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RESEARCH ARTICLE

Assessment of Azerbaijan Durum Wheat Genotypes Under Drought and Non-Stress Conditions

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ABSTRACT

In this study, as a genetic materials 50 wheat genotypes from National Genebank of Genetic Resources Institute of ANAS were tested in a randomized complete block design in two replications under drought and normal conditions in Gobustan and Absheron regions, Azerbaijan Republic during 2016-2017 growing season. Analysis of variance indicated that there were highly significant differences among the genotypes with regard to all the traits under two experimental condition. The correlation coefficients showed that stress tolerance index (STI), mean productivity (MP), harmonic mean (HM) and geometric mean productivity index (GMP) were the most desirable selection criteria for high yielding and drought tolerant genotypes. Principal component analysis and biplot showed that genotypes № 15, 28, 4, 13 and 6 were more stable under irrigated and rain-fed conditions. These genotypes can be recommended to be used as donor parents for drought tolerance genes in wheat breeding programs for drought-affected areas of Azerbaijan Republic.

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Introduction

Nowadays, cereal grains are the most important source of calories to a major part of the world population. According to the statistics, in developing countries cereals directly account for 60% of calories, with values exceeding 80% in the poorest countries (WHO, 2015). Even in developed countries, where only 30% of calories are derived directly from cereals, they remain the most important food commodity as they provide nutrients for livestock that form a major part of diet in these regions (WHO, 2015). Among cereal crops, wheat holds the third position after rice and maize with annual world production reached 750 million metric tons in 2017 (FAO, 2017).

Global climate change coupled with the high growth rate of world population has raised the problem of global food security and fresh water availability. According to the projections, the shortage of fresh water will make inevitable to transform up to 60 Mha of irrigated land into rain-fed area. Under rain-fed conditions, crops depend entirely on precipitation and are vulnerable to yield loss due to drought.

Among environmental factors affecting plant development and growth, drought is the most severe stress, which leads to substantial reductions in growth rate and biomass accumulation. Depending on the time of influence, drought stress can reduce grain yield about 17–70% (Nouri-Ganbalani et al., 2009). According to the initial forecast, only in 2017 the

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world wheat production has lost 14 million metric tons of yield due to dry and hot weather during the summer months which intensified yield reductions in northern countries (FAO, 2017).

In Azerbaijan semi-desert and dry steppe climates cover the central lowlands in the Kur region to 400 meters (1300 ft), the Caspian zone from the end of Samur River to the Gizilagaj gulf, the plains of Nakhchivan along the Araz river, and the valleys of the Talish Mountains below 1,000 meters (3300 ft). Annual precipitation accounts for 15 to 50 percent of the possible evaporation and summers can become very hot, with temperatures reaching over 40 °C. Ensuring stable crop yields under such conditions requires selection of drought-tolerant cultivars with high water use efficiency.

The main objective of this study was devoted to determine the relationship between grain yield and yield components under normal irrigation and drought stress. Also, to identify the best wheat genotypes for using in breeding program in order to create new drought resistance verity.

Materials and Methods

Fifty cultivars of durum wheat (*Triticum durum* L.) listed in Table 1 were provided from National Genebank of Genetic Resources Institute, Azerbaijan.

