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Evaluation of Drought Stress Indices in barley (*Hordeum vulgare* L.)

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ABSTRACT

In order to evaluation of drought resistant indices in barley (Hordeum vulgare L.), 10 barley genotypes evaluated in Completely Randomized Design with three Replications in two conditions, (under drought stress and in normal with irrigation in planting, flowering and grain filling stages) in Islamic Azad University, Miyaneh Branch Research Farm in 2012. Drought tolerant indices basis of yield performance in drought (Y_s) and normal (Y_p) environments such as Mean productivity (MP), Stress tolerance (TOL) Geometric mean productivity (GMP), Stress Susceptibility index (SSI) and Tolerance index (STI) and eight main crop parameters such as plant height, spike height, number seed per spike, number tiller, 100 seed weight seed yield, biomass yield and harvest index were calculated. Results showed that the difference among the majority of traits in both normal and under drought conditions was significant. Mean comparison displayed that the value of all traits under drought condition in compare with normal condition was decreased. By the way, the highest value of spike height, the number of seeds per spike, seed yield and biomass yield in both drought and normal condition devoted to genotypes number 9 and 2 respectively. Based on Drought tolerant indices the highest amounts of STI, GMP and MP were related to genotypes of Gkomega/cab117-5-9-5//Sararood/….. and Yesevi-93/6/Tokak/3/BK…. in both under drought and normal conditions. Correlation analysis between seed yield and all indices revealed that there are positive and significant relationship among STI, GMP, MP and seed yield in both under drought and normal conditions. Therefore, STI, GMP and MP are the best indices for screening drought tolerant genotypes in barley. Cluster analysis based on GMP, MP and STI indices divided 10 genotypes of barley in to two main resistant and sensitive groups. Drought tolerant genotypes were number 2 and 9.

Key words: Barley, Drought Stress Indices, Crop parameters, *Hordeum vulgar*

INTRODUCTION

Barley with scientific name of *Hordeum vulgar* is one of the most important crop families which after wheat, rice, corn and potato has the fifth rank in production point of view in world. Also, barley is the main food resource for human beings and livestock in Middle East. The adaptation of barley is better than wheat and other crops in environmental stresses condition. But, unfortunately because of lack of under ground water resources and drought circumstance in Miyaneh region the seed yield of barley (*Hordeum vulgare* L.) is decreasing strongly. In fact, in dry and semi-dry lands like Miyaneh where the amount of rainfall is approximately less than 300 mm. Also, rainfall distribution is very different in each year. For this reason, the prediction of amount and distribution of rainfall in each year is very hard. In regard with this problem a study conducted to assess drought indices and some crop parameters so that selection genotypes that are more stable in dry and semi dry regions. Ilyas Khokhar and *et al.,* [8] indicated that Based on a principal component analysis, Geometric Mean Productivity (GMP), Mean Productivity (MP) and Stress Tolerance Index (STI) were considered to be the best parameters for selection of drought-tolerant genotypes. In addition, they suggested that breeders should select better genotypes based on mainly four indices (GMP, MP, STI and YI) under stressed condition and compare results with performance under irrigated condition by using different methods of selection. Jafari and *et al*, [10] reported that Stress Tolerance Index, Geometric Mean

Productivity, and Harmonic Mean indices, which showed the highest correlation with grain yield under both optimal and stress conditions, can be used as the best indices for maize breeding programs to introduce drought tolerant hybrids. Drought indices which provide a measure of drought based on yield loss under drought condition have been used by other researchers. Moghaddam and Hadi-Zadeh [13], found Stress Tolerant Index (STI) was more useful to select favorable corn cultivars under stressful and non-stress conditions. Firozi and *et al.*, [3] displayed that MP and STI were significantly correlated with seed yield in both stress and non-stress conditions. They added that these indices are able to discriminate group A cultivars from others. Also, Sio-Se Mardeh *et al.*, [17] suggested that selection for drought tolerance in wheat could be conducted for high value of MP, GMP and STI under stress and non-stress environments. In all, this study was conducted to determine drought tolerant genotypes and high-yielding genotypes to be resistant against drought in dry land and semi dry land regions. Also, we decided to find out the best drought tolerance indices and traits which help us to release tolerant cultivars of barley in Miyeneh, Iran region.

