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Evaluation of tolerant and susceptible bread wheat genotypes under drought stress conditions

Vahid Mollasadeghi[1*], Amir Gharib Eshghi[2], Reza Shahryari[1] and Samaneh Elyasi[1]

1. Department of Agriculture, Science and Research branch, Islamic Azad University, Ardabil, Iran
2. Agriculture & Natural Resources Research Center of Zanjan Province, Iran

Corresponding author: Vahid Mollasadeghi

ABSTRACT: In order to identify genotypes tolerant to drought, this research was conducted on 12 bread wheat genotypes as split plot based on randomized complete blocks (CRBD) with 3 replication, in which the Main factor included irrigation treatments and sub factor was the genotypes being studied. The study was conducted at research farm of Islamic Azad University, Ardabil Branch Iran, in 2008-09 cropping years. Positively significant correlation (r = 0.512**) between yield under drought stress (Ys) and yield under normal humidity (Yp) was indicative of correlation between drought stress and irrigated conditions. Indices such as STI, TOL, SSI, MP, HARM and GMP and analysis into main components and Bi Plot were used to identify genotypes tolerant to drought. In total, first and second components accounted for 92.92% of the variations, and based on the coefficients of indices in first and second components, first component was designated as component of tolerance, whereas the second component was designated as component of stress susceptibility. Based on information obtained from Bi Plot, genotype 4057 was designated as tolerant, whereas genotypes such as Sissons and Saratovskaya-29 were designated as susceptible to drought.

***Keywords*: ** wheat, drought stress, indices of drought tolerance

INTRODUCTION

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. 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. So introduction of cultivars that could produce more reliable and more products in both normal irrigation and end-season drought stress conditions are very important (Mahfoozi et al., 2009).

Ever since its domestication, wheat has invariably assumed great importance and a vast expanse of arable land has gone under its cultivation. Wheat is an important cereal crop in many regions around the world and is a staple food for great part of world population (Rauf et al., 2007). Apart from being important commercially, it is also an increasingly functional tool in political and international relations all around the world. Although Iran boasts nearly 1% of world population, it consumes roughly 2.5% of wheat produced worldwide.

Wheat is a strategic good like energy and considered one of the most important indices for agriculture (Akbari et al., 2010).

Drought is one of the most important factors with limiting effect on crop production including wheat production in the world as well as in Iran (Mollasadeghi et al., 2011). Based on report by FAO, 90% of Iran is considered as arid and semiarid, while one third of arable lands in the world suffer from water limitation. Climate changes and ever-increasing world population tends to aggravate this problem and make the future look more bleak. Extended periods of drought stress heavily reduce yield in arid and semiarid area. Breeding wheat varieties for drought tolerance is one of the most important strategies of dealing with problems associated with drought (Rebtezke et al., 2006).

Drought tolerance is a quantitative trait and it is immeasurable by any direct method. This makes the identification of genotypes tolerant to drought a complex work (Tekeda and Matsuoka, 2008). Nevertheless, improvement of yield under water limitation conditions necessitates the identification of drought tolerant genotypes and management works to maximize water availability (Fischer and Maurer, 1978). Indices such as stress susceptibility index (SSI) (introduced by Rosielle and Hambelen, 1981), Tolerance index (TOL) and mean productivity (MP) (introduced by Fernandez, 1992), stress tolerance index (STI) and geometric mean productivity (GMP) (introduced by Abdomishani and shabestari, 1988) are used to identify genotypes tolerant to drought.

(Abdomishani and Shabestari ,1988) investigated 35 wheat genotypes for tolerance to drought. In their study, they introduced genotypes such as Paytik, Ataei, Khazar, Rayhan, Adl-e jadid, Mexipak, Shahi and Azar as tolerant. (Azizinia et al., 2005) studied 40 wheat genotypes for tolerance to drought, and identified the tolerant and susceptible cultivars by using indices of Fernandez and analyzing to main components. Farshadfar et al. (2001) investigated pea genotypes for drought tolerance and used drought tolerance indices and analysis to main components to identify the genotypes. (Karami et al, 2005) designated MP, GMP and STI as the most efficient indices for identifying drought tolerant genotypes of barley. Different authors conducted various experiments under both conditions and concluded that an optimally tolerant cultivar is one that produces the best response under both stressed and non-stressed conditions. They used indices such as stress susceptibility index (SSI), tolerance index (TOL), mean productivity (MP) and geometric mean productivity (GMP) to select tolerant and stable genotypes (Rosielle and Hambelen ,1981), (Abdomishani and Shabestari ,1988), (Fernandez ,1992), (Golabadi et al., 2006 and Mollasadeghi et al .,2011).

