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Study Drought Stress on Yield of Wheat (*Triticum aestivum* L.) Genotypes by Drought Tolerance Indices

[1]Alireza Dadbakhsh, [2]Amir Yazdansepas and [3]Mostafa Ahmadizadeh

[1]*Islamic Azad University-Ardabil Branch, Ardabil, Iran.*
[2]*Seed and Plant Improvement Institute, Karaj, Islamic Republic of Iran.*
[3]*Young Researchers Club, Jiroft Branch, Islamic Azad University, Jiroft, Iran.*

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ABSTRACT

The aim of this study was to evaluate drought tolerance potential in 19 bread genotypes in Markazi province of Iran and in the farm of complete random blocks design with three planting repetition. Tolerance and sensitivity to drought for calculating performance and principle component were also done according to them. Rosielle and Hamblin tolerance index had a positive and significant correlation with sensitivity to drought index of Fischer and Maurer. The correlation of these two indices was negative with the yield in stress condition and the first component. The high amount of this parameter introduced the genotypes which had less sensitivity. The correlation of the first component with the mean production, geometric mean performance, stress tolerance and harmonic performance mean indices was positive and high. Genotypes 6, 10 and 18 had a high yield in stress condition. They were among the genotypes with less sensitivity from TOL and SSI indices point of view. These genotypes showed superiority from other indices points of view, too. GMP, MP and STI were the most suitable indices and genotypes 10, 12, 13 and 11 were the most tolerant genotypes to stress, and they are offered to be planted in the areas of Markazi province of Iran which have the lack of water.

Key words: Tolerance indices, bread wheat, principle component, correlation of traits.

Introduction

Drought is a major constraint to worldwide crop production. Crop plant breeding for drought tolerance has long been part of the breeding process in most crops that have been or are being grown under dry condition. Drought tolerance improvement has become a breeders' major aim in dry areas. Nevertheless, drought tolerance is a complex trait resulted from the contribution of numerous factors [25]. Iran, with about 220 mm of average annual rainfall is located in dry part of the world and except some northern provinces which are located in the vicinity of the Caspian Sea, in the most areas of the country wheat crop encounters serious drought stress especially after anthesis [19]. Weather fluctuation including the amount, duration, frequency and timing of rain in relation to crop growth stages are primary determinants of the levels of terminal or intermittent drought stress under rained conditions. Significant variation for these seasonal factors and their interaction with genotypes complicate the selecting process in field grown nurseries [25]. Thus, drought indices which provide a measure of drought tolerance based on loss of yield under drought conditions in comparison to optimal conditions have been used for drought tolerant genotypes screening [16]. These indices are either based on drought resistance or

Corresponding Author
Mostafa Ahmadizadeh, Young Researchers Club, Jiroft Branch, Islamic Azad University, Jiroft, Iran. Tel: +989194457655
E-mail: ahmadizadeh.mostafa@yahoo.com

susceptibility of genotypes [10]. Drought stress may occur early or late season throughout the growing season, but its effect on yield reduction is highest when it occurs after anthesis [5].

The relative yield performance of genotypes in drought stress and favorable environments seems to be a common starting point in the identification of desirable genotypes for unpredictable rain-fed conditions. There is some agreement that a high yield potential is an advantage under mild stress, while genotypes with low yielding potential and high drought tolerance may be useful when stress is severe [17,21]. Breeding for drought resistance is complicated with the lack of fast, reproducible screening techniques and the inability of routinely defined creation and repeatable water stress conditions when a large amount of genotypes can be evaluated efficiently [29]. Achieving a genetic increase in yield under these environments has been recognized to be a difficult challenge for plant breeders while progress in yield grain has been much higher in favorable environment [22]. Thus, drought indices which provide a measure o f drought based on yield loss under drought conditions in comparison to normal conditions have been used for drought-tolerant genotypes screening [16].

