RESEARCH PAPER

Evaluation of barley genotypes (*Hordeum vulgar* L.) by drought tolerance indices and multivariate analysis

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Abstract

To evaluation of tolerance of different barley genotypes to drought stress, an experiment carried out in randomized block design (RCBD) with three replication during 2009-2010 growing seasons and 20 barley genotypes were studied in normal and water deficit in post anthesis stage conditions at the Saatloo Research Farm Azerbaiejan, Iran. The result of variance analysis showed that there were highly significant differences between genotypes in all of the studied traits, also it was cleared that all of traits except spike length reduced in water deficit condition as compared to normal condition and seed yield, biomass and 1000 seed weight traits had the most reduction (31, 25 and 20 percent, respectively). To identify of tolerance barley genotypes to drought stress, drought tolerance indices (STI, TOL, SSI, MP, HM and GMP), correlation coefficients, principal components analysis and cluster analysis were used. The result of correlation coefficients indicated that there were significant and positive correlation between seed yield in normal and stress conditions and drought tolerance indices. Also the result of principal components analysis showed that two components justified 99% of total variations. MP, GMP, STI and HM indices and TOL and SSI indices had the most coefficients in the first and second component, respectively, so are named tolerance and sensitivity component, respectively. At last, it were cleared that MP, HM, STI and GMP indices were appropriate indices to select of drought tolerance barley genotypes. On the other hand, the result of cluster analysis showed that 13, 14 and 7 genotypes and 18, 1 and 2 genotypes were tolerance and sensitivity genotypes to water deficit at post anthesis stage.

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Introduction

Barley is one of the most important cereal crops grown in many development countries, where it is often subject to extreme drought stress that significantly affects production (Ceccarelli *et al.,* 2007). Drought stress is a multidimensional stress that effects on total green plant surface and plant response to drought stress are very intricate (Abarshahr, *et al.* 2011; Araus *et al.*, 2003). From the beginning of agriculture, drought is the main environmental constraint, causing famine and death in many parts of the world every year, often having devastating effects on crop productivity (Ilker *et al.* 2011; Khan and Naqvi, 2011; Nazari and Pakniyat, 2010; Kazmi *et al.*, 2003; Lafitte *et al.*, 2003; Pan *et al.*, 2002). The effects of drought on yield of crops depend on their severity and the stage of plant growth during which they occur (Rauf *et al.*, 2007). Improve yield under drought is a major goal of plant breeding (Cattivelli *et al.*, 2008). The best strategy for crop productivity, yield improvement, and yield stability under drought conditions is to develop drought-tolerant crop varieties (Cattivelli *et al.*, 2008). Understanding the plant response in dry conditions has great importance and also a fundamental part of producing drought-tolerant cultivars (Zhao *et al.*, 2008).

Selecting tolerant barley genotypes based on their yield performance under drought conditions is a common approach. Other approaches to identify tolerant genotypes to dry environment are drought tolerance indices. Several indices have been utilized to evaluate genotypes for drought tolerance based on grain yield in normal and stress environments (Talebi *et al.*, 2009; Pireivatlou *et al.*, 2010) and screen drought tolerant genotypes (Mitra, 2001). The most important criteria such as Tolerance (TOL) (McCaig & Clarke, 1982; Clarke *et al.*, 1992). Mean Productivity (MP) (McCaig & Clarke, 1982; Rosielle and Hamblin. 1981), Stress Susceptibility Index (SSI) (Fischer & Maurer, 1978; Clark, *et al.* 1992; Schneider, *et al.* 1997), Geometric Mean Productivity (GMP) (Acosta-Gollegos and Adams 1991; Ramirez-Vallejo and Kelly, 1998), Stress Tolerance Index (STI) (Fernandez,

1992), Stress Intensity (SI) (Munns and James, 2003), Yield Index (YI) (Gavuzi *et al.*, 1997; Lin, *et al.* 1986) and Yield Stability Index (YSI) (Bouslama & Schapaugh, 1984) have all been employed under various conditions. sayyah *et al.* (2011) in their study on wheat genotypes reported that MP, GMP, STI indices were the most suitable drought tolerance criteria for screening substitution genotypes and when the stress was severe, SSI index was found to be more useful index in discriminating resistant genotypes. In the experiment of Khakwani *et al* (2011), MP, GMP, STI, SSI and TOL indices are recognized as beneficial drought tolerance indicators for selecting a stress tolerant variety. Ilker, *et al.* (2011) studied tolerance of indices on wheat genotypes and concluded that MP, GMP and STI values were convenient parameters to select high yielding wheat genotypes in both stress and non-stress conditions whereas RDY, TOL and SSI values were better indices to determine tolerance levels.

