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PERFORMANCE AND GRAIN YIELD STABILITY OF SOME BARLEY GENOTYPES UNDER VARYING ENVIRONMENTS

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ABSTRACT

The main objective of most breeding programs is obtaining stable and high yielding barley genotypes under targeted conditions. Two field experiments were carried out on two sowing dates, 12 November (D1) and 12 December (D2),each one included two irrigation treatments under 100% (I1) and 60% (I2) field capacity at Ras Sudr Research Station of the Desert Research Center during two seasons (2015/16 and 2016/17). The aim of this study as the determination of variation and performance criteria for eighteen genotypes under eight environments (two sowing dates × two irrigation treatments × two seasons). The obtained results can be summarized as follows: Analysis of Variance showed a wide range of differences between treatments and genotypes. The interaction between the environment and the genotypes was highly significant due to the greatest environmental effects (time of sowing). The meta-analysis showed the significance of the environments and genotypes as well as the interaction between them. The mean performance among genotypes under study differed significantly in most of the traits under study (heading date, plant height (cm), main spike length (cm), number of spikes/plant, number of spikelets/spike, number of grains/spike, Main spike grains weight (g), 1000 grain weight (g), grain yield/m^2 (g), straw yield/m^2 (g) under different environments. The results indicated that first planting date and 100% field capacity (D1I1) recorded the highest values comparing with the second planting date and 60% field capacity (D2I2) during the two seasons for most of the traits under study. The three genotypes (G2), (G11) and (G14) recorded the highest yield of grain yield with one/or more of its components, which can be used to improve barley production according to their performance across the different environments under study. Meanwhile, the index of tolerance across the two stress treatments showed that the five genotypes G1, G6, G7, G8 and G15 under D1 and the two genotypes G9 and G12 under D2 had the least drought susceptibility index for grain yield /m^2. Based on the estimates of stability criteria (bi and S^{2}di) and the coefficient of variation (CV%) of the yield and its components for different genotypes under study, they were homogeneous in determining the most stable genotypes across the studied environments. Both the G2 and G14 genotypes can be considered the best genotypes for heading date 50%, the G8 genotype for the plant height, the G3 and G4 genotypes for main spike height, and the four genotypes (G7, G8, G11 and G15) for the number of spikes/plant and G2 and G5 genotypes for the number of spikelets/spike. Three genotypes (G2, G5 and G14) for number of grains/spike, three genotypes (G2, G6 and G11) for the main spike grains weight, three genotypes (G9, G11 and G14) for the 1000- grain weight, four genotypes (G2, G5, G11 and G14) for grain yield/m^2 and G8 and G12 for straw yield/m^2. These genotypes are the least diverse in all environments under study. Based on the results of this study, it may be recommended to use early genotype G2 and the two high yielding genotypes G11 and G14 as stable genotypes for yield and its components. Therefore, these genotypes could be used for cultivating directly under undesirable environments (delayed sowing date and drought stress) as promising lines or serve as a parent in barley breeding programs under targeted environment

Key words**: *Hordeum vulgare, Sowing dates, Drought stress, G x E interaction, Stability, Regression,* Index of stress tolerance.**

INTRODUCTION

Barley is a valuable cereal crop under varying agro climatic condition. It has great adaptive potential to various habitats. It is grown across a wide range of soil variability and under many diverse climatic conditions and has a good tolerance to abiotic stresses such as salinity, drought, frost and heat, which considered as a primary staple food in the semi-arid tropics of Asia, Africa, and South America and the most adequate crop under non-favorable environmental conditions (Saleh and Farag 2016). The barley grains are usually used as food and animal fodder moreover it has also been applied as raw material for the production of beer (Ullrich 2011). The total area grown with barley worldwide in 2018 reached about 50 million hectares gave a total production of 142.37 million tons with an average 2.84 tons/ha. Meanwhile, in Egypt, barley was the main crop grown under rainfall in the northern coastal area and north and south Sinai governorate which received 100 - 200 mm annual rainfall with total area about 77.6 thousand hectares gave a total production 120.1 thousand tons with an average 1.55 tons/ha (Statistica 2018).

Recent barley breeding program in many countries aimed to increasing grain and straw yields under biotic and abiotic stresses. That context, extreme temperatures, water stress, high salt levels and mineral deficiency had significantly decreased and restricted crop yields and limit the latitudes and soils on which commercially essential species can be cultivated (Blum 1985). Drought is the main yield-limiting factor in Mediterranean region (Forster *el al* 2004). Water stress and sowing dates affected barley yield, which was reflected in the differences in yield components of early and late sown due to change in temperatures at different growth stages besides changing in sowing dates could have significant impact on barley grain yield and yield related traits and better performance of barley depends on precise field management and time of sowing (Rashid and Ullahkhan 2010 and Tabarzad *et al* 2016). Understanding the selection process requires: (i) identifying the main evolutionary forces of an environment where a species lives, and (ii) analyzing the effects of these forces on individual plant fitness through the changes in plant character architecture.

The existence of genotype × environment interactions and their effects on selection progress are widely recognized under erratic and unpredictable climatic conditions and have been evaluated in multi-location trials and determined by stability tests (Dehghani *et al* 2006, Amer *et al* 2012, Abd El- Moneam *et al* 2014 and Saleh and Farag 2016). Becker and Leon (1988) reported that a genotype is considered stable if its performance is consistent regardless of any variation in environmental conditions. While, Mühleisen *et al* (2014) concluded that the high demand on test intensity for precise assessment of yield stability exceeds the capacity of normal barley breeding programs. Testing of genotypes at multi-locations or under different growth environments produces significant genotype-environment interaction that reduces the accuracy for estimation of yield and its components and for selecting appropriate germplasm (Nachit *et al* 1992). While, the crop production is the function of genotype, environment and their interaction (G×E). Significant GEI results in changing behavior of the genotypes across different environments or changes in the relative ranking of the genotypes provides a general solution for the response of the genotypes to environmental change (Crossa, 1990).

Several parametric methods including univariate and multivariate ones have been developed to assess the stability and adaptability of varieties. The most widely used is the joint regression including regression coefficient (bi) and variance of deviations mean squares from the regression (S^2d_i) proposed by (Eberhart and Russell, 1966). Also,Tai (1971) suggested partitioning genotype x environment interaction into two components: alpha (αi) statistic that measures the linear response to environmental effects and lambda (λi) statistic that measures the deviation from linear response.

The major objectives of the current study were to evaluate response of eighteen barely genotypes as well as stress susceptibility index for irrigation experiment under eight environments (two different water supply levels and two sowing dates across two years at a newly reclaimed sandy soil and study the partitioning of the genotype by environment interaction to its stability parameters, using joint regression.

MATERIALS AND METHODS

Experimental work

The present investigation was carried out in Ras Sudr Research Station, Desert Research Center South Sinai Governorate, Egypt (29°35'N., 32°43'E.), to study genotype x environment interaction and stability parameters of some agronomic traits using 18 genotypes of barley that included 16 from: The Arab Center for the Studies of Arid zones and Dry lands (ACSAD) and two check varieties, the new released line from DRC (Su12303) and the cultivar Giza 2000 (Table 1). The barley genotypes were grown under 8 different environments, which were the combinations between two winter successive seasons (2015/2016 and 2016/2017), two water regimes (100% (I1) and 60% (I2) of soil water capacity) and two sowing dates (12 November (D1) and 12 December (D2)). The 18 barley genotypes were sown in a split-plot design with randomized complete arrangement with three replications under each of the 8 environments in the first and second seasons, respectively. The experimental plot consisted of 6 rows. Each row was 2.5 m in length and 20 cm wide. Grains were spaced at 10 cm within rows. Nitrogen (250 kg /fed.) was added in the form of ammonium nitrate (33.5% N) in three doses; the first dose was at sowing and the other two doses were applied at 20 and 40 days after sowing. The other cultural practices were followed as recommended for barley production in Ras Sudr region. Physical and chemical properties of soil showed that texture is sandy loam and affected by salinity as well as irrigation water which recorded pH 7.39 and 7.65 respectively (Table 2).

Statistical Analysis

At harvest, ten competitive plants from each plot were taken for recording data for; days to heading (50%), plant height (cm.), main spike length (cm), number of spikes/ plant, number of spikelets/spike, number of kernels/ spike, weight of grains/main spike (g.), 1000-grain weight (g), grain yield/ m^2 (g) and straw yield/m^2 . The combined analysis of variance across environments was computed according to Gomez and Gomez (1984). L.S.D. was computed to compare differences among means of environments, genotypes and their interaction at 5% level (McNicol 2013). Following the detection of significant GE interaction, homogeneity test (Bartlett 1947) for error terms of each season of analysis was practiced (data not presented).

Table 1. Name, Cross/pedigree and origin of all barley genotypes tested under Ras Sudr region.

