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Evaluation of drought tolerance of bread wheat genotypes by stress and sensitivity tolerance indices

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ABSTRACT

In order to evaluate the tolerance of bread wheat genotypes to end-season drought, an experiment was carried out by 14 genotype in the form of randomized complete blocks design with three replications along with two separate tests, one for normal irrigation and other for end- season drought stress conditions in three regional countries including Pars Abad, Bilesavar and Ardabil in 2010-2011 agricultural years. Application of sensitivity and stress tolerance indices such as MP, GMP, TOL, SSI and STI on grain yield showed that among the 14 genotypes, genotype 10 was the most desirable genotype. Also, with respect to a meaningful and positive correlation between biomass weight at anthesis stage and grain weight in spike in both normal irrigation and stressed conditions after the anthesis stage, it is recommended that the use of grain weight in spike at anthesis time in breeding programs should be considered.

Keywords: drought stress, tolerance index, morpho-physiological traits

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INTRODUCTION

Bread wheat (*Triticum aestivum* L.) is undoubtedly the most important agronomical plant and plays a major role among the few agronomical plants which are planted as food source in a vast expansion of area and it has probably been the pivot for the origination of agronomy [1]. Wheat is produced under a wide range of climactic conditions and geographical areas and due to its high adaptability with various climactic conditions of environment, its distribution range is more than that of any other plant species and it is the staple food for most of the world's increasing population [2]. Of 2.3 million hectares of irrigated wheat in the country, in a range about 900 thousand hectares of irrigated wheat varieties are planted in cold regions [3]. In these areas, farmers do not obtained desirable results in the promising irrigated cultivated varieties due to lack of sufficient water in the spring and/or lack of sufficient irrigation water allocated to agriculture by the end of the summer season and consequently wheat farming suffer the end-season drought stress [4]. Therefore, study of different traits including relative yield of genotypes under stressed and non-stressed conditions is as a starting point for understanding the drought tolerance process and selection of genotypes to improve in dry regions [5].

Gibbs [6] considered drought equivalent to the water shortage and defines it as the concept of imbalance between supply and demand of water for the plant. In order to determine how different genotypes react in stressed and non-stressed conditions [7] he divided them into four categories:

1- genotypes which have high yield in both stressed and non stressed conditions (group A)
2- genotypes which have only high yield in non-stressed conditions (group B)
3- genotypes which have only high yield in stressed conditions (group C)
4- genotypes which have poor presentation in both stressed and non-stressed conditions (Group D)
5- In Fernandez's opinion, the most appropriate selection criteria is criteria that can differentiate genotypes group A from other groups. To identify genotypes reaction to stressed conditions, indices had been presented by researchers which we have referred to some of them.

Stress sensitivity index (SSI) which presented by Fisher and Maurer [8] and is calculated as following formula:

$$SI=1-(Y_s/\ Y_p) \quad \text{sensitivity index-1}$$
$$SSI= (1-(\ Y_{si}\ /\ Y_{pi}))\ /SI \quad \text{stress sensitivity index -2}$$

In above relations, Ypi is grain yield of each genotype in non-stressed conditions; Ysi is grain yield in stressed conditions; Ys average yield of genotypes in stressed conditions and Yp is average yield of genotypes in non-stressed conditions.

Genotypes that are selected by SSI have low potential yield, but their yield is high under stressed conditions. Thus this index can not separate group A from group C, although it can separate genotypes groups B and C from other groups.

TOL and MP indices:
Proficiency index (MP) and tolerance index (TOL) were presented by Rosielle and Hamblin [9]. It is noteworthy that the selection of stress tolerant genotypes is based on low values of TOL and high values of MP. Using TOL and MP indices, it is possible to separate genotypes groups B and C of Fernandez from each other [9].

$$MP= (\ Y_{pi} + Y_{si})/2 \quad \text{Proficiency index}$$
$$TOL= (\ Y_{pi} - Y_{si}) \quad \text{Tolerance index}$$

Stress tolerance index (STI):
It was presented by Fernandez [7] which is able to identify the genotypes group A and this index is calculated as follows:

Genotype that has high STI has high drought tolerance and yield potential.

$$STI= (Y_{pi} \times Y_{si})\ /\ Y_p^2 \quad \text{Stress tolerance index -3}$$

Geometric mean of performance index (GMP):
It was presented by Fernandez and is expressed as follows [7].

$$GMP= \sqrt{}\ Y_{pi} \times Y_{si} \quad \text{Geometric mean of performance -4}$$

MP is calculated based on arithmetic average so because of presence of the relatively more intense differences between Ysi and Ypi, MP values have an oblique, while the geometric mean shows lower sensitivity to relatively more intense differences between Ypi and Ysi. So in separation of genotypes group A from three other groups, GMP is more appropriate index than MP.

