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Assessment of yield, yield-related traits and drought tolerance of barley (*Hordeum vulgare* L.) genotypes

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Abstract

Barley (*Hordeum vulgare* L.) is an important winter cereal crop grown in marginal areas. The objectives of this study were to investigate some morphological traits and drought tolerance indices of twenty promising lines and varieties of barley under pre-flowering drought stress and non-stress conditions. A field experiment was conducted in 2012-2013 growing season in Miyandoab Agricultural Research Station. A randomized complete block design with three replicates was conducted. Analysis of variance revealed significant differences among genotypes for number of grains per spike ($P<0.01$), 1000 grain weight ($P<0.01$) and harvest index ($P<0.05$) at both non-stressed and stressed conditions. Significant differences were observed among genotypes for spike number/m^2 ($P<0.01$) and grain yield ($P<0.01$) in non-stressed and for plant height at stressed conditions ($P<0.01$). The greatest grain yield under non-stressed condition was obtained by genotype 17 (6873.472 kg ha^{-1}), while, genotype 2 had the lowest yield (5050.736 kg ha^{-1}). As it was expected, drought caused a significant reduction in all agronomic traits. Maximum MP, STI and GMP was recorded for genotype 17, followed by genotypes 4 and 12. The results indicated that they have stable yield performance. Three indices of drought tolerance STI, GMP, MP had the most significant positive correlation with yield in both conditions. Bi-plot display and cluster analysis confirmed the superiority of the genotypes 17, 4, and 12 in both conditions.

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Introduction

Drought is an important abiotic stress limiting yield, and barley seems to be relatively well adapted to water deficit (Ceccarelli and Grando, 1996). Barley is typically cultivated in the arid and semi-arid regions of Iran, generally in areas with low precipitation that are not suitable for wheat production (Naghaii and Asgharipour, 2011). Drought reduces the availability of water to plants, leading to reduced yields (Gonzalez *et al.*, 2010). Drought stress tolerance is seen in almost all plants, but its extent varies from species to species and even within species (Jaleel *et al.*, 2009). The effect of drought on the yield of cereals depends on the duration and the severity of the stress (Mohammad *et al.*, 1996). Apart from environmental conditions, the final grain yield of barley is determined by three components: the number of spike m^{-2}, the number of grains/spike, and 1000-grain weight. The duration of grain filling and the growth cycle also contribute greatly to crop yield. Each yield component could be affected by temporary water deficit (Garcia del Moral *et al.*, 1991). Drought stress during grain filling dramatically reduces grain yield (Ehdaie and Shakiba, 1996). Singh *et al.*, (1973) found that drought reduces the number of the grains/spike and thereby yield. Mamnouie *et al.*, (2010) showed that water deficit significantly reduced 1000-grain weight, number of spikes m^{-2}, number of grains/spike and grain yield.

Drought indices which provide a measure of drought based on yield loss under drought conditions in comparison to normal conditions have been used for screening drought-tolerant genotypes (Mitra, 2001). To differentiate drought resistant genotypes, several selection indices have been employed under various conditions. Rosielle and Hamblin, (1981) defined stress tolerance (TOL) as the differences in yield between the stress (Ys) and non-stress (Yp) environments and mean productivity (MP) as the average yield of Ys and Yp. Fischer and Maurer, (1978) proposed a stress susceptibility index (SSI) for cultivars. Fernandez, (1992) defined an advanced index (STI= stress tolerance index), which can be used to identify genotypes that produce high yield under both stress and non-stress conditions.

The other yield based estimate for drought resistance is geometric mean productivity (GMP). The geometric mean is often used by breeders interested in relative performance, since drought stress can vary in severity in the field environments over years (Ramirez and Kelly, 1998).

The best effective approach of fighting against drought is development of the tolerant crop varieties (Ahmed *et al.*, 2013). The objective of this work was: (i) to compare yield and its components in twenty barley genotypes grown in non-stress and under drought stress conditions, (ii) to identify drought resistant/tolerant barley genotypes under drought stress (iii) to evaluate the relationship of yield components with final grain yield, (iiii) to test the effectiveness of drought resistance indices in twenty barley promising lines and varieties of barley under normal and drought stress conditions and (v) to determine the efficiency of screening methods to classify genotypes into resistant/sensitive and tolerant and (vi) to study interrelationships among the screening methods.

Materials and methods

Experimental Design and Plant Material

A field experiment was conducted in 2012-2013 growing season in Miyandoab Agricultural Research Station (36°58' latitude, 46°6' longitude, 1314 m a.s.l. with mean annual precipitation of 280 mm.), in north-west of Iran. The total rainfall during the growing season of this experiment (2012–2013) was 177.1 mm (Table 1). The experiment was established in a silt loam soil with a pH of 8.

