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Investigation of drought tolerance using tolerance indexes to identify sensitive and tolerant genotypes in wheat genotypes

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ABSTRACT

In order to find the best indexes and also to determine the best of drought tolerant wheat genotypes, five genotypes of wheat in a completely randomized block design with three replications were planted and evaluated. The experiment was conducted in two separate normal irrigation and drought tension experiments and in under drought stress treatments, after flowering the irrigation was eliminated. Analysis of variance demonstrated that there is no significant difference among the studied genotypes in normal irrigation condition however there is a significant difference among the studied genotypes in drought tension condition, at 5% probability level. By analyzing to main components the seven studied indicators were reduced to two components. Analysis of correlation between the yield in two environments and indexes and graphical Biplot based on components, showed that the most appropriate indicators to identify genotypes, is the geometric mean productivity (GMP), mean productivity (MP) and stress tolerance index (STI), respectively. The genotypes of number Mv17 were located in favorable area of Biplot, each genotype has the lower performance fluctuation of environmental conditions and they have introduced as tolerant to stress genotypes.

Keywords: Wheat, Draught Stress, tolerance indexes, component analysis

INTRODUCTION

Drought stress is considered as the most important factor limiting agricultural production in arid and semi-arid systems. Of 3.2 million acres of irrigated wheat level about 900 thousand hectares of wheat are grown in cold areas. In these areas most of the farmers because of the lack of enough water and consequently allocating the irrigation to the end of the summer season, the desired results are not achieved with the high expected cultivars since the crop faces end season draught tension. So introducing cultivars that in both normal irrigation and terminal drought stress can produce more and certain product, is very important [1]. The ongoing drought in recent years, especially drought conditions in agricultural year of 1386-87 which affected a huge area of the country, alarmed on danger of agricultural productivity and sustainability of production. Therefore, more attention to get sustainable solutions in all areas of research and operational advice to reduce the effects of natural factors is demanding. According to relative yield of genotypes in draught stress and in the without stress environment we can determine the effective traits on draught stress tolerance and the genotypes which can be used in environment with draught stress can be used [2].

In order to identify drought tolerant genotypes, some selection indices (GMP, MP, TOL, STI and SSI) were used in different conditions [3]. Sio-SeMardeh et al [4] in a study to evaluate drought tolerance indices in wheat genotypes under different environmental conditions concluded that in stressed conditions the average indices MP, GMP and STI are much more effective to recognize genotypes which have similar yield in both environments (group A cultivars). Under severe drought stress conditions, none of the applied indices could identify group A cultivars.

Farshadfar [5] in experiment which is conducted to select the 20 wheat lines by drought tolerance indices, and considering the correlation analysis between indices and yield mean in both stressed and non-stressed conditions, concluded that the most appropriate indices to screening the lines in two environments are mean proficiency (MP) and tolerance (TOL) indices. Mitra [6] stated according to yield in drought stress and normal conditions we can calculate stress tolerance indices and applied them to screening stress tolerant genotypes.

Kaya et al [8] in their study concluded that genotypes with large PC1 and small PC2 have higher yield in both stressed and non stressed conditions (stable) and genotypes with large PC1 and small PC2 have lower yield (unstable). Yan and Rajcan [9] in their study on soybean plants concluded that the correlation coefficient between the two indices is almost cosine between their vectors, so due to existence of large angle between the indices SSI, TOL, and Ys, this represents a negative correlation between them. There was positive correlation between yield in two environments and GMP, MP and STI indices, the acute angle between them was also representative of this subject. Thus, in their study indices which have positive and meaningful correlation with yield in two environments were appropriate ones to screening genotypes. Mollasadeghi [10] in their study on wheat genotypes concluded that indices MP, GMP and STI are very appropriate to identify high yield genotypes in both stressed and non-stressed conditions (group A cultivars).

MATERIALS AND METHODS

This experiment was conducted in the research farm of Islamic Azad University of Ardabil Branch in 2012. To study 5 genotypes (Table 1) received from the Agricultural and Natural Resources Research Centre of Ardabil province. Genotypes were planted and studied in two separate levels with completely randomized block design. This experiment was repeated three times. The experiment location had cold semi-arid climate and in winter temperature is often below zero and it had got 1350 m altitude from sea level, with 48.20 and 38.15 latitude and longitude, respectively. The genotypes were planted in two meters rows with spacing of one meter with 30 cm removal as marginal area. The irrigation was performed in 5 stages for normal and 3 stages for stress conditions respectively. In under drought stress treatments, after flowering the irrigation was eliminated. For statistical analysis SPSS-15, Minitab-15 and MSTAT-C software were used. In order to identify drought tolerant genotypes, mean productivity (MP), geometric mean productivity (GMP), stress tolerance index (STI), tolerance index (TOL), stress susceptibility index (SSI) and modified stress tolerance index (MSTI) was calculated using the following equations:

$MP = (Y_{Pi} + Y_{Si}) / 2$ $GMP = \sqrt{Y_{Pi} \times Y_{si}}$ $STI = (Y_{Pi} \times Y_{Si})/Y_p^2$

