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Full Length Research Paper

Selection of superior wheat genotypes against end-season drought of Ardabil in the presence of humic fertilizer by utilization of multivariate statistics

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Irrigated wheat in cold regions of Iran is faced with the end drought stress. