly significant difference among genotypes, environments, G × E, IPCA1 and IPCA2. AMMI stability value (ASV) and GE biplot revealed that, the most desired and stable genotypes were Line 1, Giza 123, California mariout, Line 8 and Line 6 for grain yield. According to genotype plus genotype × environment (GGE) biplots, the ideal genotype was Line 9 for days to 50% heading; Line 6 for plant height; Line 11 for flag leaf area; Line 1 for 1000-grain weight; Line 9 for biological yield and Line 6 for grain yield.

Key words: Barley, genotype × environment, phenotypic and genotypic stability, AMMI, water stress.

INTRODUCTION

Barley (*Hordeum vulgare* L.) is predominant to be the most drought tolerant of the small grain cereal crops (barley, durum wheat and bread wheat) and is a major crop in Middle East and North Africa countries, because it is the predominant crop lower 300 mm of annual rainfall. In Mediterranean areas barley is primarily grown as animal feed and both grain and straw yields are used.

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

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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 rainfed and irrigated conditions, though in the more favorable 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**). Breeding barley objectives in Egypt include short life cycles, high grain yields, straw yield, grain quality, drought, salt and heat tolerance, and resistance to pests and diseases. Tall, six-row lines predominate, but there are active breeding programmes and trialing of two row types (**Forster *el al.*, 2004).**

In newly reclaimed sandy soils, fertilization, irrigation and their interaction are the most important factors for increasing grain yield production (**Shaaban, 2006; Ali, 2017**). Drought is the main yield-limiting factor in Mediterranean region, therefore significant areas are watered, while the irrigation water is limited (**Forster *et al.*, 2004**). Water deficit is one of the major abiotic stresses that severely effects on barley production, it will increase frequency with climate changes. Selection of drought tolerance barley genotypes through agronomic and physiological traits is suitable indicators to increase crop yield in breeding program, and it is major goal of plant breeder nowadays.

Abiotic stresses including water stress can significantly decrease crop yields and limit the latitudes and soils on which commercially essential species can be cultivated (**Blum, 1985**). The seriousness of drought stress depends on its timing, duration and intensity (**Serraj *et al.*, 2005**). Drought stress tolerance is a complex inherited trait controlled by several genetic loci and is often confounded by changes in plants phenology (**Fleury *et al.*, 2010**). 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 (**Diab *et al.*, 2004**). 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 (**Mir *et al.*, 2012**).

Water deficit stress during barely grain-filling period lessened the net photosynthetic rate of the flag leaf (**Sánchez-Díaz *et al.*, 2002**). Thus, the main photosynthetic organs of barley are the flag leaf and ear to provide assimilates for grain filling, mainly where drought is encountered at the completion of the plants' life cycle (**Blum, 1985 ; Bort *et al.*, 1994**).

Drought stress decreases grain yield of barley genotypes through negative influence on yield components *i.e.* No. of plants/unit area, No. of spikes and grains per plant or unit area and 1000-grain weight, which are determined at different stages of plant development (**Samarah *et al.*, 2009; Hossain *et al.*, 2012; Haddadin, 2015; Al-Ajlouni *et al.*, 2016**) and Early flowering barely genotypes were better performance as reflected in higher yield compared with late flowering genotypes (**Al-Ajlouni *et al.*, 2016**). **Baum *et al.* (2003)** reported that tillering was an important trait for phenotypic plasticity to drought. A number of researchers have reported that drought tolerant genotypes perform high productivity under both well-watered and drought environments (**Samarah *et al.*, 2009; Sharafi *et al.*, 2011; Haddadin, 2015**) and can be used as parents in breeding programmes for improvement of drought tolerance in other barley cultivars (**Haddadin, 2015**). 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 (**Ali, 2016; Ali and Abdul-Hamid, 2017**).

The evaluation of barely genotypes in different environments is often performed to select the best varieties for an environment. The analysis and interpretation of genotype-environment interaction (GEI) range from simple analysis of variance to more specific analyses of genotype performance, from the univariate linear regression analysis of **Finlay and Wilkinson (1963)** and **Eberhart and Russell (1966)**, genotypic stability **(Tai, 1971)** to the multivariate AMMI (**Zobel *et al.*, 1988**) and GGE biplot (**Yan, 2001**). The AMMI has proven useful for understanding complex genotype × environment interactions. The AMMI Stability

value (ASV) proposed by **Purchase (1997) and Purchase *et al.* (2000)**. Biplots of the first two principal components were used to illustrate these relationships (**Gabriel, 1971; Kempton, 1984**).

The major objectives of the current study were to evaluate response of eighteen barely genotypes under different water supply levels over two years at newly reclaimed sandy soils and study partitioning the genotype by environment interaction to its stability parameters, using joint regression, genotypic stability, the AMMI and the sites regression (SREG) methods.

MATERIALS AND METHODS

Field Region and Barley Genotypes

Three separate trials were grown side by side with 12 m 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.

Eighteen six-row genotypes of barley (*Hordeum vulgare* L.), which were represent in thirteen promising strains 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. The pedigree of the tested barley genotypes are presented in Table 1.

Field Experiments

Field experiments were carried out in six environments which were the combination between, two years and three water regimes (800, 1100 and 1400 m^3/fad. as severe stress, moderate stress and adequate, respectively). Quantities of water irrigation were adjusted by a water counter for all irrigation treatments, 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.

The experimental field was well prepared through two perpendicular, ploughs, harrowing and good leveling. Recommended P and K fertilizers were added at the rate of 150 kg/fad., calcium super phosphate (15.5% P_2O_5) and 50 kg/fad., potassium sulphate (48% K_2O) during seed bed preparation for phosphate fertilizer and after 20 and 40 days from sowing for potassium fertilizer in two equal doses. Recommended N fertilizers was applied at the rate of 60 kg N/ fad., in the form of ammonium nitrate (33.5% N) in five equal doses, the first dose was added 14 days after sowing while the remainders were applied 10 days intervals. All other cultural practices for barley were applied as local recommendations in the region.

The soil of the experimentation site was sandy texture and the mechanical and chemical analyses of the soil and the water in the experimental sites are given in Tables 2 , 3, 4 and 5, representative soil sample used in the experimental soil were determined before preparation according to **Jackson (1973).**

Water Supply Treatments

Three water regimes were used in this study as followed: The 1st irrigation treatment, S (severe stress): All plots received a total amount of water 800 m^3/fad. This amount was given into 2 irrigations/week with 20 m^3 for each irrigation from seedling stage until heading stage and then 30 m^3 from heading stage to maturity stage. The 2nd irrigation treatment, M (moderate stress): All plots received a total amount of water 1100 m^3/ fad. This amount was given into 2 irrigations/ week with 27 m^3 for each irrigation from seedling stage to heading stage and watering with 37 m^3 from heading stage to maturity stage. The 3rd irrigation treatment, N (optimum or adequate water supply): All plots received a total amount of water 1400 m^3/fad. This amount was given into 2 irrigations/week with 34 m^3 for each irrigation from seedling stage until heading stage and then 44 m^3 from heading stage to maturity stage.

Table 1. The origin and pedigree of the eighteen barley genotypes

No.	Name	Pedigree	Origin
G1	California mariout	Land race	Egypt
G2	Line 1	Fedora/ Express/Saida	ICARDA
G3	Line 2	Arar/PI386540/Giza121/Pue/4/Deiralla106/Cel/3/Bco Mr/Mza// Apm/5106.	ICARDA
G4	Line 3	Alanda/5/Aths/4/Pro/Toll//Cer*2/Toll/3//5/06/6/Baca"S"/3/ AC253//Clo8887/Clo5761	ICARDA
G5	Giza 123	Giza 117/ FAO86	Egypt
G6	Line 4	PETUNIA2 / 3GLORIA-BAR / COME // ESPERANZA /4/… CBSS99M00349T-F-3M-1Y-IM-IY-IM-0M	ICARDA
G7	Line 5	CHENG DU 105 /4/ EGYPT4 / TERAN78 // P.STOO /3/…CBSS00Y00236T-E-0Y-0M-2Y-0M	ICARDA
G8	Line 6	TOCTE /3/CHAMICO/TOCTE//CONGONA/4/ LIGNEE 527/ CBSS99M00468T-H-1M-1Y-1M-1Y-0M	ICARDA
G9	Line 7	GLORIA-BAR / COME // LIGNEE640 /3/ S.P-B/4/SLLO /5/CBSS99M00429T-L-1M-1Y-1M-1Y-0M	ICARDA
G10	Line 8	BBSC/CONGONA//BLLU/3/CIRU CBSS00Y00225T-C-0Y-0M-2Y-1M-0M	ICARDA
G11	Line 9	FORRAJERA KLEIN/DELO CBSW98W00054S-8Y-2M-1Y-2M-1Y-0M	ICARDA
G12	Line 10	ALPHA-BAR/DURRA//CORACLE/3/ALELI/4/ CBSS99M00317T-AH-2M-1Y-1M-1Y-0M	ICARDA
G13	Line 11	JANE/TOCTE//PEREGRIN CBSS00Y00402T-AH-0Y-0M-2Y-0M	ICARDA
G14	Line 12	PETUNIA2 /3/ TOCTE / TOOCTE / TOCTE // BERROS /4/ PENCOO / CBSS00Y00475T-O-0Y-0M-2Y-0M	ICARDA
G15	Line 13	PETUNIA2 /6/ ALPHA-BAR / DURRA // CORACLE /3/ CBSS00Y00446D-F-0Y-0M-1Y-0M	ICARDA
G16	Rihane 3	As 46//Avt/Aths	ICARDA
G17	Giza 2000	Giza117/Bahteem52// Giza118/ FAO86 / 3/ Baladi16/ Gem	Egypt
G18	Giza 126	Baladi-Bahteem/SD729-por12762-Bc	Egypt

Table 2. Some physical analyses in the experimental soils

Parcel No.	Depth (cm)	CaCo$_3$ (%)	SP (%)	Gravel (%)	Particle size distribution (%)						Texture class
					2-1 mm	1-0.5 mm	0.50 0.25 mm	0.25 0.125 mm	0.125-0.063 mm	<0.063 mm	
6	0-15	0.37	17.0	0.0	6.0	30.2	38.2	19.4	5.7	0.5	CS
	15-35	0.20	17.7	0.0	1.1	30.5	43.7	17.6	6.6	0.5	CS
	35-90	0.24	18.0	0.0	0.0	7.0	50.5	35.6	6.6	0.3	MS
	90-150	0.33	17.7	0.0	0.4	12.6	52.9	26.8	6.8	0.5	MS
8	0-20	0.23	18.0	0.0	1.3	27.6	43.9	20.0	6.6	0.6	CS
	20-70	0.20	19.0	0.0	0.0	8.4	54.6	30.6	6.0	0.4	MS
	70-100	0.22	18.7	0.0	0.0	11.6	57.4	24.0	6.7	0.3	MS
	100-150	0.26	18.0	0.0	0.3	26.8	44.8	17.8	9.3	1.0	CS

SP is saturation percentage

Table 3. Some chemical analyses in experimental soils

Parcel No.	Depth (cm)	pH	EC ds/m	Soluble cations (m.eq/L)				Soluble anions (m.eq/L)			SAR	ESP
				Na^+	K^+	Ca^{++}	Mg^{++}	HCO_3^-	Cl^+	SO_4^-		
6	0-15	7.95	0.72	3.85	0.36	1.66	1.33	1.99	3.32	1.89	3.15	3.27
	15-35	8.34	0.55	2.72	0.29	1.43	1.07	1.72	2.86	0.93	2.43	2.26
	35-90	8.10	0.69	3.49	0.37	1.74	1.31	2.18	3.49	1.31	2.82	2.81
	90-150	8.19	0.56	2.67	0.44	1.42	1.07	1.78	2.85	0.98	2.39	2.21
8	0-20	8.32	0.71	5.68	0.06	0.82	0.54	1.63	4.90	0.56	6.89	8.15
	20-70	8.29	0.63	4.78	0.06	0.82	0.64	1.37	2.93	2.00	5.59	6.51
	70-100	8.62	0.31	2.23	0.03	0.53	0.33	0.33	2.34	0.42	5.09	6.50
	100-150	8.17	1.41	10.39	0.13	2.12	1.46	2.28	9.76	2.00	7.76	9.23

SAR, and ESP are sodium adsorption ratio and exchange sodium percent, respectively.