Rosielle and Hamblin [24] proposed tolerance index (TOL) and mean productivity (MP). Tolerance index is crop yield difference in two different conditions and MP is mean productivity in stress and none-stress condition. High amounts of TOL were showed plant susceptibility to stress and selection was based on low amounts of TOL. High amounts of mean productivity also showed more tolerance to stress. The other indexes of plant evaluation in different condition is stress susceptibility index (SSI) which on it grain yield in each plant measured under suitable condition and stress intensity determined based on mean yield of plant under suitable and stress condition . A low amount of SSI is due to low change of plant yield in stress condition in comparison with non stress condition which results in more tolerance of plant [11]. To reduce the disadvantage due to the significant correlation between SSI and yield under non-stress, Saulescu *et al.,* [26] suggested the use of deviations from the linear regression of SSI on yield in favorable conditions. Stress tolerance index (STI) function is base of yield in each plant in two suitable and stress conditions and mean square of yield in all experimental plant in suitable condition. STI amount is always positive and if STI amount is higher, it shows high plant tolerance to stress [7]. Kanoni *et al.,* [14] showed that stress tolerance index and mean productivity are the best suitable index for varieties recognition with high yield in two conditions of dry land farming (with stress) and irrigated (without stress). Selection based on the SSI and TOL indices favors genotypes with low yield under non-stress conditions and high yield under stress conditions [12]. Selection based on STI and GMP will result in genotypes with higher stress tolerance and yield potential will be selected [10].

Ahmadizadeh [3] studied genotypes of durum wheat landraces in drought stress and irrigation conditions. Then he announced that these indices are suitable for determination of the resistant items to drought, with taking into consideration of the significant correlation of the quantitative indices of drought tolerance such as MP, GMP, STI and TOL with the yield in both conditions. Bansal and Sinha [4] studied different species of wheat and reported that Fischer and Maurer sensitivity to drought index was less in one species of wheat in comparison with the others. It was about 0.37 while the most amount of it belonged to Torgidum wheat which is about 1.02. Therefore the difference among the species of one kind to sensitivity or drought tolerance is obvious, too.

Esmailzadeh [8] reported that mean performance, geometric mean and stress tolerance index have more efficiency in distinguishing the drought tolerated wheat genotypes compared to two sensitivities to stress and tolerance indices. Among them, stress tolerance index has more activity in distinguishing the species. Farshadfar *et al.*, [9] in evaluation of twenty one chickpea line indicated that harmonic mean, mean productivity; harmonic mean production and stress tolerance index are the best suitable index for chickpea line selection to drought tolerance.

The objective this study is to identify drought tolerant genotypes under drought stress condition. Using and comparison drought stress indices also group genotypes base on these indices, so that suitable genotypes can be recommended for cultivation in the drought prone area of Iran.

Materials and methods

This research was performed in 2008-2009 agricultural year in natural resources and agricultural research field of Markazi Province (Iran). To do the research, 19 wheat genotypes (table 1) were provided from natural resources and agricultural research center in Ardabil and they were evaluated. The genotypes were planted and evaluated in two separated experiments in the form of random complete blocks design with three repetitions. Each genotype was planted in one plat with a dimension of 1.2 ×2 square meter. 30 cm of them were deleted due to being as the margin. The seeds of the experiment were disinfected before being planted with 2 in 1000 coefficient with fungicides carboxin thiram to avoid hidden smut. The amount of seed for planting was determined according to 450 seeds in each square meter and considered the weight of one

thousand seeds for each genotype. Five stages of irrigation were considered for normal condition and three stages of irrigation for stress condition. In cases under drought stress, two times of irrigation was not done after flowering. To fight the weeds which had side leaves and also thin leaves, a mixture of Granstar and Pumasuper was used. It was respectively 20 grams and one liter in hectare in tillering stage until stem elongation. The following indices were calculated to evaluate their reaction compared to drought stress.
Rosielle and Hamblin [24] tolerance index:

$$TOL = (Ypi - Ysi)$$

Rosielle and Hamblin [24] mean production (MP):

$$MP = (Ypi + Ysi) / 2$$

Fischer and Maurer [11] sensitivity to drought index (SSI):