Seedbed was prepared by sloughing, disk harrowing and cultivation. The experimental design for this study was randomized complete block design with three replicates. Treatments were 20 barley promising lines and varieties (described in Table 2). The genotypes were grown in both stressed and non-stressed (well watering) environments. Sowing was done by an experimental drill in 1.2 m × 5 m plots, consisting of six rows 20 cm apart at 450 seeds m^{-2} for each site. Sowing date was 15 October.

Control plots were watered at tillering, Joining, flowering and grain filling stages, but stressed plots were watered at pre-flowering phase. Fertilizers were applied before sowing (100kg ha^{-1} P2O3 and 50kg ha^{-1} N) and at stem elongation (100kg ha^{-1} N). During the growth period, all plots were weeded manually. No serious incidence of insect or disease was observed and no pesticide or fungicide was applied.

Morphological measurements

The total dry weight, grain yield (kg ha^{-1}), harvest index and the thousand-kernel weight were measured at crop maturity. Five plants were randomly chosen from each plot to measure the number of grains per spike and plant height. The number of spikes per m^2 was determined at maturity from a sample of 1 m of a central row in each plot.

Calculate Drought Tolerance Indices

Drought resistance indices were calculated based on grain yield under drought-stressed and irrigated conditions using the following relationships:

SSI = [1 - (Ys / Yp)]/ SI; SI= 1 – ($\bar{Y}_s$ / $\bar{Y}_p$) (Fischer and Maurer, 1978)

TOL = Yp – Ys (Rosielle and Hamblin, 1981)

MP = (Ys + Yp) / 2 (Rosielle and Hamblin, 1981)

$GMP = \sqrt{Yp.Ys}$ (Fernandez, 1992)

STI = (Ys)(Yp) /($\bar{Y}_p$)2 (Fernandez, 1992)

Where Ys and Yp are the yield of genotypes under stress and irrigated conditions, respectively, $\bar{Y}_s$ and $\bar{Y}_p$ are the mean yields of all genotypes under stressed and non-stressed conditions, respectively, and SI is the stress intensity.

Statistical Analysis

Analysis of variance, mean comparison of traits (Duncan's multiple range test at the 0.05 significance level), correlation coefficients between Yp, Ys and indices and cluster analysis were carried out using SPSS software version 13.0 (SPSS, 2004). Principal component analysis were done, using Minitab 16.

Results and discussion

Spike number per m²

There were significant differences ($P< 0.01$) in spike number/m^2 under non-stress condition, while there was no significant difference among genotypes under stress condition (Table 3). Spike number of genotypes 11, 9, 8, 12, 16 and 13 under non-stress conditions were higher than those of other genotypes (Table 4). Drought stress decreased spike number/m^2, compared with the normal condition. Researchers have attributed the reduction in number of spikes under drought stress to the increase in the number of sterile spikes per plant and the decrease in the number of fertile spikes per plant in barley (Mogensen, 1992; Sanchez *et al.*, 2002; Samarah, 2005).

Table 1. Average monthly maximum temperature and rainfall during the 2012–2013 growing season at Miyandoab agricultural Research station.

Month	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	Jul	Total
Max. temp (°C)	25.6	16.8	9.3	5.7	11.2	13.8	19.5	21.1	28.6	32.9	
Rainfall (mm)	2	29	21.8	12.7	25.5	35.6	27.8	20.8	1.9	0	177.1

Grain number per spike

Analysis of variance revealed significant differences ($p<0.01$) among genotypes for grain number per spike both non-stress and stress conditions (Table 3). In the both non-stress and stress conditions, genotypes 6, 20 and 13 had a higher grain number per spike than the other genotypes, while the genotypes 16, 10 and 12 in non-stress conditions and the genotypes 2, 10, 16 and 12 in stress conditions had the lowest grain number per spike (Table 4). The number of grain per spike of the 6-rowed genotypes, both in the irrigated and drought stress conditions was significantly greater than that of the 2-rowed (2-rowed genotypes are 10, 12 and 16) genotypes. A reduction in number of grains per spike has been reported for barley (Mogensen, 1992; Agueda, 1999) and wheat (Dancic *et al*., 2000; Guttieri *et al*., 2001; Garcia del Moral *et al*., 2003) under drought stress.

Thousand grain weight.

The 1000-grain weight was different (P< 0.01) between of barley genotypes in both experiments (Table 3). The 1000-grain weight of genotypes 2, 18, 17, 10, 14 and 5 under non-stress conditions and in the stress conditions the genotypes 2, 17, 16, 14, 18, 10 and 5 were higher than those of other genotypes (Table 4). For both the non-stress and stress, 6, 15, 11, 3 and 8 genotypes had the lowest 1000-grain weight. The 1000-grain weight reduction could be attributed to shorter grain filling duration under drought stress, which lead to a lower accumulation of dry matter in the growing grains (Agueda, 1999, Sanchez *et al*., 2002, Garcia del Moral *et al*., 2003) or as a result of the reduction in the rate and duration of the accumulate starch in the endosperm (Brooks *et al*., 1982). Jahanbin *et al*., (2002) in their study on evaluation drought stress on barley cultivar reported that water deficiency at grain filling periods significantly reduced grain and biological yields.