Table 4. Available nutrients status and OM (%) in the experimental soils

Parcel No.	Depth (cm)	Available nutrients (ppm)							OM (%)
		N	P	K	Fe	Mn	Zn	Cu	
6	0-15	45.8	1.34	13.9	5.30	4.32	0.134	0.170	0.328
	15-35	48.2	2.48	16.6	4.93	1.82	0.122	0.130	0.188
	35-90	34.0	3.20	26.6	4.32	1.41	0.410	0.138	0.061
	90-150	21.6	2.87	23.6	2.88	1.40	0.882	0.136	0.053
8	0-20	54.0	2.25	41.0	5.84	1.71	0.128	0.494	0.331
	20-70	44.4	3.23	41.0	4.83	1.10	0.120	0.204	0.256
	70-100	34.8	2.71	34.4	6.91	1.80	0.374	0.180	0.194
	100-150	39.2	2.55	22.2	6.32	1.41	0.404	0.228	0.112

Table 5. Chemical analysis of water used in irrigation and heavy and nutrient content in water used in irrigation

Water source	pH	EC (µS/cm)	TDS (mg/l)	Units	Ca^{++}	Mg^{++}	Na^+	K^+	Total cations (epm)	CO_3^-	HCO_3^-	SO_4^-	Cr	Total anions (epm)
Canal	8.3	2960	1609.7	ppm	134.5	101.9	330	11	29.73	9	176.9	148.8	786	28.47
				epm	6.71	8.39	14.35	0.28		0.3	2.9	3.1	22.17	
				(%)	22.56	28.22	48.26	0.94		1.05	10.19	10.89	1267.7	
Well	7.9	4990	2952.3	ppm	123.4	105.8	840	7		6	149.5	527.7	35.75	
				epm	6.16	8.82	36.52	0.18	51.68	0.2	2.45	10.98	35.75	49.38
				(%)	11.92	17.06	70.67	0.35		0.41	4.96	22.24	72.39	

Table 5. Continued

Water source	Al	B	Fe	Mn	Pb	Cd	Co	Cr	Cu	Mo	Ni	Sr	V	Zn
Canal	0.143	0.179	0.189	0.011	0.009	<0.001	<0.001	<0.02	0.025	<0.003	0.002	2.56	<0.01	0.029
Well	<0.06	1.21	<0.03	<0.002	0.027	<0.001	<0.001	0.053	<0.01	<0.003	0.002	2.46	<0.01	0.578

Table 6. Relative humidity and minimum and maximum temperatures in El-Qantara Shark during the 2013/214 and 2014/2015 winter barley growing seasons

Year	Variable	Month						
		October	November	December	January	February	March	April
	Relative humidity	65.9	66.9	68.1	65.1	61.2	62.4	64.9
2013/2014	**Average daily minimum**	16.4	12.9	9.0	8.0	8.5	9.9	12.4
	Average daily maximum	28.5	24.2	19.9	18.3	18.7	20	22
	Relative humidity	63.3	64.2	65.9	63.3	59.6	60.8	61.5
2014/2015	**Average daily minimum**	17.4	13	9.5	8.8	8.9	10.5	13.0
	Average daily maximum	28.8	25.0	20.5	19.4	19.2	21.0	23.0

The three water treatments received an equal number of irrigations. The water used in irrigation was mixed from El-Salam Canal and water wells. Rainfall, minimum and maximum temperatures were recorded from meteorological stations (Table 6).

Studied Traits

Days to heading (DH), was measured as number of days from sowing to awns appearance in 50% of the plants in a plot. Plant height (PH), in cm was estimated from ground level to the top of the spike excluding awns, at maturity. Flag leaf area (FLA), in cm^2 was calculated according to the following formula, Flag leaf area = length × maximum width × 0.72 (**Lai and Subba Roa, 1951**). 1000 grain weight (GW), was determined from two random samples taken from each plot and the average was calculated (g). Biological yield (BY) and grain yield (GY) were estimated from the central rows in the plot after discarding the first and the last row to avoid border effect and the biological yield (ton/fad.) and the yield of grains (ardab/fad.) were calculated.

Statistical Analyses

The combined analyses of variance were performed according to **Steel *et al.* (1997).** The phenotypic stability analysis was computed as outlined by **Eberhart and Russell (1966)**. The genotypic stability analysis was calculated according to **Tai (1971).** The additive main effects and multiplicative interaction method (AMMI) was computed as proposed by **Gauch (1992)**. Differences among means were tested using a revised LSD test at the 0.05 level according to **Steel *et al.* (1997)**. A PC Microsoft

Excel program and SAS 9.1 ® Computer program for Windows were used for the statistical analyses.

RESULTS AND DISCUSSION

Analysis of Variance

The combined analyses of variance for days to 50% heading, plant height, flag leaf area, 1000-grain weight, biological yield (ton/fad.) and grain yield (ardab/fad.) (Table 7) showed highly significant differences among environments for all traits, suggesting that the environments under study were different. Furthermore, highly significant effects among years (Y) were obtained for the forgoing traits. This result reflects the wide differences in climatic conditions prevailing during the growing seasons. Moreover, the main effect of irrigation (I) was highly significant for all studied traits. Likewise, the studied barley genotypes (G) had also highly significant differences for all characters, reflecting the wide genetic diversity.

Subsequently, significant G × E items were detected for all studied traits, provide evidence that the studied barley genotypes differed in their response to the environmental conditions, suggestting that is essential to determine the degree of stability for each genotype.

The first order interaction of years × irrigation levels (Y × I) significantly differed for all traits except days to 50% heading, indicating the different influences of climatic conditions on irrigation treatments. Also, highly significant interactions between genotypes × years (G × Y) were found for flag leaf area and biological yield. Moreover, the combined analyses of variance showed highly significant interactions

Table 7. The combined analyses of variance over two years, water stress levels and genotypes for studied traits

SOV	df	Days to 50% heading	Plant height (cm)	Flag leaf area (cm^2)	1000 grain weight (g)	Biological yield (ton/fad.)	Grain yield (ardab/fad.)
Environment (E)	**5**	1317.90**	5252.17**	96.62**	152.83**	35.09**	167.40**
Reps/Env. (Error a)	**12**	2.36	17.92	4.01	5.49	0.24	1.58
Years (Y)	**1**	676.00**	6198.94**	243.0**	95.29**	0.00	43.03**
Y × I	**2**	4.15	62.15**	18.67**	24.97**	1.07**	1.38**
Irrigation (I)	**2**	2952.60**	9968.81**	101.38**	309.45**	86.66**	395.60**
Genotypes (G)	**17**	528.64**	174.16**	40.45**	26.74**	2.98**	37.06**
G × E	**85**	9.82**	10.31*	6.84**	3.03*	0.18*	0.65*
G × Y	**17**	1.91	4.55	5.56**	0.10	0.35**	0.67
G × I	**34**	21.08**	20.87**	4.96**	7.42**	0.17	0.92**
G × Y × I	**34**	2.53	2.64	9.35**	0.09	0.11	0.37
Pooled Error (Error b)	**204**	2.51	7.14	0.41	2.23	0.12	0.42
CV (%)		1.80	4.83	7.44	3.87	7.93	5.12

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

between genotypes and irrigation levels (G × I) for all characters except biological yield. For this reason, the genotype-irrigation interaction component (G × I) accounted for the most part of total G × E interaction, indicating that irrigation treatments had the major effect on the relative genotypic potential for these studied traits. Conversely, for the second order (G × Y × I) interactions, there weren't a differential response between genotypes to years and irrigation levels for all traits except flag leaf area. These results are in harmony with those obtained by **Chand *et al.* (2008), Lodhi *et al.* (2015), Feriani *et al.* (2016) and Ramla *et al.* (2016).**

Mean Relatively Performance

The analyses of variance revealed significant differences for all studied traits among the eighteen barley genotypes in both 1st and 2nd seasons of the three irrigation levels. Severe and moderate water stress levels caused significant reduction in all studied traits except 1000-grain weight for all barley genotypes than adequate water supply treatment (data not shown). It is clear that, the irrigation stresses caused a reduction in days to 50% heading in the 1st year by an average of 11.3% and 2.9% and in the 2nd year by an average of 10.7% and 3.5% under 1st and 2nd irrigation levels, respectively, compared with the 3rd level (adequate). For plant height, the reduction percentages were 30.21% and 10.38% in the 1st year as well as 29.32% and 12.70% in the 2nd year under 1st and 2nd irrigation levels, respectively, compared with the 3rd level (adequate).

Reduction percentages for flag leaf area were 27.96% and 19.84% in the 1st year as well as 12.72% and 2.95% in the 2nd year under 1st and 2nd irrigation levels, respectively, compared with the 3rd level. Also, reduction percentages for biological yield were 30.87% and 12.99% in the 1st year as well as 37.23% and 15.70% in the 2^{one} one under 1st and 2nd irrigation levels, respectively, compared with the 3rd level.

Correspondingly, grain yield reduced in the 1st year by an average of 25.67% and 13.44% as well as in the 2nd year by an average of 26.82% and 12.67% under 1st and 2nd irrigation levels, respectively, compared with the 3rd level.

Generally, grain yield and other traits were severely decreased at the first and second irrigation levels when compared with the third level. Similar trend of results were reported by **Sánchez-Díaz *et al.* (2002), Samarah *et al.* (2009), Sharafi *et al.* (2011), Haddadin (2015) and Al-Ajlouni *et al.* (2016)**. Moreover, **Samarah (2005)** found that the drought-stressed plants had shorter duration of grain filling than well-watered plants and reduced grain yield by reducing the number of tillers, spikes and grains per plant and individual grain weight.

The average of days to 50% heading over all environments varied from 79.0 (Giza 123) to 99.17 day (Line 1) with an average 87.13 day. In continuous, and as shown in Table 10. It is worthy to note that, plant height varied from 48.19 (Line 3) to 61.24 cm (Line 7) with an average of 55.12 cm. For flag leaf area, it ranged from 6.29 (Line 5) to 13.18 cm^2 (Giza 2000) with an average of 8.10 cm^2 across 6 environments (Table 11). Whereas, 1000- grain weight ranged from 36.91 (Line 10) to 40.82 g (Line 1) with an average of 38.43g. Moreover, biological yield varied from 3.73 (Giza 2000) to 5.0 (Line 6) with an average of 4.51 (ton/fad.) over six environments. In the same way, grain yield varied from 10.69 (Giza 126) to 15.07 (Line 6) with an average of 13.17 (ardab/fad.). (Table 12). These results are in well agreement with those of **Sharafi *et al.* (2011), Haddadin (2015) and Al-Ajlouni *et al.* (2016)**. Moreover, **Ceccarelli *et al.* (1987)** reported that environmental stresses such as drought, salinity, heat and cold are common, and together with low soil fertility and traditional agronomic managements are the major cause of low barley productivity (about 1.0 ton/ha).

Regression Analysis

Mean squares due to joint regression analysis of variance for days to 50% heading, plant height, flag leaf area, 1000-grain weight, biological yield and grain yield of the eighteen barley genotypes under six environments are presented in (Table 8). Results revealed significant differences among genotypes (G), environments (E) and the G × E interaction for all traits, indicating the presence of genetic and environmental variability among the studied genotypes. Environment + Genotype ×

Environment (E + G × E) had highly significant effects for all characters. The G × E interaction was further partitioned into linear and non-linear (pooled deviation) components. The mean squares due to environment (linear) were highly significant for all traits, indicating that differences existed between environments and revealed predictable component shared G × E interaction with un-predictable. Additionally, the linear interaction (G × E linear) was highly significant when tested against pooled deviation for all these characters, showing genetic differences among genotypes for their regression on the environmental-index, so it could be proceeded in the stability analysis (**Eberhart and Russell, 1966**) for the studied characters.

The non-linear responses as measured by pooled deviations from regressions were highly significant for days to 50% heading and flag leaf area, indicating that differences in linear response among genotypes across environments did account for all the G × E interaction effects, and therefore, the fluctuation in performance of genotypes grown in various environments was fully predictable. Significant effects for G x E interaction for many barley characters were previously reported (**Chand *et al.*, 2008; Lodhi *et al.*, 2015; Feriani *et al.*, 2016; Ramla *et al.*, 2016)**.

Days to 50% Heading

Phenotypic stability parameters have been computed according to **Eberhart and Russell (1966)**, for evaluating the eighteen barley genotypes for mentioned traits.

The importance of both linear (b_i) and non-linear (s^2_{di}) sensitivity for the expression of the trait was thus evident. **Eberhart and Russell (1966)** procedure involves the use of joint linear regression where the yield of each genotype is regressed on the environmental mean yield.

Results obtained in Table 10 clarify that, the regression coefficient (b_i) of barley genotypes ranged from 0.62 (Line 4) to 1.36 (Line 13) for days to 50% heading, indicating the genetic variability among barley genotypes in their regression response. However, the obtained (b_i) values were not deviated significantly from unity in barley genotypes; Line 1, Line 6, Line 8, Line 9, Line 10, Line 11, Rihane 3, Giza 2000

Table 8. Joint regression analysis of variance over two years, water irrigation levels and genotypes for studied traits

SOV	Traits df	Days to 50% heading	Plant height (cm)	Flag leaf area (cm²)	1000 grain weight (g)	Biological yield (ton/fad.)	Grain yield (ardab/fad.)
Model	107	51.13**	93.76**	5.46**	4.60**	0.75**	4.74**
Genotype (G)	17	176.21**	58.05**	13.48**	8.91**	0.99**	12.35**
Environment (E)	5	439.30**	1750.72**	32.21**	50.94**	11.70**	55.80**
G × E	85	3.27**	3.44*	2.28**	1.01*	0.06*	0.22*
E + G × E	90	27.50**	100.51**	3.94**	3.78**	0.71**	3.30**
Environment (linear)	1	1220.28**	4863.12**	89.46**	141.51**	32.49**	155.00**
G × E (linear)	17	68.40**	234.45**	6.80**	9.51**	1.60**	7.71**
Pooled deviation	72	1.27**	2.74	2.08**	0.52	0.05	0.16
Pooled Error	204	0.84	2.38	0.14	0.74	0.04	0.14

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

Table 9. AMMI analysis of variance over six environments (two years and three water irrigation levels) for studied traits

SOV	Traits df	Days to 50% heading MS	Percent	Plant height (cm) MS	Percent	Flag leaf area (cm²) MS	Percent	1000 grain weight (g) MS	Percent	Biological yield (ton/fad.) MS	Percent	Grain yield (ardab/fad.) MS	Percent
Environment (E)	5	1317.90**	38.87	5252.17**	80.59	96.62**	25.65	152.83**	33.18	35.09**	65.21	167.40**	48.56
Reps/Env.	12	2.36		17.92		4.01		5.49		0.24		1.58	
Genotype (G)	17	528.64**	53.01	174.16**	9.09	40.45**	36.51	26.74**	19.74	2.98**	18.84	37.06**	36.55
G × E	85	9.82**	4.93	10.31*	2.69	6.84**	30.84	3.03*	11.17	0.18*	5.69	0.65*	3.20
IPCA1	21	32.27**	81.16	20.97**	50.23	11.66**	42.14	8.55**	69.79	0.36**	49.83	1.15**	43.91
IPCA2	19	6.76**	15.38	16.52**	35.79	8.85**	28.93	3.85**	28.48	0.19*	23.82	1.10**	37.84
IPCA3	17	0.81	1.64	4.34	8.41	7.66**	22.40	0.19	1.26	0.12	12.83	0.51	15.85
IPCA4	15	0.73	1.31	2.14	3.66	2.32**	6.00	0.06	0.32	0.10	10.09	0.07	1.95
IPCA5	13	0.33	0.51	1.29	1.91	0.24	0.53	0.03	0.16	0.04	3.42	0.02	0.45
Pooled Error	204	2.51		7.14		0.41		2.23		0.12		0.42	

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

Table 10. Genotype means over six environments and stability parameters of the eighteen barley genotypes for days to 50% heading and plant height

Traits	Days to 50% heading								Plant height (cm)							
Genotype	Mean ($\bar{g}_i$)	P_i	b_i	S^2_{di}	α_i	λ_i	ASV	Rank	Mean ($\bar{g}_i$)	P_i	b_i	S^2_{di}	α_i	λ_i	ASV	Rank
G1 (California mariout)	81.44	-5.69	0.75**	0.28	-0.25*	0.28*	3.52	13	52.13	-2.99	1.05	3.87	0.05	0.88	2.73	8
G2 (Line 1)	99.17	12.03	1.15	0.80	0.15	0.81	2.42	11	54.77	-0.35	1.22	7.23*	0.22	1.65	9.89	18
G3 (Line 2)	87.22	0.09	1.85**	2.50*	0.85*	2.49	13.09	18	52.62	-2.50	1.01	3.89	0.01	0.89	1.88	5
G4 (Line 3)	79.17	-7.97	0.89**	0.16	-0.11*	0.16*	1.84	7	48.19	-6.93	1.00	4.18	0.00	0.95	2.72	7
G5 (Giza 123)	79.00	-8.13	0.85**	0.11	-0.15*	0.11*	2.23	10	52.50	-2.62	1.13**	0.19	0.13*	0.04*	3.87	13
G6 (Line 4)	91.22	4.09	0.62**	1.33	-0.38*	1.33	6.47	16	55.12	0.00	0.86	3.60	-0.15	0.82	5.71	15
G7 (Line 5)	92.72	5.59	0.69**	0.15	-0.31*	0.14*	4.44	14	56.53	1.41	1.05	0.80	0.05	0.18*	1.05	2
G8 (Line 6)	90.78	3.64	1.00	0.17	0.004	0.17*	0.48	2	52.86	-2.27	0.97	0.93	-0.03	0.21*	0.36	1
G9 (Line 7)	86.39	-0.75	1.19**	0.39	0.19*	0.40	2.96	12	61.24	6.12	1.01	1.65	0.01	0.38*	1.78	4
G10 (Line 8)	84.83	-2.30	1.10	0.54	0.10	0.55	2.16	9	57.62	2.50	1.09	7.44**	0.09	1.70	5.40	14
G11 (Line 9)	83.89	-3.25	0.97	0.12	-0.03	0.13*	0.30	1	59.21	4.09	0.86	2.09	-0.14	0.47	5.91	16
G12 (Line 10)	89.78	2.64	0.98	0.37	-0.02	0.37	0.81	5	58.65	3.53	1.01	3.46	0.01	0.79	1.14	3
G13 (Line 11)	87.28	0.14	1.01	0.72	0.01	0.73	1.05	6	55.46	0.34	0.79*	2.62	-0.21*	0.59	8.31	17
G14 (Line 12)	90.33	3.20	0.50**	12.75**	-0.50*	12.89*	10.60	17	58.48	3.36	0.96	2.01	-0.05	0.46	3.00	11
G15 (Line 13)	83.56	-3.58	1.36**	0.65	0.36*	0.65	5.71	15	55.61	0.49	0.89	2.16	-0.11	0.49	2.86	9
G16 (Rihane 3)	89.61	2.48	1.05	0.06	0.05*	0.06*	0.74	3	53.39	-1.73	1.12**	0.50	0.12*	0.11*	2.72	7
G17 (Giza 2000)	94.44	7.31	1.09	0.42	0.09	0.53	1.98	8	55.53	0.41	1.04	0.84	0.04	0.24*	2.91	10
G18 (Giza 126)	93.39	6.25	0.95	0.88	-0.05	1.34	0.76	4	55.44	0.32	0.95	1.07	-0.05	0.37*	3.46	12
Mean ($\bar{\bar{X}}$)	87.13								55.12							
LSD' 0.05	0.96								1.73							

$\bar{g}_i$ = Mean of genotype, (P_i)= Phenotypic index ($\bar{g}_i - \bar{\bar{X}}$), b_i= regression coefficient and S^2_{di}= mean square deviations from linear regression, α_i= linear response to environmental effects, λ_i = the deviation from linear response and ASV =AMMI stability value.
* , ** Significant at 0.05 and 0.01 levels of probability, respectively.

and Giza 126 for this trait, indicating that these genotypes could be grown under wide range of environments.

Four barley genotypes *i.e.,* Line 6, Line 11, Rihane 3 and Giza 2000 exhibited regression coefficient (b_i) values equal unity, therefore could be grown under wide range of environments. Meanwhile, the barley genotypes Line 9, Line 10 and Giza 126 had $b_i < 1$ and not significant. In contrast, the barley genotypes, Line 1, and Line 8 had $b_i > 1$ and not significant. According to **Breese (1969)** genotypes with regression coefficient greater than unity would be adapted to more favorable environments.

While, those with coefficient less than one would relatively be better adapted to less favorable growing conditions.

The deviations from regression (s^2_{di}) ranged from 0.06 (Rihane 3) to 12.75 (Line 12). All studied barely genotypes were stable, because they had lowest s^2_{di} values and not significant except Line 2, Line 4 and Line 12.

When the mean performance ($\bar{g}$), regression coefficient value (b_i) and the deviation from the regression (s^2_{di}) are considered together, then the most stable genotype would be Line 9 with an earliest mean $\bar{g}$ = 83.89, b_i = 0.97 and s^2_{di} =

0.12; Rihane 3 with $\bar{g}$ = 89.61, b_i = 1.05 and s^2_{di}= 0.06; Line 11 with $\bar{g}$ = 87.28, b_i = 1.01 and the s^2_{di} = 0.72, and Line 6 with $\bar{g}$ = 90.78, b_i = 1.0 and the s^2_{di} = 0.17. These genotypes could be useful in barley breeding programs for improve this trait.

Genotypic stability parameters of **Tai's (1971)** measured the deviation from the linear response in terms of the magnitude of error variance , and proposed partitioning the G × E interaction effect of the ith genotype into two statistics measures namely linear response to environmental effects (α_i) and the deviation from linearity (λ_i). Accordingly, perfectly stable barley genotypes would not change its performance from one environment to another. This is corresponding to stating that α_i = -1 and λ_i=1. Because perfectly stable barley genotypes probably do not exist, barley breeders will have to be satisfied with the accessible levels of stability, *i.e.* average stability α = 0.0 and λ_i=1, below average stability α_i > 0 and λ_i=1 and above average stability α_i < 0 and λ_i=1. Table 9 and Fig. 1 show that barley genotypes *i.e.*, G2, G8, G10, G11, G12, G13, G17 and G18 were stable and insignificant for linear response to environmental effects (α_i), as well as, G2, G3, G4, G7, G10, G12, G13, G15, G17 and G18 for the deviation from linear (λ_i). To clarify, G13 (Line 11) and G17 (Giza 2000) had the best genotypic stability values (α = 0.01 and 0.09 and λi = 0.73 and 0.53, respectively).

AMMI analysis showed that environments (E), barley genotypes (G) and the G × E interaction mean squares were significant for days to 50% heading (Table 9). The IPCA scores of barley genotypes in the AMMI and SREG analyses were significant for IPCA1 and IPCA2. Variance components (%) of the sum of squares varied from 53.01% for genotypes, 38.87% for environments and 4.93% for GEI. IPCA 1 score explained 81.16% and IPCA 2 had 15.38% of the total GEI for AMMI models. Also, IPCA 1 score explained 91.85% and IPCA 2 had 6.89% of the total GEI for SREG models.

A barley genotype with the smaller AMMI stability value (ASV) is considered as more stable **(Lopez, 1990; Kang, 2002)**. According to the ASV ranking in Table 10 and either Fig. 2, the barley genotypes, G11, G8, G16, G18, G12,

and G13 were more stable, they located near the origin and less responsive than the corner barley genotypes. On the contrary, the genotypes G3, G14, G6, G7 and G15, thus they were located far away from the origin.

An ideal barley genotype should have the lowest mean performance for days to 50% heading and be absolutely stable (*i.e.,* perform the best in all environments). G11 (Line 9) was ideal barley genotype, it had the lowest vector length of the lower barley genotype and with zero GEI, as represented by the arrow pointing to it (Fig. 2).

The angle between the vectors of two environments is related to the correlation coefficient among them. The environments E_2, E_3, E_5 and E_6 were positively correlated because all angles among them were smaller than 90˚, while the environments E_1 and E_4 had negatively correlated with four other environments (Fig. 2).

Plant Height

The regression coefficient (b_i) of 18 barley genotypes ranged from 0.79 (Line 11) to 1.13 (Giza 123), indicating the genetic variability among barley genotypes in their regression response for plant height (Table 10). The obtained (b_i) values were deviated significantly from unity (bi>1) in Giza 123 and Rihane 3. Therefore they good adapted to favorable environments, whereas, the (b_i) values were significantly less than unity (b_i<1) in Line 11, hereby this relatively better adapted to low water level as less favorable environment. However, barley genotypes, *i.e.*, California mariout, Line 1, Line 2, Line 3, Line 4, Line 5, Line 6, Line 7, Line 8, Line 9, Line 10, Line 12, Line 13, Giza 2000 and Giza 126 had the (b_i) values were not deviated significantly from unity and thus could be grown under wide range of environments (Table 10).