This study aims to evaluate drought tolerance in 12 bread wheat genotypes in Ardabil. Results from this study may be used in breeding programs.

MATERIALS AND METHODS

In order to evaluate drought tolerance in 12 bread wheat genotypes, the genotypes listed in Table 1 were considered as sub factor and irrigation and non-irrigation treatments as main factor in an experiment conduced as split plot based on randomized complete blocks design with three replications. The experiment was conducted in research farm of Islamic Azad University, Ardabil Branch Iran, based in Hasan-barough village, in 2008-09 cropping years. In this experiment, the genotypes were sown in October of 2008. Irrigation was done for all the plants during plantation. Each experimental plot included 3, 3m long rows recurring 20cm from each other. Amount of seed usage was based on 450 seeds per 1m2 and weight of 1000 grains for each variety, which were sown in late October. Irrigation was done traditionally, which included two autumnal and three vernal irrigations. In treatments under drought stress, two times of irrigations were deleted after anthesis. No chemical or toxic fertilizer was applied during the experiment to deal with weeds, whereas throughout growth stages from tillering to grain-filling, weed control was done either mechanically or manually. The field was under a wheat-fallow rotation. Cultivation on the field before plantation included plowing after harvest of preceding crop, two times disking, two times cultivation with leveler and furrowing. It should be mentioned that after applying stress, there was no effective rainfall in either of years.

Table 1 . name of genotypes being studied in this Experiment

Number	Genotypes	Number	Genotypes
1	Gascogene	7	MV17/Zrn
2	Sabalan	8	Sardari
3	4057	9	4061
4	Ruzi-84	10	4041
5	Gobustan	11	Sissons
6	Saratovskaya-29	12	Tous

After harvest of genotypes, yield traits and biomass were measured. Dry weight of aerial organs (without root) was measured as value for biomass. Indices such as stress tolerance index, TOL, stress susceptibility index, mean productivity, geometric mean productivity were measured using yield value under both stressed (Ys) and non-stressed (Yp) conditions, whereas tolerant and susceptible genotypes were identified by method of analyzing to main components and preparation of Bi Plot. MSTAT-C, SPSS-16, Minitab-15 and Snagit-8 software were used to do analysis on data. Mean comparison was done using Duncan's multiple range tests.

RESULTS AND DISCUSSION

In this experiment, humid condition (drought stress and normal) produced a significant difference for both yield and biomass traits, at 1% probability level. In addition, there was a significant variation among the genotypes in terms of yield, at 5% probability level, whereas genotypes did not vary significantly in terms of biomass. Interaction of "genotype × humid condition" was not significant in either yield or biomass (Table 2). The insignificant interaction represents equal responses of genotypes under stressed and normal humidity conditions. Thus, yield of genotypes have been stable under various conditions. In general, drought stress has decreased the grain yield and biomass of genotypes being studied by 19.31% and 20.59%, respectively. Positive and significant correlation (r = 0.512**) between yield under drought stress (Ys) and yield under normal humidity (Yp) indicated that there is a correlation between yields under diem and irrigated conditions. This correlation represents the independence of yields from each other under the two conditions and so that any breeding for each conditions should be done separately. Genotypes producing high yield under normal humidity condition may not produce satisfactory yield under drought stress condition. These results are consistent with Fernandez theory (1992) who found the correlation between Yp and Ys ranging from zero to 0.50. However, the results are not consistent with those reported by (Karami et al .,2005), (Farshadfar et al .,2001), and (Golabadi et al .,2006). Based on Table 3, among 12 genotypes, Tous had the highest yield under both drought stress (3.93 ton/ha) and normal humidity (3.96 ton/ha) conditions.