$TOL = (Y_{Pi} - Y_{Si})$ $SSI = (1-(Y_{si}/Y_{pi})) / SI$; $SI = 1- (Y_s/Y_p)$

Table 1 - Genotype names used in this research

Number	Genotypes
1	Sabalan
2	Azar2
3	Fenkang
4	Gaspard
5	Mv17

RESULTS AND DISCUSSION

Analysis of variance (Table2) demonstrated that there is no significant difference among the studied genotypes in normal irrigation condition however there is a significant difference among the studied genotypes in drought stress condition, at 5% probability level. This is due to the genetic diversity among them. The comparison of mean values showed that (Table 3), in the normal condition MV17 genotype with an average of 102.40 kg per hectare had maximum and Gaspard genotype with an average of 80.15 kg per hectare, got the lowest yield among all genotypes. In drought stress conditions also Azar2 genotype with an average of 79.10 kg per hectare had maximum and Gaspard genotype with an average of 34.83 kg per hectare, got the lowest yield among all genotypes.

2 - Table of yield variance analysis in both environments (Normal irrigation and drought stress)

Source	df	Mean of Squares	
		normal irrigation	drought stress
Replication	2	538.203	0.933
Genotypes	4	245.374	832.46*
Error	8	463.898	153.637
C. V %		24.37	20.46

** Significantly at p < 0.05, respectively.*

Table 3 - Comparison of mean wheat genotypes using Duncan method

Genotypes	Grain yield (kg/ha)			
	normal irrigation		drought stress	
Sabalan	90.88	a	58.90	a
Azar2	80.90	a	79.10	a
Fenkang	87.55	a	59.50	a
Gaspard	80.15	a	34.83	b
Mv17	102.40	a	70.57	a

Differences between averages of each column which have common characters are not significant at probability level of 5%.

Khalil Zadeh and Karbala'i Khiyavy [11] believed that the most appropriate index to select stress tolerant cultivars is an index which has a relatively high correlation with grain yield in both stressed and non-stressed conditions. So evaluating the correlation between stress tolerance indices and yield in both stressed and non stressed conditions, the identification of the most appropriate indices would be possible. Since indices including mean proficiency, geometric mean of proficiency, transformed stress tolerance index and Fernandez's index showed high correlation in normal irrigation and drought stress conditions, are introduced as the best indicators.

Farshadfar et al [12] in a study on Pea reported that there is positive and meaningful correlation between all the indices with yield under non-stressed conditions and also stated that there is negative and un-meaningful correlation between TOL index with yield under stressed conditions. Fernandez [3] in a three-year study under low-stress and normal conditions found that there is meaningful correlation between stress sensitivity index (SSI) and grain yield. Also, the results of this study are compatible with Noormand et al [13].

They reported that the correlation of GMP and STI indices with wheat is positive and meaningful. Shafa Zadeh et al [14] in evaluation of wheat genotypes reported that there is positive and highly meaningful correlation between yield in stressed environment and indices MP, GMP and STI and also stated that there is positive and meaningful correlation between yield in non-stressed environment and all drought tolerance and drought sensitive indices.

Table 4- Correlation between drought tolerance indices with grain yield under normal irrigation and drought stress conditions

	YP	YS	MP	GMP	SSI	TOL	STI
Yp	1						
Ys	0.332	1					
MP	0.58*	0.834**	1				
GMP	0.706*	0.738*	0.980**	1			
SSI	0.033	0.820**	0.708*	0.584*	1		
TOL	0.109	-0.749*	-0.570*	-0.429	-0.981**		
STI	0.551*	0.860**	0.999**	0.970**	0.736*	-0.603*	1

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

The study showed that correlation between yields in two conditions and drought tolerance indexes showed that (Table 4) among the yields in two conditions and MP, GMP and STI indexes there was a meaningful positive correlation and among the yields in drought stress condition and TOL and SSI indexes there was a meaningful negative correlation and among the yields in normal irrigation condition and TOL indexes there was a meaningful positive correlation.

To further explore the relation between genotypes and drought tolerance indexes, analysis to main components was performed. Table 5 shows the latent roots and Eigen-vectors of genotypes of the first two components maximum of the changes between data items are expressed by two components as (94.66%). The first vector shows 49.397 percentages of changes by the indexes of GMP, MP and STI had the maximum positive coefficient. Since the high values of this index is favorable and because of positive relation of the first component with this indexes, if we select the high values then genotypes which in different conditions (stress after pollination, no stress conditions) are Stable and have high yield will be selected. This component can be named as yield component. The second component contained 49.397% of the variations, and this component was a high positive correlation with SSI and TOL, and was named as sensitive to stress component. After analysis to main components analysis to examine relations among variables based on the first and second component bi-plot was drawn (Figure 1), so that the horizontal axis was dedicated to the first component and the vertical axis of was dedicated the second component. Based on the component values, the location and grouping of genotypes was given in bi-plot. If the angle between two vectors or lines that indicate the yields in two environmental situations have been placed in the end of it be closer together, in other words, the angle between them be less than 90 degrees, it indicates a positive correlation, and if the angle between the lines be greater than 90 degrees it indicates a negative correlation. The correlation coefficient between the two indexes is approximately cosine of the angle between vectors [9].