Since different barley genotypes have different responses to drought stress, this research has founded. The purpose of this study was the evaluation of drought stress influences on different barley genotypes and assessment of their tolerance and sensitivity to stress conditions and finally select the best suitable parents for hybridization in the breeding patterns.

Materials and methods

Expremental Design and Plant Material

Twenty lines of winter barley (*Hordeum vulgare* L.) were chosen for investigation based on their reputed differences in yield performance under normal and drought stress conditions (the name of barley genotypes showed in table 1). Two separate field experiments were conducted the 2007-2008 and 2008-2009 growing seasons at the Saatloo Research Farm (1338 m above sea level, 35N, 45E), West Azerbaijan, Iran. Saatloo has 375mm annual rainfall on a long term average. The soil texture is clay-loom (30% clay, 53% silt and 17% sand) with 1.27% organic matter, a pH of 6.2 and EC of 2.5dS/m. The experiments were laid out as randomized complete

block design (RCBD) with three replications. Control plots were watered at tillering, Joining, flowering and grain filling stages, but stress plots were watered at pre-flowering phases. Before planting, the soil surface was ploughed during autumn and then disked twice in September. Fertilizers were applied before sowing (100kg ha-1 P2O3 and 50kg ha-1 N) and at stem elongation (50kg ha-1 N).

Calculate Drought Tolerance Indices
Drought resistances were calculated using the following indices:

Where Ys is the grain yield of genotype under drought stress, Yp the grain yield of genotype under non-stress, $\overline{Y}_s$ and $\overline{Y}_p$ the mean yields of all genotypes under stress and non-stress conditions, respectively, and $1 - \left(\dfrac{\overline{Y}_s}{\overline{Y}_p}\right)$ is the stress intensity.

Statistical Analysis
Analysis of variance, correlation among traits, correlation among indices and grain yield in two environments and Multivariate statistical analysis such as principle component analysis and cluster analysis were performed using SAS (SAS Institute 2002) and SPSS (version 21) software.

Results and discussions
Agronomical traits
The result of variance analysis of agronomical traits in normal and water deficit conditions demonstrated that there were high significant different between genotypes, years and genotypes × years (results do not shown). These results indicated that there were extremely genetic diversities between barley genotypes which can be used to select of appropriate genotypes for planting in any regains that exposed to water deficit at the end of vegetative stages, also genetic diversities between genotypes can be used in breeding programs and produced drought tolerance barley genotypes. On the other hand genotypes × year interaction was significant which shows that the genotypes responded differently to different treatments. Also Results of Khakwani, *et al.*, (2011) experiment showed highly significant difference among wheat varieties in all the studied traits and water stress conditions decreased them significantly (Abarshahr, *et al.* 2011).

Table 1. Code and Name of Genotypes.

Code	Genotpye
1	(EDB82-9)Rhn-03//L.527/NK1272
2	Manitou//Alanda/Zafraa
3	Pamir-149/ Victoria
4	AcuarioT75/Azaf
5	Pamir-146//EA389-3/EA475-4
6	Alpha/Durra/Pamir-160
7	Pamir-013/Sonata
8	Robur/WA2196-68//Wysor
9	Bugar/DZ48-232
10	Rhn-03//Lignee527/NK1272/5/Lignee527/Chn-01/4/Lignee527/
11	Mnitou//Alanda/Zafraa
12	Kny/K-273
13	Pamir-065
14	Pamir-168
15	Prodcutiv/3/Rono//Alger/Ceres362-1-1
16	Belt67-1608/Slr/3/Dicktoo/Cascade//Hip/4/CWB117-77-9-7
17	Belt67-1608/Slr/3/Dicktoo/Cas
18	U.Sask.1766/Api//Cel/3Weeah/4/Lignee527/NK1272/5/Express
19	(EC82-6)TWWd85-37/Kavir
20	(Bahman)WA196-68,F1//Scotia I