Table 2. Name and pedigree of barley genotypes used in this study.

NO	Pedigree	Row type
1	NC86/INTseg07	6
2	L.527/MB2367//(CI7117-9/DeirAlla106)/3/Bahtim 7DL(Mza-Gva)	6
3	L.1242/Hesk//Alger(CI10117/Choyo…)	6
4	Robur/WA2196-68//DoNor/3/Rhn-03//L.527/NK1272/5/L.527/Chn-01/4/…/(As46/Aths//Slb-100)	6
5	Sutter/Alanda	6
6	Sadik-02*2//Radical/PA8444-78	6
7	Afzal/3/Torsh/9cr.279//Bgs	6
8	YEA 38903/YEA475.4//73M4-30/3/Ceres//WI2192/Emir/3/Karoon	6
9	L.527/Hortland//ICNB93-328	6
10	Grecale//Sonata/Arta	2
11	Alger/(CI10117/Choyo…)//ICNB93-328	6
12	L.527/MB2367//(CI7117-9/DeirAlla106)/3/Beecher	2
13	ADC-1	6
14	ADC-20	6
15	Bahman	6
16	EDC-3	2
17	D-10	6
18	Yousef	6
19	Makouei	6
20	(EDBYT82-9)Rhn-03//L.527/NK1272(national check)	6

Grain Yield

Grain yield of barley genotypes were significantly differed (P< 0.01) under non- stress conditions, while there was no significant difference among genotypes in drought stress condition (Table 3). Grain yield of genotypes 17, 15, 12, 4, 8, 13, 9, 14, 18, 16, 10, 1, 11, 6, 20 and 7 under non-stress conditions were higher than those of other genotypes (Table 4). Grain yield of all barley genotypes were reduced when plants were subjected to drought stress at reproductive stages. The percentage of reduction in genotypes 15, 13, and 11 was much higher than the other genotypes (20.99%, 17.62% and 17.19%, respectively).

The decline in total grain yield under the drought stress was due to the reduction in grain yield components, such as individual grain weight (Gunzalez *et al*., 1999; Mogensen, 1992; Samarah *et al*., 2009), grain number per spike (Agueda, 1999; Samarah, 2005), spike number (Agueda, 1999; Sanchez *et al*., 2002; Garcia del Moral *et al*., 2003) and the number of tillers per plant (Samarah, 2005).

Harvest index

Significant differences (P<0.05) were observed among genotypes for harvest index at both conditions (Table 3).

Harvest index of genotypes 8, 4, 17, 9, 14, 15, 20 and 1 under non-stress conditions and at stress condition genotypes 17, 14, 4, 11, 3, 7, 18, 9, 8, 1and 20 were higher than those of other genotypes (Table 4). Agueda, (1999) reported that vegetative production and grain yield affects the harvest index.

Table 3. Analysis of variance of yield and yield components and some morphological traits of barley genotypes.

Source of variation	d.f	Mean Square					
		Spike number (m^{-2})		Grain number ($spike^{-1}$)		1000 grain weight (g)	
		Non-stressed	Stressed	Non-stressed	Stressed	Non-stressed	Stressed
Replication	2	218645.00**	29915.000	80.241*	26.911	137.485**	52.686
Genotype	19	113217.105**	46089.123	154.475**	170.224**	95.902**	96.502**
Error	38	32908.158	27569.386	19.708	27.645	12.389	16.966
CV (%)		28.161	20.851	13.641	15.783	8.464	10.027

*, **: Significant at 1% and 5% probability level, respectively.

Continued Table 3.

Source variation	of d.f	Mean Square					
		Grain yield (Kg h-1)		Harvest index (%)		Plant high (cm)	
		Non-stressed	Stressed	Non-stressed	Stressed	Non-stressed	Stressed
Replication	2	820304.072	8097476.852**	370.914964**	82.99989	353.881	49.101
Genotype	19	825774.946**	699421.422	40.80500422*	58.66829*	143.621	258.269**
Error	38	320141.226	591391.267	21.815	28.853	123.635	57.041
CV (%)		9.221	13.044	11.191	13.886	9.564	6.125

Plant height

Differences among genotypes for plant high were found significant ($P<0.01$) at stress condition, while there was no significantly difference among genotypes in non-stress condition (Table 3). Plant high of genotypes 20, 19, 13 and 6 under stress conditions were higher than those of other genotypes (Table 4). The decrease in plant high in response to water stress may be due to decrease in relative turgidity and dehydration of protoplasm, which is associated with a loss of turgor and reduced expansion of cell and cell division (arnon, 1972). Innes *et al.*, (1981) declared that in stressed conditions tall genotypes were superior to dwarf genotypes. This phenomenon may be attributed to the greater ability to absorb water from soil.