MATERIALS AND METHODS

The experiment was conducted in Scientific and Research farm of Islamic Azad University, Miyaneh Branch, Iran in 2012. Ten genotypes of barley (Table 1) were compared in 2 under drought and normal conditions (irrigation in planting, flowering and grain filling stages) in a Completely Randomized Design with 3 replications. Each plot consisted of six rows with three meter in length, spaced 20 cm apart with seed density of 400 seeds/m^2.

Crop Parameters: The average of agronomic parameters of 20 plants in each plot such as plant height, spike height, number seed per spike, number tiller, 100seed weight seed yield, biomass yield and harvest index were recorded at the appropriate phonological stages.

Table 1.The name\pedigree of ten barley genotypes which studied in this research

No.	Genotypes\pedigree	No.	Genotypes\pedigree
1	Pamir-168/Gara arpa	6	Aday-1/4/Tokak/3/…
2	Gkomega/cab117-5-95//Sararood/…..	7	Aday-1/5/Tokak/4/scio/3/….
3	Pamir-168/4/ICB-102893/3/…	8	Yesevi-93/6/Tokak/5/cwB117….
4	Uzno-Kazakastan/3/cwB117….	9	Yesevi-93/6/Tokak/3/BK….
5	Tokak/4/Mal-w/J-126//…	10	Orza-96/4/Tokak/3/CW117-77-9-7//…

Drought resistance indices were calculated by using the following formula:

$TOL = (Y_P - Y_S)$ [7].

$GMP = \sqrt{Y_p - Y_s}$ [2].

$STI = (Y_P \times Y_S) / (M_S)^2$ [2].

$SI = 1-(M_s / M_p)$

$SSI = (1- (Y_S/Y_P)) /SI$ [4].

Where, SI is Stress Intensity and M_S and M_p are means of all genotypes under drought and normal conditions, respectively.

$MP = (Y_P+Y_S)/ 2$ [7].

In these relationships Y_s is the yield of lines under stress, Y_p the yield of lines under irrigated conditions, Y_s and Y_p are the mean yield of all cultivars under stress and non-stress conditions, respectively.

MSTAT_C computer software program was used to analysis of variance and Mean comparison of traits. Correlation and cluster analysis of diagram was done by using SPSS 13 software and the mean of total traits were calculated by using EXCEL software.

RESULTS AND DISCUSSION

According to Table 2 and 3, there were significant differences among all genotypes based on all traits in short of 100 weight seed in both under drought and normal conditions. Karimi and *et al*. [11] also displayed that the differences

among all traits in barley genotypes were significant. Therefore we can conclude that there is genetic diversity among different genotypes that allow us to select the tolerant genotypes in drought condition.

Table2. Mean squares of seed yield and yield components of barley in normal condition.

S O V	df	MS							
		plant height	Spike height	No. seed per spike	No. tiller per plant	100 weight seed	Seed yield	biomass yield	Harvest index
Rep	2	189.3**	0.86	2.60	0.040	8.84	2178872.7**	3461210.5*	270.43**
Genotype	1	109.21**	1.65**	8.63**	6.98**	5.88	219001.8**	1561493.1**	8.81*
Error	2	7.15	0.096	1.609	1.018	4.3	59570.04	502367.3	6.69
CV%	-	3.2	3.3	6.8	15.9	6.5	6.4	6.01	8

**and ** : Significant at the 5% and 1% levels of probability, respectively.*

Table3. Mean squares of seed yield and yield components of barley under drought condition
*******and ** : Significant at the 5% and 1% levels of probability, respectively.*