The results of statistical parameters of agronomical traits in normal and water deficit conditions (table 3) showed that all of agronomical traits except spike length reduced in water deficit condition as compared

to normal condition. Seed yield (31%), biomass (25%) and 1000 seed weight traits (20%) had the most reduction, respectively, whereas time of spike (0%) and time of maturity traits (6%) had the least reduction and spike length trait (-9%) not only reduced but also increased in water deficit condition as compared to normal condition, so these traits introduced as resistant traits to water stress. These results coincide with the findings of Khan and Naqvi (2011), Zhou *et al.* (2007), Chandler and Singh (2008) and Bayoumi *et al.* (2008) who observed that drought caused reductions in all of agronomical traits. Oak *et al.* (2006) and Panthuwan *et al.* (2002) in rice and Pandey *et al.* (2001) in wheat expressed that grain yield, spike number, 1000 seed weight and plant height traits decreased in drought stress condition by 10% to 80%, So, the overall effect of the drought stress depends on its intensity and length of stress (Bukhat, 2005). On the other hand Johnson & Kanemasu (1982) believed that under late season drought stress conditions, a fast decrease of current photosynthesis will be occurred which limits the translocation of assimilates into the grains.

Table 2. Drought Tolerance Indices.

Stress Tolerance Indices	equation	Reference
Stress Susceptibility Index	$SSI = (1 - \left(\dfrac{Y_s}{Y_p}\right)) \div (1 - \left(\dfrac{\overline{Y_s}}{\overline{Y_p}}\right))$	Fischer and Maurer (1978)
Geometric Mean Productivity	$GMP = \sqrt{Y_p \times Y_s}$	Fernandes (1992) and Kristian *et al.* (1997)
Mean Productivity	$MP = \dfrac{Yp + Ys}{2}$	Rosielle and Hambling (1981)
Harmonic Mean	$HM = \dfrac{2(Y_p \times Y_s)}{(Y_p + Y_s)}$	Jafari *et al.* (2009)
Tolerance Index	$TOL = (Yp - Ys)$	Rosielle and Hambling (1981)
Stress Tolerance Index	$STI = \dfrac{(Y_p)(Y_s)}{(\overline{Y_p})^2}$	Fernandes (1992)
Reduction (%)	$\dfrac{Y_p - Y_s}{Y_p} \times 100$	

Also the results of coefficient of variance (CV%) in normal and water deficit conditions (table 3) showed that seed yield, biomass and seed number of spike had the most diversity which can be used in breeding programs. Khakwani *et al* (2011) stated that total grain yield per plant, biological yield per plant and harvest index were higher diversity in wheat varieties, which put they as a good candidate for selection criteria in wheat breeding program for drought resistance.

The results of correlation coefficient between traits (table 4) showed that there were positive and significant correlations between seed yield in normal and water deficit conditions with harvest index, biomass, number of spike, plant height and spike length traits, so if these traits improve, seed yield would improve, subsequently. Also it is cleared that genotypes had more height, there were more stored photosynthesis materials in their stems and had more 1000 seed weight, harvest index and seed yield, subsequently. So selection of higher genotype in drought stress will improve seed yield in barely genotypes. On the other hand, there were significant and negative correlations between seed yield at normal and water deficit conditions with spike length, time of spike and time of maturity traits. So the selection of precocious genotypes improve seed yield of barely genotypes and safe the plant from drought and high temperature stresses at the end of growth

stage. Jongdee *et al.* (2006) have been reported that, in severe drought stress conditions, early flowering feature was a very important mechanism to escape from drought stress. Therefore, differences in flowering time among genotypes under these conditions can be used as stress tolerance index.

Table 3. Statistical parameters of agronomical traits on Barley genotypes in normal and stress conditions.

