BIHAREAN BIOLOGIST 6 (2): pp.94-98
Article No.: 121114

http://biozoojournals.3x.ro/bihbiol/index.html

Assessment of drought tolerance in some bread wheat genotypes using drought resistance indices

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Received: 27. May 2012 / Accepted: 14. September 2012 / Available online: 14. October 2012 / Printed: December 2012

Abstract. The aim of this study was to assessment of drought tolerance in genotypes of bread wheat (*Triticum aestivum* L.). For this purpose twenty genotypes were evaluated in research field of Razi University using randomized completely block design with three replications in both rain-fed (stress) and irrigated (normal) conditions. Eight drought resistance indices including Stress Tolerance Index (STI), Tolerance Index (TOL), Stress Susceptibility index (SSI), Mean Productivity (MP), Geometric Mean Productivity (GMP), Yield Index (YI), Yield Stability Index (YSI) and Harmonic Mean (HAM) were calculated for each genotype based on grain yield under stress and normal conditions. Result of combined analysis of variance revealed significant differences between genotypes for grain yield. Drought stress reduced grain yield of investigated genotypes, significantly. Result of correlation analysis between grain yield in both conditions and calculated drought resistance indices showed that STI, GMP and HAM were the best indices for identifying high yielding genotypes in both conditions (drought tolerant genotypes). Based on STI, GMP and HAM and biplot analysis, genotypes No. 9, 12, and 14 comparatively identified as drought tolerant and genotypes No. 10 and 13 identified as susceptible genotypes.

Key words: *Triticum aestivum*, Drought resistance, Bi-polt, Grain yield

Introduction

Drought is a wide-spread problem seriously influencing bread wheat production and quality (Sio Se-Mardeh et al. 2006). The best option for crop production, yield improvement and yield stability under drought stress conditions is to develop drought tolerant cultivars (Siddique 2000). The relative yield performance of genotypes in drought stressed and irrigated conditions seems to be a common starting point in the selection of genotypes for use in breeding programs for dry prone environments (Sio Se-Mardeh et al. 2006). Based on grain yield production in stress and non-stress conditions, Fernandez (1992) divided genotypes into four groups: (1) genotypes producing high yield under both conditions (A group), (2) genotypes with high yield under non-stress condition (B group), (3) genotypes with high yield under drought stress condition (C group) and (4) genotypes with low yield production under both conditions (D group). The best indices should distinguish genotypes of group A from other groups (Drought tolerant genotypes).

Several selection indices have been suggested based on grain yield in stress and normal conditions to identifying drought tolerance genotypes (A group) (Najaphy & Geravandi 2011). Stress Susceptibility Index (SSI) suggested by Fisher and Maurer (1978). These researchers explained that genotypes with an SSI lesser than 1 are drought resistant. Rosielle and Hamblin (1981) defined stress tolerance (TOL) as the difference in yield between the stress and non-stress environments, and mean productivity (MP) as the average yield in both conditions. Genotypes selected on the basis of TOL have relatively high yield under stress and low yield under irrigated conditions (Pourdad 2008). Fernandez (1992) defined Stress Tolerance Index (STI), which can be used to identify genotypes that produce high yield under stress and non-stress conditions. Genotypes with high STI are superior in performance under both stressed and non-stressed conditions. This author suggested the Geometric Mean of Productivity (GMP) as another useful criterion (Pourdad 2008).

Many authors studied the relationships of these indices with grain yield under stress and non-stress conditions. Sio-Se Mardeh et al. (2006) reported that under moderate stress, MP, GMP and STI were more effective in A group cultivars, but under severe stress regression coefficient (b) and SSI were found to be more useful in discriminating resistant cultivars. Najaphy and Geravandi (2011) showed that YI and SSI were more appropriate selection indices to identify genotypes adapted to stress environment and SSI should be used along with yield data under stress (Ys). Golabadi et al. (2006) suggested that that STI, MP and GMP are the superior criteria for selection of high yielding genotypes both under stress and non-stress conditions in durum wheat. The objectives of current research were to assess drought tolerance in some cultivars and advanced bread wheat genotypes and identifying drought tolerant ones.