No.	Genotypes	Pedigree/selection history	Origin
1	ACSAD 1766	ACSAD1644/4/ALANDA/HAMRA/3/AW BLACK/ATHS//RHN-08 ACS-B-12105-2008-22IZ-1IZ-2IZ-0IZ	ACSAD*
2	ACSAD 1772	ACSAD1644/6/BARBARA/4/BACA"S"/3/AC253//C108887/C105761 /5/BARBARA/4/BACA'S'/3/AC253. ACS-B-12106-2008-24IZ-3IZ-2IZ-0IZ	ACSAD*
3	ACSAD 1791	BUCK M8.88/E.ACACIA//MSEL /3/ ACSAD 1644 ACS -B - 1233 (2010)- ١٢IZ -1IZ-1IZ-0IZ	ACSAD*
4	ACSAD 1793	BUCK M8.88/E.ACACIA//MSEL/3/ACS-B-11393-21 IZ ACS -B - 12332 (2010)- 15IZ -3IZ-1IZ-0IZ	ACSAD*
5	ACSAD 1806	ACSAD 1632/ACSAD 1640 ACS -B- 12461 (2010)-6IZ-2IZ-3IZ-0IZ	ACSAD*
6	ACSAD 1811	ACSAD 1644 // ETHIRA/B/69-2 ACS - B -12620 (2012) - 25IZ -3IZ-2IZ	ACSAD*
7	ACSAD 1813	ACSAD 1632 / 9C7-1 ACS - B -12633 (2012) - 1Z -3IZ-3IZ	ACSAD*
8	ACSAD 1814	ACSAD 1641 / 9C7-1 ACS - B -12633 (2012)- 22IZ -١IZ-2IZ	ACSAD*
9	ACSAD 1816	ACSAD 1700 // LITANI/MUNDAH ACS - B -12644 (2012) - 7IZ -3IZ-1IZ	ACSAD*
10	ACSAD 1817	ACSAD 1460 / 9C7-1 ACS - B -12651 (2012) - 19IZ -2IZ-3IZ	ACSAD*
11	ACSAD 1818	ACSAD 1460 / 9C7-1 ACS - B -12652 (2012) - 8Z -1IZ-1IZ	ACSAD*
12	ACSAD 1820	ACSAD 1706 /6/ ARIZONA5908/ATHS//AVT/ ATTIKI/3/S.T.BARLEY/4/ ATHS/LIGNEE686/5/BARJOUJ. ACS - B -12661 (2012) - 1IZ -١IZ-1IZ	ACSAD*
13	ACSAD 1821	ACSAD 1706 / NIBOLA ACS - B -12664 (2012) - 20IZ -2IZ-3IZ	ACSAD*
14	ACSAD 1822	ACSAD 1708 /6/ ARIZONA5908/ATHS//AVT/ ATTIKI/3/S.T.BARLEY/4/ ATHS/LIGNEE686/5/BARJOUJ ACS - B -12673 (2012) - 1IZ -15IZ-1IZ-1IZ	ACSAD*
15	ACSAD 1833	ACSAD 1708 /6/ ARIZONA5908/ATHS//AVT/ATTIKI /3/S.T.BARLEY/4/ ATHS/LIGNEE686/5/BARJOUJ ACS - B -12673 (2012) - 16IZ -15IZ-2IZ-1IZ	ACSAD*
16	ACSAD 1824	ACSAD 1708 /5/ RHN/LIGNEE527/3/ARAR//HR /NOPAL/4/ALANDA// LIGNEE527/ARAR ACS - B -12674 (2012) - 7IZ -١IZ-3IZ-2IZ	ACSAD*
17	Su12303	ICB 86/Giza123*-C03-3Su-15Su-2Su-5Su – 0 Su	Egypt
18	Giza 2000	Giza 117/Bahteem 52//Giza 118/FAO 86/3/Baladi 16/Gem.	Egypt

***: The Arab Center for the Studies for Arid zones and Dry lands.**

Table 2. Soil physical and chemical properties and irrigation water chemical analysis at the experimental location (Ras Sudr).

<table>
<tr><td colspan="10">a) Soil physical analysis</td></tr>
<tr><td colspan="2" rowspan="2">Constituents</td><td>Clay%</td><td colspan="2">Silt%</td><td>Sand%</td><td colspan="4">Texture</td></tr>
<tr><td>15.33</td><td colspan="2">20.48</td><td>64.19</td><td colspan="4">Sandy loam</td></tr>
<tr><td colspan="10">b) Soil Chemical analysis</td></tr>
<tr><td rowspan="2">pH</td><td rowspan="2">EC ds/m</td><td colspan="4">Cations (meq/L)</td><td colspan="4">Anions (meq/L)</td></tr>
<tr><td>Ca^{++}</td><td>Mg^{++}</td><td>Na^{+}</td><td>K^{+}</td><td>Cl^{-}</td><td>HCo_3^{-}</td><td>SO_4^{--}</td><td>Co_3^{--}</td></tr>
<tr><td>7.39</td><td>8.54</td><td>21.21</td><td>10.86</td><td>48.04</td><td>5.62</td><td>43.8</td><td>10.85</td><td>25.2</td><td>…</td></tr>
<tr><td colspan="10">C) Irrigation water chemical analysis</td></tr>
<tr><td rowspan="2">pH</td><td rowspan="2">EC ds/m</td><td colspan="4">Soluble cations (mg/100g)</td><td colspan="4">Soluble anions (mg/100g)</td></tr>
<tr><td>Na^{+}</td><td>Ca^{++}</td><td>Mg^{++}</td><td>K^{+}</td><td>Co_3^{-}</td><td>HCO_3^{-}</td><td>Cl^{-}</td><td>So_4^{--}</td></tr>
<tr><td>7.65</td><td>7.94</td><td>46.38</td><td>24.73</td><td>15.17</td><td>0.41</td><td>-----</td><td>2.65</td><td>62.75</td><td>21.29</td></tr>
</table>

Stability analysis was performed whenever the genotype x environment interaction was determined to be statistically significant ($P<0.01$) according to Finlay and Wilkinson (1963), Eberhart and Russell (1966) and (Tai 1971) under 8 environments (two seasons x two irrigation treatments x two sowing dates. Coefficient of variation (C.V.%) proposed by Francis and Kannenberg (1987) was also used as a stability parameter.

The index of stress tolerance: stress susceptibility index (SSI)

Stress susceptibility index (SSI) was suggested by Fisher and Maurer (1978). the susceptibility of barley genotypes under drought stress is the ratio of each genotype yield under stress to the genotype yield under non-stress conditions with respect to stress intensity (SI) according to the following formula: $SSI=1-(Ys/Yp)/SI$ in which Yp is the average yield of the genotype under non-stress conditions and SI is the stress intensity.SSI is calculated with respect to the stress intensity (SI), using the following formula:

$SI = 1 - (\bar{Y}s/\bar{Y}p)$, in which $\bar{Y}p$ is the average of grain yield for all genotypes under non-stress conditions and $\bar{Y}s$ is the average of grain yield for all genotypes under stress conditions.

In this formula if the Ys is closer to Yp, the stress intensity of the genotype under drought is less and hence the SSI values of genotype is less. If SSI is less than 1, it indicates that the genotype is more tolerant under drought stress.

RESULTS AND DISCUSSION

Analysis of variance and mean performance across environments

Combined analysis of variance on phenotypic data for the studied traits were obtained from the effect of environmental conditions (sowing dates, irrigation water regimes, seasons and their interactions) on 18 genotypes of barley showed highly significant variances, indicating the existence of a genetic variability among barley genotypes related to the traits under study (Table 3). The interaction between seasons and the two other effects (sowing dates and irrigation water regimes) were significant for most of the barley traits, reveals presence of highly significant variances for environments (sowing dates and water regimes treatments), genotypes and their interactions, suggesting that the combination of environmental components were sufficient to obtain reliable information about the barley genotypes under study. These results are in agreement with those reported by Abdel-Sattar (2005), Dehghani *et al* (2006), Amer *et al* (2012), Farag *et al* (2012), Sabaghnia *et al* (2013), Abd El- Moneam *et al* (2014), Saleh and Farag (2016) Amabile *et al* (2017), Ahmed *et al* (2018), El-Hashash and Agwa (2018) and Megahed *et al* (2018).

The mean performances of the 18 barley genotypes across 8 different environments for the studied traits are presented in two Tables (4 and 5). Results indicated that the magnitude of difference between genotypes, water regimes and sowing dates were high for all traits under the experiment conditions. Regarding days to heading (50%), the combined analysis for environments under study had significant differences with mean values ranged from 73.68 days for I2D1 (water regime 60% and sowing date 12 Nov.) to 97.86 days for I1D2 (water regime 100% and sowing date 12 Dec.).

Table 3. Mean squares for combined analysis of variance across 8 environments (two seasons, two irrigation regimes and two sowing dates) for the studied traits of barley genotypes.

SOV	df	Days to heading (50%)	Plant height (cm)	Main Spike length (cm)	No. of spikes/plant	No. of spikelets/spike
Seasons (S)	1	50202.89**	6541.11**	0.91	1.13	325.52**
Water regimes (I)	1	64.56**	18947.50**	136.46	62.01**	2146.69**
I×S	1	1500.06**	339.56**	0.62	0.18	1.69
Error (1)	8	1.84	2.65	0.04	0.001	1.47
Sowing dates (D)	1	65342.52**	7408.61**	38.76**	13.47**	647.78**
D×S	1	2765.39**	311.78**	0.01	0.37**	8.61**
D×I	1	1.95	357.52	0.53**	0.37**	0.001
D×S ×I	1	14.45**	150.52**	0.40**	0.13	0.02
Error (2)	8	0.61	0.79	0.05	0.001	0.49
Genotypes (G)	17	793.28**	148.43**	12.27**	0.80**	146.91**
G×S	17	323.31**	27.79**	0.86**	0.70**	12.77**
G×I	17	6.83**	28.98**	0.36**	0.18**	2.59**
G×S×I	17	6.83**	27.42**	0.50**	0.19**	2.40**
G×D	17	63.78**	17.89**	0.30**	0.15**	1.34**
G×S×D	17	135.15**	16.56**	0.26**	0.26**	1.71**
G×I×D	17	3.32*	15.11**	0.27**	0.28**	3.01**
G×I×D×S	17	5.32*	40.40**	0.11*	0.17**	1.61**
Pooled error	272	1.34	1.74	0.02	0.002	0.71