$$SSI = (1-(Ysi/Ypi)) / SI \; ; \; SI = 1- (Ys/Yp)$$

Fernandez [10] stress tolerance index (STi):

$$STI = (Ypi \times Ysi)/Yp2$$

Geometric mean performance (GMP) in two environments:

$$GMP = \sqrt{\ } Ypi \times Ysi$$

Harmonic mean of yield in two conditions:

$$HARM= 2 (Ypi \times Ysi) / (Ypi+Ysi)$$

Where in these equations Y_{si} and Y_{Pi} are yields of a given genotype under stress and optimum condition, respectively. Y_s and Y_p are average yield of all genotypes under stress and optimal conditions, respectively.

The studied genotypes were classified in four groups of A, B, C and D according to Fernandez [10] method from yield potential and tolerance points of views. These four groups were determined in three dimension diagrams according to yield in stress condition (Ys), yield in normal irrigation condition (Yp) and stress tolerance Index (STI). For statistical calculations, software's such as Minitab-15, SPSS-16 and MSTAT-C were used.

Results and discussion

Genotypes 12 and 15 had the most amounts of TOL and SSI (table 2). The amounts higher than TOL and SSI index show more sensitivity to drought stress, so the genotypes are chosen according to less amount of TOL. Since, in this case the genotypes will have less yield decrease in stress condition compared to normal condition [24]. Fernandez [10] declared that the selection on this base is in profit of the genotypes with low yield in normal condition and the genotypes with high yield in drought stress condition. This index does not have efficiency in distinguishing the genotypes with high yield. As it observed in tables 2, genotypes 16 and 18 which had the least amounts of this index, and in the other words showed less sensitivity to stress, were not among the best genotypes from yield in normal condition point of view. Guttieri *et al.*, [13] suggested that SSI will indicate above average susceptibility to drought stress in spring wheat cultivars more than 1. SSI has been widely used by researchers to identify sensitive and tolerant genotypes [6,28,29,12]. Acosta and Adams [1] declared that the selection according to SSI is effective when the experiment condition is a dry condition. Less amount of SSI shows the less changes of a genotypes yield in stress condition and it also shows its more stability [11].

Genotypes 6, 10 and 12 had the highest mean production (MP), geometric performances mean (GMP) and stress tolerance index (STI) and genotype 19 had the least amount of these indices (table 2). Genotype 10 had the highest yield in normal condition. Considering TOL index, genotype 15 had the most yield decrease among the genotypes due to stress; while the genotype 10 had less yield decrease than genotype 15 (table 2). Therefore it seems that it is possible to introduce the tolerated genotype by genotype 15 after several years of evaluation and selection in stress condition. Fernandez [10] declared that STI index is able to separate the genotypes which have a high yield and are tolerated against drought stress. Genotypes 6, 10 and 18 had a high yield in stress condition and they were among the genotypes which had less sensitivity from TOL and SSI points of view. These genotypes showed superiority from other indices points of views, too.

As it is observed from table 2, mean production (MP) has introduced genotype 12 among three superior genotypes, while this genotype did not have a high yield in stress condition. It is also considered among the sensitive genotypes from TOL and SSI indices points of views. Fernandez [10] introduced mean production index among the indices with low efficiency, because this index cannot distinguish the tolerated genotypes and the genotype with high yield at the same time in drought stress condition and normal condition. He also indicated that geometric performance mean index is less affected by the final value of the traits, and it can distinguish the genotypes of group A from the rest of them.

The scatter of the genotypes according to their yield in stress and normal conditions and STI has

Table 1: List of wheat genotypes used in study.