The deviations from regression (S^2_{di}) for plant height ranged from 0.19 (Giza 123) to 7.44 (Line 8). The stable barley genotypes with lowest S^2_{di} values were Giza 123, Line 5, Line 6, Rihane 3 and Giza 2000. The unstable genotypes with the highest and significant S^2_{di} values were Line 1 and Line 8. The best stable genotypes according to phenotypic stability for plant height were Line 6 with a mean performance across
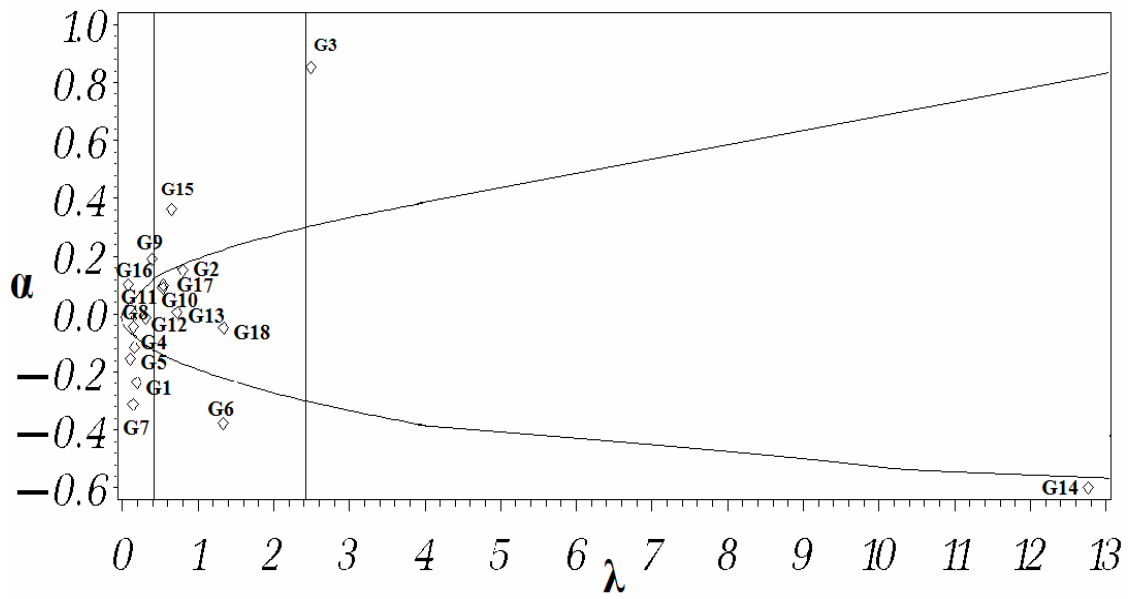
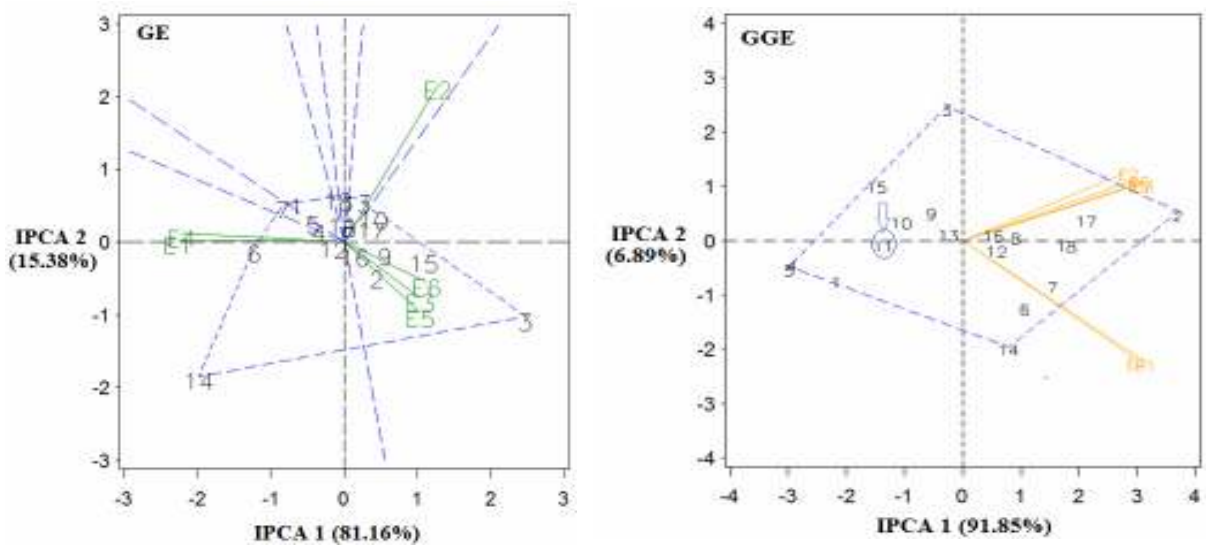**Fig. 1. Genotypic stability parameters (α and λ) of 18 barley genotypes for days to 50% heading**

Fig. 2. Graphics display of the GE and GGE biplots for 18 barley genotypes (assessed G1 - G18) and six environments (assessed E1- E6) in the AMMI and SREG models, respectively for days to 50 % heading

environments $\bar{g}$ = 52.86, b_i = 0.97 and the S^2_{di} = 0.93, followed by Line 5 ($\bar{g}$ = 56.53, b_i = 1.05 and Sd_i^2 = 0.80), then Giza 2000 ($\bar{g}$ = 55.53, b_i = 1.04 and S^2_{di} =0.84).

Regarding genotypic stability parameters, (Table 10 and Fig. 3) showed that all barley genotypes were stable and insignificant for linear response to environmental effects (α_i) except Giza 123, Line 11 and Rihane 3 and also for the deviation from linear (λ_i) except Giza 123, Line 5, Line 6, Line 7, Rihane 3, Giza 2000 and Giza 126. This suggests that California mariout, Line 2, Line 3 and Line 10 had the best genotypic stability values.

AMMI analysis showed that environments (E), barley genotypes (G) and the G × E interaction mean squares were significant for plant height (Table 9). The IPCA scores of a barley genotype in the AMMI and SREG analyses were significant for IPCA1 and IPCA2. Variance components (%) of the sum of squares varied from 9.09% for barley genotypes, 80.59% for environments and 2.69% for GEI. IPCA 1 score explained 50.23% and IPCA 2 had 35.79% of the total GEI for AMMI model. While for SREG model, IPCA 1 score exhibited 77.71% and IPCA 2 had 11.35% of the total GGEI (Fig. 4).

According to the ASV ranking Table 9 and either Fig. 4, the barley genotypes, Line 6 (G8), Line 5 (G7), Line 10 (G12), Line 7 (G9) and Line 2 (G3) were more stable, these barley genotypes were located near the origin and had small ASV. On the other hand, the barley genotypes G4, G11, G13, G6, G15, G3, G2 and G10 were unstable for this trait.

As can be seen GGE biplot for the SREG model (Fig. 4) showed that, Line 6 (G8) was ideal genotype for plant height, it had the lowest vector length of the lower barley genotype and with zero GE, as represented by the mark with an arrow pointing to it. The environments E_6 with E_3 and E_5, E_1 with E_2 were positively correlated because all angles among them were smaller than 90˚, while the environment E_4 had negatively correlated with E_3 and E_6.

Flag Leaf Area

Phenotypic stability parameters indicated that, regression coefficient (b_i) for flag leaf area of 18 barley genotypes ranged from -0.09 (Line 6) to 1.50 (Line 11) (Table 11). The (b_i) values were deviated significantly from unity ($b_i>1$) in Line 1, Line 2, Line 3, Line 8 and Line 11 and less than unity ($b_i<1$) in Line 9 and Giza 126. On the other side, (b_i) values of the other barley genotypes were not deviated significantly from unity, indicating that these genotypes were adapted well under wide range of environments for flag leaf area.

The deviations from regression (S^2_{di}) for flag leaf area ranged from 0.08 (Giza 126) to 5.84 (Line 8). All barley genotypes in this study were unstable; they had significant S^2_{di} values except Giza 126.

Results of genotypic stability parameters (Table 11 and Fig. 5) showed that all barley genotypes were stable and insignificant for linear response to environmental effects (α_i) except Line 9, Line 11 and Giza 126. Moreover, for the deviation from linear (λ_i), all barley genotypes were unstable and significant except Line 11 and Giza 126.

AMMI analysis revealed that environments (E), barley genotypes (G) and the G x E interaction mean squares were highly significant for flag leaf area (Table 9). The IPCA scores of barley genotypes in the AMMI and SREG models were significant for IPCA1 and IPCA2. Variance components (%) of the sum of squares varied from 36.51% for barley genotypes, 25.65% for environments and 30.84% for GEI. IPCA 1 score explained 42.14 % and IPCA 2 had 28.93% of the total GEI for AMMI model. Moreover, For SREG model, IPCA 1 score exhibited 60.73% and IPCA 2 had 15.83% of the total GGEI (Fig. 6).

A barley genotype with least ASV is the most stable, in respect to flag leaf area as given in Table 10 and illustrated in Fig. 6 the barley genotypes G13, G4, G1, G6, G16, G15, G4, G11 and G18 were the most desired and stable genotypes for flag leaf area. Conversely, the vertex barley genotypes G3, G10, G9, G8, G17, G5 and G14 were unstable, they located far away from the origin for this trait and are more responsive to the environmental changes.
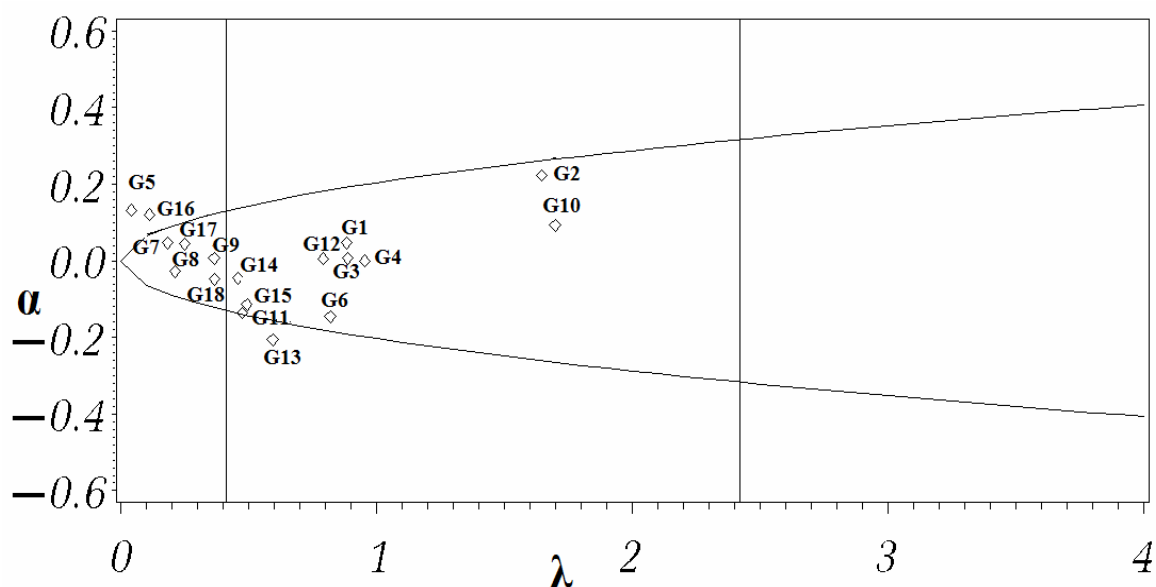
Fig. 3. Genotypic stability parameters (α and λ) of 18 barley genotypes for plant height
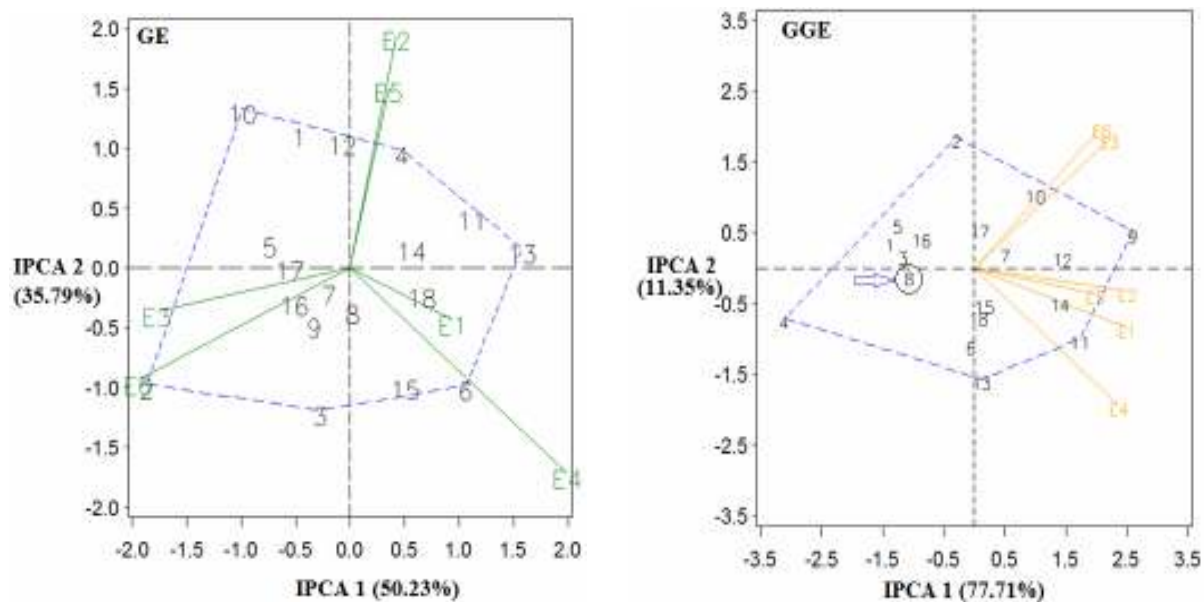