Source	df	No. of kernels/spike	Weight of grains/main spike (g)	1000-grain weight (g)	Grain yield/m^2 (g)	Straw yield/m^2 (g)
Seasons (S)	1	4595.56**	32.92**	2568.98**	293874.66**	2055656.46**
Water regimes (I)	1	18083.39**	76.95**	3094.92**	3999892.34**	24444834.34**
I×S	1	35.02	6.72	1986.57**	119588.36**	850111.54**
Error (1)	8	3.90	0.01	2.89	57.26	402.38
Sowing dates (D)	1	4556.50**	21.73**	1004.03**	994030.49**	6017811.41**
D×S	1	1.02*	0.73**	126.33**	1848.18**	18393.19**
D×I	1	14.45**	0.09**	204.20**	59931.46**	374225.97**
D×S ×I	1	44.72**	0.07	11.12*	2287.86**	8124.65**
Error (2)	8	0.78	0.001	1.22	51.05	375.67
Genotypes (G)	17	2590.18**	4.22**	297.59**	38919.13**	188740.41**
G×S	17	136.71**	0.80**	257.10**	23661.87**	156839.83**
G×I	17	72.64**	0.24**	114.29**	5525.86**	37235.43**
G×S×I	17	38.53**	0.30**	115.90**	8954.44**	63017.53**
G×D	17	45.25**	0.11**	23.65**	5356.23**	31395.51**
G×S×D	17	28.67**	0.06	15.77**	6982.85**	44583.63**
G×I×D	17	16.61**	0.10**	47.47**	8477.79**	51154.21**
G×I×D×S	17	16.81**	0.13**	41.20**	6927.49**	36025.91**
Pooled error	272	1.68	0.01	4.17	136.19	895.53

***,** = denote significant at 0.05 and 0.01 level of probability respectively.**

Meanwhile, the genotype G2 was the earliest under different environments recorded 67.84 days for I2D1 (water regime 60% and sowing date 12 Nov.) and the two latest genotypes G10 and G13 under different environments recorded 102.00 days for I1D2 (water regime 100% and sowing date 12 Dec.). While, for plant height, the combined analysis showed highly significant differences among the individual environments with mean values ranging from 54.92cm at I2D2 (water regime 60% and sowing date 12 Dec.) to 76.44cm at I1D1 (water regime 100% and sowing date 12 Nov.) and genotypes gave significant differences which had mean values for genotypes ranged from 48.84 cm for G1 under I2D2 (water regime 60% and sowing date 12 Dec.) conditions to 83.00 cm for the G 5 under I1D1 (water regime 100% and sowing date 12 Nov.) conditions. With respect of main spike length, results showed that highly significant differences for combined among the individual environments with mean values ranging from 5.50cm at I2D2 (water regime 60% and sowing date 12 Dec.) to 7.22cm at I1D1 (water regime 100% and sowing date 12 Nov.) and the two genotypes G3 and G4 recorded the highest values for all studied environments (Table 4).

For no. of spikes/plant, the combined means of individual environments ranged from 1.41 spikes under I2D2 (water regime 60% and sowing date 12 Dec.) to 2.51 spikes under I1D1 (water regime 100% and sowing date 12 Nov.), the genotype G11 recorded the highest no of spikes /plant 2.92, 2.03, 2.56 and 1.79 /plant meanwhile, the genotype G2 recorded the lowest no of spikes /plant 1.83, 1.33, 1.57 and 1.00 spikes/plant for all studied environments I1D1, I1D2, I2D1 and I2D2 respectively. Regarding (Table, 4) no. of spikelet's/ spike, the environments gave mean values varied from 19.45 spikelet's/spike at I2D2 to 26.36 spikelet's/spike at I1D1. The two genotypes G5 and G6 recorded the highest values with significant differences ranging from 24.17 spikelet's/spike for G5 at I2D2 to 33.50 spikelet's/spike for G5 under I1D1.

Table 4. Mean performance of 18 barley genotypes for heading date (50%), plant height (cm.), no. of spikes/plant, spike length (cm.) and no. of spikelets/spike over 8 environments (E) (the combined of the two seasons (S) , two water regimes (I.) and two sowing dates (D.).

Genotypes	Days to heading (50%)				Plant height (cm.)				Main Spike length (cm.)			
	I 1		I 2		I 1		I 2		I 1		I 2	
	D 1	D 2	D 1	D 2	D 1	D 2	D 1	D 2	D 1	D 2	D 1	D 2
G1	98.34	97.00	81.34	85.84	74.17	61.50	69.50	48.84	8.22	5.74	6.30	5.27
G2	75.34	75.17	67.84	69.84	73.67	64.17	68.50	53.17	6.44	5.40	5.80	5.07
G3	99.34	99.50	71.84	71.67	78.00	68.00	70.83	54.00	7.03	6.03	6.50	4.99
G4	98.50	99.83	73.67	72.83	80.67	71.50	73.67	60.34	7.22	5.92	6.37	5.47
G5	97.17	97.84	73.00	72.34	83.00	68.00	72.34	55.67	8.75	7.83	8.22	7.25
G6	98.00	99.33	72.17	71.50	76.84	66.83	70.83	59.34	8.53	7.80	8.18	6.98
G7	99.83	100.67	73.84	73.17	78.50	67.17	69.67	56.67	6.92	5.83	6.42	5.45
G8	99.17	99.83	72.00	72.33	77.67	65.17	70.50	50.84	6.87	5.52	6.34	4.77
G9	98.50	99.50	73.17	73.34	74.50	64.50	71.17	53.50	5.98	5.13	5.32	4.62
G10	100.5	102.00	74.83	75.83	78.34	65.50	68.84	57.34	6.74	5.62	5.95	4.62
G11	98.17	98.50	77.00	76.83	77.50	70.17	76.67	59.17	6.49	5.59	6.29	5.17
G12	97.84	99.84	73.33	74.00	73.34	64.84	68.34	58.33	7.17	5.85	5.82	5.57
G13	100.1	101.67	73.50	75.17	73.00	62.67	65.00	53.84	7.52	6.32	6.97	5.90
G14	99.00	100.17	74.67	74.67	75.00	62.67	69.33	56.17	7.90	6.59	7.42	6.24
G15	95.50	95.17	73.50	73.50	75.17	60.17	70.34	52.50	7.10	5.73	6.23	5.20
G16	97.17	97.50	73.17	73.50	74.67	59.84	68.00	50.83	6.87	5.57	6.04	4.97
G17	98.84	99.67	73.33	73.50	77.34	66.00	69.17	55.67	6.75	5.72	6.27	5.60
G18	97.67	98.34	74.00	74.33	74.67	61.67	67.17	52.34	7.50	6.30	6.99	5.85
Mean	97.17	97.86	73.68	74.12	76.44	65.02	69.99	54.92	7.22	6.03	6.52	5.50
LSD 5%												
Seasons (S)	n.s				0.36				0.05			
Water regimes(I)	0.25				0.36				0.05			
I×S	0.35				0.51				0.06			
Sowing dates (D)	0.19				0.20				0.05			
D×S	0.27				0.28				n.s.			
D×I	n.s				0.28				0.07			
D×I× S	0.38				0.39				0.10			
Genotypes (G)	0.62				0.75				0.08			
G×S	0.87				1.06				0.12			
G×I	0.87				1.06				0.12			
G×S×I	1.24				1.50				0.16			
G×D	0.87				1.06				0.12			
G×D×I	1.24				1.50				0.16			
G×I×D×S	1.75				2.12				0.23			

Table 4. Cont.

Genotypes	No. of spikes/plant				No. of spikelets/spike			
	I 1		I 2		I 1		I 2	
	D 1	D 2	D 1	D 2	D 1	D 2	D 1	D 2
G1	2.90	1.66	1.77	1.34	27.84	22.00	25.00	20.50
G2	1.83	1.33	1.75	1.00	25.84	21.84	24.50	20.00
G3	2.23	1.82	2.01	1.55	25.83	23.00	23.34	19.50
G4	2.45	1.69	2.06	1.33	25.83	22.34	23.00	19.33
G5	2.70	2.00	2.46	1.41	30.50	25.50	28.17	24.17
G6	2.91	1.98	2.34	1.34	33.50	28.00	30.00	26.67
G7	2.46	1.89	2.25	1.47	25.84	21.84	23.50	18.67
G8	2.49	1.80	2.24	1.67	23.83	19.84	21.67	16.00
G9	2.69	1.46	2.00	1.33	22.17	17.34	18.67	14.84
G10	2.49	1.57	1.81	1.35	22.84	19.50	21.50	16.83
G11	2.92	2.03	2.56	1.79	24.84	20.34	22.34	17.84
G12	2.69	1.55	1.79	1.53	26.84	22.67	23.00	19.17
G13	2.12	1.46	1.80	1.21	26.33	21.50	24.50	17.67
G14	2.47	1.79	2.25	1.56	25.83	21.33	23.50	18.17
G15	2.25	1.55	2.02	1.32	25.34	20.83	23.34	19.67
G16	2.30	1.57	1.79	1.54	27.00	21.50	24.50	19.67
G17	2.67	1.75	2.21	1.35	26.33	22.17	23.17	19.84
G18	2.67	1.83	2.23	1.17	28.00	22.84	24.17	21.67
Mean	2.51	1.71	2.08	1.40	26.36	21.91	23.77	19.45
LSD 5%								
Seasons (S)	0.01				0.27			
Water regimes(I)	n.s				0.27			
I×S	0.01				0.38			
Sowing dates (D)	0.01				0.16			
D×S	0.01				n.s			
D×I	0.01				0.22			
D×I× S	0.02				0.48			
Genotypes (G)	0.03				0.68			
G×S	0.04				0.68			
G×I	0.04				0.96			
G×S×I	0.05				0.68			
G×D	0.04				0.96			
G×D×I	0.02				1.36			
G×I×D×S	0.03				0.48			