Number	pedigree
1	Shahryar
2	Local Check
3	Local Check
4	Gascogene// Rsh*2/ 10120/3/ Alvd// Aldan/Las58
5	Alvd// Alaan/ las58/3/ Mv17/4/ Evwyt2/ Azd// Rsh*2/10120
6	(Alvd// Aldan/ Las)* 2/3/ Gaspard
7	Mhdv/ Soissons/4 / Bb/7C* 2/ Y50 E/ Kal*3
8	F4141- W-1- / PASTOR// PYN/ BAU
9	AU// YT542/ N10B/3/118260/4/JI/ HYS/5/YUNNATODESSKIY/6/ KS82 W409/SPN
10	ID800994. W/ VEE/3/ URES/JUN// KAUZ/ 4BUL 5052.1
11	Basswood/ Mv17
12	Basswood/ Mv17
13	Bhr* 5/Aga//Sni/3 /Trk13/4/Gaspard
14	Gds/4/ Anza/3 Pi/ Nar// Hys/5/ Vee/ Nac/6/ Gascogne
15	Gds/4/ Anza/3 Pi/ Nar// Hys/ 5/ Vee/ Nac/6/ Gascogne
16	Omid// H7/ 4P839/3/ Omid/ Tdo/ 41CWHA81-1473/5/90 Zhong/6/OwI
17	Soissons/M- 73-4//OWI852524-*3H-*O-*HOH
18	BILINMEYEN-6
19	SN64//SKE/2*ANE/3/SX/4BEZ/5/SERI/6/CHERVONA/7/ KLEIBER/2* FL80// DONSK POLUK

Table 2: Drought Tolerance Indices and Mean yield of 19 wheat genotypes in stress and normal conditions.

Genotypes	Yp (kg/h)	Ys (kg/h)	TOL	MP	GMP	SSI	STI	Harm
1	4096	2350	1746	3223	3103	0.98	0.42	2987
2	4921	2661	2260	3791	3619	1.06	0.57	3454
3	4619	2211	2408	3415	3196	1.20	0.45	2990
4	4275	2789	1486	3532	3453	0.80	0.52	3375
5	5149	2583	2566	3866	3647	1.15	0.58	3441
6	4633	3478	1155	4056	4014	0.58	0.70	3973
7	5181	2695	2487	3938	3737	1.11	0.61	3545
8	4710	2928	1782	3819	3713	0.87	0.60	3611
9	4287	2856	1431	3571	3499	0.77	0.53	3428
10	5933	3245	2688	4589	4388	1.05	0.84	4195
11	4996	2811	2185	3904	3747	1.01	0.61	3598
12	5810	2806	3004	4308	4037	1.19	0.71	3784
13	5308	2811	2497	4060	3863	1.09	0.65	3676
14	4532	2878	1654	3705	3611	0.84	0.57	3520
15	5624	2350	3274	3987	3636	1.34	0.58	3315
16	4398	2322	2076	3360	3196	1.09	0.45	3040
17	4561	2500	2061	3531	3377	1.04	0.50	3230
18	4439	3200	1239	3820	3769	0.64	0.62	3719
19	3455	2050	1405	2753	2661	0.94	0.31	2573

been shown in 3 dimensional diagrams (figure 1). Normand *et al.,* [20] studied bread wheat in drought and normal conditions. They drew a three dimensional species yield in both two conditions and GMP and STI indices. They showed that the genotypes in group A. had high STI and GMP. They introduce these two indices as the best indices.

The Correlation among Drought Tolerance Indices and Yield:

TOL had a positive and significant correlation with SSI in 1% possibility level (table 3). As Rosielle and Hamblin [24] declared in most of the experiments he correlation between these two indices have been positive, and the selection according to SSI index is in profit of the genotypes which have low yield potential in normal condition and high yield in stress condition.

MP index showed a positive and significant correlation in 1% possibility level with GMP, STI and Harm indices. SSI index showed a negative correlation with Harm index. The correlation of STI index with Harm was positive and very significant. Tolerance, mean production, geometric mean production, sensitivity to stress, tolerance indices and also harmonic mean had a significant correlation with the yield of the genotypes in stress and normal conditions. The correlation between TOL and SSI indices with yield in stress condition was negative. Therefore the more the increase of the yield in stress condition, therefore the decrease of these two indices will be.