Table 4. Mean† traits of barley genotypes under non-stress and drought stress conditions.

Gen	Spike number (m^{-2})		Grain number ($spike^{-1}$)		1000- grain weight(g)	
	Non-stressed	stressed	Non-stressed	stressed	Non-stressed	stressed
1	740.000 C-E	490.000	31.733 D-G	29.800 D-F	41.831 B-F	41.351 C-I
2	766.667 C-E	680.000	26.867 GH	17.667 G	51.480 A	51.075 A
3	740.000 C-E	573.333	30.667 D-G	35.733 B-D	36.077 F-I	35.648 G-I
4	773.333 C-E	583.333	37.600 B-D	37.200 A-D	42.841 B-F	39.292 D-I
5	706.667 C-E	696.667	29.800 E-G	33.733 B-D	45.680 A-D	45.857 A-F
6	730.000 C-E	646.667	45.867 A	45.267 A	31.664 I	33.415 HI
7	823.333 B-D	653.333	34.800 C-F	37.867 A-D	41.039 C-F	38.917 E-I
8	990.000 A-C	786.667	36.533 B-E	36.067 B-D	37.743 E-I	35.812 G-I
9	1090.000 AB	593.333	32.200 D-G	29.600 D-F	39.455 D-G	37.441 G-I
10	600.000 DE	586.667	19.133 I	20.800 G	47.631 A-C	46.248 A-F
11	1150.000 A	836.667	28.667 F-H	31.667 CD	33.192 G-I	33.891 HI
12	900.000 A-C	836.667	21.867 HI	22.867 E-G	44.227 B-E	42.960 B-G
13	856.667 A-D	640.000	40.400 A-C	41.133 AB	42.959 B-E	37.859 G-I
14	606.667 DE	480.000	36.800 B-E	40.200 A-C	46.819 A-C	46.959 A-D
15	756.667 C-E	690.000	35.467 C-F	37.933 A-D	32.735 HI	32.631 I
16	900.000 A-C	893.333	18.733 I	22.067 FG	42.651 B-F	47.947 A-C
17	720.000 C-E	573.333	34.267 C-F	31.333 D-E	48.567 AB	49.228 AB
18	796.667 E	583.333	35.533 C-F	36.733 A-D	48.603 AB	46.715 A-E
19	503.333 E	446.667	31.000 D-G	38.167 A-D	38.485 E-H	38.777 F-I
20	776.667 D-E	613.333	42.933 AB	40.440 AB	38.065 E-I	39.527 D-I

*Means followed by the same letter are not significantly different at P=0.05 (Duncan's test).

Continued Table 4.

Gen	Grain yield (Kg h-1)		Harvest index (%)		Plant high (cm)	
	Non-stressed	stressed	Non-stressed	stressed	Non-stressed	stressed
1	6299.798 A-D	6077.636	42.201 A-F	39.252 A-C	124.573	122.600 C-E
2	5050.736 E	5044.815	37.361 EF	28.236 E	108.667	121.213 D-F
3	5743.280 B-E	5736.34	39.429 C-F	41.433 A-C	112.170	122.000 C-E
4	6638.669 AB	6575.363	47.530 AB	43.219 AB	113.213	117.833 D-G
5	5710.615 B-E	5510.763	39.611 C-F	34.188 C-E	124.727	108.257 G
6	5946.832 A-E	5762.132	36.951 F	37.499 B-D	127.867	134.467 A-C
7	5835.798 A-E	5491.258	37.881 D-F	41.313 A-C	117.067	113.937 E-G
8	6532.099 AB	5918.533	49.847 A	39.260 A-C	121.560	125.383 B-E
9	6441.594 A-C	5970.601	45.519 A-D	40.370 A-C	113.523	124.133 B-E
10	6316.73 DE	5230.447	40.180 B-F	30.269 DE	105.613	117.667 D-G
11	5952.958 A-E	5664.006	40.353 B-F	41.938 A-C	113.400	122.533 C-E
12	6646.534 AB	6475.773	40.638 B-F	37.249 B-D	114.533	120.000 D-G
13	6531.455 AB	5380.749	40.301 B-F	37.285 B-D	129.690	135.267 AB
14	6438.679 A-C	6432.572	44.806 A-E	43.380 AB	119.400	114.413 E-G
15	6819.242 AB	5387.447	43.182 A-F	36.511 B-E	106.690	121.200 D-F
16	6347.012 A-C	6193.572	42.013 B-F	38.008 B-D	118.813	109.450 FG
17	6873.472 A	6776.231	46.985 A-C	47.679 A	108.220	125.213 B-E
18	6371.367 A-C	6323.005	41.037 B-F	40.849 A-C	110.500	127.200 B-D
19	5406.080 C-E	5391.748	36.274 F	36.706 B-E	117.923	140.983 A
20	5900.059 A-E	5483.727	42.590 A-F	38.992 A-D	117.133	142.337 A