	Min		Max		Range		Average ± SE			CV %	
	Normal	Stress	Normal	Stress	Normal	Stress	Normal	Stress	Reduction %	Normal	Stress
Yield	4.5	2.51	5.64	4.25	1.14	1.74	4.98 ± 0.31	3.42 ± 0.46	31	12.59	14.29
Harvest Index	32.07	29.22	45.53	39.63	13.46	10.41	38.73 ± 4.09	34.28 ± 3	11	6.15	6.37
Biomass	10.93	6.75	16.06	11.45	5.13	4.69	12.94 ± 1.63	9.65 ± 1.34	25	12.66	11.83
Seed Number of Spike	20.17	17	37.67	30.17	17.5	13.17	27.63 ± 5.6	22.65 ± 3.68	18	10.55	11.62
1000 Seed Weight	30.06	23.94	49.93	43.47	19.88	19.53	45.21 ± 4.47	36.07 ± 4.63	20	4.98	6.06
Spike Number	48.67	45.67	83	73	34.33	27.33	64.13 ± 10.46	57.04 ± 8.1	11	8.56	10.8
Plant Height	61.65	47.8	82.96	71.6	21.31	23.8	72.57 ± 6.24	61.67 ± 6.65	15	1.87	1.93
Peduncle Length	18.27	18.74	31.72	26.29	13.45	7.56	24.76 ± 3.71	22.29 ± 2.39	10	8.35	8.11
Spike Length	3.81	4.64	6.72	7.57	2.91	2.93	5.58 ± 0.76	6.11 ± 0.75	-9	9.24	9.23
Time of Spike	120.17	120	129.67	130.33	9.5	10.33	124.24 ± 2.41	123.74 ± 2.76	0	0.92	1.12
Time of Maturity	165.67	155.17	180	170.67	14.33	15.5	173.03 ± 4.43	163.4 ± 3.58	6	0.56	0.57

Drought tolerance indices

The results of variance analysis of drought tolerance indices and seed yield in normal and water deficit conditions (Table 5) showed that there were significant differences between genotypes, years and genotypes × years. These results indicated that there are extremely diversity between barley genotypes from tolerance, resistance and sensitivity to water deficit stress. Also it enables us to select drought resistance genotypes to arid regions. Drikvand, *et al* (2012) in their study on wheat genotypes reported that there were highly significant differences among GMP, MP and STI and non-significant differences between SSI and TOL indices. This indicates the existence of genetic variation for the attributes studied and the possibility of selection for drought tolerance genotypes. The other researches such as Nazari and Pakniyat (2010) in barley genotypes reported high significant differences for all criteria. The results of compare means of seed yield in normal and water deficit conditions and drought tolerance indices (Table 6) showed that seed yield in all of genotypes reduced in water deficit condition as compared to normal condition. But the procedure of

reduction had different severities in barley genotypes, for example 1 and 2 genotypes had good yield in normal condition but their yield reduced in water deficit condition severity, whereas 13 and 3 genotypes had good yield in the both conditions, which indicated these varieties had stable performance, and produced a better yield under water deficit. The differential response of varieties to imposed water stress condition indicates the tolerance ability of barley varieties. These results are endorsed by sayyah *et al.* (2011) who observed yields in the normal conditions were positively correlated with yields in the stress conditions.

Among the stress tolerance indicators, a larger of TOL and SSI represent relatively more sensitivity to stress, thus a smaller value of TOL and SSI are favored to select of drought resistance genotypes. The lower these indices are, the more genotypes are drought resistance (Sio-Se Mardeh *et al.*, 2006; Clarke *et al.*, 1992). Several authors noticed that selection based on these two criteria favors genotypes with low yield potential under non stress conditions and yield under stress conditions (Golabadi *et al.*, 2006; Zangi, 2005;

Fernandez, 1992). In this study cleared that 13 genotype had the least value of TOL and SSI indices. It was more stable and showed high tolerance over water stress and introduced as resistant genotype. On the other hand 1 and 2 genotypes had the most value of TOL and SSI indices, so these genotypes are recommended as sensitivity genotypes. These results are in consistent with those reported by Zeinali *et al.*

(2004), Sio- Se Mardeh (2006), Talebi (2009), Sanjari and Yazdansepas (2008), Nouri *et al.* (2011), Mohammadi *et al.* (2010), Karimizadeh and Mohammadi (2011) and Mohammadi *et al.* (2011). All of whom found these resistance indices to be suitable for discriminating the best genotypes under stress and irrigated conditions.

Table 4. Correlation coefficients of agronomical traits on Barley genotypes in normal (below diagonal) and stress condition (above diagonal).