Materials and Methods

In this study 20 lines and varieties of bread wheat (Table 1) which in this manuscript identified shortly as No. 1-20, were planted under rain-fed and irrigated conditions in research filed of Razi University, Kermanshah, Iran (34°19'N, 47°03'E, 1322 m above sea level, Koppen climate classification, CS_3) during 2008-09 season cropping. Field experiments were carried out in a randomized complete block design (RCBD) with three replications. The meteorological statistics of experiment location was mentioned in Table 2. Plant spacing was as plots with five rows in 3 m in length, 20 cm apart and the seeding rate was 400 seeds per m^2 for all plots. Non-stressed plots were irrigated three times and stressed plots received no water. The planting date was 8 November 2008. At maturity stage after separation of border effects from each plot, grain yield were measured and eight drought resistance indices were calculated using the following formula:

Table 1. Pedigree of investigated genotypes*

Genotype No.	Name/Pedigree
1	WS-82-9
2	DN-11
3	Flt/90 Zhong87
4	Alvd/Nanjing8343/Kauz
5	Snb/3/Jup/Bjy/Kauz"s"Ald
6	Seri/Avd/3/Rsh//Ska/Afn/4/Jup/Bjy//Kauz
7	Zrn/Soissons/3/Alvd//Aldan"s"/Las58
8	Tbs/Flt/3/Evwyt2/Azd//Rsh*2/10120/4/M-75-4
9	Tbs/Flt/3/Evwyt2/Azd//Rsh*2/10120/4/M-75-7
10	Alvd//Aldan/las/3/Rsh
11	M-75-4/4/Kal/Bb//CJ"s"/3/Hork"s"/5/1-66-22/Inia
12	Mhdv/Soissons/4/Bloudan/3/Bb/7C*2//Y50/Kal*2
13	Kauz"s"/Nik
14	Gaspard/Flt
15	Alvd//Nanjing8343/Kauz
16	CND/R143/ENTE/MEXI_2/3/AEGILOPS/SQUARROSA (TAUS)/4/WEAVER/5/2*KAUZ
17	CHEN/AEGILOPS SQUARROSA (TAUS)//BCN/3/BAV92
18	CHUM18/7*BCN
19	Marvdasht (check)
20	Sardari (check)

*: Genotypes number 1 to 18 were advanced genotypes of bread wheat and genotypes number 19 and 20 were used as check

Table 2. Meteorological statistics of experiment location (Field of Agricultural Research of Razi University, Kermanhsh Iran).

Longitude	47 (grad) and 9 (minute)
Latitude	34 (grad) and 21 (minute)
Height from sea surface	1319 (meter)
Mean of rainfall	480-450 (millimeter)
Tissue of soil	Silt-clay
Weather condition and natural condition	Middleman cool, northern Zagrose mountain strings
Mean of yearly temperature	5.9 and 22.6 °C
Measure of rainfall in examination implement years	509.5 (millimeter)

$SSI = \frac{1-(Y_S/Y_P)}{1-(\bar{Y}_S/\bar{Y}_P)}$ (Fischer and Maurer 1978),

$MP = \frac{Y_S + Y_P}{2}$ (Rossielle and Hamblin 1981),

$GMP = \sqrt{(Y_S \times Y_P}$ (Fernandez 1992),

$STI = \frac{Y_S \times Y_P}{\bar{Y}_P^{\,2}}$ (Fernandez 1992),

$TOL = Y_P - Y_S$ (Rossielle and Hamblin 1981),

$YI = \frac{Y_S}{\bar{Y}_S}$ (Gavuzzi et al. 1887),

$YSI = \frac{Y_S}{Y_P}$ (Bouslama and Schapaugh 1984),

$HAM = \frac{2(Yp \times Y_S)}{Y_P + Ys}$ (Yousefi 2004),

In these formula Y_S and Y_P are the grain yield of each genotypes in rain-fed (stress) and irrigated (normal) conditions and $\bar{Y}S$ and $\bar{Y}p$ are the means of grain yield for all genotypes in rain-fed and irrigated conditions respectively. Statistical analysis was performed using MSTAT-C, SPSS version 16 and MINITAB version15 packages.