S O V	df	MS							
		plant height	Spike height	number seed per spike	No. tiller per plant	100 weight seed	Seed yield	biomass yield	Harvest index
Rep	2	3.60	1.08	0.076	5.025*	13.30	619526.4**	5041154.4**	26.4
Genotype	1	61.48**	1.88**	9.99**	4.47**	12.12	174241.6**	14653.6**	23.2*
Error	2	23.52	0.192	0.914	0.72	8.25	55086.9	268705.7	14.43
CV%	-	6.9	5.7	5.8	17.8	10.5	8.2	5.6	12.2

Based on Table 4, we can see that genotype number 9 had the highest amount of spike height, number seed per spike, 100 seed weight, seed yield and biomass yield in normal condition. But, the highest number of tiller per plant was related to number 6. Also, highest percentage of harvest index observed in genotype number 9 with value of 35 percent.

Mean comparison of traits under drought condition showed that the highest value of spike height, seed yield and biomass yield was related to genotype number 9 (Table 5). It seems that genotype number 9 in both normal and under drought condition had the highest amount of seed yield. The percentage of harvest index and number tiller per plant under drought condition with value of 36.6% and 7 respectively were devoted to genotype number 6. In all we can conclude that drought stress had significant influence on the majority of traits and based on spike height, the number of seeds per spike, seed yield and biomass yield we can select the best and resistant genotypes in dry land area. The results also have revealed that, traits like number of seeds per spike and biomass yield could be used as selection indexes for improving grain yield in the studied barley cultivars. In regard with our result Karami and *et al* [11] in assessing of drought resistance in barley also reported that Drought stress caused decrease in days to maturity, plant height, peduncle length, leaf number per plant, grain yield per plant, thousand- kernel weight value as well as harvest index.

Table 4.Mean comparison of seed yield and yield components of barley in normal condition

No. Genotypes	Plant height (cm)	Spike height(cm)	No. seed per spike	No. tiller per plant	100 seed weight(gr)	Seed yield(kg/ha)	Biomass yield(kg/ha)	Harvest index(%)
1	80.3bc	9.6bcd	19abc	7.3bc	30.4b	3464.1b	11338b	30.6ab
2	84.6b	6.2cd	19.6ab	5.8bcdef	34.3ab	4164.3ab	12284b	34.3ab
3	81.3bc	9.7abc	18bc	4.8ef	30.9ab	3462.3c	11396b	30.6ab
4	90.3a	8.1e	19.6ab	4.3f	33ab	3799.5bc	11703.6b	32.6ab
5	89.3a	9.2cd	19.3abc	6.8bcd	31ab	3893.8abc	11670b	33.3ab
6	73.3d	9.1d	14.6d	9.3a	31.9ab	3791.4bc	11353.3b	33.3ab
7	91.3a	8.3e	17.3bc	6.5bcdef	31.8ab	3665.3c	11377b	32ab
8	79c	8.2e	18.3ca	5.4cdef	32.4ab	3861.6abc	11111.6b	35a
9	80.3bc	10.2a	20.6a	7.6ab	34.6a	4281.4a	13530a	31.6b
10	77cd	9.9ab	17c	5.2ef	31.6ab	3613.1c	12250.3b	29.6b

Means with same letters in each column are not significantly different at 0.05 of probability level

According to seed yield in normal condition (Y_p), seed yield under drought condition (Y_s) and five quantitative drought tolerant indices in Table 6, genotypes of Gkomega/cab117-5-9-5//Sararood/….. and Yesevi-93/6/Tokak/3/BK…. had the highest value of STI and GMP. Khalili and *et al*. [12] reported that based on Geometric Mean Productivity (GMP) and STI indices, corn hybrids with high seed yield in both normal and drought environments can be selected. Therefore, results showed that genotypes of Gkomega/cab117-5-9-5//Sararood/….. and Yesevi-93/6/Tokak/3/BK…. were more resistant than other genotypes in Miyaneh region. Other researchers