Table 1. The pedigree of the tested *T. durum Desf.* wheat cultivars

№	Cultivar	№	Cultivar
1	*v.leucurum*	26	*v.aegiptiacum*
2	*v. mutico leucurum*	27	*v.boeuffi*
3	*v.hordeiforme*	28	*v.apulicum*
4	*v.mutico hordeiforme*	29	*v.coerulescens*
5	*v.mutico hordeiforme*	30	*v.coerulescens*
6	*v.murciense*	31	Ag bugda *v.affine*
7	*v.murciense*	32	Sari bugda *v. hordeiforme*
8	*v.affine*	33	Qaraqilchiq *v.provinciale*
9	*v.affine*	34	Qara bugda *v. leucomelan*
10	*v.mutico affine*	35	Bozakh *v.hordeiforme*
11	*v.erythromelan*	36	Vuqar *v. leucurum*
12	*v.melanopus*	37	Arandeni *v.apulicum*
13	*v.melanopus*	38	Sherq *v.leucurum*
14	*v.mutico melanopus*	39	Khoranka *v.horanoleucurum*
15	*v.coerulescens*	40	Sevinj *v. hordeiforme*
16	*v.niloticum*	41	Jafari *v.horanoleucurum*
17	*v.obscurum*	42	Ag bugda 13 *v.leucurum*
18	*v.obscurum*	43	Shirvan 3 *v.affine*
19	*v.alboprovinciale*	44	Mugan *v.leucomelan*
20	*v.alexandrinum*	45	Mirbeshir 50 *v.leucurum*
21	*v.reichenbachii*	46	Qaraqilchıq 2 *v.apulicum*
22	*v.africanum*	47	Tartar *v.provinciale*
23	*v.lybicum*	48	Bereketli 95 *v.hordeiforme*
24	*v.lybicum*	49	Alinje 84 *v.leucurum*
25	*v.hordeiforme*	50	Qarabag *v.provinciale*

They were assessed in a randomized complete block design with two replications under two drought and normal conditions in 2016-2017 growing season in the experimental field of the Absheron experimental station of the Institute of Genetic Resources (under irrigation) and Gobustan Regional Experimental Station of Crop Husbandry (rain-fed condition).

Each genotype was planted in 4 rows of 2 m length, 20 cm apart and ten plants of each replication were examined for a set of 9 agromorphological characters. Measured traits included plant height, spike per m^2, peduncle length, number grains per spike, grain weight per spike, spike length, spike weight, number of spikelet per spike and 1000 kernel weight.

Drought resistance indices were calculated using the following relationships:

Stress susceptibility index (Fischer and Maurer, 1978):

$$SSI = \frac{1-\frac{Ysi}{Ypi}}{1-(Ys-Yp)} \quad (1)$$

Tolerance (Rosielle and Hamblin, 1981):

$$TOL = Ypi - Ysi \quad (2)$$

Geometric mean productivity (Fernandez, 1992):

$$GMP = \sqrt{YpiYsi} \quad (3)$$

Mean productivity (Rosielle and Hamblin, 1981):

$$MP = \frac{Ypi+Ysi}{2} \quad (4)$$

Stress tolerance index (Fernandez, 1992):

$$STI = \frac{Yp \times Ys}{2} \quad (5)$$

Harmonic mean (Kristin et al., 1997):

$$HM = \frac{2\,(Yp \times Ys)}{(Yp+Ys)} \quad (6)$$

In the above formulas, Ysi, Ypi, Ys and Yp represent yield under stress, yield under non-stress for each genotype, yield mean in stress and non-stress conditions for all genotypes, respectively.

Results and Discussion

Genetic variability in breeding materials is essential for a successful plant breeding program. Understanding the magnitude of variability in crop species is pivotal since it provides the foundation for selection. The results of analysis of variance showed high significant diversity between studied durum wheat genotypes for all morphological traits like plant height, spike per m^2, peduncle length, number grains per spike, grain weight per spike, spike length, spike weight, number of spikelet per spike and 1000 kernel weight (Table 2). The results showed that genotypic differences were highly significant in both drought and irrigated conditions. G×C interaction was significant for traits such as plant height, peduncle length, number of grain per spike, grain weight per spike, spike length, spike weight and number of spikelet per spike. In this study there was no genotype × environment interaction for spike per m^2 and 1000 kernel weight. This indicates that the magnitude of differences in cultivars was sufficient to select them against drought. Also, results indicated that there is a high variation for all traits which revealed the presence of genetic diversity for these attributes in the materials. Therefore, these traits have good potential for selection of the most tolerant and most sensitive cultivars for using in cross together and create genetically variation or using of direct culture for tolerant cultivars in Azerbaijan drought affected area.