Fig. 4. Graphics display of the GE and GGE biplots of 18 barley genotypes (assessed G1 - G18) and six environments (assessed E1-E6) in the AMMI and SREG models, respectively for plant height (cm)

Table 11. Genotype means over six environments and stability parameters of the eighteen barley genotypes for Flag leaf area and 1000 grain weight

Traits	Flag leaf area (cm²)								1000 grain weight (g)							
Genotype	**Mean** $(\overline{g_i})$	P_i	b_i	S^2_{di}	α_i	λ_i	**ASV**	**Rank**	**Mean** $(\overline{g_i})$	P_i	b_i	S^2_{di}	α_i	λ_i	**ASV**	**Rank**
G1 (California mariout)	8.86	0.76	1.05	0.95**	0.05	5.85*	0.67	2	39.92	1.49	1.58**	0.50	0.60*	0.31*	4.53	15
G2 (Line 1)	10.11	2.02	1.36*	1.86**	0.37	11.40*	2.32	8	40.82	2.39	0.90	0.78	-0.10	0.53	1.05	4
G3 (Line 2)	9.31	1.22	1.91*	3.39**	0.95	20.45*	7.14	18	37.67	-0.75	0.76	0.59	-0.25	0.40	1.87	8
G4 (Line 3)	7.64	-0.45	1.50*	0.94**	0.52	5.66*	1.44	4	40.67	2.24	0.79*	0.08	-0.22*	0.05*	1.80	6
G5 (Giza 123)	8.11	0.01	1.36	2.09**	0.38	12.82*	5.28	14	38.74	0.31	0.91	0.05	-0.09	0.03*	0.85	3
G6 (Line 4)	7.21	-0.89	0.84	0.58**	-0.17	3.55*	2.69	9	36.44	-1.99	1.48**	0.36	0.49*	0.22*	3.96	13
G7 (Line 5)	6.29	-1.81	0.43	0.73**	-0.60	4.32*	3.68	12	38.85	0.42	1.57**	0.43	0.59*	0.27*	4.53	16
G8 (Line 6)	7.26	-0.84	-0.09	2.60**	-1.14	15.38*	3.18	11	38.68	0.26	1.26*	0.29	0.27	0.19*	1.86	7
G9 (Line 7)	8.58	0.48	1.07	3.52**	0.07	21.74*	5.37	15	37.33	-1.10	1.58**	0.32	0.60*	0.19*	4.59	17
G10 (Line 8)	8.71	0.62	1.48*	5.84**	0.50	35.99*	5.55	16	37.37	-1.06	0.50*	2.28*	-0.52	1.53	4.13	14
G11 (Line 9)	7.95	-0.15	0.13*	1.21**	-0.91*	7.02*	0.72	3	37.74	-0.69	1.20	0.95	0.21	0.64	1.92	9
G12 (Line 10)	7.14	-0.96	0.65	2.24**	-0.37	13.75*	3.96	13	36.91	-1.52	0.94	0.01	-0.06	0.01*	0.38	1
G13 (Line 11)	9.45	1.35	1.50*	0.33**	0.52*	1.90	0.63	1	39.00	0.57	1.01	0.36	0.01	0.24*	0.54	2
G14 (Line 12)	9.29	1.19	1.06	4.40**	0.07	27.22*	6.47	17	38.15	-0.28	0.59**	0.18	-0.42*	0.11*	3.29	12
G15 (Line 13)	8.55	0.45	0.99	0.62**	-0.02	3.86*	2.17	7	38.77	0.34	-0.18**	1.39	-1.22*	0.82	9.28	18
G16 (Rihane 3)	9.11	1.01	1.33	0.87**	0.35	5.33*	2.08	6	39.81	1.39	1.15	0.42	0.16	0.28*	1.17	5
G17 (Giza 2000)	13.18	5.08	1.17	4.11**	0.17	31.72*	3.16	10	38.67	0.24	0.70**	0.09	-0.31*	0.07*	2.39	11
G18 (Giza 126)	9.03	0.94	0.28**	0.08	-0.75*	0.40	2.07	5	38.27	-0.16	1.26*	0.12	0.27*	0.12*	2.29	10
Mean ($\overline{\overline{X}}$)	8.10								38.43							
LSD' 0.05	0.39								1.01							

$\overline{g_i}$ = Mean of genotype, (P_i)= Phenotypic index ($\overline{g_i} - \overline{\overline{X}}$), b_i= regression coefficient and S^2_{di}= mean square deviations from linear regression, α_i= linear response to environmental effects, λ_i = the deviation from linear response and ASV =AMMI stability value.
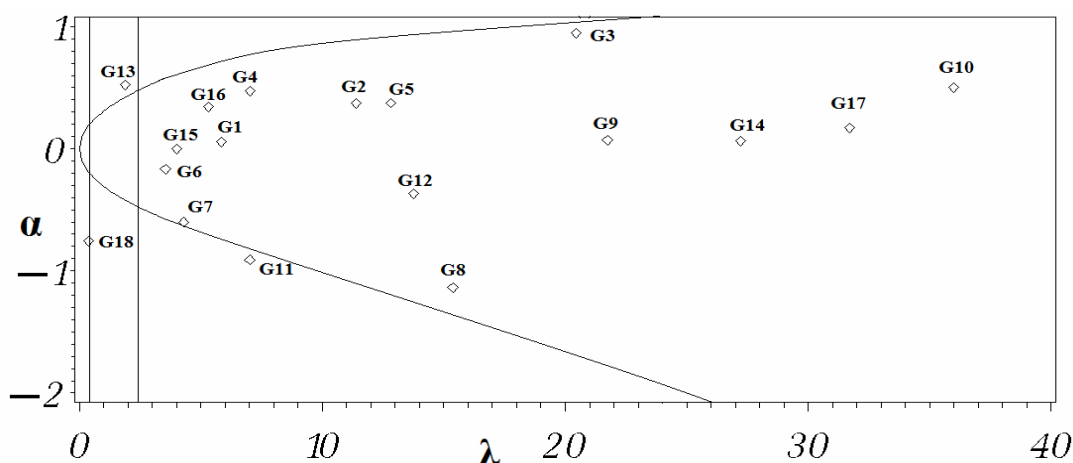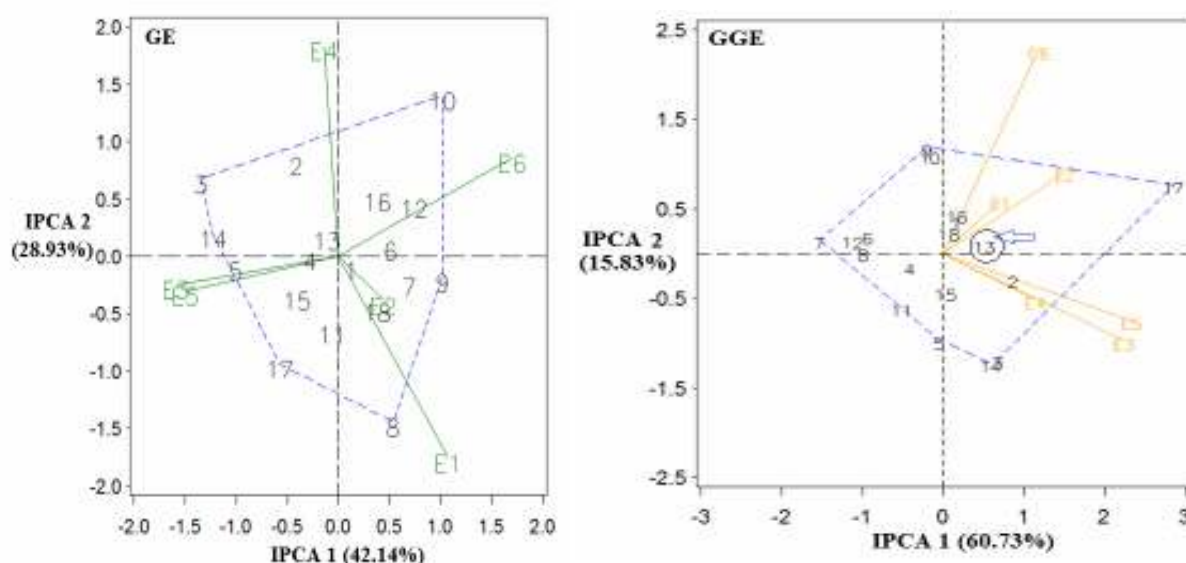* , ** Significant at 0.05 and 0.01 levels of probability, respectively.

Fig. 5. Genotypic stability parameters (α and λ) of 18 barley genotypes for flag leaf area (cm²)

Fig. 6. Graphics display of the GE and GGE biplots of 18 barley genotypes (assessed G1 - G18)and six environments (assessed E1- E6) in the AMMI and SREG models, respectively for flag leaf area (cm^2)

GEI biplot graph for the AMMI showed that, Environments E_6, E_1, E_4 and E_5 were the most differentiating environments for flag leaf area. On the other side, environment E_2 was less responsive for this trait.

GGEI biplot graph for the SREG model showed that, G13 (Line 11) was ideal barley genotype for flag leaf area (Fig. 6). Barley genotype G8 was more desirable genotype, this was located closer to the ideal genotype. The environments E_5, E_4 and E_3 were positively correlated, while the environment E_6 had negatively correlated with E_5, E_4 and E_3.

1000-Grain Weight

Phenotypic stability parameters exhibited that, regression coefficient (b_i) for 1000-grain weight of eighteen barley genotypes ranged from -0.18 (Line 13) to 1.58 (California mariout and line 7), indicating the genetic variability among barley genotypes in their regression response for 1000-grain weight (Table 11). The (b_i) values were deviated significantly from unity (bi>1) in California mariout, line 3, Line 4, Line 5, Line 6, Line 7 and Giza 126 and less than unity (b_i<1) in Line 3, Line 8, line 12, Line 13 and Giza 2000. On the other side, barley genotypes, *i.e.,* Line1, Line 2, Giza 123, Line 9, Line 10, Line 11 and Rihane 3 had the (b_i)

values were not deviated significantly from unity, indicating that these barley genotypes were adapted well under wide range of environments for 1000-grain weight.

The deviations from regression (S^2_{di}) for 1000-grain weight ranged from 0.01 (Line 10) to 2.28 (Line 8). All barley genotypes in this study were stable, they had lowest S^2_{di} values and not significantly different from zero except Line 8.

The best stable barley genotypes according the three phenotypic stability parameters ($\bar{g}$, bi and S^2_{di}) for 1000-grain weight were Line 1 (G2), followed by Line 11 (G13), then Rihane 3 and Giza 123. These genotypes gave mean values above grand mean and their regression coefficients (b_i) did not differ significantly from unity with minimum deviation mean squares S^2_{di}, revealing that these barley genotypes were more phenotypic stable.

Results of genotypic stability parameters (Table 11 and Fig. 7) show that 9 out 18 barley genotypes were stable and insignificant for linear response to environmental effects (αi). Moreover, for the deviation from linear (λ_i), all barley genotypes were unstable and significant except, Line 1, Line 2, Line 8, Line 9 and Line 13.

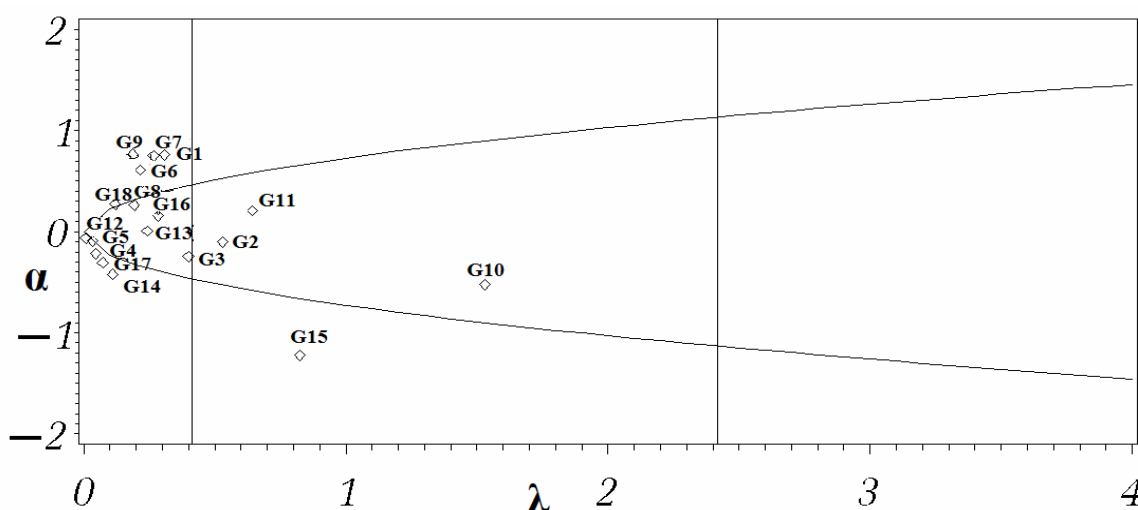AMMI analysis showed that environments (E), barley genotypes (G) and the G × E interaction

Fig. 7. Genotypic stability parameters (α and λ) of 18 barley genotypes for 1000 grain weight (g)

mean squares were significant for 1000-grain weight (Table 9). The IPCA scores of barley genotypes in the AMMI and SREG models were highly significant for IPCA1 and IPCA2. Variance components (%) of the sum of squares valued 19.74% for barley genotypes, 33.18% for environments and 11.17% for GEI. IPCA 1 score explained 69.79% and IPCA 2 had 28.48% of the total GEI for AMMI model. Moreover, For SREG model, IPCA 1 score exhibited 64.29% and IPCA 2 had 24.87% of the total GGEI.