such as Imamjomah [9] and Farshadfar and Sutka [1] introduced STI and GMP as useful indices for screening genotypes in check pea and maize respectively. Also, we observed that according to Tables 4 and 5 genotypes of number 2 and 9 had the highest amount of seed yield in both under drought and normal conditions with 4164.3, 4281.4 and 2963.4, 3399.5 kg ha^{-1} respectively. Again, based on Table 6, genotypes number 9 and 2 had the highest value of MP. Salehi and *et al.*, [16] indicated that MP had the main role in screening drought tolerant genotypes in lentil (Lens Culinaris *Medik*) and genotypes with high amount of MP were more stable in drought condition. For this reasons, genotypes number 2 and 9 are more desirable in low rainfall area. The genotypes of number 1 and 10 had the lowest value of TOL and SSI (Table 6). Nazari and Pakniyat, [15] reported that among stress tolerance indicators, a larger value of TOL and SSI represent the sensitive genotypes under drought condition .Thus, genotypes with low value of TOL and SSI are Favorite in dry and semi-dry regions. Besides, Golabadi and *et al*.,[5] indicated that Selection based on TOL and SSI distinguish genotypes with low seed yield in normal condition and high seed yield under drought condition. It is necessary to mention that in this present experiment the value of SI was estimated 0.254 as Fisher and Maurer [4].

Table 5.Mean comparison of seed yield and yield components of barley under drought condition

No. Genotypes	Plant height (cm)	Spike height(cm)	No. seed per spike	No. tiller per plant	100 seed weight(gr)	Seed yield(kg/ha)	Biomass yield(kg/ha)	Harvest index(%)
1	69bc	8.7a	16.6cde	4.6bc	29a	2667.1b	8962.3bcd	30ab
2	75.3ab	8ab	19.3a	5.9ab	29.5a	2963.4b	9698.3ab	30.6ab
3	68bc	6.8cd	16.03cde	3.2a	25a	2558.6c	8931.6bcd	28.6b
4	72.3abc	6.6d	17.3bc	4.7bc	26a	2749.1b	8505.3d	32.6ab
5	78.3a	7.4bc	15.3df	4.8bc	26.5a	2662.6b	9554.3abc	28b
6	64.3c	8.4a	16cde	7a	25.1a	2897.03b	8054.6d	36.6a
7	67.3bc	6.5d	17bcd	4c	25a	2707.5b	9929.3a	27.3b
8	70.6abc	7.5bc	13f	3.3c	28.3a	2757.8b	8791.6bcd	33ab
9	70.6abc	8.5a	18.6ab	6ab	30.3a	3399.5a	10282.6a	32.3ab
10	64c	8.1ab	15e	4.03c	28.06a	2975.8b	8685.3cd	31.3ab

Means with same letters in each column are not significantly different at 0.05 of probability level

Table 6.Seed yield in normal condition (Y_p), seed yield under drought condition (Y_s) and five quantitative drought tolerant indices for 10 barley genotypes

genotypes	STI	GMP	MP	SSI	Tol	Y_p	Y_s
1	0.6399	3039.5	3065.6	0.905	797	3464.1	2667.1
2	0.8547	3512.9	3563.8	1.134	1200.9	4164.3	2963.4
3	0.6135	2976.3	3010.4	1.026	903.79	3462.3	2558.6
4	0.7234	3231.9	3274.3	1.087	1050.4	3799.5	2749.1
5	0.7181	3219.8	3278.2	1.243	1231.2	3893.8	2662.6
6	0.76077	3314.1	3344.2	0.927	894.3	3791.4	2897/03
7	0.6873	3150.2	3186.4	1.027	957.8	3665.3	2707.5
8	0.7376	3263.3	3309.7	1.124	1103.8	3861.3	2757.8
9	1.008	3815.05	3840.4	0.8103	881.9	4281.4	3399.5
10	0.7445	3278.6	3294.1	0.6946	638	3613.1	2975.8

**and **Means significant at 5 and 1% levels of probability, respectively. Y_p: Yield under non-stress condition, Y_s: Yield under stress condition, TOL: Tolerance index, GMP: Geometric mean productivity, SSI: Stress susceptibility index, Yr: Yield reduction ratio, STI: Stress tolerance index*