Table 2. Mean squares for studied traits of 50 wheat varieties evaluated under drought stress and non-stress conditions

	S.O.V								
	Rep	**Co**	**Geno**	**G×C**	**Error**	**LSD5%**	**ECV%**	**GCV%**	**$h^2_{b.s}$**
DF	1	1	49	49	99	-	-	-	-
Plant height (cm)	**	**	**	**	52.18	11.27	7.18	12.18	0.68
Spike per m^2 (gr)	NS	**	**	NS	219.92	30.48	12.15	21.86	0.78
Peduncle length (cm)	NS	**	**	**	17.25	4.83	9.25	17.15	0.81
Number of grains per spike	**	**	**	**	10.68	8.52	11.58	30.48	0.91
Grain weight per spike (gr)	*	**	**	**	0.125	0.652	16.85	41.28	0.88
Spike length (mm)	NS	**	**	**	0.589	1.58	5.85	12.85	0.92
Spike weight (gr)	**	**	**	**	0.228	0.895	4.28	31.28	0.95
Number of spikelets per spike	NS	**	**	**	0.782	2.12	10.85	16.52	0.87
1000 kernel weight (gr)	*	**	**	NS	16.75	7.58	3.55	24.18	0.79

DF: degree freedom, Rep: replication, Co: conditions (irrigation and non-irrigation), Geno: genotypes, G×C: interaction genotypes with conditions, ECV: coefficient of environment variation, GCV: coefficient of genetic variation, h^2 *bs*: broad sense heritability; **, * and Ns; significant at 1%; 5% level of probability and non-significance, respectively.

The environmental coefficient variation of experimental design was obtained from 3.55 to 16.85. The experiment showed an adequate experimental precision according to Resende and Duarte (2007) once the F values were greater than 2.0. When considering the environmental coefficients of variation, the values of small magnitude for all studied traits (Table 2), also indicated an adequate experimental precision. The genotypic coefficient of variation ranged from 12.18 percent to 41.28 percent (Table 2). The result of genotypic coefficient of variation revealed that grain weight per spike, spike weight and number of grain per spike exhibited highest genotypic coefficient of variation of 41.28, 31.28 and 30.48 percent, respectively. The high GCV observed are evident from their high variability that in turn offers good scope for selection in both drought and non-stress conditions.

Heritability estimates give an insight into the extent of genetic control to express a particular trait and phenotypic reliability in predicting its breeding value (Ndukauba et al., 2015). High heritability indicates less environmental influence in the observed variation (Eid, 2009). Broad sense heritability only indicates whether or not there is sufficient genetic variation in a population, which implies whether or not a population will respond to selection pressure (Gatti et al., 2005; Milatovic et al., 2010; Ullah et al., 2012). In the present investigation high estimates of heritability (above 80%) in broad sense were recorded for all characters studied, except traits like plant height, spike per m^2 and 1000 kernel weight with 68%, 78% and 79%, respectively. High heritability value for these traits indicated that the variation observed was mainly under genetic control and was less influence by environment. So, these traits may be used as selection criteria for yield improvement in confirmation with the result of earlier workers viz., Islam et al. (2012), Kumar et al. (2014) and Fellahi et al. (2013).

In this study, Genotypes № 15, 28 and 4 under irrigated conditions and the genotypes № 45 and 49 under rain-fed conditions were genotypes with better grain yield. Plant height is an important trait to be considered when developing lodging tolerant crops. If there is limited scope for plant breeders to counter the greater lodging risk caused by heavier yielding varieties by further shortening plants in some countries like Azerbaijan, then it follows that the biophysical components that support the plant (stem and anchorage system) must be strengthened. For the plant height in Absheron region (normal condition) the genotypes № 8 and 26 were the tallest genotypes, the genotypes № 46 and 49 were evalutaed as a shortest genotypes. In Gobustan region (rain-fed condition) the tallest genotypes were № 22, 27, 31 and 36, the genotypes № 5 and 29 were shortest genotypes.