Indices of Drought Tolerance and Sensitivity

In order to select most tolerant genotypes to drought, yield potential (Yp), stress yield (Ys), values of SSI, TOL, MP, GMP and STI were calculated (Table 5). In both non-stress (6873.472 Kg h^{-1}) and stress (6776.231 Kg h^{-1}) conditions, the highest grain yield was obtained by genotype 17 and in both conditions the lowest grain yield was obtained by genotype 2 (Yp = 5050.736, Ys = 5044.815). The percentage of reduction of yield in genotypes 17 and 2 was 1.41% and 0.11%, respectively. Based on ranking, a greater SSI and TOL value was related to the genotype 20 followed by genotypes 13 and 10, indicating that these had a higher drought sensitivity and larger grain yield reduction under stressed condition and; lowest SSI and TOL was found in genotypes 14 and 2, respectively, therefore, these genotypes had a lower drought sensitivity and lower grain yield reduction under stressed condition. Based on ranking, highest MP, GMP and STI indices were observed in genotype the 17, followed by genotypes 4 and 12 and the least values in genotype 2 followed by genotype 19 and 5. Based on MP, GMP and STI indices Check genotype (20) had the sixteen rank. In general, similar ranks for the genotypes were observed by GMP and MP parameters as well STI, which suggesting these three parameters are in equal for selecting genotypes (Mohammadi *et al.*, 2010).

To determine the most desirable drought-tolerant criteria, the correlation coefficients between Yp, Ys and other quantitative indices of drought tolerance were calculated (Table 6). The results indicate MP, GMP and STI were strongly correlated ($P<0.01$) with yield under both conditions, suggesting that these parameters are suitable to screen drought-tolerant, high yielding genotypes (e.g. G17) in both stressed and non-stressed conditions. Similar results were reported by Fernandez, (1992); Naghaii and Asgharipour, (2011); Sio Se-Mardeh *et al.*, (2006) and

Mohammadi *et al.*, (2010), all of whom found these parameters to be suitable for discriminating the best genotypes under stressed and non-stressed conditions. The correlation between Ys and SSI and TOL was negative (P<.05), suggest that selection based on TOL will result in reduced yield under non-stress conditions, hence the MP, GMP and STI were better pridictors of Yp and Ys than TOL and SSI (Nazari and pakniyat, 2010). Same results was obtained by Clarke *et al.*, (1992), Sio-Se Mardeh *et al.*, (2006) ; Rizza *et al.*, (2004), however, showed that a selection based on minimum yield decrease under stress with respect to favourable conditions (TOL) failed to identify the best genotypes. SSI and TOL had positive significant (P<0.01) correlations. The correlation between MP, GMP and STI indices was positive (P<0.01).

Table 5. Estimation of stress tolerance indices [and ranks] from the potential yield and the stress yield data for barley genotypes.

NO Gen	Yp(kg.ha^{-1})	Ys (kg.ha^{-1})	SSI	TOL	MP	GMP	STI
1	6299.798[12]	6077.636[7]	0.626[12]	222.163[12]	6188.717[9]	6187.720[9]	0.999[9]
2	5050.736[20]	5044.815[20]	0.021[2]	5.921[1]	5047.775[20]	5047.775[20]	0.665[20]
3	5743.280[17]	5736.34[11]	0.021[3]	6.940[3]	5739.810[15]	5739.809[15]	0.860[14]
4	6638.669[4]	6575.363[2]	0.169[6]	63.306[6]	6607.016[2]	6606.941[2]	1.139[2]
5	5710.615[18]	5510.763[13]	0.621[11]	199.852[11]	5610.689[18]	5609.799[18]	0.821[18]
6	5946.832[14]	5762.132[10]	0.551[10]	184.700[10]	5854.482[12]	5853.753[12]	0.894[12]
7	5835.798[16]	5491.258[14]	1.048[14]	344.541[14]	5663.528[17]	5660.907[17]	0.836[17]
8	6532.099[5]	5918.533[9]	1.667[17]	613.567[17]	6225.316[7]	6217.752[7]	1.009[7]
9	6441.594[7]	5970.601[8]	1.298[16]	470.993[16]	6206.097[8]	6201.628[8]	1.004[8]
10	6316.730[11]	5230.447[19]	3.052[18]	1086.283[18]	5773.589[14]	5747.984[14]	0.862[15]
11	5952.958[13]	5664.006[12]	0.861[13]	288.953[13]	5808.482[13]	5806.685[13]	0.880[13]
12	6646.534[3]	6475.773[3]	0.456[9]	170.761[9]	6561.154[3]	6560.598[3]	1.123[3]
13	6531.455[6]	5380.749[18]	3.127[19]	1150.706[19]	5956.102[11]	5928.248[11]	0.917[11]
14	6438.679[8]	6432.572[4]	0.017[1]	6.107[2]	6435.626[4]	6435.625[4]	1.081[4]
15	6819.242[2]	5387.447[17]	3.726[20]	1431.795[20]	6103.344[10]	6061.213[10]	0.959[10]
16	6347.012[10]	6193.572[6]	0.429[8]	153.439[8]	6270.292[6]	6269.823[6]	1.026[6]
17	6873.472[1]	6776.231[1]	0.251[7]	97.242[7]	6824.852[1]	6824.678[1]	1.216[1]
18	6371.367[9]	6323.005[5]	0.135[5]	48.362[5]	6347.186[5]	6347.140[5]	1.051[5]
19	5406.080[19]	5391.748[16]	0.047[4]	14.332[4]	5398.914[19]	5398.909[19]	0.761[19]
20	5900.059[15]	5483.727[15]	1.252[15]	416.332[15]	5691.893[16]	5688.085[16]	0.844[16]