Traits	Yield (1)	Harvest Index (2)	Biomass (3)	Seed Number of Spike (4)	1000 Seed Weight (5)	Spike Number (6)	Plant Height (7)	Peduncle Length (8)	Spike Length (9)	Time of Spike (10)	Time of Maturity (11)
(1)	1	0.58 **	0.64 **	-0.24 *	0.35 **	0.74 **	0.40 **	0.59 **	-0.50 **	-0.39 **	-0.43 **
(2)	0.22 *	1	0.03	-0.03	0.29 **	0.64 **	0.25 **	0.53 **	-0.66 **	-0.37 **	-0.41 **
(3)	0.83 *	-0.32 **	1	-0.38 **	0.32 **	0.42 **	0.28 **	0.31 **	-0.01	-0.34 **	-0.28 **
(4)	0.06	0.05	-0.01	1	-0.46 **	-0.30 **	0.05	-0.16	-0.05	0.17	0.22 *
(5)	0.05	-0.13	0.13	-0.31 **	1	0.47 **	0.03	0.30 **	-0.19 *	-0.36 **	-0.31 **
(6)	0.74 *	0.14	0.63 **	-0.1	0.05	1	0.26 **	0.59 **	-0.56 **	-0.44 **	-0.42 **
(7)	0.57 **	0.22 *	0.45 **	-0.18	0.38 **	0.43 **	1	0.64 **	-0.12	-0.37 **	-0.11
(8)	0.42 *	0.19 *	0.31 **	-0.09	0.33 **	0.29 **	0.56 **	1	-0.52 **	-0.43 **	-0.24 **
(9)	-0.50 **	-0.42 **	-0.26 **	-0.32 **	0.30 **	-0.38 **	-0.17	-0.06	1	0.29 **	0.23*
(10)	-0.52 **	0.04	-0.53 **	0.18	-0.29 **	-0.57 **	-0.36 **	-0.17	0.19 *	1	0.36 **
(11)	-0.30 **	-0.08	-0.26 **	0.07	-0.11	-0.41 **	-0.09	-0.13	0.22 *	0.41 **	1

Table 5. Variance analysis of normal and stress yield and tolerance indexes on Barley genotypes.

S.O.V	Df	Yp	Ys	TOL	MP	SSI	GMP	STI	HM
Year	1	169.58 **	78.04 **	17.56 *	119.4 **	0.002	112.25 **	0.65 **	106.07 **
Error a	4	0.33	1.12	1.53	0.34	0.13	0.44	0.003	0.56
Genotype	19	0.59	1.27 **	1.31 *	0.60 **	0.15 **	0.69 **	0.005 **	0.82 **
× Year Genotype	19	1.06 **	1.45 **	2.54 **	0.62 **	0.23 **	0.72 **	0.006 **	0.88 **
Error b	76	0.39	0.24	0.61	0.16	0.05	0.16	0.001	0.17
Cv %	---	12.59	14.29	15.24	9.61	18.23	9.72	19.32	10.3

Since MP index calculates by the mean performance of seed yield at normal condition and seed yield at drought stress condition (Rosielle & Hamblin, 1981). So it is a sample and important index to select resistance and sensitivity genotypes. Seed yield of resistance genotypes have poor difference in normal and water deficit condition, so these genotypes have the higher MP value as compared to sensitivity genotypes. Fernandez (1992) believed that the

selection on MP index redounded that genotypes with high potential yield are selected. In this study, 7 and 14 genotypes and 1 and 16 genotypes had the most and the least MP, so they are nominated resistance and sensitivity genotypes, respectively. Sio-Semardeh *et al.* (2006) reported that genotypes with relatively low yield exhibited high MP values under stress conditions. As described by Farshadfar and Sutka

(2002), selection for MP increased yield in both stress and non-stress environments.

GMP and HM are geometric and harmonic means of seed yield in normal and water deficit conditions, respectively. So genotypes adjustments to drought stress and have high yield in normal and stress conditions, they have high geometric and harmonic means and nominated drought resistance genotypes (Abebe, *et al.*, 1998). In this study, 2 and 7 genotypes had the least and the most GMP and HM indices, so they are nominated sensitivity and resistance genotypes, respectively.

Table 6. Means compares of normal and stress yield and tolerance indexes on Barley genotypes.