n.s= not significant

Concerning no. of kernels/spike, the means of combined environments ranged from 40.01 kernels/spike at I2D2 to 59.17 kernels/spike at I1D1. The three genotypes G2, G3 and G14 recorded the highest values with significant differences under all studied environments ranged from 46.00 kernels/spike for G2 under I2D2 to 72.50 kernels/spike for G3 under I1D1. While, for the three traits weight of grains/main spike , 1000-grain weight and grain yield /m^2, the combined means of individual environments ranged from 1.55, 34.47 and 130.90 g. to 2.80, 41.62 and 413.70 g. for the three traits under I1D1 and I2D2 respectively, the genotype G11 recorded the highest values 3.63, 2.89, 3.03 and 2.23 g. for weight of grains/main spike, 53.45, 52.48, 52.04 and 50.98 g. for 1000-grain weight and 588.77 , 274.5, 351.85, 169.84 g. for grain yield/m^2, followed by the two promising genotypes G2 and G14 with significant differences under all studied environments I1D1, I1D2, I2D1 and I2D2, respectively. Taking mean performance for straw yield/plant the means of combined individual environments ranged from 322.27 to 1019.17 g. under I2D2 and I1D1, respectively. Moreover, the genotype G5 produced the highest mean values 1483.69, 616.71, 965.84 and 484.16 under the following environments I1D1, I1D2, I2D1 and I2D2, respectively (Table 5).

In conclusion, the four environments; I1D1 and I2D1 produced the highest mean values for grain yield and its components than other environments, which due to the suitable environmental conditions through different barley growth stages. While, the genotype G2 was the earliest which recorded the lowest values for days to heading (50%) and moderate in yield and its component production and the two genotype G11 and G14 had the highest values for grain yield and one/or more of yield components under all studied environments, which could be used for barley yield improvement under Ras Sudr conditions. Similar findings were obtained by (Amer *et al* 2012, Farag *et al* 2012, Sabaghnia *et al* 2013, Abdel-Moneam *et al* 2014, Saleh and Farag 2016).

The tolerance index of different barley genotypes

Data concerning tolerance index of different traits under study are presented in Table 6.

Table 5. Mean performance of combined analysis for 18 barley genotypes (G.) over 8 environments (E) (two seasons (S), two water regimes (I.) and two sowing dates (D.).

Genotypes	No. of kernels/spike				Weight of grains/main spike (g)				1000-grain weight (g)			
	I 1		I 2		I 1		I 2		I 1		I 2	
	D 1	D 2	D 1	D 2	D 1	D 2	D 1	D 2	D 1	D 2	D 1	D 2
G1	66.17	50.83	56.84	44.17	3.35	2.38	2.84	1.91	43.18	39.26	42.27	35.96
G2	72.00	57.00	63.00	51.84	2.67	1.97	2.42	1.49	43.94	42.74	40.76	36.38
G3	65.50	55.50	60.50	47.33	3.50	2.11	2.63	1.69	40.38	38.28	36.41	36.49
G4	66.00	45.83	57.00	41.67	2.66	1.71	2.37	1.30	37.40	31.57	35.16	28.55
G5	27.50	22.17	25.00	18.00	1.66	1.18	1.36	1.06	34.33	31.21	32.07	26.75
G6	27.67	20.50	25.83	18.83	1.68	1.16	1.59	1.13	40.87	36.47	39.94	31.82
G7	62.17	45.84	50.34	39.83	2.64	2.10	2.35	1.20	41.88	38.84	39.42	25.63
G8	56.34	45.67	52.34	40.00	2.71	2.32	2.45	1.76	40.49	42.71	39.53	37.09
G9	57.17	40.84	46.83	37.84	2.60	1.89	2.12	1.75	38.56	41.29	38.49	39.38
G10	56.17	43.50	47.67	35.00	3.35	2.03	2.59	1.43	50.39	39.13	44.86	35.95
G11	66.00	45.84	51.34	39.84	3.63	2.89	3.03	2.23	53.45	52.48	52.04	50.98
G12	64.50	51.84	58.00	43.17	2.67	2.17	2.40	1.81	36.99	37.34	35.01	35.86
G13	60.50	47.67	57.67	40.50	2.80	1.80	2.27	1.27	36.36	32.62	33.29	29.57
G14	71.50	59.17	65.84	51.00	2.90	2.01	2.50	1.66	50.15	50.08	45.71	49.87
G15	62.50	50.00	57.50	44.50	2.83	2.30	2.62	1.61	39.03	38.85	38.35	30.82
G16	61.67	46.84	56.00	37.67	2.90	2.06	2.45	1.58	39.85	37.30	37.20	29.28
G17	61.67	45.84	53.84	41.00	2.85	1.93	2.38	1.46	39.22	36.13	37.52	31.19
G18	60.00	50.67	55.67	48.00	3.00	2.11	2.50	1.64	42.65	35.38	38.34	28.91
Mean	59.17	45.86	52.29	40.01	2.80	2.00	2.38	1.55	41.62	38.98	39.24	34.47
LSD 5%												
Seasons (S)	0.44				0.01				0.35			
Water	0.44				n.s.				0.35			
I×S	0.62				0.02				0.49			
Sowing dates	0.27				0.01				0.32			
D×S	n.s.				0.02				0.45			
D×I	0.28				0.02				0.45			
D×I× S	0.39				0.03				0.64			
Genotypes	0.74				0.04				1.14			
G×S	1.04				0.06				0.58			
G×I	1.04				0.06				0.58			
G×S×I	1.47				0.09				0.82			
G×D	1.04				0.06				0.58			
G×D×I	1.47				0.09				0.82			
G×I×D×S	2.08				0.12				1.16			

Table 5. Cont.

Genotypes	Grain yield /m² (g.)				Straw yield/m² (g.)			
	I 1		I 2		I 1		I 2	
	D 1	D 2	D 1	D 2	D 1	D 2	D 1	D 2
G1	385.45	229.69	301.76	142.47	781.62	417.47	595.34	244.04
G2	462.53	236.19	335.58	154.53	855.69	609.40	752.34	297.81
G3	444.94	215.04	307.73	134.15	1210.24	584.91	837.02	414.87
G4	386.74	182.80	283.20	103.30	935.91	442.38	685.34	249.99
G5	267.68	142.97	203.89	89.13	1483.69	616.71	965.84	484.16
G6	299.47	137.55	242.13	90.36	844.50	387.89	682.79	254.82
G7	383.98	194.80	307.98	128.61	902.35	457.79	723.76	302.22
G8	397.53	215.51	326.48	150.45	922.26	578.92	757.44	294.01
G9	428.70	165.18	255.03	138.76	908.83	350.16	540.65	294.16
G10	424.27	184.06	279.62	136.63	1285.10	480.39	729.82	356.61
G11	588.77	274.50	351.85	169.97	994.43	507.80	756.48	306.31
G12	408.65	197.65	284.56	157.59	988.92	478.30	688.63	394.39
G13	360.91	146.23	244.72	91.12	1053.86	426.98	714.57	266.08
G14	492.38	249.54	338.90	162.84	929.16	471.96	734.93	345.11
G15	381.28	208.35	326.30	127.36	1128.57	578.82	760.44	376.98
G16	397.99	188.61	263.33	146.23	1064.21	504.33	704.13	391.02
G17	454.44	207.83	314.59	117.58	1036.13	473.85	717.27	268.08
G18	480.92	225.44	334.76	115.11	1019.54	477.93	709.68	260.25
Mean	413.70	200.11	294.58	130.90	1019.17	491.44	725.36	322.27
LSD 5%								
Seasons (S)	1.21				3.31			
Water regimes(I)	1.25				3.31			
I×S	1.72				4.69			
Sowing dates (D)	1.68				4.66			
D×S	2.38				6.58			
D×I	2.38				6.58			
D×I× S	3.37				9.31			
Genotypes (G)	6.56				16.80			
G×S	9.28				23.75			
G×I	9.28				23.75			
G×S×I	13.12				33.59			
G×D	9.28				23.75			
G×D×I	13.12				33.59			
G×I×D×S	18.55				17.06			

n.s= not significant

Table 6. Stress susceptibility index (SSI) of grain yield/m^2 and agro-morphological traits for different barley genotypes estimated under two water regimes (I.) and two sowing dates (D.).