This study does not aim to identify high yielding genotypes under either drought stress or normal humidity conditions; rather it focuses on identifying genotypes tolerant and susceptible to drought by using indices. Yield is a function of various conditions such as sowing date, concentration, application rate of fertilizer, irrigation, growth type, and soil and weather conditions. Any change in these conditions causes the yield of the genotypes to change, however this does not undermine method of indentifying tolerant and susceptible genotypes through the indices, since the underlying factor for calculation by indices is the ratio of yield under drought stress condition to yield under normal condition. Therefore, if these conditions led to any change in yield, the change is applied equally on both drought stress and normal conditions, so the yield ratio remains the same; hence the values of indices remain unchanged.

Table 2 . degree of freedom and mean squares of biomass and grain yield of wheat genotypes at irrigation l vels

S.O.V	df	Mean of Squares	
		Biological yield	Grain yield
Replication	2	14.236	1.492
Irrigation conditions	1	51.901*	9.746*
Error	2	5.852	0.33
Genotypes	11	1.308	8.104*
Irrigation conditions × Genotypes	11	1.909	2.283
Error	44	18.68	12.981
C.V.%		18.68	15.89

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

Table 3 . Mean comparison of traits being evaluated in bread wheat genotypes at water stress levels

Genotypes	Grain yield Normal irrigation (ton/ha)	Grain yield Drought stress (ton /ha)	Biological yield normal irrigation (ton /ha)	Biological yield rought Stress (ton /ha)
Gascogene	3.873 ab	2.467 cd	7.04	5.673 bc
Sabalan	3.797 ab	3.157 abc	8.15	6.203 bc
4057	4.377 a	3.390 ab	8.98	6.897 abc
Ruzi-84	4.003 ab	2.873 bcd	8.24	5.973 bc
Gobustan	3.727 ab	2.753 bcd	8.64	6.483 bc
Saratovskaya-29	3.093 b	2.267 d	7.780	5.37 c
MV17/Zrn	3.623 ab	3.250 abc	7.153	6.32 bc
Sardari	3.927 ab	3.09 abcd	7.733	6.647 abc
4061	3.877 ab	3.163 abc	8.91	7.407 abc
4041	3.670 ab	3.53 ab	8.31	7.617 ab
Sissons	3.877 ab	2.733 bcd	9.19	5.463 c
Tous	3.460 ab	3.927 a	8.80	8.467 a

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

Results from determining the correlation between the tolerance indices being studied and grain yield under drought stress and normal humidity conditions have been given in Table 4. The highest correlation was between grain yield under drought stress condition and indices such as STI, MP and GMP. These results are consistent with findings of researches conducted by (Sadeghzadeh Ahari ,2006), (Sanjari ,1998) and Radmehr and Kajbaf (1996). Furthermore, results from study on correlation between grain yield under normal humidity condition and stress tolerance indices showed that the highest correlations belonged to STI, MP, HM and GMP.

(Ahari ,2006) claimed that indices such as MP and GMP maintain the highest correlation with grain yield under normal humidity condition, therefore these indices are efficient tools to estimate yield stability and select high yielding genotypes. (Mollasadeghi et al .,2011) in an experiment conducted to evaluate tolerance to terminal drought of 12 bread wheat concluded that indices such as MP, GMP, STI and MSTI, which had the highest correlation with yield under both normal irrigation and drought stress conditions, were designated as comparatively more efficient indices.

(Sadeghzadeh Ahari ,2006) introduced indices such as MP and STI as the most efficient indices that can be used to indentify drought tolerance in wheat, whereas (Karami et al .,2005) introduced the same indices as the most efficient indices to identify drought tolerance in barley. (Ceceareli et al .,1987) reported that there was a negatively significant correlation between grain yield under drought stress condition and SSI. This is consistent with results of this study.