Under normal condition, simple correlation analysis showed significant positive correlation between grain yield with all studied traits, except plant height, peduncle length and number of grain per spike. Under drought condition grain yield had positively and significantly correlation with all traits, except number spikelet per spike and number spike per m^2. Simple correlation of all studied traits were observed under normal and water stress conditions as shown in Table 3. The analysis of correlation of different traits with grain yield can help to make decision about the relative importance of these traits and their merits as selection criteria (Naghavi and Khalili, 2017).

To determine the most desirable drought tolerance criteria, the correlation coefficient between Yp, Ys and other quantitative indices of drought tolerance were calculated (Table 4). Grain yield had a positive highly significant correlation with all calculated tolerance in control condition, whereas, the correlation between YS with SSI and TOL indices was negative. These results were accordance with the records reported by Mursalova et al. (2015).

Table 3. Coefficient correlation between studied traits in normal (above main diagonal) and drought stress (under main diagonal)

	PH	m^2 sp	Ped	GrN	GrW	SpL	SpW	Spikle	Kernel
PH	1	-0.115	0.776**	-0.185	0.086	0.126	-0.168	0.271	-0.15
m^2sp	-0.057	1	0.010	0.084	0.576**	0.429**	0.497**	0.315*	0.234
Ped	0.556**	-0.246	1	-0.38*	0.036	0.144	-0.156	0.072	-0.14
GrN	-0.02	0.143	-0.192	1	0.321*	-0.031	0.04	-0.049	0.17
GrW	0.175	0.001	-0.026	0.516**	1	0.544**	0.618**	0.575**	0.252
SpL	0.511**	-0.027	0.389**	0.065	0.509**	1	0.67**	0.534**	0.077
SpW	0.37**	0.032	0.183	0.354*	0.608**	0.364**	1	0.574**	0.37**
Spikle	0.226	-0.269	0.38**	0.149	0.061	-0.244	-0.255	1	0.249
Kernel	0.276	-0.011	0.063	0.181	0.878**	0.556**	0.556**	-0.016	1

PH: plant height, m^2sp: spike per m^2, ped: peduncle length, GrN: number grain per spike, GrW: grain weight per spike, SpL: spike length, SpW: spike weight (grain yield), spikle: spikelet per spike, Kernel: 1000 kernel weight.

Table 4. Simple correlation coefficients between tolerance and susceptibility indices of wheat genotypes

Traits	Yp	Ys	SSI	TOL	GMP	STI	MP	HM
Yp	1							
Ys	0.338**	1						
SSI	0.575**	-0.508**	1					
TOL	0.766**	-0.346**	0.92**	1				
GMP	0.832**	0.800**	0.078	0.283*	1			
STI	0.886**	0.736**	0.163	0.381**	0.993**	1		
MP	0.886**	0.736**	0.163	0.381**	0.993**	1.00**	1	
HM	0.768**	0.851**	-0.004	0.184	0.993**	0.972**	0.972**	1

Yp: yield under normal conditions; Ys: yield under stress conditions, SSI: stress susceptibility index, TOL: tolerance index, GMP: geometric mean productivity, STI: stress tolerance index, MP: mean productivity, HM: harmonic mean, **and* significant at the 0.01and 0.05 probability levels, respectively.

Since coefficients of correlation may singly not provide thorough information about the relations of different traits and given the various advantages of multivariate statistical analyses for deep understanding of data structure, principal component analysis was used in the current study. According to principal component analysis, 2 components accounted for 98.90% of the total variance (data not shown *(because of big data)*). The first component justified most of the variance between the genotypes. The first factor mainly emphasized the grain yield in stress and normal conditions of MP, GMP, HM and STI with positive factor loads. This factor which constitutes 68.02% percent of the total changes is called “resistance factor”. The second principal component justified 30.88% of the remaining variation and revealed high score of TOL, SSI, and Yp. Therefore, we can refer to this component as tolerance index. As such, the second principal component plays an important role in distinguishing groups of cultivars under normal conditions for the purposes of yield. Our findings correspond to the findings of Mursalov et al. (2015) and Ashrafi Parchin et al. (2013).