Genotypes	Days to heading (50%)		Plant height (cm.)		No. of spikes/plant		Main spike length (cm)		No. of spikelets/spike	
	D 1	D 2	D 1	D 2	D 1	D 2	D 1	D 2	D 1	D 2
G1	0.72	0.47	0.75	1.33	2.26	1.08	2.42	1.13	1.04	0.61
G2	0.45	0.32	0.32	0.78	0.20	1.12	0.45	0.19	0.23	0.38
G3	1.25	1.29	0.42	0.93	0.45	0.67	0.34	0.78	0.44	0.69
G4	1.14	1.23	0.39	0.71	0.72	0.96	0.53	0.34	0.50	0.61
G5	1.13	1.18	0.58	0.82	0.40	1.33	0.27	0.34	0.35	0.24
G6	1.19	1.27	0.35	0.51	0.54	1.46	0.19	0.48	0.47	0.21
G7	1.18	1.24	0.51	0.71	0.39	1.01	0.33	0.29	0.41	0.66
G8	1.24	1.25	0.42	1.00	0.45	0.33	0.35	0.61	0.41	0.88
G9	1.16	1.19	0.20	0.77	1.16	0.40	0.50	0.45	0.71	0.65
G10	1.16	1.16	0.55	0.56	1.24	0.63	0.53	0.81	0.27	0.62
G11	0.98	0.99	0.05	0.71	0.74	0.54	0.14	0.34	0.46	0.56
G12	1.13	1.17	0.31	0.45	1.51	0.06	0.85	0.22	0.65	0.70
G13	1.20	1.18	0.50	0.64	0.68	0.77	0.33	0.30	0.31	0.81
G14	1.11	1.15	0.34	0.47	0.40	0.58	0.27	0.24	0.41	0.67
G15	1.04	1.03	0.29	0.58	0.46	0.67	0.55	0.42	0.36	0.25
G16	1.12	1.11	0.40	0.68	1.00	0.09	0.55	0.49	0.42	0.39
G17	1.17	1.19	0.48	0.71	0.78	1.03	0.32	0.09	0.54	0.48
G18	1.10	1.08	0.45	0.68	0.75	1.63	0.31	0.32	0.62	0.23
Genotypes	**No. of kernels/spike**		**Weight of grains/main spike (g)**		**1000-grain weight (g)**		**Grain yield/m^2 (g)**		**Straw yield/m^2 (g)**	
	D 1	D 2	D 1	D 2	D 1	D 2	D 1	D 2	D 1	D 2
G1	1.21	1.03	1.02	0.88	0.37	0.73	0.75	1.10	0.83	1.21
G2	0.57	0.41	0.42	1.10	0.33	0.67	1.24	1.56	0.55	2.31
G3	0.35	0.67	1.12	0.90	0.44	0.21	1.40	1.70	1.40	1.32
G4	0.62	0.41	0.49	1.09	0.27	0.43	1.21	1.97	1.21	1.97
G5	0.41	0.85	0.82	0.46	0.30	0.65	1.08	1.70	1.58	0.97
G6	0.30	0.37	0.24	0.12	0.10	0.58	0.87	1.55	0.87	1.55
G7	0.86	0.59	0.50	1.94	0.27	1.54	0.90	1.54	0.90	1.54
G8	0.32	0.56	0.43	1.09	0.11	0.60	0.81	1.37	0.81	2.23
G9	0.82	0.33	0.84	0.34	0.01	0.21	1.83	0.72	1.83	0.72
G10	0.68	0.88	1.03	1.34	0.50	0.37	1.54	1.17	1.96	1.17
G11	1.01	0.59	0.75	1.03	0.12	0.13	1.82	1.72	1.08	1.80
G12	0.46	0.76	0.46	0.75	0.24	0.18	1.37	0.92	1.37	0.79
G13	0.21	0.68	0.86	1.33	0.38	0.42	1.46	1.71	1.46	1.71
G14	0.36	0.62	0.62	0.79	0.40	0.02	1.41	1.57	0.95	1.22
G15	0.36	0.50	0.34	1.36	0.08	0.94	0.65	1.76	1.48	1.58
G16	0.42	0.89	0.70	1.05	0.30	0.97	1.53	1.02	1.53	1.02
G17	0.57	0.48	0.75	1.10	0.20	0.62	1.39	1.97	1.39	1.97
G18	0.33	0.24	0.75	1.01	0.46	0.83	1.38	2.21	1.38	2.06

The estimates of stress susceptibility index (SSI) provides a measure of stress resistance based on minimization of the trait loss under stress as compared to optimum conditions, rather than on trait level under stress *per se*, which has been used to characterize relative stress tolerance (Fischer and

Maurer, 1978 and Clarke *et al* 1992). This index was computed for different genotypes under the two water regimes and across combined environments for different traits, i.e., days to heading (50%), plant height (cm.), main spike length (cm), number of spikes/plant, number of spikelets/spike, number of kernels/spike, weight of grains/main spike (g.), 1000-grain weight (g), grain yield/m^2 (g) and straw yield/m^2 to obtain the major selection criteria for improved adaptation to stress environments in many breeding programs.

Results showed that application of the stress susceptibility index across the two stress treatments indicated that mean SSI values, for days to heading (50%) for the three genotypes G1, G2 and G11 and for no. of spikes/plant the 7 genotypes G3, G4, G8, G11, G13, G14 and G15, as well as the most genotypes for the following traits: plant height, main spike length (cm.), no. of spikelets/spike, no. of kernels/spike and 1000-grain weight (g.) recorded the lowest SSI values ($S < 1$) under the two stresses treatments which synonymous with higher stress resistance.

Meanwhile, for grain yield/m^2 (g.) the five genotypes G1 , G6, G7, G8 and G15 under D1 and the two genotypes G9 and G12 under D2 showed the least drought susceptibility index. While, for straw yield/m^2 (g.) the six genotypes G1, G2, G6, G7, G8 and G14 under D1 and the three genotypes G5,G9, and G12 had mean S values less than unity indicating their tolerance to drought stress for these traits. Our finding showed that different traits under study considered as quantitative characters controlled by multiple genes and are highly influenced by environmental conditions which affected on difference among the genotypes and responses to stresses for grain yield and agro-morphological traits studied in different environments (combination of year, location and water regime conditions). Similar findings were obtained by, Khalili *et al* (2016), Taherian *et al* (2017), Jamshidi and Javanmard (2018) and Naceur *et al* (2018)

Phenotypic Stability

The results of stability analysis based on Eberhart and Rusell (1966), showed that the effects of mean squares for days to heading (50%), plant height (cm.), main spike length (cm), number of spikes/plant, number of spikelets/spike, number of kernels/spike, weight of grains/main spike (g.), 1000-grain weight (g), grain yield/ m^2 (g) and straw yield/m^2 indicated that the barley genotypes, environments and G x E were highly significant for the most studied traits indicating that barley genotypes differed in their regression on the environmental index and proceeded further to estimate bi values (Table 7 and 8). Similar findings for one or more traits were also showed earlier (Kavitha *et al* 2009, Farag *et al* 2012, Sabaghnia *et al* 2013, Abd El- Moneam *et al* 2014, Al-Ajlouni *et al* 2016, Saleh and Farag 2016, Elakhdar *et al* 2017, Ali 2017, Ali and Abdul-Hamid 2017, Ahmed *et al* 2018, El-Hashash and Agwa 2018 and Ali and Sayed 2019) .

Table 7. Mean squares of stability analysis of variance for dayes to heading (50%), plant height, main spike length , no. of spikes/plant and no. of spikelets/spike traits of 18 barley genotypes over 8 environments.

SOV	df	Days to heading (50%)	Plant height (cm)	Main Spike length (cm)	No. of spikes/plant	No. of spikelets/spike
Genotypes (G)	7	15471.23**	4864.80**	25.39**	10.81**	447.19**
Environment (E.)	17	327.49**	148.46	12.25**	0.77**	146.92**
G×E	119	69.77**	124.84**	10.38**	10.27**	103.63**
Env.+ GxEnv.	126	925.41**	693.72	1.77**	0.85**	28.27**
Env. (linear)	1	108298.58**	24053.58**	167.70**	65.66**	3030.33**
GxEnv (linear)	17	170.52**	22.71	0.55**	0.23**	3.36**
c)Pooled Dev.	108	50.04**	23.79**	0.33**	0.26**	3.47**
G1	6	251.73**	15.29**	1.48**	0.90**	1.50**
G2	6	512.40**	5.01**	1.09**	0.40**	1.65**
G3	6	13.39**	15.17**	0.26**	0.38**	6.21**
G4	6	12.65**	12.13**	1.24**	0.09	3.88**
G5	6	12.56**	26.45**	1.09**	0.36**	2.00**
G6	6	8.50**	12.62**	0.14**	0.31**	2.86**
G7	6	15.03**	41.54**	0.63**	0.33**	1.97**
G8	6	5.70**	17.65**	0.04	0.08	6.85**
G9	6	2.38**	40.28**	0.44**	0.22**	3.02**
G10	6	5.74**	48.60**	0.73**	0.19**	3.31**
G11	6	5.62**	18.63**	1.25**	0.12	0.87
G12	6	13.16**	52.65**	0.16**	0.76**	7.20**
G13	6	8.96**	27.71**	0.28**	0.07	6.98**
G14	6	6.49**	25.05**	0.19**	0.06	1.99**
G15	6	10.30**	31.89**	1.24**	0.12**	3.10**
G16	6	7.11**	16.38**	0.26**	0.14**	4.49**
G17	6	0.81	17.50**	0.05	0.03	1.18**
G18	6	8.18**	43.69**	0.40**	0.09	3.48**
Pooled error	272	1.18	27.52	0.06	0.52	0.71

*** and** = denote significant differences at 0.05 and 0.01 levels, respectively.**

Table 8. Mean squares of stability analysis of variance for the studied traits of 18 barley genotypes over 8 environments.