Table 4 .correlation coefficients between various drought tolerance indices and grain yield under drought stress and normal irrigation conditions

	Yp	Ys	STI	TOL	SSI	MP	HM
Ys	0.600**	1					
STI	0.812**	0.951**	1				
TOL	0.107	-0.731**	-0.489	1			
SSI	-0.091	-0.850**	-0.648*	0.980**	1		
MP	0.848**	0.933**	0.996**	-0.473	-0.605*	1	
HM	1.000**	0.600*	0.812**	0.107	-0.091	0.848**	1
GMP	0.820**	0.950**	0.997**	-0.481	-0.644*	0.998**	0.820**

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

Analysis to main components showed that first two components accounted for 99.92% of variations, 73.75% of which belonged to first component and 26.17% to second component. Eigenvectors of first and second components based on indices are given in Table 5. Since the lower values of indices such as TOL and SSI and higher values of other indices represent higher tolerance to drought and considering the coefficients of these indices, the first component is designated as component of drought tolerance. In addition, since the second component is affected by TOL and SSI with positively high coefficients and by HM, STI and GMP with lower coefficients, this component is designated as component of susceptibility to drought stress. Thus, these components can be used to select drought tolerant genotypes (Figure 1).

Based on obtained results, genotype 4057 was introduced as tolerant to drought, whereas genotypes such as Saysonse and Saratovskaya-29 were introduced as susceptible to drought. Furthermore, genotypes such as Sardari and Ruzi-84 were introduced as semi-susceptible. An interesting point about indentifying tolerant and susceptible genotypes is interaction of “genotype × environment” (environment includes weather, sowing condition, irrigation condition etc.) This interaction results in different conclusions to be made of studies on same genotypes but in different regions. Thus, if we intend to use the introduced genotypes in a region other than Ardabil, which has a different climate, we should evaluate their tolerance to drought in that region.

Apart from method of analysis to main components, there is another even simpler method to use all the indices. Once the indices have been quantified, the following equation can be used to calculate tolerance rate of each genotype:

Tolerance rate = HM + GMP + STI + MP + SSI – TOL

In this equation, indices that their higher values indicate high tolerance have positive coefficient, whereas indices their lower values indicate high tolerance have negative coefficient. The downside for this equation is that indices with high values have more effect on the results. In order to overcome this problem, the indices must be standardized by using Z. Then, tolerance rate can be calculated using standardized data. Comparison of genotype rankings obtained from these two methods reveals a small difference in genotype rankings; however this difference is not significant.

Drought tolerance is the resultant of several different traits. Once the tolerant genotypes have been identified, these traits must be identified and studied in detail. It is possible to produce cultivars highly tolerant to drought by collecting efficient traits for drought tolerance.

Table 5 . Coefficients of first and second components in Analysis to components

Tolerance Index	Components	
	First Components	Second components
YP	0.784	0.621
YS	0.967	-0.254
STI	0.997	0.051
TOL	-0.534	0.846
SSI	-0.689	0.724
MP	0.994	0.111
HM	0.783	0.621
GMP	0.998	0.061
% of Variance	73.752	26.170
Cumulative %	73.752	99.922

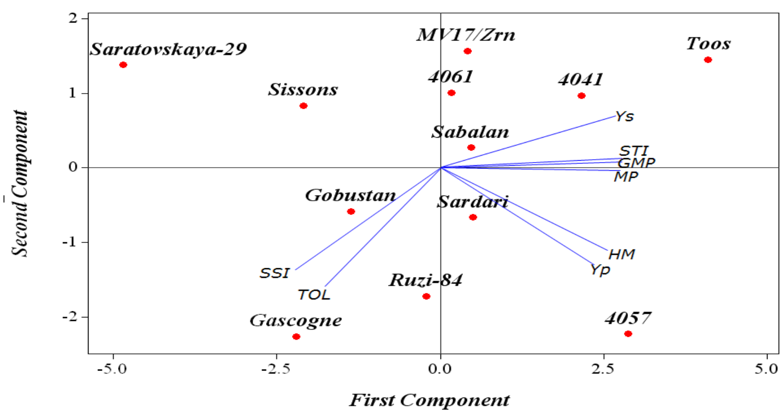

Figure 1. Bi Plot for indices of drought tolerance in 12 bread wheat genotypes based on first tow components

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