According to Bi-plot of the indexes MP, GMP and STI and yield in two conditions there is a maximum positive correlation among them. It indicates the simple correlations. Based on this research, the above three indexes are the most suitable indexes for screening genotypes. Since the indexes GMP and STI are close to each other, they have the same value. The results obtained in this study are consistent with the results of Fernandez [3], Galabad, et al [7], Kaya et al [8] and Mollasadeghi [10]. Based on Bi-plot MV17 genotype have higher and stable yield.

Table 5- Vectors and special amounts, relative and cumulative variance for three main components from principal components over drought tolerance indices of 5 wheat genotypes under normal irrigation and drought stress conditions

Tolerant indices \ Special vectors of component	1	2
Yp	**0.927**	-0.186
Ys	0.505	**0.782**
MP	**0.796**	0.584
GMP	**0.889**	0.427
SSI	0.192	**0.970**
TOL	-0.021	**-0.982**
STI	**0.770**	0.620
Special amount	3.458	3.168
Relative variance	49.397	45.263
Cumulative variance	49.397	94.66

In addition to the Bi-plot method, three-dimensional diagram based on STI index and yields in two environments was drawn. Fernandez [3] showed that STI is able to distinguish group A genotypes from other groups. (Group A: genotype with high yield in stress and non-stress environments). Genotype No. 2, 14 and 15 are located in part of the three-dimensional graph, thus the grain yield in the two environments is high and are tolerant to stress (graph is not included). This method confirmed the Bi-plot technique. The above results are consistent with the results of Fernandez [3], Ahmadi et al [15], Farshadfar [5] and Mollasadeghi [10]. Finally, it was concluded that GMP, MP and STI indexes were most appropriate indexes and Mv17 were the most tolerant genotypes to drought stress and are recommended for planting in arid areas.

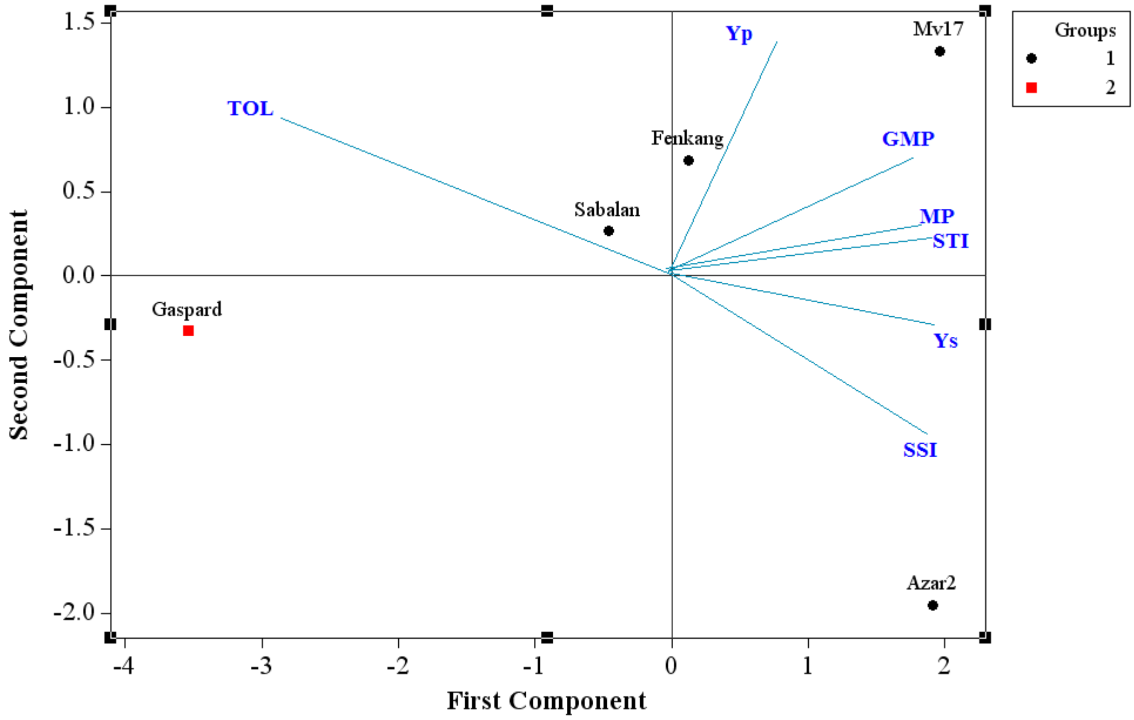

Figure 1 - Bi-plots of 5 wheat genotypes and seven drought tolerance indexes based on first and second components in both normal irrigation and drought stress conditions

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