Genotype Code	Yp	Ys	TOL	MP	SSI	GMP	STI	HM	TT	Rank
1	5.06 a	2.78 bc	2.28 a	3.92 abcd	0.79 ab	3.73 abc	0.13 bc	3.55 bcd	6.00	19
2	4.67 a	2.51 c	2.15 a	3.59 abcd	0.84 a	3.41 c	0.11 c	3.24 d	5.35	20
3	4.78 a	3.85 ab	0.93 a	4.32 abcd	0.37 ab	4.28 abc	0.18 abc	4.25 abc	8.41	4
4	4.94 a	3.14 abc	1.81 a	4.04 abcd	0.72 ab	3.92 abc	0.15 abc	3.80 abcd	6.77	16
5	5.16 a	3.50 abc	1.66 a	4.33 abcd	0.57 ab	4.24 abc	0.18 abc	4.15 abcd	7.69	10
6	4.67 a	3.81 ab	0.86 a	4.24 abcd	0.34 ab	4.21 abc	0.16 abc	4.18 abcd	8.30	5
7	5.64 a	3.90 ab	1.74 a	4.77 a	0.54 ab	4.68 a	0.21 ab	4.59 a	8.59	2
8	4.51 a	2.96 bc	1.55 a	3.73 abcd	0.60 ab	3.63 bc	0.13 bc	3.53 cd	6.44	17
9	5.08 a	3.75 ab	1.34 a	4.42 abcd	0.44 ab	4.33 abc	0.18 abc	4.25 abc	8.19	7
10	5.01 a	3.65 abc	1.36 a	4.33 abcd	0.47 ab	4.26 abc	0.17 abc	4.19 abcd	7.99	9
11	4.67 a	3.80ab	0.87 a	4.24 abcd	0.38 ab	4.20 abc	0.18 abc	4.17 abcd	8.26	6
12	5.11 a	3.69 abc	1.42 a	4.40 abcd	0.48 ab	4.33 abc	0.18 abc	4.26 abc	8.11	8
13	4.94 a	4.25 a	0.70 a	4.60 abc	0.28 b	4.57 ab	0.22 a	4.54 ab	9.22	1
14	5.32 a	3.93 ab	1.39 a	4.63 ab	0.55 ab	4.53 ab	0.21 ab	4.43 abc	8.45	3
15	5.54 a	3.30 abc	2.24 a	4.42 abcd	0.64 ab	4.18 abc	0.16 abc	3.98 abcd	7.10	12
16	4.86 a	3.14 abc	1.72 a	4.00 abcd	0.60 ab	3.89 abc	0.14 abc	3.78 abcd	6.87	14
17	4.86 a	3.31 abc	1.55 a	4.08 abcd	0.64 ab	3.98 abc	0.16 abc	3.88 abcd	7.13	11
18	4.50 a	2.80 bc	1.70 a	3.65 abcd	0.74 ab	3.54 c	0.12 bc	3.44 cd	6.05	18
19	5.31 a	3.13 abc	2.17 a	4.22 abcd	0.68 ab	4.05 abc	0.16 abc	3.90 abcd	6.88	15
20	5.04 a	3.28 abc	1.76 a	4.16 abcd	0.67 ab	4.02 abc	0.15 abc	3.89 abcd	7.04	13

Study of drought effects on crops showed that seed yield of drought sensitivity genotypes reduce in drought stress condition, severely. So these genotypes have the least of STI value, whereas resistance genotypes have good yield in normal and stress conditions and their differences are very little. So these genotypes have the most of STI value. In totally, the STI index is used to select resistance and sensitivity genotypes in drought stress conditions (Fernandez, 1992). In this study, 2 and 13 genotypes had the least and the most STI index, so they are nominated sensitivity and resistance genotypes, respectively. Pireivatlou *et al.* (2010) was also noted that STI can be a reliable index for selecting high yielding genotypes. In this regard, Moghaddam and Hadi-Zadeh (2002) found that STI was more useful index in order to select favorable cultivars under stressful and stress-free conditions.

In totally, genotypes have the least of SSI and TOL indices and the most of HM, MP, GMP, STI and SI are nominated drought resistance genotypes. So another index is identified that it is ranking genotypes on all of drought tolerance indices. This index is calculating on blow equation:

$$TTI = HM + GMP + STI + MP + SI - SSI - TOL$$

In this equation, the genotypes have higher value; they are resistant to drought stress. Inversely, the genotypes have lower value; they are sensitivity to

drought stress. The results of this index are shown in table 6. According this index, 13, 7 and 14 genotypes and 1, 2 and 18 genotypes had the most and the least value, so they are identified the resistance and sensitivity genotypes to drought stress, respectively.

To study of liner relationships between seed yield in normal and water deficient stress conditions and drought tolerance indices, correlation coefficients are calculated (table 7). The results of correlation coefficients showed that seed yield in both conditions had positive and significant correlation with together. These results are confirmed with Karami *et al.* (2005), Farshadfar *et al.*, (2001) and Golabadi *et al.*, (2006), completely. Whereas, Feranandez (1992) in his research reported that the genotypes with good yield in normal condition may hadn't desirable yield in water deficient stress condition.