Results and Discussion

Results of combined analysis of variance for grain yield over both environments showed that drought stress reduced grain yield significantly (P≤0.05) and genotypes differed for grain yield significantly (P≤0.05) (Table 3). In stress conditions highest values for grain yield belonged to genotypes No. 14, 9 and 1. The genotypes No. 10 and 19 had lowest grain yield in stress conditions. In irrigated conditions highest amount of grain yield production belonged to genotypes No. 19, 6, 8 and 12. In irrigated conditions genotype No. 10 produced lower amount of grain yield rather than other genotypes (Table 4).

Results of correlation analysis between grain yield in both conditions and calculated drought resistance indices

Table 3. Combined analysis of variance of grain yield for 20 genotypes of bread wheat over irrigated and rain-fed conditions.

S.O.V	df	Mean Square Grain Yield
Conditions	1	1.758**
Error1	4	0.003
Genotype	19	0.019*
Gen.× Con.	19	0.023*
Error2	76	0.012
C.V.%	--	14.01

*, ** significant at 0.05 and 0.01 levels of probability, respectively; S.O.V= source of variation; df= degree of freedom; Gen= genotype; Con= Conditions; C.V=coefficient of variation.

(Table 5) showed that only STI, GMP and HAM had positive and significant correlations with Yp and Ys. Therefore these indices were able to discriminate group A genotypes from other genotypes. The similar results were proposed by Jafari et al. (2009) in Mays.

There was non-significant positive correlation between Ys and Yp. This result indicated that high grain yield performance under optimal conditions doesn't necessarily result in improved yield under stress conditions. This result is in agreement with Sio-Se Mardeh et al. (2006), Najaphy and Geravandi (2011) and Niari Khamsi (2011). This result emphasizes the need to select genotypes in target environments to improve their yield under drought stress.

SSI and TOL had non-significant negative correlation with Ys and highly significant negative correlation with Yp. The high positive correlation of TOL and SSI with Yp (Table 5) implies that selection based on these indices will result in yield reduction under irrigated conditions. Similar results were found by Golabadi et al. (2006) and Najaphy and Geravandi (2011). MP had positive and significant correlation with Yp. The correlation of MP with Ys was not significant. Therefore MP can not select high yielding genotypes in both stressed and non-stressed environments. This result is in agreement with Hohls (2001).

YI was positively correlated with Ys but there wasn't significant correlation between this index with Yp (Table 5). This index ranks the genotypes only based on their yield under stress conditions. This index can't distinguish A group genotypes from other groups. YSI was positively correlated with Ys and had significant negative correlation with Yp, So highest values of YSI belonged to genotypes that exhibited least yield in irrigated conditions, but exhibited high yield under rain-fed conditions (Table 5). These results previously implied by Sio-Se-Mardeh et al. (2006).

Based on STI, GMP and HAM values (Table 4), genotypes No 6, 9, 12, 14 and 19 identified as drought tolerant genotypes. These genotypes had greater values for STI, GMP

Table 4. Mean grain yield under stress (Ys) and normal conditions (Yp) and eight drought resistance indices.