In Biplot (Figure 1) drawn based on the first and second principal component genotypes within the groups that are associated with yield and stress tolerance. In consequence, selection of genotypes that have high PCA1 and PCA2 are suitable for both stress and non-stress conditions (Kaya et al. 2006). The higher scores for first component and lower scores for second component (part A from Fig. 1) were high drought tolerance. Whereas, low scores for both first and second components showed drought-sensitive genotypes (part D from Fig. 1). Genotypes with lower first component and higher second scores had low grain yields (part C from Fig. 1). Since the first factor has more contribution in total variation, genotypes in part B of the biplot (having high scores of first and second components) had a moderately tolerant reaction to drought conditions and high production potential under control conditions (part B from Fig. 1).

In this research, based on the analysis of drought indices between studied wheat accessions, genotypes № 49, 45, 43 and 41 were selected as the most drought-tolerant genotypes. The genotypes № 15, 28, 6, 13 and 4 were stable genotypes for both conditions. Hence, these genotypes can be recommended to be used as donor parents for drought tolerance genes in wheat breeding programs for drought-affected areas of Azerbaijan Republic.

Cluster analysis has been widely used for description of genetic diversity and grouping based on similar characteristics (Souri et al., 2005). Separate cluster analysis (using Ward's method) based on Yp, Ys and other drought stress indices were performed for wheat genotypes.

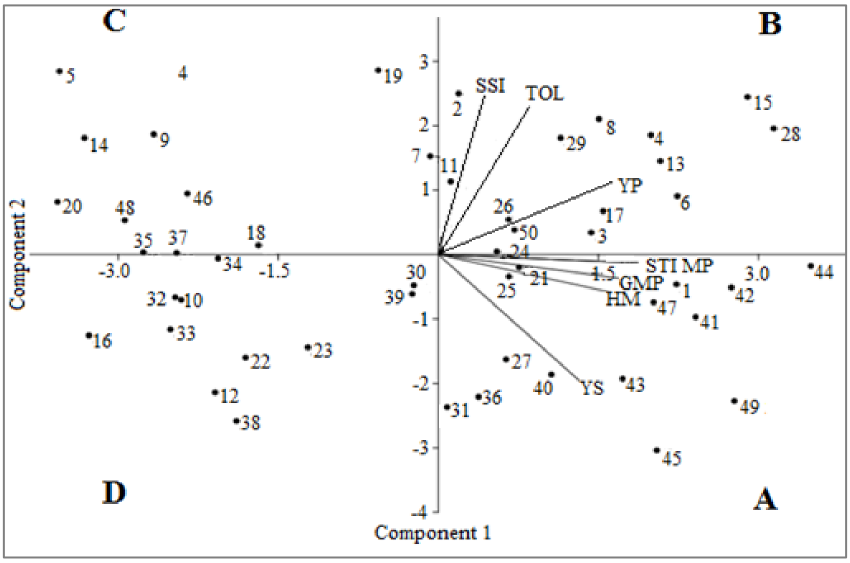

Figure 1. Dispersion of the genotypes according to first and second component of principal components under normal and drought stress conditions

