INNSPUB

International Journal of Biosciences | IJB |
ISSN: 2220-6655 (Print), 2222-5234 (Online)
http://www.innspub.net
Vol. 6, No. 2, p. 331-337, 2015

RESEARCH PAPER OPEN ACCESS

Evaluation of bread wheat (*Triticum aestivum* L.) genotypes based on resistance indices under field conditions

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Key words: Biplot, Drought stress, Grain yield, Wheat, Tolerance indices.

http://dx.doi.org/10.12692/ijb/6.2.331-337 Article published on January 27, 2015

Abstract

Among the different abiotic stresses, drought is the limitation that induces a highly negative effect on crop production. In order to classify drought tolerant genotypes in bread wheat, an experiment was conducted in a split plot experimental on the basis of randomized complete block design with three replications under two irrigation and water deficit stress conditions during 2013-2014 cropping season in Isfahan Province of Iran. Five drought resistance indices including Tolerance Index (TOL), Stress Susceptibility index (SSI), Stress Tolerance Index (STI), Geometric Mean Productivity (GMP) and Mean Productivity (MP) were calculated for each genotype based on both grain yields under non-stress and stress conditions. Result of correlation analysis between grain yields and calculated drought resistance indices revealed that MP, GMP and STI were the best indices for identifying high yielding genotypes in non-stress and stress conditions. Gabriel Biplot Multivariate chart revealed that 'Ouhedi' genotype relatively identified as drought tolerant. Therefore it is recommended to be used as parents for improvement of drought tolerance in other cultivars.

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Introduction

Wheat is one of the most important cereal crops grown in arid and semi-arid regions where drought stress significantly affects production. It has been estimated that more than one billion people suffer from food shortage and this figure is predicted to double by 2050 (Debasis and Khurana, 2001). Additionally, this crop is one of the most important and widely cultivated crops in the world, used mainly for human consumption and support nearly 35% of the world population. Nearly 95% of wheat grown today is hexaploid, used for the preparation of bread and other baked products Identification of better genotypes with desirable yield and related traits use in breeding program and establishment of suitable selection criterion can helpful for successful varietals improvement program (Tahmasebi *et al,* 2013).

Biotic and abiotic stresses cause changes in normal physiological functions of all plants, including economically important cereals as well (Khalili *et al,* 2013). Among the abiotic stress drought is a significant limiting factor for agricultural productivity and generally inhibits plant growth through reduced water absorption and nutrient uptake (Pour-Aboughadareh *et al,* 2013). Drought stress as an abiotic stress is one of the most common environmental stresses that affects growth and development of plants (Aslam *et al,* 2006; Poursiahbidi *et al,* 2013). Thus, improvement of drought tolerance in crop is a major objective of most crop breeding programs, particularly in arid and semi-arid areas of the world (Moustaf *et al,* 1996).

Loss of yield is the main concern of plant breeders, and hence emphasize on yield performance under stress conditions (Khalili *et al,* 2012). Although drought stress is the most serious problem affecting production, however progress in the development of resistant cultivars is limited due to the lack of effective selection criteria. Thus, drought indices which provide a measure of drought based on loss of yield under drought-conditions in comparison to normal conditions have been used for screening drought-tolerant genotypes (Mitra, 2001). Some researchers believe in selection under favorable conditions (Betran *et al,* 2003), others in a target stress condition (Mohammadi *et al,* 2011) while others yet have chosen a mid-point and believe in selection under both favorable and stress conditions (Byrne *et al,* 1995; Sio-Se Mardeh *et al,* 2006; Mohammadi *et al,* 2010). However, drought indices which provide a measure of drought based on loss of yield under drought conditions in comparison to normal conditions have been used for screening drought-tolerant genotypes (Mitra, 2001). Several selection criteria have been proposed to select genotypes based on their performance in stress and non-stress environments. Fischer *et al* (1998) suggested that relative drought index (RDI) is positive indices for indicating stress tolerance. Lan (1988) defined new indices of drought resistance index (DI), which was commonly accepted to identify genotypes producing high yield under both stress and non-stress conditions. Rosielle and Hamblin (1981) defined stress tolerance (TOL) as the differences in yield between stress and irrigated environments and mean productivity (MP) as the average yield of genotypes under stress and non-stress conditions. The geometric mean productivity (GMP) is often used by breeders interested in relative performance, since drought stress can vary in severity in field environments over years (Fernandez, 1992). Fischer and Maurer (1978) suggested the stress susceptibility index (SSI) for measurement of yield stability that apprehended the changes in both potential and actual yields in variable environments.

The present study was undertaken to assess the selection criteria for identifying drought tolerance in bread wheat genotypes, so that suitable genotypes can be recommended for cultivation in drought prone areas of Iran.

Materials and methods

Plant materials, design and experimental sites

Twelve genotypes of wheat listed in Table 1. They were evaluated using a split plot experimental on the basis of randomized complete block design with three replications under two irrigation and water deficit

stress conditions during 2013-2014 growing season at the Research Station of Isfahan Province of Iran (This province is located within 30° 42' and 34° 30' north latitude and 49° 36' and 55° 32' east longitude). Sowing was done by hand in plots with five rows 4 m in length and 75 cm apart. All plots were irrigated after sowing and subsequent irrigations in beginning stem elongation were carried out after flowering. At harvest time, yield potential (Yp) and stress yield (Ys) were measured from two rows in 1 m length.

Statistical analysis

In order to study drought tolerance five drought tolerance indices including Mean production (MP), Geometric mean productivity (GMP), Stress susceptibility index (SSI), Stress tolerance index (STI), Tolerance (TOL), were calculated using the following relationships:

(1) SSI = $(1-(Ys/Yp)/(1-((\bar{Y}s)/(\bar{Y}p))$, $1-(\bar{Y}s/\bar{Y}p)$ is the stress intensity.

(2) STI= $(Ys \times Yp)/(\bar{Y}p)^2$

(3) GMP= $\sqrt{(Ys)(Yp)}$

(4) MP = $(Ys+Yp)/2$

(5) TOL= $Yp-Ys$

Where, Ys and Yp represent yield in stress and non-stress conditions respectively. Also, $\bar{Y}s$ and $\bar{Y}p$ are mean yield in stress and non-stress conditions respectively (for all genotypes). Finally, correlation among indices and both grain yields under normal and stress conditions, cluster analysis and principal component analysis (PCA) were performed by Minitab software.

Result and discussion

To study suitable stress resistance indices for selection of genotypes under drought stress condition, yield of genotypes under both normal and stress conditions were recorded for calculating different sensitivity and tolerance indices (Table 2). In the non-stress condition the highest values for grain yield belonged to genotypes No. 9, 10 and 11, while genotypes No. 2, 3 and 6 had the lowest grain yield in this condition. On the other hand, under stress condition the highest grain yield related to genotypes No.1, 7 and 11 and genotypes No.2, 3 and 6 had the lowest grain yield. Based on the TOL index genotypes No. 1, 3 and 7 exhibited the lowest value. Also, according to SSI the lowest value belonged to genotype No. 1, 7 and 8, thus these genotypes were found as drought tolerance. In the terms of MP and GMP indices genotypes No.7, 11 and 12 identified as drought tolerant genotypes. Also, in the case of the STI index genotypes No.7, 11 and 12 recognized as more drought tolerant genotypes.

Table 1. Genotype of wheat used for drought tolerance assessment.

No	Genotype	No	Genotype
4	Seymareh	10	Sabalan
5	S-83-3	11	Ouhedi
6	Dena	12	Karkheh
7	Azar-2	13	Sardari
8	Behrang	14	Saji
9	Mahdavi	15	Rizhav

Albeit selection based on a combination of indices may provide a more useful criterion for improving drought tolerance, however correlation analysis between grain yield and drought tolerance indices can be a good criterion for screening the best genotypes and indices (Khalili *et al,* 2012). Thus, a suitable index must significantly correlated with grain yield under both the conditions (Mitra, 2001). Results of correlation analysis between both grain yields under non-stress and stress conditions and drought tolerance indices (Table 3) revealed that MP, GMP and STI had positive and significant correlations with Yp and Ys. Therefore these indices were able to discriminate group A genotypes from other genotypes (Fernandez, 1992). A significant negatively correlation was showed between SSI and yield under stress condition. Therefore, as for the positive correlation between SSI and yield under non-stress

condition (Yp) and a negative correlation between SSI and yield under stress condition (Ys) recommended that selection based on SSI index will be result in increased yield under non-stress conditions (Sio-Se-Mardeh *et al,* 2006; Khalili *et al*, 2014). Khalili *et al* (2012) reported that GMP, MP, and STI were significantly and positively correlated with grain yield in non-stress and stress conditions. Also, Naghavi *et al* (2013) showed that correlation between MP, GMP, Ys and Yp was positive. In the study conducted by Ilker *et al* (2011) STI, MP and GMP were positively significant correlated with grain yield over both conditions, whereas of the three primary grain yield components, with either positive or negative correlation between grain yield and plant height. Dehghani *et al* (2009) reported that GMP, MP and STI were significantly and positively correlated with stress yield. Farshadfar *et al* (2001) believed that most appropriate index for selecting stress tolerant cultivars is an index which has partly high correlation with seed yield under stress and non-stress conditions. In general, in line with our results, Sio-Se-Mardeh *et al* (2006), Farshadfar *et al* (2012), Khalili *et al* (2012), Naghavi *et al* (2013), Khalili *et al* (2014) and Mirzaei *et al* (2014) reported that the drought tolerance indices such as MP, GMP and STI can be suitable for identify tolerant genotypes.

Table 2. Drought resistance indices for bread wheat genotypes studied.

Code	YS	Yp	SSI	TOL	MP	GMP	STI
1	2161.00	3195.00	0.72	1034.00	2678.00	2627.62	0.60
2	1501.00	2892.00	1.07	1391.00	2196.50	2083.48	0.38
3	1524.00	2772.00	1.00	1248.00	2148.00	2055.37	0.37
4	1895.00	3320.00	0.95	1425.00	2607.50	2508.27	0.55
5	1650.00	3128.00	1.05	1478.00	2389.00	2271.83	0.45
6	1522.00	2925.00	1.07	1403.00	2223.50	2109.94	0.39
7	2269.00	3553.00	0.80	1284.00	2911.00	2839.32	0.70
8	2067.00	3414.00	0.88	1347.00	2740.50	2656.45	0.61
9	1645.00	2944.00	0.98	1299.00	2294.50	2200.65	0.42
10	1982.00	3553.00	0.98	1571.00	2767.50	2653.69	0.61
11	2239.00	4438.00	1.10	2199.00	3338.50	3152.25	0.87
12	1914.00	4518.00	1.28	2604.00	3216.00	2940.66	0.75

Ys: Yield in stress condition; Yp: Yield in non-stress condition; SSI: Stress Susceptibility Index; STI: Stress Tolerance Index; TOL: Tolerance Index; MP: Mean Productivity; GMP: Geometric Mean Productivity. For Genotypes name see Tab. 1.

Table 3. Correlation coefficients between drought resistance indices.

	YS	Yp	SSI	TOL	MP	GMP	STI
YS	1						
Yp	0.656*	1					
SSI	-0.419	0.406	1				
TOL	0.197	0.869**	0.802**	1			
MP	0.838**	0.961**	0.141	0.700*	1		
GMP	0.903**	0.916**	0.009	0.598*	0.991**	1	
STI	0.887**	0.927**	0.044	0.623*	0.993**	0.998**	1

*and ** Significant at 1 and 5 percent respectively.