MATERIALS AND METHODS

In this study, 14 wheat genotypes (Table 1) derived from breeding programs of cold stations of country which have winter growth type were studied in an experiment. The experiment compared yield in the form of randomized complete blocks design (RCBD) with three replications in both normal irrigation and stressed conditions after anthesis stage in three areas (Pars Abad, Bilesavar and Ardabil) in 2010-2011 agricultural years. Each genotype was planted in a plot with 6 × 1.2 m2 dimensions with 30 cm removal which was considered as marginal. Consumption Seed rate for cultivation was determined based on 450 seeds per square meter and with regard to 1000 seed weight for each genotype. Irrigation was conducted as flooding. Five stages irrigation had been considered for normal conditions and three stages were considered for stressed. In treatments under drought stress, there was no double-irrigation after anthesis. To combat broad-leaved weeds and narrow leaf weeds, mixture of Grown Star and Pumasuper herbicides were used for 20 g and 1 l/ha tillering to stem elongation stages, respectively. All the samplings were performed from the middle rows and competitor plants and in order to measuring traits other than yield per unit area, 10 plants selected randomly and then were transferred to the laboratory. Traits such as biomass of anthesis time, biomass of ripeness time, grain weight per spike, 1000 seed weight, harvest index and grain yield were measured. For end season drought tolerance using grain yield mean in normal (Yp) and stressed (Ys) conditions, indices like tolerance index (TOL), geometric mean (GMP), mean proficiency (MP), stress sensitive index (SSI) and stress tolerance index (STI) was calculated. For statistical calculations, softwares such as SPSS-16, Minitab-15 and MSTAT-C were used.

Table 1- Names of under-study genotypes in this experiment

Number	Pedigree
1	Viking/5/Gds/4/Anza/3/Pi/Nar//Hys/6/Spn/Mcd//
2	Bkt/90-Zhong
3	ATAY/GALVEZ87
4	Aghbugda/90Zhong87/4/Spn/Mcd//Cama/3/Nzr
5	Azar2
6	ID800994. W/ VEE/3/ URES/JUN// KAUZ/ 4BUL 5052.1
7	Basswood/ Mv17
8	LFN/STDY//LOV24(ES8424)/5/
9	PYN/BAU/3/AGR1/BJY//VEF
10	ID800994. W/ VEE/3/ URES/JUN// KAUZ/ 4BUL 5052.1
11	Fenkan
12	Alvd/90-Zhong 87
13	BILINMEYEN-6
14	Viking/5/Gds/4/Anza/3/Pi/Nar//Hys/6/Spn/Mcd//

RESULTS AND DISCUSSION

In order to identify drought stress tolerant genotypes, stress sensitive and stress tolerance indices were studied in three computation stations which presented in table 2 by the end of 2008-2009. According to table 2, based on stress tolerance indices (STI) genotype 10 has had the most tolerance to drought. Evaluation of genotypes by SSI index had been categorized experimental materials only based on resistance and susceptibility to stress, that is, using this index we can determine sensitive and tolerant genotypes regardless of their potential yield [10].

Stress sensitive index was evaluated based on yield ratio of each variety in stressed conditions to non-stressed conditions as compared with the proportion in the total varieties. Thus, two cultivars with high yield or low in both conditions can have the same amount of SSI, so selection process based on this index lead reformers to make a mistake [11]. In stress sensitive index (SSI), it was observed that genotype 10 had the lowest SSI amount.

Based on tolerance index (TOL), genotype 10 showed higher resistance to drought end season stress. In proficiency index (MP), genotype 10 showed higher tolerance to end-season stress. Also, based on geometric mean index (GMP), genotype 10 had higher tolerance to end-season stress at three locations. Behmaram *et al* [12] in their reports in field of evaluation of drought tolerance in spring canola cultivars expressed that STI index can better applied to evaluate drought tolerance of varieties than SSI and TOL indices. They in evaluation of drought tolerant sources in lentil genotypes in Ardabil found that of under-study indices, indices MP, GMP and STI have meaningful and positive correlation with yield in both stressed and non-stressed conditions.