Table 6. The correlation coefficients between Yp, Ys and drought tolerance indices.

	Yp	Ys	SSI	TOL	MP	GMP	STI
Yp	-						
Ys	0.636**	-					
SSI	0.380	-0.471*	-				
TOL	0.400	-0.453*	0.999**	-			
MP	0.902**	0.907**	-0.057	-0.036	-		
GMP	0.890**	0.918**	-0.082	-0.062	1.00**	-	
STI	0.880**	0.925**	-0.103	-0.082	0.998**	0.999**	-

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

Table 7. Results of principal component analysis for Yp, Ys and drought tolerance indices on barley genotypes.

Component	Eigenvalue	Percent of variation	Drought tolerance indices						
			Yp	Ys	SSI	TOL	MP	GMP	STI
PC1	4.647	66.4	0.404	0.433	-0.058	-0.048	0.463	0.463	0.464
PC2	2.350	33.6	0.322	-0.233	0.647	0.649	0.044	0.028	0.014

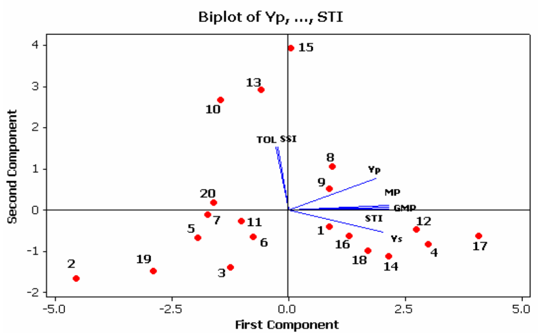

Fig 1. Drawing bi-plot based on first and second components for barley genotypes and different indices.

Bi-plot display through principal component analysis technique was divided into four components. The first two components in total, explained 100 percent of the variation between the data in the both conditions (Table 7). Thus, bi-plot was drawn based on the first two components. The first component justified 66.4% of variation in the matrix of the data and showed highly coordination with Yp, MP, GMP and STI indices. Therefore, it was named as yield potential and drought tolerance component. This component separates drought tolerant genotypes with high yield in both environments. The second component justified, 33.6% of total variation. This component had negative correlation with yield in stress condition (Ys) and high positive correlation with the TOL and SSI indices and yield in non-stress (Yp) condition. Thus, it was called as stress susceptibility component. This component separated genotypes with low and high difference yield in different environments. Regarding the results of principal components analysis of indices (Table 7) and bi-plot (Fig. 1) , and based on two first components, the genotypes 17, 4, 12 and 14, in the vicinity of drought tolerance indices were identified as stable high yielding genotypes in both conditions.

The genotypes 15, 13 and 10 were identified as drought sensitive genotypes (Fig. 1). Biplot analysis has been used by many researchers for comparison of different genotypes for different criteria and in different plant species (Nazari and pakniyat, 2010; Mohammadi *et al.*, 2011; Mohammadi *et al.*, 2010).

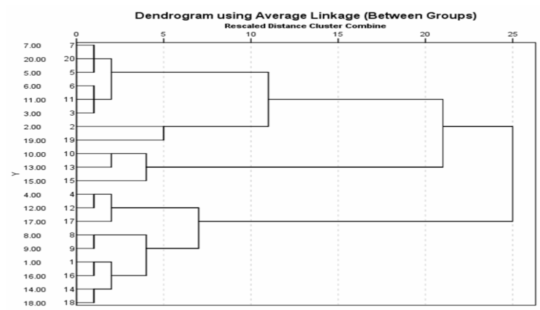

Fig. 2. Dendrogram of measured traits mean for barley genotypes by using of the UPGMA method.