Genotype*	Ys (g/m²)	Yp (g/m²)	TOL** (g/m²)	MP (g/m²)	GMP (g/m²)	STI	YI	YSI	SSI	HAM (g/m²)
1	319.86	480.31	160.45	400.08	387.49	0.562	1.19	0.69	0.62	375.63
2	324.48	360.88	36.39	342.68	336.73	0.442	1.21	1.03	-0.0	330.93
3	254.37	529.36	274.99	391.86	366.06	0.513	0.95	0.49	1.02	342.16
4	264.03	561.02	296.98	412.52	384.50	0.555	0.98	0.47	1.06	358.47
5	272.33	401.85	129.52	337.09	326.47	0.397	1.01	0.73	0.55	316.57
6	250.73	687.29	431.01	471.78	417.51	0.640	0.95	0.38	1.26	365.09
7	259.24	505.20	243.94	383.23	362.90	0.483	0.97	0.51	0.98	342.02
8	267.47	609.50	342.02	438.48	379.19	0.566	0.99	0.46	1.08	339.66
9	319.35	594.45	275.10	456.89	433.36	0.688	1.19	0.55	0.91	411.38
10	193.36	323.56	130.20	258.46	245.26	0.249	0.72	0.58	0.84	233.68
11	286.87	498.15	211.27	392.51	373.33	0.514	1.07	0.61	0.77	355.81
12	283.34	616.82	333.47	450.08	416.55	0.646	1.05	0.46	1.10	385.89
13	246.38	371.57	125.18	308.97	293.64	0.326	0.92	0.79	0.41	279.67
14	391.27	436.47	311.86	447.20	416.32	0.637	1.08	0.50	1.01	388.17
15	243.03	478.42	230.53	363.15	344.21	0.439	0.92	0.51	0.99	322.02
16	292.26	477.26	185.00	384.76	371.10	0.506	1.09	0.62	0.76	358.14
17	252.62	536.98	284.36	394.80	368.26	0.499	0.94	0.47	1.08	343.51
18	254.22	523.72	269.50	388.97	361.67	0.512	0.95	0.50	1.02	336.85
19	223.75	780.18	556.43	501.96	417.71	0.666	0.83	0.28	1.46	347.65
20	240.61	507.57	266.96	374.09	348.28	0.450	0.89	0.48	1.06	324.58
Mean	271.98	514.03	254.76	394.98	367.53	0.515	1	0.56	0.90	342.89

*: Genotypes name according to table 1.
**: TOL=Tolerance Index; MP=Mean Productivity; GMP=Geometric Mean Productivity; STI=Stress Tolerance Index; YI=Yield Index; YSI=Yield Stability Index; SSI=Stress Susceptibility index; HAM=Harmonic Mean.

Table 5. Correlations between different drought resistance indices with grain yield in normal and stress conditions.

	Y_P	Y_S	TOL	MP	GMP	STI	YI	YSI	SSI	HAM
Y_P	1									
Y_S	-0.140	1								
TOL	-0.170	-0.922**	1							
MP	0.314	0.888**	0.841**	1						
GMP	0.495*	0.773**	0.684**	0.961**	1					
STI	0.463*	0.798**	0.721**	0.973**	0.989**	1				
YI	0.856**	-0.068	-0.282	0.273	0.482*	0.438	1			
YSI	0.329	-0.771**	-0.898**	-0.633**	-0.497*	-0.524*	0.477*	1		
SSI	-0.329	0.771**	0.898**	0.633**	0.497*	0.524*	-0.477*	-1	1	
HAM	0.675**	0.559*	0.426	0.825**	0.947**	0.915**	0.699**	-0.276	0.276	1

*, ** significance in probability level 5% and 1%, respectively; Yp=grain yield under normal condition; Ys=grain yield under stress condition; TOL=Tolerance Index; MP=Mean Productivity; GMP=Geometric Mean Productivity; STI=Stress Tolerance Index; YI=Yield Index; YSI=Yield Stability Index; SSI=Stress Susceptibility index; HAM=Harmonic Mean.

Table 6. Principle component analysis for different drought resistance indices and grain yield under normal and stress conditions.

Component	Numeral of particular	Share of relative (%)	Share of collective (%)	Particlarly of vectores (coefficients of normaled variables)							
				Y_S	Y_P	TOL	MP	GMP	STI	YI	SSI
PC_1	5.0170	62.7%	62.7%	0.091	0.412	0.399	0.441	0.418	0.424	0.071	0.329
PC_2	2.5981	32.5%	95.2%	-0.572	0.169	0.260	-0.077	-0.210	-0.184	-0.598	0.367

PC1=component 1; PC2= component 2; Ys=grain yield under stress condition; Yp=grain yield under normal condition; TOL=Tolerance Index; MP=Mean Productivity; GMP=Geometric Mean Productivity; STI=Stress Tolerance Index; YI=Yield Index; SSI=Stress Susceptibility index.