A barley genotype with least ASV is the most stable, in respect to 1000-grain weight as given in Table 10 and illustrated in Fig. 8. The barley genotypes *i.e.,* G12, G4, G5, G13 and G16 were the most desired and stable genotypes for this trait, whereas genotypes G18, G8, G14 and G17 were moderate ones. Otherwise, the vertex barley genotypes G15, G10, G1, G7 and G11, were unstable for 1000-grain weight and more responsive to the environmental changes.

GGEI biplot graph for the SREG model (Fig. 8) showed that, Line 1 (G2) was ideal barley genotype for 1000-grain weight, it had the heaviest vector length of the heavier genotype and with zero GEI. Further, barley genotypes G4, G16 and G13 were more desirable genotypes, they were located closer to the ideal genotype. The environments E_1, with E_4; E_2 with E_5 and E_3 with E_6 were positively correlated. While the environment E_1 and E_4 had negatively correlated with E_3 and E_6.

Biological Yield (ton/fad.)

The regression coefficient (b_i) for biological yield of 18 barley genotypes varied from 0.57 to 1.16 for Line 5 and Line 6, respectively (Table 12). The (b_i) values were deviated significantly and less than unity ($b_i<1$) in Line 4, Line 5, Line 12 and Line 13, therefore these barley genotypes were adapted to water defect environments. However, the (b_i) values were deviated significantly and more than unity ($b_i>1$) in Line 1, Line 3, Line 6, Line 8 and Rihane 3. On the other side, the remaining barley genotypes exhibited regression coefficient values not deviated significantly from unity in California mariout, Line 2, Giza 123, Line 7, Line 9, Line 10, Line 11, Giza 2000 and Giza 126. Hence these genotypes were adapted well under wide range of environments for biological yield (ton/fad.).

The deviations from regression (S^2_{di}) for this trait varied from 0.00 (G4 and G15) to 0.13 (G7). All barley genotypes were in this study stable with lowest S^2_{di} values and not significantly different from zero except G5, G7 and G12.

Based on the simultaneous consideration of three phenotypic stability parameters ($\bar{g}$, b_i and S^2_{di}) the most desired and stable genotypes were Line 9 ($\bar{g}$ = 4.92, b = 1.07 and S^2_{di} = 0.06); Line 7 ($\bar{g}$ = 4.46, b = 1.00 and S^2_{di} = 0.04) and Line 2 ($\bar{g}$ = 4.10, b = 1.10 and S^2_{di} =0.04). Obviously,
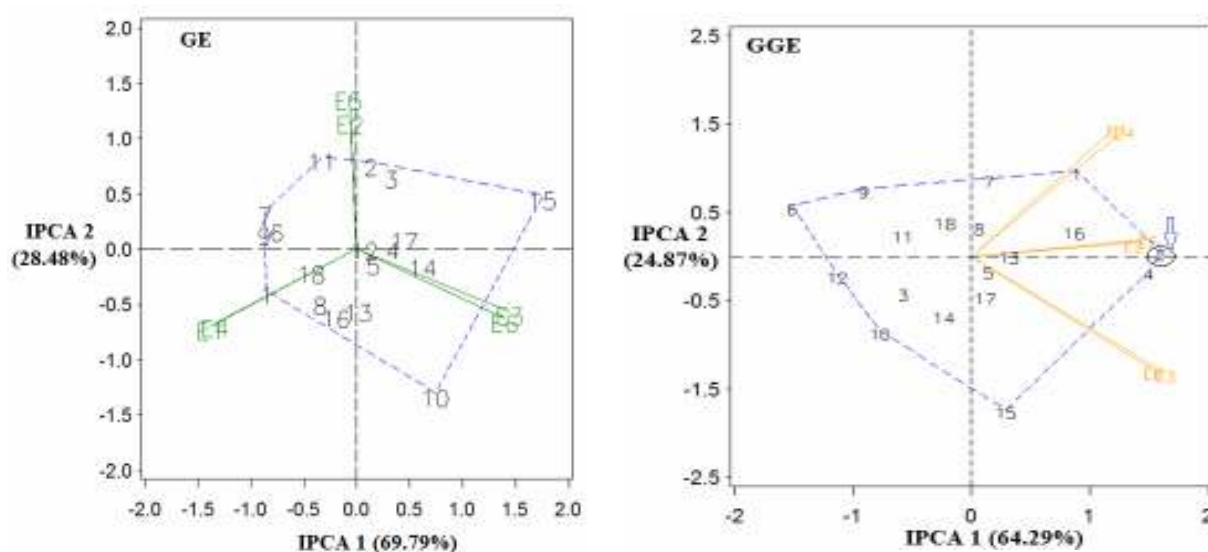
Fig. 8. Graphics display of the GE and GGE biplots of 18 barley genotypes (assessed G1 - G18) and six environments (assessed E1- E6) in the AMMI and SREG models, respectively for 1000 grain weight (g)

Table 12. Genotype means over six environments and stability parameters of the eighteen barley genotypes for biological yield and grain yield

Traits	Biological yield (ton/fad.)								Grain yield (ardab/fad.)							
Genotype	Mean $(\overline{g}_i)$	P_i	b_i	S^2_{di}	α_i	λ_i	ASV	Rank	Mean $(\overline{g}_i)$	P_i	b_i	S^2_{di}	α_i	λ_i	ASV	Rank
G1 (California mariout)	3.85	-0.66	0.93	0.09	-0.07	1.90	1.16	8	10.76	-2.41	0.93	0.02	-0.07	0.05*	0.44	3
G2 (Line 1)	4.17	-0.34	1.12*	0.05	0.12	0.97	1.36	12	11.75	-1.42	1.03	0.03	0.03	0.09*	0.24	1
G3 (Line 2)	4.10	-0.41	1.10	0.04	0.10	0.75	0.68	4	11.76	-1.40	0.79**	0.03	-0.21*	0.08*	1.94	14
G4 (Line 3)	4.36	-0.15	1.13*	0.00	0.13*	0.03*	0.71	5	12.45	-0.72	0.87**	0.01	-0.13*	0.02*	1.50	12
G5 (Giza 123)	4.10	-0.41	1.02	0.10*	0.02	2.16	2.24	16	12.17	-0.99	1.10	0.05	0.10	0.13*	0.34	2
G6 (Line 4)	4.90	0.39	0.87*	0.04	-0.13	0.87	0.37	3	14.43	1.27	0.96	1.06**	-0.04	3.01*	4.44	17
G7 (Line 5)	4.74	0.23	0.57*	0.13*	-0.43*	2.64	3.84	18	14.97	1.80	0.88**	0.02	-0.12*	0.05*	1.36	11
G8 (Line 6)	5.00	0.49	1.16*	0.03	0.16	0.70	1.28	10	15.07	1.90	0.96	0.01	-0.04	0.04*	0.56	5
G9 (Line 7)	4.46	-0.05	1.00	0.04	0.00	0.84	0.88	7	12.91	-0.25	1.05	0.07	0.06	0.20*	0.61	6
G10 (Line 8)	4.53	0.02	1.14	0.02	0.14	0.38*	1.25	9	13.21	0.04	0.94	0.01	-0.06*	0.01*	0.53	4
G11 (Line 9)	4.92	0.41	1.07	0.06	0.07	1.31	0.80	6	14.68	1.51	1.05	0.09	0.05	0.27*	1.14	10
G12 (Line 10)	4.98	0.47	0.97	0.12*	-0.03	2.53	2.28	17	13.83	0.66	1.10	0.05	0.10	0.15*	1.12	9
G13 (Line 11)	4.35	-0.16	1.07	0.03	0.07	0.71	1.46	13	12.93	-0.24	0.78*	0.33*	-0.22	0.93	0.88	7
G14 (Line 12)	4.44	-0.07	0.83*	0.04	-0.17	0.92	0.34	2	12.07	-1.10	0.76**	0.07	-0.24*	0.19*	2.64	16
G15 (Line 13)	4.01	-0.50	0.89*	0.00	-0.11*	0.10*	0.18	1	11.48	-1.68	1.44**	0.58**	0.45*	1.63	5.75	18
G16 (Rihane 3)	4.46	-0.05	1.11*	0.04	0.11	0.74	1.31	11	11.92	-1.25	1.14*	0.09	0.14	0.24*	1.58	13
G17 (Giza 2000)	3.73	-0.78	0.96	0.07	-0.04	1.74	2.17	15	10.89	-2.28	1.04	0.22	0.04	0.78	2.18	15
G18 (Giza 126)	3.84	-0.67	1.04	0.04	0.04	1.39	1.70	14	10.69	-2.48	1.16**	0.02	0.16*	0.07*	1.11	8
Mean ($\overline{\overline{X}}$)	4.51								13.17							
LSD' 0.05	0.21								0.39							

$\overline{g}_i$ = Mean of genotype, (P_i)= Phenotypic index $(\overline{g}_i - \overline{\overline{X}})$, b_i= regression coefficient and S^2_{di}= mean square deviations from linear regression, α_i= linear response to environmental effects, λ_i = the deviation from linear response and ASV =AMMI stability value.
* , ** Significant at 0.05 and 0.01 levels of probability, respectively.

these barley genotypes gave mean values above grand mean and their regression coefficients (b_i) did not differ significantly from unity with minimum deviation mean squares (S^2_{di}). Accordingly, these genotypes could be useful in barley breeding programs for improving this trait under water defect in newly reclaimed sandy soils.

Genotypic stability parameters given for biological yield in Table 12 and Fig. 9 show that, all barley genotypes were stable and insignificant for linear response to environmental effects (α_i) except Line 3, Line 5 and Line 13. Moreover, for the deviation from linear (λ_i), all barley genotypes were stable and insignificant except Line 3, Line 8 and Line 13. A simultaneous consideration of the two genotypic stability parameters (α_i and λ_i), the most desired and stable barley genotypes were G3, G9, G11 and G13.

AMMI analysis of variance showed that, environments (E), genotypes (G) and the G x E interaction mean squares were significant for biological yield (Table 9). The IPCA scores of a genotype in the AMMI and SREG analyses were significant for IPCA1 and IPCA2. Variance components (%) of the sum of squares varied from 18.84% for genotypes, 65.21% for environments and 5.69% for GEI. IPCA 1 score explained 49.83% and IPCA 2 had 23.82% of the total GEI for AMMI models. For SREG model, IPCA 1 score explained 80.72% and IPCA 2 had 10.18% of the total GGEI.

Based on ASV as given in Table 11 and illustrated in Fig. 10, the barley genotypes G15, G14, G6, G3, G4, G11 and G9 were the most desired and stable genotypes, whereas barley genotypes G9, G10, G16 and G13 were moderate one. Otherwise, the vertex barley genotypes G8, G2, G12, G7, G17 and G18 were unstable for this trait and more responsive to the water stress changes.

GE biplot graph for the AMMI model showed that environments E_6 and E_5 were the most differentiating environments for biological yield, they were located far away from the origin and they were more responsive to environmental changes (Fig. 10). Conversely, environments E_4 and E_3 were less responsive for biological yield.

GGE biplot graph for the SREG model showed that, Line 9 (G11) was ideal barley genotype for biological yield (Fig. 10). A barley genotype is more desirable as it is located closer to the ideal genotype, such as G6, G8 and G9. The environments E_1, E_2, E_3 and E_4 were positively correlated. Whereas, the environment E_1 was negatively correlated with E_5 and E_6.

Grain Yield (ardab/fad.)