Table 7. Correlation coefficients of normal and stress yield and tolerance indexes on Barley genotypes.

	Yp	Ys	TOL	MP	SSI	GMP	STI	HM
Yp	1	0.64 **	0.61 **	0.93 **	0.25 **	0.88 **	0.86 **	0.83 **
Ys		1	-0.22 *	0.88 *	-0.56 **	0.93 **	0.93 **	0.96 **
TOL			1	0.27 **	0.89 **	0.16	0.14	0.07
MP				1	-0.12 **	0.99 **	0.98 **	0.98 **
SSI					1	-0.22 *	-0.23 *	-0.30 **
GMP						1	0.99 **	0. 99 **
STI							1	0.99 **

On the other hand, it is cleared there were positive and significant correlations between seed yield in both conditions with GMP, MP, STI and HM indices. These results indicated that GMP, MP, STI and HM indices are very good criteria to select genotypes with high yield in normal and water deficient stress conditions. Therefore, it seems that selection planning based on these parameters can lead to determine tolerance barley is one of the most plausible strategies for better crop improvement under water deficient stress conditions. Blum (1996); Panthuwan *et al.*,(2002) and Sio-Se Mardeh *et al.*, (2006) believed that the effectiveness of selection indices depends on the stress severity supporting the idea that only under moderate stress condition, potential yield greatly influences yield under stress.

Table 8. Eigen value and vectors of principal component analysis for potential yield (YP), stress yield (YS) and stress tolerance indices.

| component	YP	YS	TOL	MP	SSI	GMP	STI	HM	Cumulative %	Eigen value
1	0.92	0.66	-	0.94	-0.34	0.88	0.84	0.82	76.4	4.4
2	-0.4	0.75	-	0.35	-0.91	0.48	0.50	0.57	98.5	3.5

Nazari and Pakniyat (2010) showed the significant and positive correlation of Yp and Ys with MP, GMP and STI, as well as, significant negative correlation of SSI and TOL. At last they revealed that selection for high values of MP, GMP and STI and low values of SSI and TOL could be useful. They also stated STI, MP and GMP are the best criteria for selection of high yielding genotypes both under stress and non-stress conditions. Drikvand, *et al* (2012) in wheat genotypes, Siose Marde *et al.* (2006); Golabadi *et al.* (2006) in durum wheat reported that GMP, MP and STI indices that were correlated with grain yield under both conditions, so they are suitable indices for screening wheat genotypes. Talebi *et al.* (2009) also reported that cultivars producing high yield in both drought and well watered conditions can be identified by STI, GMP and MP values.

Multivariate analysis
*Principal analysis*

In order to further investigation on relationship among genotypes and stress tolerance indices, principal component analysis were performed (Table 8) that was reduced six indices down two components that they could overall justify about 99% of total variance. PCA revealed that the first component explained 74% of the total variation and the Yp, Ys, HM, MP, GMP and STI indices had the highest coefficients. Thus, the first dimension can be named as the yield potential and water deficient tolerance and these indices are the most important criteria to select favorite genotypes under normal and stress conditions. Talebi *et al.* (2009) also reported that cultivars producing high yield in both drought and well watered conditions can be identified by STI, GMP and MP values. These results coincide with the findings of Golabadi *et al.* (2006) in durum wheat, Farshadfar and sutka (2002) in wheat. The second PCA explained 25% of the total variation and SSI and TOL indices had the highest coefficients, so this component is named sensitive component. Fernandez (1992) believed that among the stress tolerance indicators, a larger of TOL and SSI represent relatively more sensitivity to stress, thus a smaller value of TOL and SSI are favored. Several authors noticed that selection based on these two indexes favors genotypes with low yield under non-stress conditions (Golabadi *et al.*, 2006).
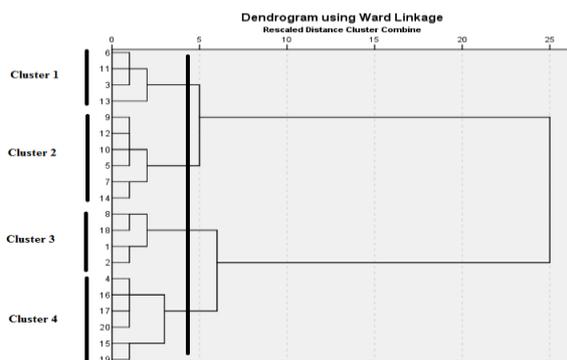
Fig. 1. Dendrogram from cluster analysis based on stress tolerance indices and yield of barley genotypes in both normal and stress conditions.