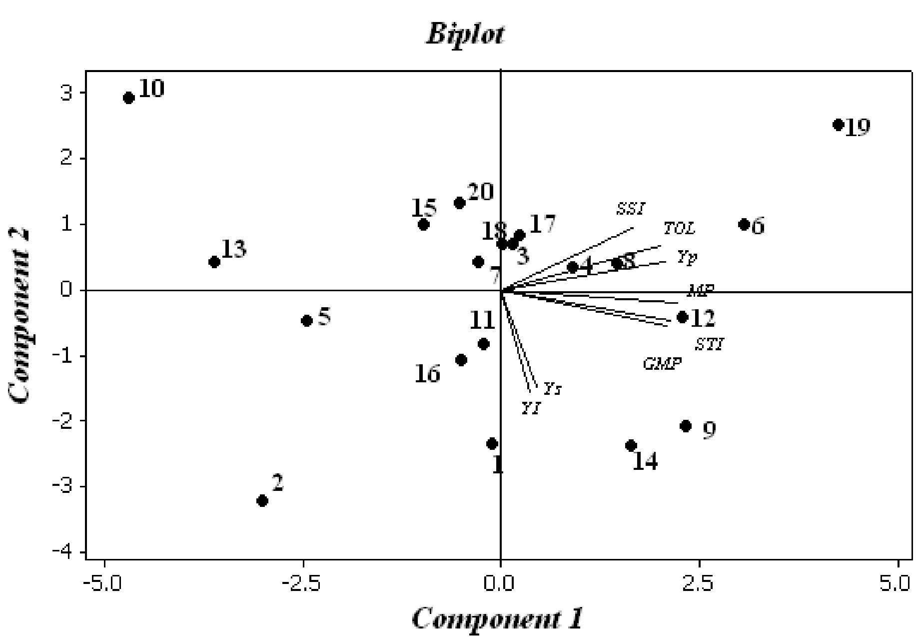

Figure 1. Bi-plot of genotypes and drought resistance indices based on first and second components. In this figure points 1 to 20 as genotypes numbers according to table 1 and YI, GMP, MP, STI, TOL, SSI, Yp and Ys were mentioned in table 4.

and HAM. Genotypes No. 10 and 13 identified as susceptible genotypes, because of their low values for STI, GMP and HAM.

For more understanding and visualizing the relationships between calculated indices and genotypes performance, principal component analysis (PCA) was performed. Result of this analysis showed that the first two components explained more than 95% of the total variance (Table 6). The first component (PC1) was mostly affected by Ys, Yp, STI, MP and GMP. Therefore this component was related to yield potential and drought tolerance. The genotypes with higher values of PC1 are expected to have high yield under both conditions. The most effective indices in second component (PC2) were Yp, SSI and TOL. So PC2 is associated with low grain yield under stress conditions and stress susceptibility. The genotypes with higher values of PC2 are expected to be drought sensitive and low yielding genotypes. Similar results previously proposed by Golabadi et al. (2006) in durum wheat. Based on these results selection of genotypes that have high PC1 and low PC2 are suitable. Kaya et al. (2002) suggested that wheat genotypes with higher PC1 and lower PC2 values had high yields (stable genotypes) and genotypes with lower PC1 and higher PC2 scores had low yield (unstable genotypes). Based on biplot graph (Fig. 1) genotypes No. 14, 9, 12 had greater values for PC1 and low values for PC2. Therefore these genotypes identified as drought tolerance. Genotypes No. 10 and 13 because of greater values for PC2 and lower values for PC1 identified as drought susceptible genotypes. Genotypes No. 19 and 6 had high yielding performance but these genotypes were sensitive to drought stress in respect of their high values for both PC1 and PC2. Genotype No. 2 was susceptible to drought stress and had low grain yield performance, because this genotype had lower amounts of both PC1 and PC2 in comparison to other genotypes.

Finally, results of this research showed that STI, GMP and HAM are the suitable indices for identifying genotypes that produce higher yields in both stress and non-stress conditions (drought tolerant genotypes). Based on values of genotypes for these indices and biplot analysis, genotypes No. 9, 12, and 14 identified as drought tolerant and genotypes No. 10 and 13 identified as susceptible genotypes in comparison to other genotypes.

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