Baldini *et al* (quoting Fernandez [7]) in a study realized that there is no relation between stress sensitivity index (SSI) and the grain yield. Evaluating of some drought tolerance indices in some spring barley genotypes, they reported meaningful correlation between the STI, MP and GMP in both stressed and non-stressed conditions. Rosielle and Hamblin [13] showed that in most comparison experiments the correlation yield was positive between

MP and YP and also between MP and YS. According to their reports, selection based on MP index generally lead to increasing average yield in both normal and stress conditions.
Mollasadeghi [14] in a study evaluating 12 bread wheat genotypes concluded that the indices MP, GMP, STI and MSTI having the highest correlation with yield under normal irrigation and drought stress conditions were introduced as superior indices.ListenRead phonetically

Regarding Average Rating (R) of five stress sensitive and stress tolerance indices, genotype 10 with Mean R = 2 was identified as best genotype in all stations.

Table2- comparison of yield means in non-stressed (YP) conditions and drought tolerance indices 14 bread wheat genotypes

Genotypes	Yp	Ys	STI	SSI	TOL	MP	GMP
1	5934	3768	0.62	1.08	2166	4851	4728
2	6392	3842	0.68	1.18	2550	5117	4956
3	6328	3776	0.66	1.19	2553	5052	4888
4	5929	4070	0.67	0.93	1859	4999	4912
5	5722	3613	0.57	1.09	2109	4667	4546
6	6015	4417	0.73	0.78	1598	5216	5154
7	6284	4130	0.72	1.01	2155	5207	5094
8	5583	4008	0.62	0.83	1575	4796	4730
9	5446	3927	0.59	0.82	1519	4687	4625
10	6096	4690	0.79	0.68	1407	5393	5347
11	6171	4338	0.74	0.88	1833	5255	5174
12	6422	3917	0.69	1.15	2505	5169	5015
13	5925	3596	0.59	1.16	2329	4761	4616
14	5972	4387	0.72	0.78	1585	5179	5118
Mean	6016	4034	0.67	0.97	1982	5025	4922

Grain yield in drought stress conditions :*Ys* *Grain yield in normal conditions* :*Yp*

Table 3 shows correlation coefficients between traits measured in the normal irrigation conditions using average of three stations (Pars Abad, Bilesavar and Ardabil) in 2010-2011 agricultural years. These traits is derived from mean of three replications of the above three stations. According to observations in this table, there is negative correlation between grain yield (YLD) and biomass weight at anthesis and ripeness stages and also there is positive correlation between grain yield (YLD) and seed weight per spike and 1000 seed weight. The results showed that there is meaningful and positive correlation between biomass weight at maturity stage and seed weight per spike in probability level of 1 percent, in other words increasing seed weight per spike, biomass weight increases in the maturity stage. The correlation of rest traits with each other was presented in table 3.

Table 3- Correlation coefficients between traits measured in normal irrigation conditions in three stations including Pars Abad, Bilesavar and Ardabil in 2010-2011 agricultural years

	Biomass weight in anthesis stage (gr)	Biomass weight in maturity stage(gr)	Seed weight per spike (gr)	1000 seed weight (gr)
Biomass weight in maturity stage(gr)	0.408	1		
Seed weight per spike(gr)	0.211	0.807**	1	
1000 seed weight(gr)	0.084	-0.284	-0.124	1
Grain yield (kg/ha)	-0.351	-0.312	0.018	0.422

** and ** Significantly at $p < 0.05$ and < 0.01, respectively*

Table 4 shows correlation coefficients between traits measured under drought stress conditions using average of three stations (Pars Abad, Bilesavar and Ardabil) in 2008-2009 agricultural years. These traits is derived from mean of three replications of the above three stations. According to observations in this table, there is positive correlation between grain yield (YLD) and biomass weight at anthesis and 1000 seed weight and also there is negative correlation between grain yield (YLD) and biomass weight in maturity stage and seed weight per spike. The results showed that there is meaningful and positive correlation between biomass weight at maturity stage and seed weight per spike in probability levels of 5 and 1 percent. The correlation of rest traits with each other was presented in table 4.

Table 4- Correlation coefficients between traits measured in drought stress conditions in three stations including Pars Abad, Bilesavar and Ardabil in 2010-2011 agricultural years

	Biomass weight in anthesis stage(gr)	Biomass weight in maturity stage(gr)	Seed weight per spike(gr)	1000 seed weight(gr)
Biomass weight in maturity stage(gr)	0.822**	1		
Seed weight per spike(gr)	0.520*	0.785**	1	
1000 seed weight(gr)	-0.222	-0.295	-0.025	1
Grain yield (kg/ha)	0.107	-0.136	-0.096	0.412

** and ** Significantly at p < 0.05 and < 0.01, respectively*

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