Farshadfar *et al.,* [9] studied chickpea and reported the positive and significant correlation of all indices with yield in normal condition. They also reported TOL index negative and non-significant correlation with yield in stress condition. Normand *et al.,* [19] reported the positive and significant correlation of GMP and STI indices with yield in wheat. Shafazadeh *et al.,* [27] studied the genotypes of wheat and they also reported a positive and very significant correlation between the yield in stress and MP, GMP and STI indices. They also reported a positive and significant correlation between the yield in normal condition and all tolerance indices and

Table 3: Correlation between drought tolerance indices with yield under normal irrigation and drought stress conditions.

	YP	YS	TOL	MP	GMP	SSI	STI
YS	0.337	1					
TOL	0.821**	-0.260	1				
MP	0.907**	0.702**	0.505*	1			
GMP	0.811**	0.823**	0.333	0.982**	1		
SSI	0.533*	-0.612**	0.918**	0.130	-0.057	1	
STI	0.814**	0.815**	0.341	0.980**	0.996**	-0.047	1
HM	0.687**	0.914	0.151	0.928**	0.982**	-0.240	0.977**

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

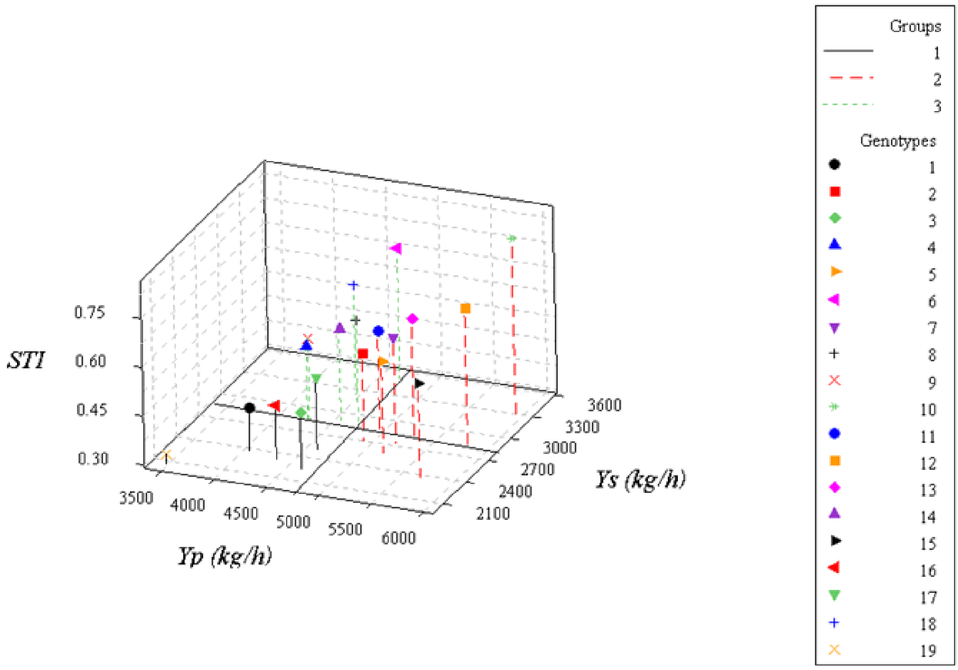

Fig. 1: Scatter plot between Ys, Yp and stress tolerance index (STI).

sensitivity to drought. They indicated the positive and significant correlation among the indices and yield in both conditions which shows the suitability of these indices for evaluating tolerance to drought in the genotypes. Selection against tolerance increases the yield in stress condition since genetic correlation between tolerance and yield is positive in stress condition [10]. Similar results were reported by Clark *et al.*, [6], Sio-Se Mardeh *et al.*, [28] and Talebi *et al.*, [29]. Rizza *et al.*, [23], however, they showed that under stress selection based on minimum yield decreasing with respect to favorable conditions (TOL) failed to identify the best genotypes.