Cluster analysis has been widely used for description of genetic diversity and grouping based on similar characteristics (Mohammadi *et al.*, 2011; Nouri *et al.*, 2011). Genotype grouping by cluster analysis (UPGMA method), using Yp, Ys, SSI, TOL, MP, GMP and STI indices are shown in the figure 2. Cluster analysis showed that the genotypes, tended to group into five groups with 6, 2, 3, 3 and 6 genotypes, respectively (Fig. 2). The genotypes 10, 13 and 15 were located in the same group (third group) that was already classified in bi-plot (Fig. 1). These genotypes, were identified as drought sensitive genotypes, according to SSI and TOL indices. Dendrogram showed that the genotypes 4, 12 and 17 were located in the same group (fourth group) that was already classified in bi-plot (Fig. 1). These genotypes, in terms of yield in both conditions were superior compared to other genotypes, according to MP, GMP and STI indices.

References

Agueda G. 1999. Barley yield in water-stress condition. The influence of precocity, osmotic adjustment and stomatal conductance. Field Crops Research **62,** 23–34.
http://dx.doi.org/10.1016/S0378-4290(99)00002-7

Ahmed IM, Dai H, Zheng W, Cao F, Zhang G, Sun D, Wu F. 2013. Genotypic differences in physiological characteristics in the tolerance to drought and salinity combined stress between Tibetan wild and cultivated barley. Plant Physiology and Biochemistry **63,** 49-60.
http://dx.doi.org/10.1016/j.plaphy.2012.11.004

Arnon I. 1972. Crop production in dry regions (Ed. N Polunin), Vol. **1**. Leonard Hill Book, London. 203-211.

Brooks A, Jenner CF, Aspinall D. 1982. Effects of water deficit on endosperm starch granules and on grain physiology of wheat and barley. Australian Journal of Plant Physiology **9,** 423–436.
http://dx.doi.org/10.1071/PP9820423

Ceccarelli S, Grando S. 1996. Drought as a challenge for the plant breeder. Plant Growth Regulation **20,** 149–155.
http://dx.doi.org/10.1007/BF00024011

Clarke JM, De Pauw RM, Townley-Smith TM. 1992. Evaluation of methods for quantification of drought tolerance in wheat. Crop Science **32,** 728-732.
http://dx.doi.org/10.2135/cropsci1992.0011183X003200030029x

Dancic S, Kastori R, Kobiljski B, Duggan B. 2000. Evaluation of grain yield and its components in wheat cultivars and landraces under near optimal and drought conditions. Euphytica **113,** 43-52.
http://dx.doi.org/10.1023/A:1003997700865

Ehdaie B, Shakiba MR. 1996. Relationship of internode-specific weight and water-soluble carbohydrates in wheat. Cereal Research Communications **24,** 61-68.

Fernandez GCJ. 1992. Effective selection criteria for assessing plant stress tolerance. In Proceedings of the international Symposium on "adaptation of vegetables and other food crops in temperature and water stress". (Ed., CG Kuo). Publication, Tainan, Taiwan. 257-270.

Fischer RA, Maurer R. 1978. Drought resistance in spring wheat cultivars. 1. Grain yield response. Australian Journal of Agricultural Research **29,** 897-912.
http://dx.doi.org/10.1071/AR9780897

Garcia del Moral LF, Ramos JM, Garcia del Moral MB, Jimenez-Tejada MP. 1991. Ontogenetic approach to grain production in spring barley based on path-coefficient analysis. Crop Science **31,** 1179-1185.
http://dx.doi.org/10.2135/cropsci1991.0011183X003100050021x

Garcia del Moral LF, Rharrabti Y, Villegas D, Royo C. 2003. Evaluation of grain yield and its components in durum wheat under Mediterranean condition. Agronomy journal **95,** 266–274.
http://dx.doi.org/10.2134/agronj2003.0266

Gonzalez A, Bermejo V, Gimeno BS. 2010. Effect of different physiological traits on grain yield in barley grown under irrigated and terminal water deficit conditions. The Journal of Agricultural Science **148,** 319–328.
http://dx.doi.org/10.1017/S0021859610000031

Gunzalez A, Martin I, Ayerbe L. 1999. Barley yield in water-stress conditions. The influence of precocity, osmotic adjustment and stomatal conductance. Field Crop Research **62,** 23-34.
http://dx.doi.org/10.1016/S0378-4290(99)00002-7

Innes P, Blackwell RD, Austin RB, Ford MA. 1981. The effects of selection for number of ears on the yield and water economy of winter wheat. The Journal of Agricultural Science **97(03),** 523-532.
http://dx.doi.org/10.1017/S0021859600036844

Jahanbin Sh, Tahmasebi Sarvestani Z, Modarres-Sanavi A, Karimzadeh G. 2002. Effect of drought stress on yield, yield components and drought tolerant indices in naked barley genotypes. Agricultural Sciences and Natural Resources **10(4),** 25-34.