According to the result of PCA, the selection of genotypes that have high PCA1 and low PCA2 are suitable for water deficient environments. Therefore in this study 13, 14, 7 genotypes introduced as suitable

and tolerant genotypes and 1, 2 and 18 genotypes introduced the most sensitive genotypes to orobanche weed stress. Drikvand, *et al* (2012) in their study on wheat genotypes reported that Principal component analysis reduced five indices down to two components with 99.49% proportional cumulative variance. Correlation and principal component analysis indicated that the most suitable criteria for the identification of genotypes under irrigated and rain fed conditions were GMP, MP and STI indices.
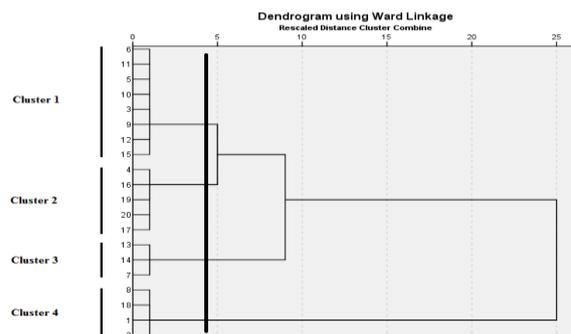
Fig. 2. Dendrogram from cluster analysis based on HM, GMP, MP ant TOL indices and yield of barley genotypes in both normal and stress conditions.

Cluster analysis
In order to classify of barley genotypes, cluster analysis on Wards Method is used. The result of cluster analysis on all of the drought tolerance indices (dendrogram 1) showed that studied barley genotypes classified in 4 classes. The numbers of genotypes in each class were 4, 6, 4 and 6 genotypes, respectively. The genotypes in each cluster evaluated together on agronomical traits and tolerant indices. Also the results of cluster analysis were compared to the ranking of genotypes in the table 6. At last it is confirmed that the results of cluster analysis on all of the tolerant indices were not accurate results. So the cluster analysis was performed on STI, MP, GMP and HM indices (the most important criteria that confirmed on correlation coefficients and principal component analysis, formerly). The results showed (dendrogram 2) that the tobacco genotypes classified in 4 classes. The numbers of genotypes in each class were 8, 5, 3 and 4 genotypes. These results were completely agreement to the ranking of genotypes in table 6. The genotypes in each class evaluated on agronomical traits and tolerant indices. At last it is

cleared that the genotypes in the first, second, third and fourth class were resistance, sensitive, very resistance and very sensitive genotypes, respectively. The other researchers such as sayyah *et al.* (2011), Drikvand, *et al* (2012) and Azizinia *et al.* (2005) on wheat genotypes, Abarshahr *et al.* (2011) on rice genotypes, Farshadfar *et al.* (2001) on chickpea genotypes used cluster analysis for grouping genotypes on stress tolerance indices.

Overall conclusion

In totally, the results of the present study showed that there were high genetic differences between barley genotypes on agronomical traits and drought tolerance indices, so these genetic differences between barley genotypes can be used in breeding programs to product appropriate genotypes at normal and drought conditions. So in this study, it is confirmed that drought tolerance indices as efficiency criteria could be used to select drought resistant and sensitivity genotypes. Also the results of correlation coefficients and principal components analysis showed that GMP, MP, STI and HM indices were good criteria to select genotypes with high yield and drought resistance. Cluster analysis is used for classifying barley genotypes. Overall, in this study cleared that 7, 13 and 14 identified as resistant genotype, so these genotypes recommended to normal and drought regions, but 1, 2 and 18 genotypes identified as sensitivity genotypes, so these genotypes only recommended to normal regions.

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Abbreviation

Stress Susceptibility Index (SSI), Geometric Mean Productivity (GMP), Mean Productivity (MP), Harmonic Mean (HM), Tolerance Index (TOL), Stress Tolerance Index (STI), Randomized Complete Block Design (RCBD), Variation Coefficient (CV), Standard Deviation (Std).