SOV	df	No.of kernels/spike	Weight of grains/main spike (g)	1000-grain weight (g)	Grain yield/m^2 (g.)	Straw yield/m^2 (g)
Genotypes (G)	7	3904.38**	18.68**	1382.49**	753795.99**	4637856.89**
Environment (E.)	17	2589.83**	3.43**	614.71**	32543.73**	157863.70**
G×E	119	950.62**	30.27**	2076.91**	9471.81**	59546.99**
Env.+ GxEnv.	126	264.72**	1.29	127.22	50823.15**	313897.54**
Env. (linear)	1	22330.64**	100.75**	3577.46**	5276571.91**	32464998.23**
GxEnv (linear)	17	363.12**	0.70**	355.74**	12857.81**	99383.58**
c)Pooled Dev.	108	80.10**	0.19	260.23**	8412.61**	49968.25**
G1	6	25.61	0.41**	152.83**	21889.02**	131839.80**
G2	6	77.75**	0.13	21.14	14341.76**	68507.48**
G3	6	69.09**	0.17	41.20	1022.27	8585.57
G4	6	73.77**	0.07	26.85	870.71	6144.71
G5	6	6.71	0.64**	132.03**	6884.92**	54355.17**
G6	6	51.26**	0.57**	277.85**	9976.96**	73187.96**
G7	6	21.72	0.61**	180.25**	4039.90	24017.11
G8	6	33.45**	0.21	49.51	4784.28	24928.60
G9	6	45.49**	0.48**	9.00	30653.12**	143469.50**
G10	6	49.37**	0.17	165.38**	5772.02**	39348.65**
G11	6	30.76**	0.15	145.12**	8813.35	44053.13
G12	6	20.02	0.05	14.96	14705.40**	90901.91**
G13	6	21.49	0.07	18.45	5125.95	39364.00
G14	6	38.58**	0.14	24.84	3299.66	16922.72
G15	6	6.58	0.20	20.08	10111.14**	82246.98**
G16	6	39.65**	0.07	144.40**	1941.20	14582.02
G17	6	71.44**	0.48**	141.69**	4456.51	25537.59**
G18	6	19.06	0.10	18.52	2738.91	11435.67
Pooled error	272	56.55	0.45	100.43	36225.10	237550.79

*** and** = denote significant differences at 0.05 and 0.01 levels, respectively.**

Highly significant mean squares due to Environment (E) + genotype x environment (L x E) and environment (linear) mean squares were also highly significant for all studied traits, providing evidence that genotypes were more sensitive to changes in the environments. Also, Env.+ (G.xEnv.) interaction revealed that genotypes interacted considerably with the eight environmental conditions. A major portion of these interactions may be attributable to Env. (linear) component. These results are in line with the findings of Gebremedhin *et al* (2014), Saleh and Farag (2016) and Ahmed *et al* (2018), who reported that the response to environments was genetically controlled and revealing the differential response of barley genotypes to different agro-climates. Pooled deviation mean squares for all studied traits were non-significant indicating that the linear regression model fits the data, (Table 7 and 8). Similar findings were also reported by (Mohammadi and Mahmoodi 2008, Kavitha *et al* 2009, Amer *et al* (2012), Abd El- Moneam *et al* 2014, Al-Ajlouni *et al* 2016, Saleh and Farag 2016, Ali 2017, Ali and Abdul-Hamid 2017, Ahmed *et al* 2018, El-Hashash and Agwa 2018, Megahed *et al* 2018 and Ali and Sayed 2019)

Consequently, the regression coefficient (bi) and deviation from regression (S^2di) pooled across the eight environments for different traits under study for each genotype and its coefficient of variation (CV%) were listed in Tables (9, 10 and 11) and presented graphically in Fig's (1 to 10). The stable genotype had high mean performance across a wide range of environments, the regression coefficient (bi) insignificantly different from unity, $b_i<1$, and the deviation from regression (S^2di) near to zero Eberhart and Russell (1966), Also, the targeted barley genotypes recorded the lowest coefficient of variation values Francis and Kanenberg (1978). Such genotypes i.e., G2 ang G14 for Days to heading (50%), G8 for plant height, G3 and G4 for main spike length (cm.), G7, G8, G11 and G15 for number of spikes/plant, G2 and G5 for number of spikelets/spike, G2, G5 and G14 number of kernels/spike, G2, G6 and G11 weight of grains/main spike, G9, G11 and G14 for 1000-grain weight, G2, G5, G11 and G14 for grain yield/plant and G8 and G12 for straw yield/plant. These genotypes seemed to be consistent in its performance across all environments suggesting the consistency of their response ability to different traits under environmental conditions tested, indicating that these lines could be grown under both stressed and favourable environmental conditions. On contrary, most genotypes had (bi) values significantly different from unity for other traits, reflecting their instability.

Table 9. Stability parameters for 18 barley genotypes (G.) for heading date (50%), plant height, main spike length and no. of spikes/plant traits over the 8 environments.

G.	Days to heading (50%)					Plant height (cm)				
	bi	S^2di	ʎi	Wi	CV.%	bi	S^2di	ʎi	Wi	CV.%
G1	0.43	83.51**	484.80	41.47	8.70	1.15**	4.52**	7.98	4.56	7.40
G2	0.71	-0.13	468.16	43.06	15.42	1.00**	1.09**	2.62	1.02	6.88
G3	1.07**	4.07**	15.21	1.36	10.57	1.06**	4.48**	7.92	3.29	8.46
G4	1.08**	3.82**	15.15	1.35	9.66	0.99**	3.46**	6.34	2.46	7.71
G5	1.06**	3.79**	12.79	1.16	9.13	1.12**	8.24**	13.81	6.30	7.21
G6	1.08	2.44**	13.02	1.13	10.16	0.81	3.63**	6.58	4.77	5.88
G7	1.11	4.61**	21.82	1.91	9.92	1.05**	3.27**	6.03	2.49	7.88
G8	1.09	1.50**	11.81	1.01	10.22	0.60	0.30	9.20	5.91	8.11
G9	1.05**	0.40	4.18	0.36	9.54	1.19**	12.85**	21.04	8.18	6.89
G10	1.06**	1.52	7.41	0.65	9.50	1.12**	15.62**	25.39	10.24	5.80
G11	0.93**	1.48**	8.88	0.77	8.25	0.92**	5.63**	9.73	4.21	6.88
G12	1.04**	3.99**	11.60	1.07	9.23	0.78	16.97**	27.48	13.92	5.53
G13	1.09	0.59	13.98	1.21	9.60	0.93**	5.32**	9.25	3.90	7.38
G14	1.06**	3.77**	8.27	0.73	9.00	1.17**	7.77**	13.09	5.16	7.44
G15	0.97**	3.04**	8.62	0.80	8.79	1.00**	10.05**	16.66	6.47	7.15
G16	1.04**	1.98**	6.79	0.62	8.96	1.04**	9.88**	8.55	3.42	7.17
G17	1.09	170.40**	1.71	0.62	9.98	0.95**	5.26**	9.14	3.75	7.58
G18	1.04**	2.33**	7.58	0.70	8.83	1.13**	13.99**	22.82	9.94	9.71
Average	1.00					1.00				

G.	Main Spike length (cm)					No. of spikes/plant				
	bi	S^2di	ʎi	Wi	CV.%	bi	S^2di	ʎi	Wi	CV.%
G1	1.75**	0.49**	63.12	31.87	0.50	1.20**	0.30**	427.34	17.46	1.05
G2	1.12**	0.08**	3.88	2.59	0.30	0.63	0.13**	186.78	9.42	4.40
G3	0.70	0.01	11.20	3.74	0.40	0.71	0.15**	180.55	8.40	5.80
G4	0.71	0.01	10.40	3.18	0.38	1.00**	0.13**	45.27	1.79	5.50
G5	0.87**	0.02**	3.73	1.54	0.42	1.09**	0.12**	172.15	6.93	5.40
G6	0.86**	0.04**	6.02	2.26	0.52	1.32**	0.10**	146.95	7.27	4.81
G7	0.87**	0.01	1.77	0.93	0.43	0.81	0.01	156.10	6.69	4.48
G8	1.20**	0.20**	27.68	9.30	0.33	0.88	0.01	38.60	1.74	6.30
G9	0.78**	0.14**	19.18	6.89	0.45	1.31**	0.07**	100.84	5.36	5.00
G10	1.15**	0.24**	32.05	10.21	0.35	1.24**	0.06**	89.54	3.78	6.00
G11	0.82**	0.08**	10.70	4.00	0.50	0.84	0.02	54.87	3.04	4.80
G12	0.94**	0.04**	6.79	2.14	0.52	1.25**	0.25**	360.46	15.14	5.20
G13	0.97**	0.09**	12.23	3.74	0.34	0.87	0.04**	31.97	1.65	5.14
G14	1.00**	0.06**	8.22	2.49	0.33	0.88	0.08**	29.37	1.36	6.10
G15	1.15**	0.07**	10.68	3.45	0.35	0.87	0.03	56.35	2.49	6.60
G16	1.10**	0.08**	11.49	3.70	0.31	0.69	0.06**	61.65	3.85	5.21
G17	1.04**	0.06	2.04	2.60	0.42	1.15**	0.01	15.66	0.93	4.40
G18	0.99**	0.13**	17.68	5.36	0.46	1.29**	0.03**	37.94	2.69	6.23
Average	1.00					1.00				

bi = the linear regression coefficient of genotypes means on the average of all genotypes in each environment, S2di = the mean square of deviation from regression for each genotype, ʎi = Tai's stability parameter, CV% = coefficient of variation.

Table 10. Stability parameters for 18 barley genotypes (G.) for no. of spikelets/spike, no. of kernels /spike and weight of grains/main spike traits over the 8 environments.