Phenotypic stability revealed that, regression coefficient (b_i) for grain yield of 18 barley genotypes ranged from 0.76 (Line 12) to 1.44 (Line 13), indicating the genetic variability among barley genotypes in their regression response for grain yield (Table 12). The (b_i) values were deviated significantly from unity ($bi > 1$) in Line 13, Rihane 3 and Giza 126, indicating greater sensitivity to environmental changes and were relatively suitable in favorable environments with adequate water and other inputs. Meanwhile, the (b_i) values were deviated significantly and less than unity ($b_i < 1$) in G3, G4, G7, G13 and G14. On the other hand, barley genotypes, *i.e.*, G1, G2, G5, G6, G8, G9, G10, G11, G12 and G16 had the (b_i) values were not deviated significantly from unity, therefore these barley genotypes were adapted well under wide range of environments for grain yield (ardab/ fad.).

The deviations from regression (S^2_{di}) for barley grain yield varied from 0.01 (G4, G8 and G10) to 1.06 (G6). All barley genotypes in this study were stable with lowest S^2_{di} values and not significant except G6, G13 and G15.

The desirable and stable barley genotypes according to three stability parameters ($\bar{g}$, b_i and S^2_{di}) for grain yield were G8 with a mean yield $\bar{g}$ = 15.07, b = 0.96 and the S^2_{di} = 0.01; G11 ($\bar{g}$ = 14.68, b = 1.05 and S^2_{di} = 0.09) and G12 ($\bar{g}$ = 13.83, b = 1.10 and S^2_{di} =0.05). These genotypes gave mean values above grand mean and their regression coefficients (b_i) did not differ significantly from unity, also, minimum deviation mean squares (S^2_{di}) were detected.

Genotypic stability parameters given for grain yield in Table 12 and Fig. 11 show that, the most barley genotypes had stable and insignificant for linear response to environmental effects (α_i) were G1, G2, G5, G6, G8, G9, G11,
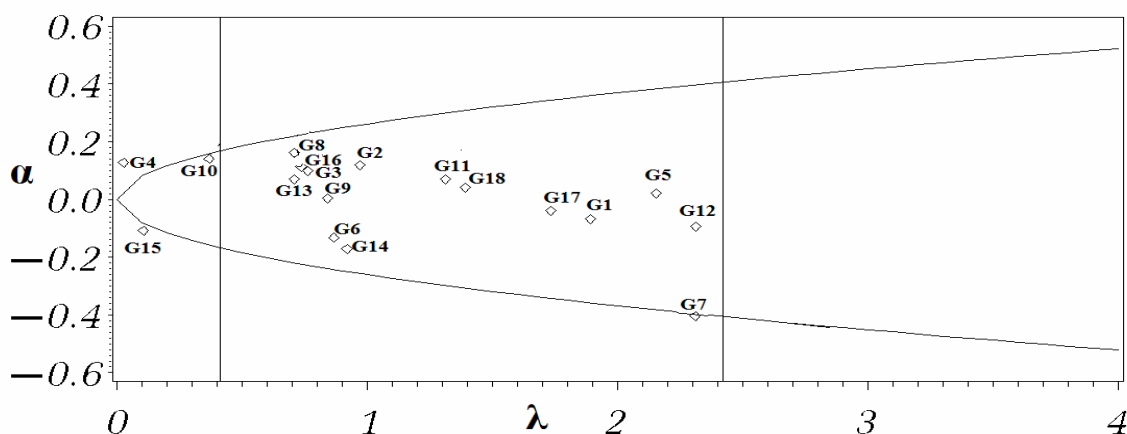
Fig. 9. Genotypic stability parameters (α and λ) of 18 barley genotypes for biological yield (ton/fad.)
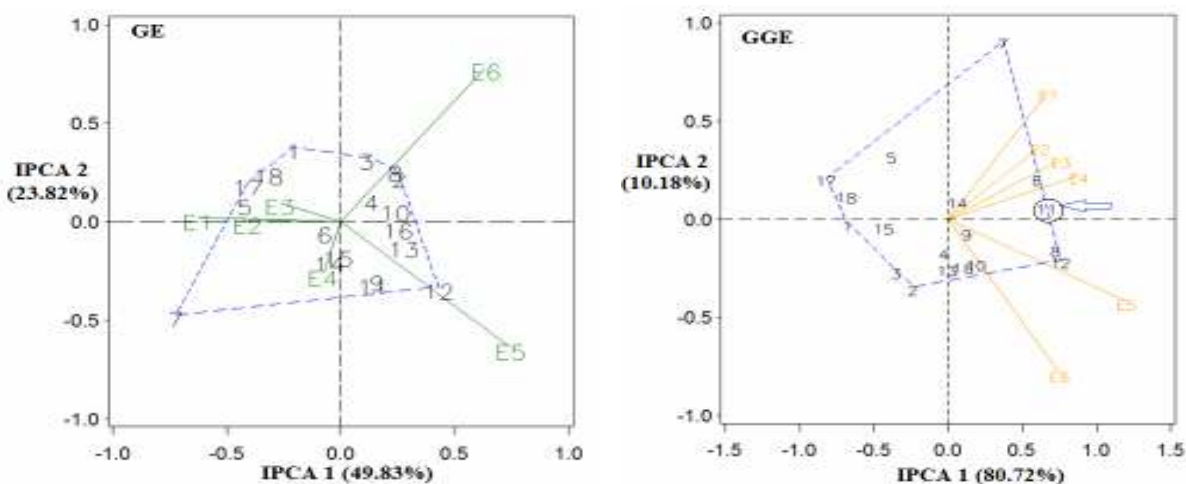

Fig. 10. Graphics display of the GE and GGE biplots of 18 barley genotypes (assessed G1-G18) and six environments (assessed E1-E6) in the AMMI and SREG models, respectively for biological yield (ton/fad.)
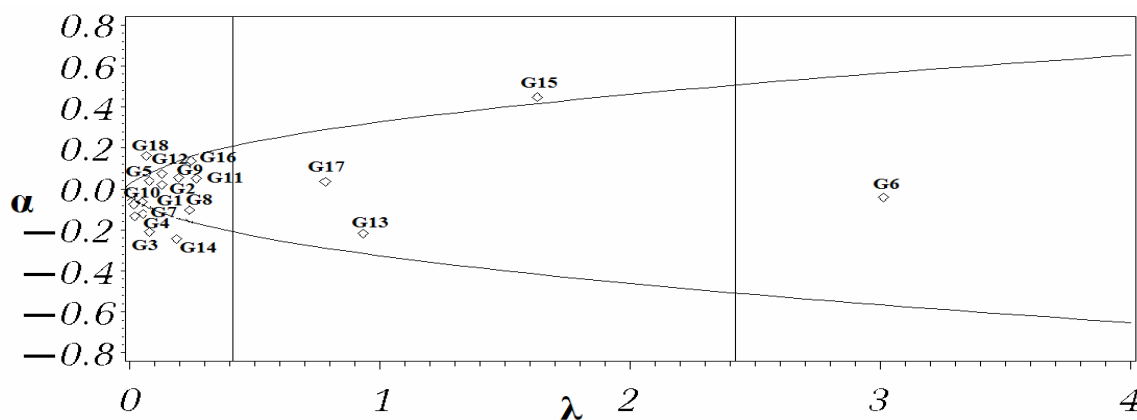

Fig. 11. Genotypic stability parameters (α and λ) of 18 barley genotypes for grain yield (ardab/fad.)

G12, G13, G16 and G17. Moreover, for the deviation from linear (λ_i), all barley genotypes were unstable and significant except G13, G15 and G17.

AMMI analysis of variance showed that environments (E), barley genotypes (G) and the G x E interaction mean squares were highly significant for grain yield (Table 8). The IPCA scores of a barley genotype in the AMMI and SREG analyses were significant for IPCA1 and IPCA2. Variance components (%) of the sum of squares varied from 36.55% for genotypes, 48.56% for environments and 3.2% for GEI. IPCA 1 score had 43.91% and IPCA 2 had 37.84% of the total GEI for AMMI models. For SREG model, IPCA 1 score exhibited 92.5% and IPCA 2 had 3.15% of the total GGEI. Highly significant effects for G x E interaction for many barley characters were previously reported (**Mohammadi *et al.,* 2015; Kendal, 2016; Elakhdar *et al.,* 2017).**

A barley genotype with least ASV is the most stable, in respect to grain yield as given in (Table 12) and illustrated in (Fig. 12). The barley genotypes G2, G5, G1, G10 and G8 were the most desired and stable genotypes (0.24, 0.34, 0.44, 0.53 and 0.56, respectively), as

opposed to, barley genotypes G13, G17, G15, G6 and G14 were unstable for this trait and more responsive to the environmental changes.

GE biplot graph for the AMMI model illustrated that, environments E_5 and E_6 were the most differentiating environments for grain yield, they were located far away from the origin and they were more responsive to environmental changes (Fig. 12). Whereas environments E_2 and E_3 were less responsive for grain yield.

GGE biplot graph for the SREG model as illustrated in (Fig. 12) showed that, G8 (Line 6) was ideal barley genotype for grain yield, it had the highest vector length of the high yielding genotypes and with zero GE, as represented by the dot with an arrow pointing to it in (Fig. 12). A barley genotype is more desirable if it is located closer to the ideal barley genotype, thus G7, G6, G11 and G12 were desirable genotypes. The environments E_3, E_2 and E_5 were positively correlated. Whereas, the environment E_6 had negatively correlated with E_1 and E_4. The ideal test environment was E_2, it had large IPCA1 scores and small IPCA2 scores. The favorable environment was E5, but the unfavorable ones were severe stress environments (E_1 and E_4) for grain yield.
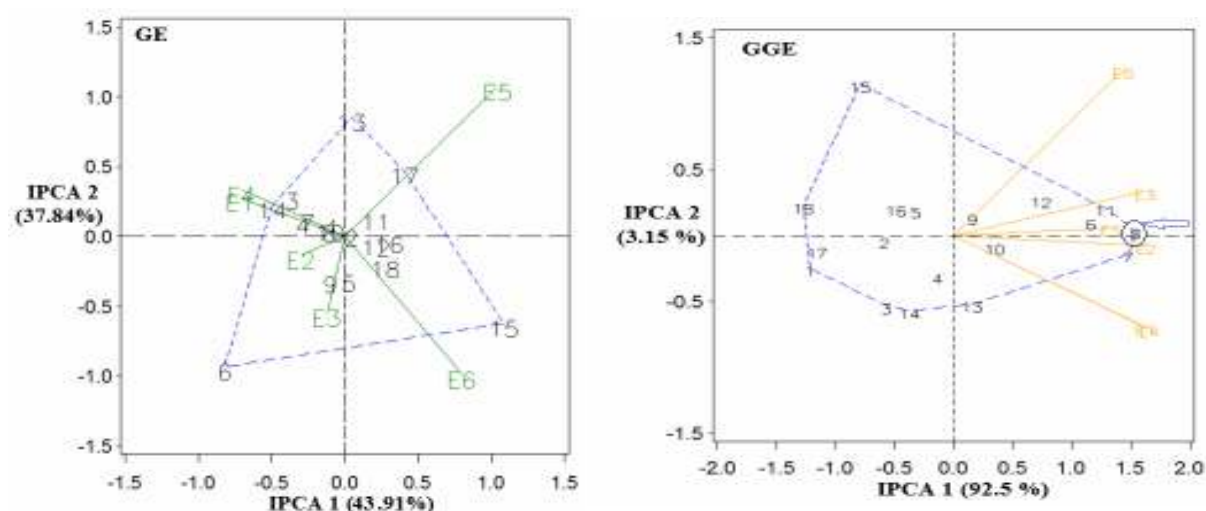

Fig. 12. Graphics display of the GE and GGE biplots of 18 barley genotypes (assessed G1 - G18) and six environments (assessed E1- E6) in the AMMI and SREG models, respectively for grain yield (ardab/fad.)

Conclusion

Days to 50% heading (earliness), plant height, flag leaf area and 1000-grain weight are major selection criteria used to develop low soil watery tolerant genotype in newly reclaimed sandy soils.

Accordingly, the three stability methods, *i.e.* phenotypic stability, genotypic stability and AMMI, the most desired and stable genotypes were Line 9 and Line 11 for days to 50% heading; Line 6 and Line 5 for plant height; Line 11 and Giza 126 for flag leaf area; Line 1, Giza 123 and Line 11 for 1000-grain weight; Line 9, Line 7 and Line 2 for biological yield (ton / fad.) and Line 6, Line 9 and Line 3 for grain yield (ardab/fad.). These genotypes could be useful in barley breeding programs for improving these traits under water stress in newly reclaimed sandy soils.

Therefore from GGE biplots, the ideal barley genotype was Line 9 for days to 50% heading; Line 6 for plant height; Line 11 for flag leaf area; Line 1 for 1000-grain weight; Line 9 for biological yield and Line 6 for grain yield. These genotypes had the most suitable under wastes stress and drought conditions.