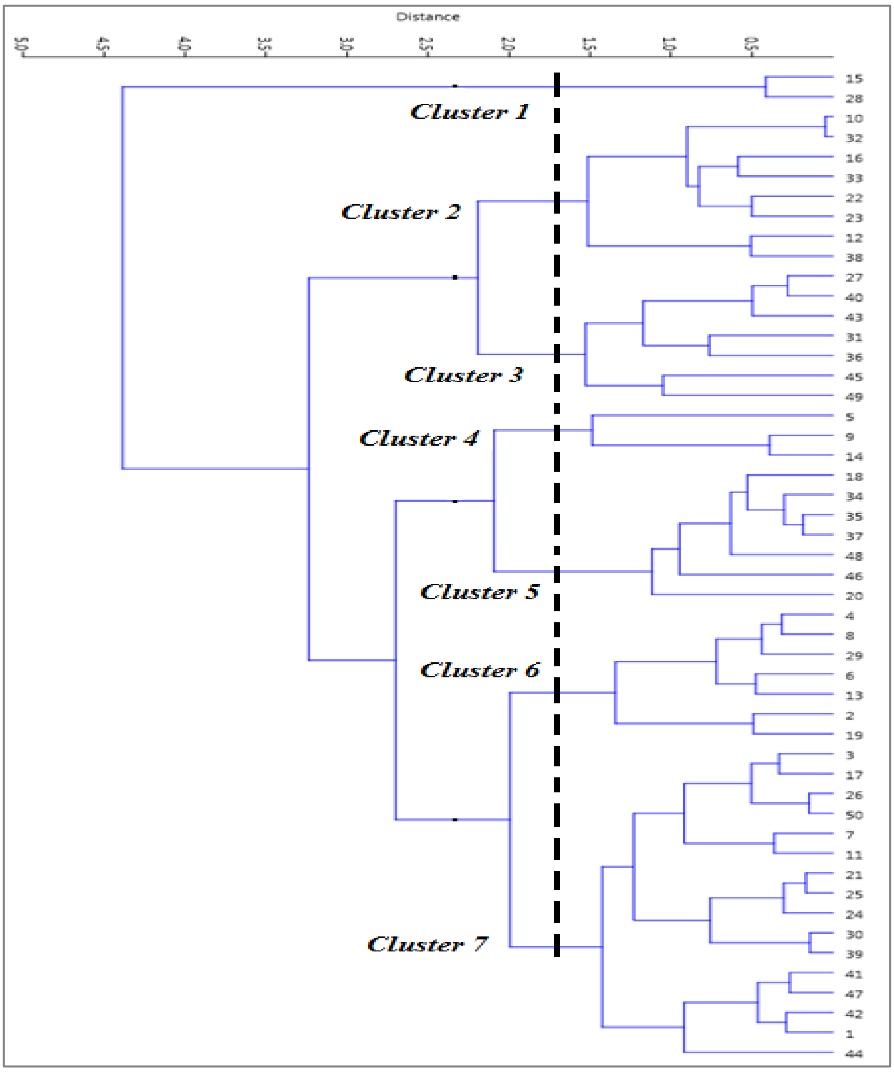

Figure 2. Dendrogram of wheat genotypes based on cluster analysis by various drought tolerance indices

The discriminate function analysis allowed the highest differences among groups when genotypes were categorized into seven groups (Figure 2). By cluster analyses, genotypes № 15 and 28, which had the highest PCA1 and PCA2, was located in the first cluster. Genotypes № 10, 32, 16, 33, 22, 23, 12 and 38, which had lower PCA1 and PCA2, were placed in the second cluster that were low yield and sensitive wheat genotypes. Therefore, cluster analysis supported the results of principal component analysis. These genotypes were resided in D part of biplot. The genotypes that were classified in third cluster has high PCA2 and low PCA1 scores. Cultivars № 27, 40, 43, 31, 36, 45 and 49 with high PCA1 and low PCA2 were placed in the fourth cluster. Thus, these genotypes with low fluctuations under stress environment can be considered as "drought resistant" genotypes. The wheat genotypes like № 18, 34, 35, 37, 48, 46 and 20 which grouped in fifth cluster are evaluated as low yield genotypes. The genotypes that are resided in sex cluster like the genotypes in third cluster has high PCA2 and low PCA1 scores. The seventh cluster are consisted of 16 genotypes that all can be suggested to be used as best genotypes to plant in drought-affected areas of Azerbaijan.

Conclusion

In this research the morphological traits, like number of grain per spike (GrN), spike length (SpL) and and wight (SpW) were the best criteria for improving grain yield in durum wheat under drought and normal conditions. Durum wheat genotypes № 15, 28, 6, 13 and 4 had the highest tolerance to drought stress and produced the highest grain yield in both (normal and drought) conditions.

The selected durum wheat genotypes can be recommended as promising genotypes for drought areas. These genotypes can be utilized through appropriate selection as donor parents in wheat breeding programs for further improvement of wheat germplasm for drought tolerance.

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