G.	No. of spikelets/spike					No. of kernels/ spike					Weight of grains/main spike (g.)				
	bi	S^2di	ʎi	Wi	CV.%	bi	S^2di	ʎi	Wi	CV.%	bi	S^2di	ʎi	Wi	CV.%
G1	1.13**	0.31*	1.91	2.75	2.29	1.22**	7.98**	13.84	3.78	7.71	1.10**	0.14**	65.49	7.98	5.55
G2	0.86	0.26	2.11	3.07	1.91	0.57	1.02	4.19	0.79	6.21	0.67	0.01	21.03	2.78	4.69
G3	0.98**	1.83**	7.92	8.64	2.50	1.76**	22.47**	37.33	21.25	11.46	1.61**	0.05**	22.85	11.65	6.18
G4	0.90**	1.05**	4.94	6.75	1.92	0.41	24.03**	39.88	8.93	8.67	1.14**	0.10**	11.32	1.81	4.01
G5	0.82	0.34	2.54	3.04	2.07	0.50	1.68	3.62	7.01	3.61	1.11**	0.05**	21.64	5.18	2.83
G6	0.94**	0.72**	3.65	4.26	2.18	1.25**	3.19**	6.08	9.89	3.29	0.70	0.01	41.99	7.14	2.56
G7	0.96**	0.42*	2.51	2.79	1.94	1.47**	7.68**	11.74	2.28	6.77	1.06**	0.03**	17.09	2.12	4.52
G8	1.25**	2.04**	8.72	12.04	2.83	0.96**	10.59**	18.09	3.37	5.58	0.93**	0.07**	33.37	4.06	4.66
G9	0.99**	0.77**	3.84	4.19	2.08	0.88**	14.60**	24.60	4.92	6.07	0.38	0.12**	56.36	15.85	2.67
G10	0.96**	0.87**	4.22	4.62	1.92	1.22**	15.90**	26.69	6.13	8.25	1.63**	0.10**	23.31	12.23	7.10
G11	1.00**	0.05	1.10	1.21	2.10	0.83**	9.69**	16.63	3.76	5.10	0.72	0.01	23.48	3.88	3.54
G12	1.28**	2.16**	9.17	13.17	2.69	1.15**	6.11**	10.82	2.60	6.57	0.86*	0.04**	8.03	2.02	3.47
G13	1.14**	2.09**	8.89	10.51	2.69	1.32**	6.60**	11.61	4.75	9.08	1.24**	0.03**	9.88	2.58	4.36
G14	1.18**	0.42*	2.53	4.00	2.29	0.53	1.63	20.86	4.68	8.19	0.92**	0.04**	21.77	2.71	3.71
G15	0.91**	0.80**	3.96	4.61	1.93	1.00**	5.80**	3.56	0.66	6.30	1.19**	0.06**	31.51	4.60	5.19
G16	0.98**	1.26**	5.72	6.24	2.46	0.75*	12.66**	21.44	5.56	6.17	0.92**	0.02**	11.69	1.55	3.76
G17	0.90**	0.16	1.50	2.08	1.81	0.99**	6.59**	11.59	2.14	6.88	0.80*	0.16**	75.63	9.89	4.93
G18	0.83	0.92**	4.43	6.03	2.00	1.18**	12.30**	10.30	7.51	4.34	1.02**	0.03**	16.57	1.96	4.03
Average	1.00					1.00					1.00				

bi = the linear regression coefficient of genotypes means on the average of all genotypes in each environment, S2di = the mean square of deviation from regression for each genotype, ʎi = Tai's stability parameter, CV% = coefficient of variation.

Table 11. Stability parameters for 18 barley genotypes (G.) for 1000-grain weight, grain yield/m², and straw yield/m² traits over the 8 environments.

G.	1000-grain weight (g.)					Grain yield /m² (g.)					Straw yield/m² (g.)				
	bi	S^2di	ʎi	Wi	CV.%	bi	S^2di	ʎi	Wi	CV.%	bi	S^2di	ʎi	Wi	CV.%
G1	0.48	16.26**	11.85	4.61	3.29	1.58**	7251.95**	149.18	20.42	13.69	1.61**	43655.48**	137.00	20.73	17.25
G2	0.96**	5.70**	4.74	1.39	3.61	0.73	36.19	97.73	7.75	9.28	0.84**	22544.71**	71.19	6.45	10.30
G3	0.93**	12.38**	9.24	2.72	3.42	1.02**	4996.36**	6.97	0.55	9.20	1.12**	2570.74**	8.92	1.07	12.52
G4	1.46**	20.60**	6.02	2.65	4.17	0.98**	245.84**	5.93	0.48	8.88	0.95**	9757.12**	6.39	0.58	10.74
G5	1.56**	42.66**	29.61	9.96	6.12	0.73	50.58	46.92	5.61	5.84	0.86**	17827.27**	56.49	5.07	8.52
G6	2.38**	91.27**	62.30	26.18	9.22	0.88**	3281.26**	67.99	5.68	6.44	1.01**	24104.87**	76.05	6.20	9.08
G7	1.00**	25.40**	18.00	5.26	5.19	0.96**	3502.24**	27.54	2.69	9.23	0.81**	7714.59**	24.96	2.98	10.84
G8	0.52	15.15**	11.10	4.22	4.10	0.93**	1550.37**	32.61	3.28	7.12	0.78	18.42	25.91	3.35	8.25
G9	-0.31	0.65	2.00	7.72	1.36	0.89**	10173.31**	208.89	16.65	9.69	0.75	47532.05**	149.09	13.80	10.27
G10	1.76**	20.44**	14.66	6.69	5.38	1.28**	1879.61**	39.33	5.17	12.03	1.35**	12825.10**	40.88	6.46	15.70
G11	0.46	0.69	10.12	4.16	2.40	0.75	93.39	60.06	4.71	10.99	0.88**	14393.26**	45.78	4.09	11.82
G12	0.28	4.64**	3.35	3.17	2.24	1.02**	4857.41**	100.22	9.43	8.52	0.72	89.52	94.47	9.65	10.31
G13	1.20**	4.80**	4.14	1.38	3.88	1.02**	1664.26**	34.93	2.74	8.67	1.20**	12830.22**	40.90	4.37	12.66
G14	0.61	0.93	5.57	2.27	3.19	0.74	55.49	22.49	1.84	8.87	0.83**	35349.79**	17.59	2.16	9.71
G15	1.47**	11.34**	4.50	2.25	5.04	1.03**	2325.99**	68.90	5.40	7.45	1.23**	27124.54**	85.46	8.34	11.03
G16	0.88**	13.45**	9.96	2.97	3.53	1.07**	3402.67**	13.23	1.47	8.28	0.94**	4569.56**	15.15	1.33	11.07
G17	0.74*	45.88**	31.78	9.56	6.02	1.12**	2441.11**	30.37	2.73	11.08	1.02**	8221.41**	26.54	2.18	12.63
G18	1.62**	4.82**	4.15	2.82	4.24	1.28**	1868.58**	18.66	3.43	11.38	1.09**	3520.77**	11.89	1.18	12.07
Average	1.00					1.00					1.00				

bi = the linear regression coefficient of genotypes means on the average of all genotypes in each environment, S2di = the mean square of deviation from regression for each genotype, ʎi = Tai's stability parameter, CV% = coefficient of variation.

Fig. 1. Genotypic stability parameters (α and λ) of 18 barley genotypes to change in environmental indexes for days to heading (50%).

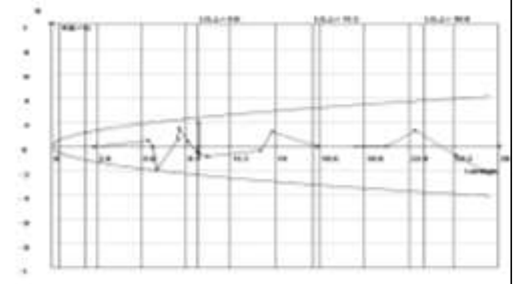

Fig. 2. Genotypic stability parameters (α and λ) of 18 barley genotypes to change in environmental indexes for plant height (cm).

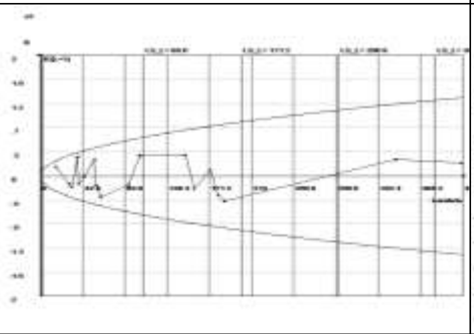

Fig. 3. Genotypic stability parameters (α and λ) of 18 barley genotypes to change in environmental indexes for number of spikes/plant.

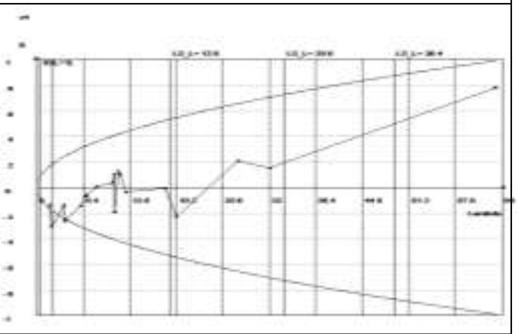

Fig. 4. Genotypic stability parameters (α and λ) of 18 barley genotypes to change in environmental indexes for main spike length (cm).