Table 7.Correlation coefficients among Y_p, Y_s and drought tolerance indices

Variables	Y_s	Y_P	TOL	SSI	MP	GMP	STI
Y_S	1						
Y_P	0.74*	1					
TOL	0.21	0.49	1				
SSI	-0.53	0.16	0.93**	1			
MP	0.92**	0.94**	0.17	-0.17	1		
GMP	0.94**	0.92**	0.11	-0.23	0.99**	1	
STI	0.94**	0.91**	0.10	-0.24	0.99**	0.99**	1

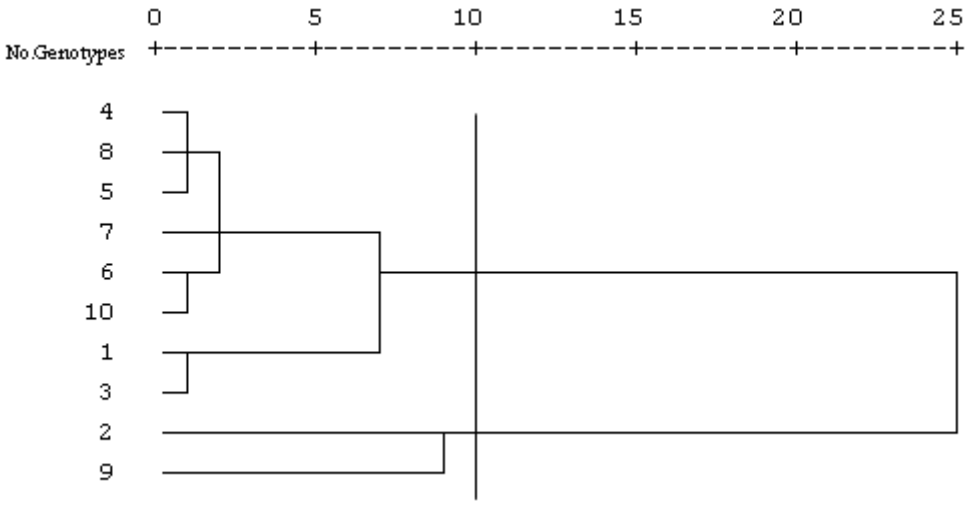
**and **Means significant at 5 and 1% levels of probability, respectively.*

To determine the accurate drought tolerance indices for screening barley genotypes, the correlation coefficient between Y_s, Y_p and five quantitative indices calculated. Results showed that correlation coefficient between TOL and SSI in regard with seed yield in both normal and drought conditions were insignificant and the correlation between Yp and Y_s were positively significant ($r_{=}0.74$). Also, insignificant correlation observed between TOL with GMP and TOL with STI (Table 7). Based on Table 7, SSI index had negative and insignificant correlation with seed yield under drought condition and positive and insignificant correlation in normal condition. Guttieri and *at el.*, [6] used SSI in their investigation and suggested that the value of SSI more than one indicates above-average

susceptibility to drought stress. Correlation analysis showed that Y_p and Y_s had highly significant and positive correlation with STI, MP and GMP. Also, the correlation among STI, MP, and GMP were positive and significant (Table 7). Thus, STI, MP and GMP can be the most desirable indices for screening drought tolerant genotypes in barley. The same results reported by Talebi and *et al*., [18] in drum wheat and Salehi *et al*., [16] in lentil.

Cluster analysis of date based on GMP, MP and STI can show the stable and sensitive genotypes precisely. According to Figure 1, Cluster analysis divided ten barley genotypes in to two main groups which included drought tolerant genotypes (Number 2 and Number 9) and genotypes which were not suitable in drought condition and had less amount of seed yield in compare with other genotypes (numbers 1, 3, 4, 5, 6, 7, 8 and 10). Using cluster diagram and cluster analysis for selection of drought resistant items was assessed and confirmed by Salehi *et al*, [16] in lentil and Farshadfar *et al*, [1] in Chickpea and Mohammadi *et al* [14] in drum wheat.

Fig1.Dendrogram produced by UPGMA cluster analysis of ten barley genotypes



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