Ys: Yield in stress condition; Yp: Yield in non-stress condition; SSI: Stress Susceptibility Index; STI: Stress Tolerance Index; TOL: Tolerance Index; MP: Mean Productivity; GMP: Geometric Mean Productivity.

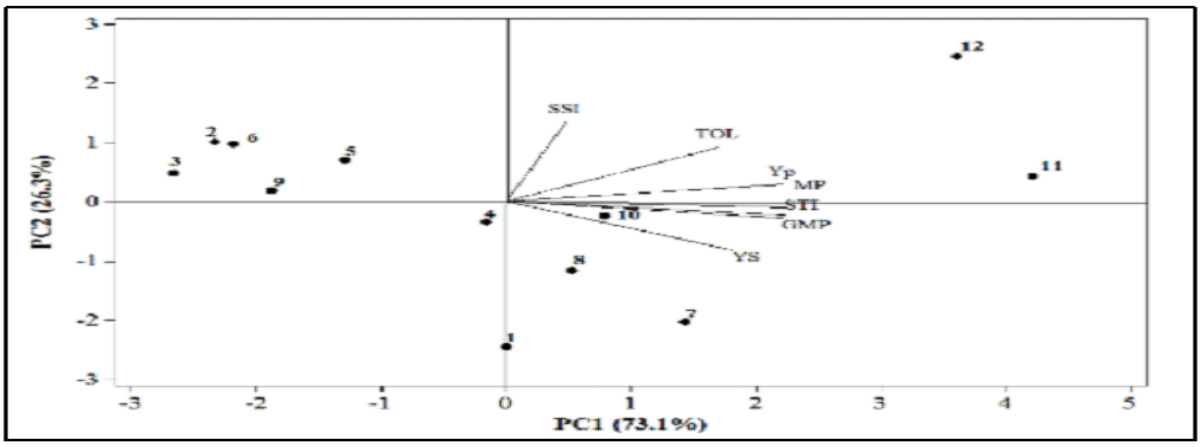

Fig. 1. Biplot for drought tolerance indices in 15 spring safflower genotypes based on first two components. Numbers inside the figure are genotypes number. For Genotypes name see Tab. 1.

To better understand the relationships, similarities and dissimilarities among the indicators of drought tolerance, biplot displayed based on principal component analysis (PCA). This analysis revealed that the two first PCA explained 99.4% of total grain yield variation (Fig. 1). The first principal component (PCA1) explained 73.1% of the variation and had positive correlation with Yp, Ys, MP, GMP, and STI. On the other hand, the second PCA explained 26.3% of the total variability and had high positive correlation with TOL and SSI indices. Hence, these component can be named as the yield stability and stress susceptibility, respectively. The genotypes with higher values of PCA1 are expected to be drought tolerant and high yielding genotypes. The biplot showed that, the genotypes No.11 and 12 had higher values for PC1 and PCA2, thus these genotypes identified as high yielding genotypes in both conditions. Genotypes No.4, 8 and 10 for the reason that placed among of PCA1 and PCA2 recognized as semi tolerance to drought stress. In spite of the fact that genotypes No.11 had high grain yield over both conditions and this genotype were desirable to drought stress in respect of their high values for PCA1 and low value of PCA2. Genotypes No.2, 3, 5, 6 and 9 were susceptible to drought stress and had low yield performance, because this genotypes had lower amounts of both PCA1 in comparison to other genotypes. Finally, our results were consistent with those reported by Golabadi *et al* (2006), Kaya *et al* (2002), Talebi *et al* (2011) and Khalili *et al* (2014).

Conclusion

In conclusion, results of present study indicated that STI, MP and GMP are the suitable indices for screening tolerant genotypes that produce higher yields in both stress and non-stress conditions. Screening drought tolerant genotypes using biplot discriminated 'Ouhedi' genotype as the most drought tolerant. Therefore it is recommended to be used as parents for improvement of drought tolerance in other cultivars.

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