REFERENCES

Al-Ajlouni, Z.I., A.M. Al-Abdallat, A.A. Al-Ghzawi, J.Y. Ayad, J.M. Abu Elenein, N.A. Al-Quraan and P. Stephen Baenziger (2016). Impact of pre-anthesis water deficit on yield and yield components in barley (*Hordeum vulgare* L.) plants grown under controlled conditions. Agron., 6 (33): 1-14.

Ali, M.M.A. (2016). Estimation of some breeding parameters for improvement grain yield in yellow maize under water stress. J. Pl. Prod., Mansoura Univ., 7 (12): 1509-1521.

Ali, M.M.A. (2017). Stability analysis of bread wheat genotypes under different nitrogen fertilizer levels. J. Pl. Prod., Mansoura Univ., 8 (2): 261-275.

Ali, M.M.A. and M.I.E. Abdul-Hamid (2017). Yield stability of wheat under some drought and sowing dates environments in different irrigation systems. Zagazig J. Agric. Res., 44 (3): 865 – 886.

Baum, M., S. Grando, G. Backes, A. Jahoor, A. Sabbagh and S. Ceccarelli (2003). QTLs for agronomic traits in the Mediterranean environment identified in recombinant inbred lines of the cross 'Arta' 9 H. spontaneum 41–1. Theor. Appl. Genet., 107:1215–1225.

Blum, A. (1985). Breeding crop varieties for stress environment. CRC Rev. Pl. Sci., 2: 199–238.

Bort, J., A. Febrero, T. Amaro and J.L. Araus (1994). Role of awns in ear water use efficiency and grain weight in barley. Agron., 2: 133–139.

Breese, E.L. (1969). The measurement and significance of genotypes environment interaction in grasses. Heredity, 24: 27-44.

Ceccarelli, S., S. Grand and J. A. G. Van Leur (1987). Genetic diversity in barley landraces from Syria and Jordan. Euphitica 36: 389-405.

Chand, N., S.R. Vishwakarma, O.P. Verma and M. Kumar (2008). Phenotypic stability of elite barley lines over heterogeneous environments. Barley Genet. Newsletter, 38: 14-17.

Diab, A.A., B. Teulat-Merah, D. This, N.Z. Ozturk, D. Benscher and M.E. Sorrells (2004). Identification of drought-inducible genes and differentially expressed sequence tags in barley. Theor. Appl. Genet, 109: 1417–1425. DOI: 10.3923/ajcs.2016.43.51

Eberhart, S.A. and W.W. Russell (1966). Stability parameters for comparing varieties. Crop Sci., 6: 36 – 40.

Elakhdar, A., T. Kumamaru, K.P. Smith, R.S. Brueggeman, L.J.A. Capo-chichi and S. Solanki (2017). Genotype by environment interactions (GEIs) for barley grain yield under salt stress condition. J. Crop Sci. Biotechnol. 20: 193-204. https://doi.org/10.1007/s12892-017-0016-0

FAOSTAT (2018). Food and Agricultural Organization Statistical Database. http://www. fa.org/ faostat / en / #data/QC

Feriani, W., S. Rezgui and M. Cherif (2016). Grain yield assessment of genotype by environment interaction of Tunisian doubled-haploid barley lines. J. New Sci., Agric. and Biotechnol., 27(7): 1507-1512.

Finlay, K.W. and G.N. Wilkinson (1963). The analysis of adaptation in a plant-breeding programme. Aust. J. Agric. Res., 14: 742–754.

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

Forster, B.P., R.P. Ellis, J. Moir, V. Talamè, M.C. Sanguineti, R. Tuberosa, D. This, B. Teulat-Merah, I. Ahmed, S.A.E.E. Mariy, H. Bahri, M.E.L. Ouahabi, N. Zoumarou-Wallis, M. El-Fellah and M. Ben Salem (2004). Genotype and phenotype associations with drought tolerance in barley tested in North Africa. Ann. Appl. Biol., 144:157-168.

Gabriel, K.R. (1971). The biplot graphic display of matrices with application to principal component analysis. Biometrika, 58: 453–467.

Gauch, H.G. (1992). Statistical analysis of regional trials: AMMI analysis of factorial designs. Elsevier, Amsterdam, Netherlands. 278 p.

Haddadin, M.F. (2015). Assessment of drought tolerant barley varieties under water stress. Int. J. Agric. and Forestry, 5 (2): 131-137.

Hossain, A., J.A. Teixeira da Silva, M.V. Lozovskaya, V.P. Zvolinsky and V.I. Mukhortov (2012). High temperature combined with drought affect rainfed spring wheat and barley in southeastern Russia: Yield, relative performance and heat susceptibility-index. J. Pl. Breed. and Crop Sci., 4 (11): 184-196.

Jackson, M.L. (1973). Soil chemical analysis Prentice Hall of Inchan, Private New Delhi.

Kang, M.S. (2002). Genotype-environment interaction: Progress and Prospects, 221–243. In M.S. Kang (ed.) Quantitative Genetics, Genomics, and Plant Breeding. CABI Publ., Wallingford, Oxon, UK.

Kempton, R.A. (1984). The use of biplots in interpreting variety by environmental interactions. J. Agric. Sci., 103 : 123–135.

Kendal, E. (2016). GGE biplot analysis of multi-environment yield trials in barley (*Hordeum vulgare* L.) cultivars. Ekin J. Crop Breed. and Genet., 2(1):90-99.

Lai, K.N. and M.S. Subba Rao (1951). A rapid method of leaf area determination. Nat., 167: 72.

Lodhi, R.D., L.C. Prasad, S.S. Bornare, A.H. Madakemohekar and R. Prasad (2015) Stability analysis of yield and its component traits of barley (*Hordeum vulgare* L.) genotypes in multi-environment trials in the north eastern plains of India. SABRAO J. Breed. Genet., 47 (2): 143-159.

Lopez, J. (1990). Estudio de la base geneetica del contenido en taninos condensadaos en la semilla de las habes (*Vicia faba* L.). Doctoral dissertation, Cardoba Univ., Spain.

Mir, R.R., M. Zaman-Allah, N. Sreenivasulu, R. Trethowan and R.K. Varshney (2012). Integrated genomics, physiology and breeding approaches for improving drought tolerance in crops. Theor. Appl. Genet 125: 625–645.

Mohammadi, M., A.A. Noorinia, G.R. Khalilzadeh and T. Hosseinpoor (2015). Application of GGE biplot analysis to investigate GE interaction on barley grain yield. Curr. Opin. Agric., 4 (1): 25–32.

Purchase, J.L. (1997). Parametric analysis to describe genotype x environment interaction and yield stability in winter wheat. Ph. D. Thesis, Agron. Dept., Fac. Free State, Bloemfontein, South Africa.

Purchase, J.L., H. Hatting and C.S. Van Deventer (2000). Genotype x environment interaction of winter wheat (*Triticum aestivum* L.) in South Africa: II. Stability analysis of yield performance. S. Afr. J. Plant Soil, 17: 101-107.

Ramla, D., M.S. Yakhou, N. Bilek, M. Hamou, A. Hannachi, A. Aissat and L. Mekliche-Hanifi (2016). Grain yield stability analysis

of barley doubled haploid lines in algerian semi-arid zones. Asian J. Crop Sci., 8: 43-51.

Samarah, N.H. (2005). Effects of drought stress on growth and yield of barley. Agron. Sustain. Dev., 25: 145–149.

Samarah, N.H., A.M. Alqudah, J.A. Amayreh, G.M. McAndrews (2009). The effect of late-terminal drought stress on yield components of four barley cultivars. J. Agron. and Crop Sci., 195 (6): 427-441.

Sánchez-Díaz M., J.L. García, M.C. Antolín and J.L. Araus (2002). Effects of soil drought and atmospheric humidity on yield, gas exchange, and stable carbon isotope composition of barley. Photosynthetica, 40: 415–421.

Serraj, R., C.T. Hash and S.M.H. Rivzi (2005). Recent advances in marker-assisted selection for drought tolerance in pearl millet. Pl. Prod. Sci., 8:334–337. doi: 10.1626/ pps. 8.334.

Shaaban, S.M. (2006). Effect of organic and inorganic nitrogen fertilizer on wheat plant under water regime. J. Appl. Sci. Res., 2 (10): 650-656.

Sharafi S., K. Ghassemi-Golezani, S. Mohammadi, S. Lak and B. Sorkhy (2011). Evaluation of drought tolerance and yield potential in winter barley (*Hordeum vulgare L.*) genotypes. J. Food, Agric. and Environ., 9: 419-422.

Steel, R.G.D., J.H. Torrie and D.A. Dickey (1997). Principles and Procedures of Statistics: A Biometrical Approach. 3rd Ed. McGraw Hill Book Co. Inc. New York.

Tai, G.C.C. (1971). Genotypic stability analysis and its application to potato regional trials. Crop Sci., 11:184-190.

Yan, W. (2001). GGEbiplot: A windows application for graphical analysis of multi-environment trial data and other types of two-way data. Agron. J., 93: 1111–1118.

Zobel, R.W., M.J. Wright and H.G. Gauch (1988). Statistical analysis of a yield trial. Agron. J., 80: 388-393.

تحليل الثبات للتراكيب الوراثية للشعير تحت مستويات مختلفة من الإجهاد المائي

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يعتبر الإجهاد المائي العامل الرئيسي المحدد للمحصول في مصر والعالم، لذلك أجريت هذه الدراسة بهدف تقييم 18 تركيب وراثي من الشعير لصفات عدد الأيام حتى طرد 50% من السنابل، ارتفاع النبات، مساحة ورقة العلم، وزن الألف حبـة، المحصول البيولـوجي ومحصـول الحبـوب، وذلك تحـت 6 بيئـات مختلفة (موسمين زراعيـين خـلال موسـمي 2013/2014 و 2014/2015 وثلاثة مستويات إجهاد مائي بمعدل 800 ، 1100 و 1400 م³ ماء/فدان تحت ظروف الأراضي الرملية بمنطقة القنطرة شرق)، أظهرت نتائج التحليل التجميعي وجود اختلافات عالية المعنوية بين التراكيب الوراثية تحت الدراسة وكذلك البيئات والتفاعل بين التركيب الوراثي × البيئة لجميع الصفات تحت الدراسة، أظهرت النتائج انخفاض قيم جميع الصفات تحت الدراسة تحت مستوى الإمداد المائي الأول والثاني مقارنة بالمستوى الثالث (الأمثل) ماعدا صفة وزن الالف حبة، أظهرت نتائج تحليل الثبات المظهري وجود اختلافات عالية المعنوية للتفاعل الخطى بين التركيب الوراثي × البيئة لجميع الصفات تحت الدراسة، كذلك بالنسبة لتفاعل البيئة + التركيب الوراثى × البيئة، أظهرت مقاييس الثبات المظهري تميز وثبات سلوك السلالة 9 و ريحان 3 والسلالة 11 لصفات عدد الأيام حتى ظهور 50% من السنابل، بينما تميزت السلالات 5 و 6 والصنف جيزة 2000 بالثبات لصفه ارتفاع النبات ، بينما أظهر الصنف جيزة 126 ثبات لصفة مساحة ورقة العلم ، والسلالات 1 و 11 والأصناف ريحان 3 وجيزة 123 لصفة وزن الألف حبة ، والسلالات 9، 7 و 2 لصفة المحصول البيولوجي والسلالات 6 ، 9 و 10 لصفة محصول الحبوب، أظهرت نتائج تحليل الثبات الوراثي تميز السلالة 11 والصنف جيزة 2000 بالثبات لصفة عدد الأيام حتى طرد 50% من السنابل ، والسلالة 2 لصفات ارتفاع النبـات وزن الألـف حبـة والمحصـول البيولـوجي وكاليفورنيـا مـاريوت وجيزة 123 والسـلالات 4 ، 6 و7 لصفة محصول الحبوب، بينما أظهر تحليل الثبات الوراثي (AMMI) اختلافات عالية المعنوية بين التراكيب الوراثية والبيئات والتفاعل بين التركيب الوراثي × البيئة، وأوضحت نتائج التحليل أن تراكيب الشعير الأكثر ثباتاً كانت السلالة 1 و جيزة 123 وكاليفورنيا ماريوت والسلالة 8 والسلالة 6 لصفة محصول الحبوب، وأظهر تحليل التفاعل GGE أن التركيب الوراثي النموذجي كان السلالة 9 لصفة عدد الأيام حتى طرد 50% من السنابل، السلالة 6 لصفة ارتفاع النبات، السلالة 11 لصفة مساحة ورقة العلم والسلالة 1 لصفة وزن الألف حبة، والسلالة 9 للمحصول البيولوجي والسلالة 6 لصفة محصول الحبوب ، ويشير ذلك إلى أهمية هذه التراكيب الوراثية فى برامج تربية الشعير لتحسين إنتاجية محصول الحبوب والمحصول البيولوجي تحت ظروف الإجهاد المائي وخاصة بالأراضي المستصلحة حديثًا.