Jaleel CA, Manivannan P, Wahid A, Farooq M, Somasundaram R, Panneerselvam R. 2009. Drought stress in plants: a review on morphological characteristics and pigments composition. International Journal of Agriculture & Biology **11,** 100–105.

Mamnouie E, Fotouhi Ghazvini R, Esfahany M, Nakhoda B. 2010. The effects of water deficit on crop yield and the physiological characteristics of barley (*Hordeum vulgare* L.) varieties. Journal of Agriculture Science and Technology **8,** 211-219.

Guttieri MJ, Stark JC, Brien KO, Souza E. 2001. Relative sensitivity of spring wheat, grain yield and quality parameters to moisture deficit. Crop Science **41,** 327-335.
http://dx.doi.org/10.2135/cropsci2001.412327x

Mitra J. 2001. Genetics and genetic improvement of drought resistance in crop plants. Current Science-Bangalore **80,** 758-763.

Mogensen VO. 1992. Effect of drought on growth rates of grains of barley. Cereal Research Communications **20,** 225–231.

Mohammad J, Aaziri M, Nazir A, Shah D, Jamal H. 1996. Wheat Yield Components as Affected by Low Water Stress at Different Growth Stages. Sarhad Journal of Agriculture **12,** 19- 26.

Mohammadi M, Karimizadeh R, Abdipour M. 2011. Evaluation of drought tolerance in bread wheat genotypes under dryland and supplemental irrigation conditions. Australian journal of crop science **5(4),** 487-493.

Mohammadi R, Armion M, Kahrizi D, Amri A. 2010. Efficiency of screening techniques for evaluating durum wheat genotypes under mild drought conditions. International Journal of Plant Production **4(1),** 11-24.

Naghaii V, Asgharipour MR. 2011. Difference in drought stress responses of 20 barley genotypes with contrasting drought tolerance during grain filling. Advances in Environmental Biology **5(9),** 3042-3049.

Nazari L, pakniyat H. 2010. Assessment of drought tolerance in barley genotypes. Journal of Applied Sciences **10(2),** 151-156.
http://dx.doi.org/10.3923/jas.2010.151.156

Nouri A, Etminan A, Teixeira da Silva, JA, Mohammadi R. 2011. Assessment of yield, yield-related traits and drought tolerance of durum wheat genotypes (*Triticum turjidum var. durum Desf.*). Australian journal of crop science **5(1),** 8-16.

Ramirez P. and Kelly JD. 1998. Traits related to drought resistance in common bean. Euphytica **99,** 127-136.
http://dx.doi.org/10.1023/A:1018353200015

Rizza F, Badeck FW, Cattivelli L, Lidestri O, Fozo ND, Stanca AM. 2004. Use of a water stress index to identify barely genotypes adapted to rain fed and irrigated conditions. Crop Science **44,** 2127-2137.
http://dx.doi.org/10.2135/cropsci2004.2127

Rosielle AA, Hamblin J. 1981. Theoretical aspects of selection for yield in stress and non-stress environment. Crop Science **21,** 943-946.
http://dx.doi.org/10.2135/cropsci1981.0011183X002100060033x

Samarah NH, Alqudah AM, Amayreh JA, McAndrew GM. 2009. The Effect of Late-terminal Drought Stress on Yield Components of Four Barley Cultivars. Journal of Agronomy & Crop Science **195(6),** 427-441.
http://dx.doi.org/10.1111/j.1439-037X.2009.00387.x

Samarah, N. H. 2005: Effects of drought stress on growth and yield of barley. Agronomy for Sustainable Development **25,** 145–149.
http://dx.doi.org/10.1051/agro:2004064

Sanchez D, Garcia J, Antolin M. 2002: Effects of soil drought and atmospheric humidity on yield, gas exchange, and stable carbon isotope composition of barley. Photosynthetica **40,** 415–421.
http://dx.doi.org/10.1023/A:1022683210334

Singh T, Paleg L, Aspinal D. 1973. Stress metabolism III. Variations in response to water deficit in the barley plant. Australian Journal of Biological Sciences **26(1),** 65-76.
http://dx.doi.org/10.1071/BI9730065

Sio-Se Mardeh A, Ahmadi A, Poustini K, Mohammadi V. 2006. Evaluation of drought resistance indices under various environmental conditions. Field Crops Research **98,** 222–229.
http://dx.doi.org/10.1016/j.fcr.2006.02.001

SPSS, 2004. SPSS User's guide, SPSS Inc., Chicago, IL. USA.