Principal Components Analysis:

According to the results of Principal components analysis (Table 4), the first two components justify the most percentage of data changes (99.83%). The first component had a positive but low correlation with SSI and TOL indices. It had a positive and high correlation with the yield in both conditions and other indices. The second component justifies 32.33% of total data changes (table 4). This component had a positive and high correlation with SSI and TOL indices and it was positive in yield in normal condition and negative in stress condition. So to identify the tolerated genotypes to high amounts of both components i.e. pay attention to the right side and the top part of by-plot diagram (figure 2). In this part, genotypes 10, 12, 13 and 11 exist. They were among the best genotypes from yield in from stress condition view. Considering the by-plot, there is the most positive correlation among MP, GMP and STI indices and yield in both conditions. This subject confirms the simple correlations. Since GMP and STI indices are close to each other, they have the same value. The obtained results in this research correspond to the results of Fernandez [10], Golabadi *et al.*, [12], Kaya *et al.*, [15], Mollasadeghi [18].

According to the by-plot, genotypes 10, 12, 13 and 11 genotypes have higher and more yield and stable. And genotypes 10 and 12 have big PC1 and rather small PC2, so they have superiority the other genotypes. This result corresponds the results of Kaya *et al.*, [15] and Golabadi *et al.*, [12] results. Fernandez [10] showed that STI index is able to separate genotypes of group A from the other groups. (Group A: the genotypes which have a high performance in stress and without stress conditions. Genotypes 10, 12, 13 and 11 have been there in part A of three dimensional diagrams, so they have more

Table 4: Vectors and special amounts, relative and cumulative variance for three main components from principal components over drought tolerance indices of 19 wheat genotypes under normal irrigation and drought stress conditions

Component	Total	% of Variance	Yp	Ys	TOL	MP	GMP	SSI	STI	HM
1	5.4	67.496	0.865	0.764	0.424	0.995	0.995	0.041	0.994	0.959
2	2.586	32.329	0.501	-0.645	0.905	0.09	-0.097	0.997	-0.088	-0.282

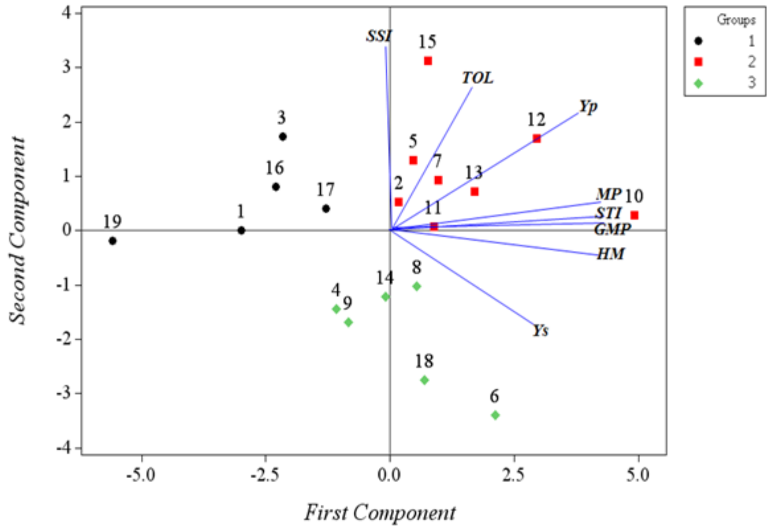

Fig. 2: Biplot based on PC1 and PC2 resulted from drought tolerance indices of 19 wheat genotypes.

grain yield in both conditions and they are tolerated against stress. This confirms the method of by-plot. The above result corresponds to the results of Fernandez [10], Ahmadi *et al.*, [2], Farshadfar *et al.*, [9] and Mollasadegi [18]. The sensitive genotypes which have high SSI and TOL and low STI (genotypes 14, 9 and 4) are specified in the vicinity of the center of coordinates (figure 2). Also the angles between the lines of the components (figure 2) show the correlation among the indices. It is a confirmation for the results of table 2. Finally it was concluded that GMP, MP and STI are the most suitable indices and genotypes 10, 12, 13 and 11 were the most tolerated genotypes to stress, and they are advised to be planted in less water areas of Arak province of Iran.

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