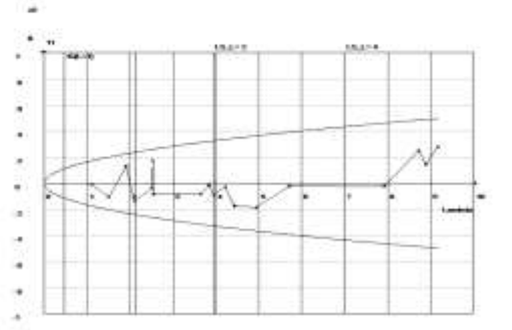

Fig. 5. Genotypic stability parameters (α and λ) of 18 barley genotypes to change in environmental indexes for no. of spikelets/spike

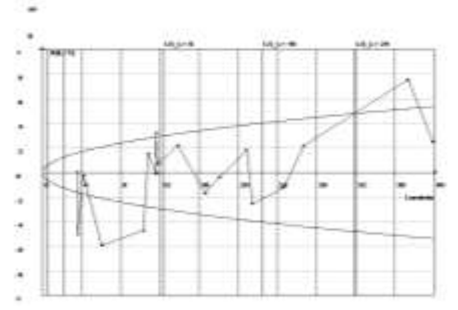

Fig. 6. Genotypic stability parameters (α and λ) of 18 barley genotypes to change in environmental indexes for no. of kernels/spike.

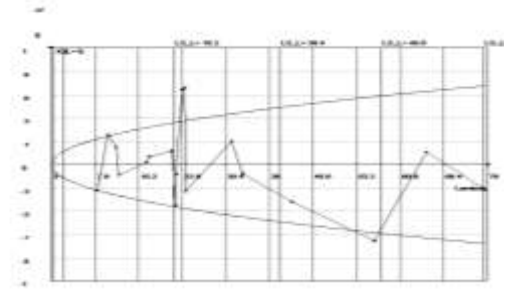

Fig. 7. Genotypic stability parameters (α and λ) of 18 barley genotypes to change in environmental indexes for weight of grains/main spike (g).

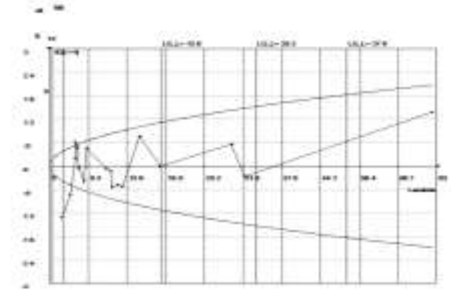

Fig. 8. Genotypic stability parameters (α and λ) of 18 barley genotypes to change in environmental indexes for 1000-grain weight (g).

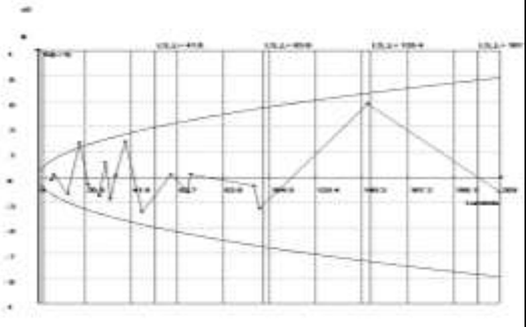	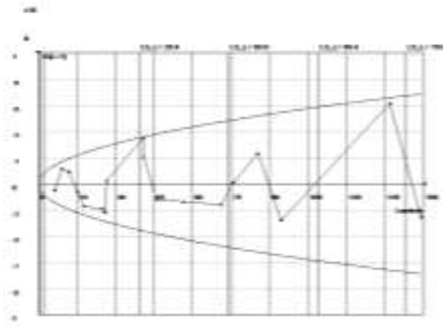
Fig. 9. Genotypic stability parameters (α and λ) of 18 barley genotypes to change in environmental indexes for grain yield/m^2 (g).	**Fig. 10. Genotypic stability parameters (α and λ) of 18 barley genotypes to change in environmental indexes for straw yield/m^2 (g)**

These findings are more or less in harmony with the previous results of Dehghani *et al* 2006, Mohamed *et al* 2011, Farag *et al* 2012, Abd El-Moneam *et al* 2014, Al-Ajlouni *et al* 2016, Saleh and Farag 2016, Ali 2017, Ali and Abdul-Hamid 2017, Amabile *et al* 2017, Elakhdar *et al* 2017, Ahmed *et al* 2018 and Ali and Sayed 2019.

It could be concluded that early genotype G2 and the two high yielding genotypes G11 and G14 as stable genotypes for yield and its components performed well for stability and grain yield and its components. Thus these genotypes may be recommended to be grown under undesirable environments (delayed sowing date and drought stress as new elite genotypes or used as a parent in barley breeding programs under targeted environment.

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أداء وثبات محصول الحبوب لبعض التراكيب الوراثية من الشعير تحت بيئات متباينة

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يعد الهدف الرئيسي لمعظم برامج التربية هو الحصول على تراكيب وراثية ذات محصول عالي وثابتة من الشعير تحت الظروف المستهدفة، حيث نفذت تجربتين حقليتين في موعدين زراعيين الأول ١٢ نوفمبر D1- والثاني ١٢ ديسمبر-D2 وتضمن كل موعد معاملتين للري تحت سعة حقلية ١٠٠% - I1 و ٦٠%- I2 في محطة بحوث رأس سدر التابعة لمركز بحوث الصحراء خلال موسمي (٢٠١٥/٢٠١٦ – ٢٠١٦/٢٠١٧) بهدف تقييم التباين ومتوسطات الصفات المظهرية وتقدير معايير الثبات لعدد ثمانية عشر تركيب وراثي متباعد من الشعير (تتضمن عدد ٢ صنف مقارنة هما الصنف المستنبط في مركز بحوث الصحراء Su 12303 و الصنف جيزة ٢٠٠٠) من الشعير سداسي الصفوف تحت ثماني بيئات مختلفة (موعدين زراعيين x معاملتين للري x موسمين) ويمكن تلخيص النتائج المتحصل عليها على النحو التالي: أوضحت بيانات تحليل التباين مدى واسع من الاختلاف بين المعاملات المختلفة وكذلك الأصناف المختبرة، كما أن التفاعل بين البيئة والتركيب الوراثي كان عالي المعنوية ويرجع التأثير الأكبر للتأثيرات البيئية (موعدي الزراعة). وقد أظهر التحليل التجميعي معنوية البيئات والتراكيب الوراثية وكذلك التفاعل بينهما، ومن ثم فان التراكيب الوراثية المختبرة بينها مدى واسع من التباينات مما أدى الى اختلاف ترتيبها بين موعدي الزراعة ومعاملتي الري المدروسة. اختلفت التراكيب الوراثية المختبرة فيما بينها معنويا في معظم الصفات تحت الدراسة (تاريخ طرد ٥٠% من السنابل، متوسط ارتفاع النبات (سم)، طول السنبلة الرئيسية (سم)، عدد السنابل/النبات، عدد السنيبلات/السنبلة، عدد الحبوب/السنبلة، وزن حبوب السنبلة الرئيسية (جم)، وزن ١٠٠٠ حبة (جم)، محصول الحبوب/م^2 (جم)، محصول القش/م^2 (جم) تحت البيئات المختلفة. وأشارت النتائج الى تفوق معاملة موعد الزراعة الأول والسعة الحقلية ١٠٠%(D1I1) على موعد الزراعة الثاني و السعة الحقلية ٦٠% (D2I2) خلال الموسمين لمعظم الصفات تحت الدراسة. بينما سجلت الثلاثة تراكيب وراثية (G2) و(G11) و (G14) أعلى مردود لمحصول الحبوب مع واحد/أو أكثر من مكوناته، والتي يمكن استخدامها لتحسين إنتاج الشعير وفقًا لأدائها عبر البيئات المختلفة تحت الدراسة، بينما أظهر مؤشر التحمل لمعاملتي الإجهاد أن خمسة سلالات G1 و G6 و G7 و G8 و G15 تحت معاملةD1 والسلالتين G9 و G12 تحت معاملة D2 سجات أقل قيم لمؤشر الحساسية تحمل الجفاف لمحصول الحبوب/م^2. بناءا على تقديرات معايير

الثبات (معامل الانحدار، ومجموع مرع الانحرافات عن الخط المستقيم) ومعامل الإختلاف البيئى للمحصول ومكوناته للتراكيب الوراثية المختلفة موضع الدراسة كانت متجانسة في تحديد التراكيب الوراثية الأعلى ثباتا عبر البيئات المدروسة. يمكن اعتبار كلا من السلالتين G2 وG14 افضل التراكيب الوراثية لصفة تاريخ طرد ٥٠% من السنابل، و السلالة G8 لصفة ارتفاع النبات، والسلالتين G3 وG4 لصفة ارتفاع السنبلة الرئيسية، وأربعة سلالات(G7 و G8 وG11 و G15) لصفة عدد السنابل/نبات، والسلالتين G2 وG5 لصفة عدد السنيبلات/سنبلة، وثلاثة سلالات (G2 وG5 وG14) لصفة عدد الحبوب/سنبلة، وثلاثة سلالات (G2 وG6 وG11) لصفة وزن حبوب السنبلة الرئيسية، وثلاثة سلالات (G9 وG11 وG14) لصفة وزن ١٠٠٠ حبة، وأربعة سلالات (G2 وG5 وG11 وG14) لصفة محصول الحبوب/م٢، والسلالتين G8 و G12 لصفة محصول القش/م٢، وتعد تلك السلالات الأقل اختلافا على مستوى كافة البيئات تحت الدراسة. ويمكن أن يوصى بناء على نتائج هذه الدراسة باستخدام السلالة المبكرة G2 والسلالتينG11 وG14 كتراكيب وراثية عالية المحصول وذات ثبات لمحصول الحبوب ومكوناته. لذا يمكن الاستفادة بهما بالزراعة مباشرة تحت البيئات غير المرغوبة (زراعة متأخرة والجفاف) كسلالات مبشرة أو إدخاله كأحد الآباء في برامج تربية الشعير تحت البيئات المستهدفة.

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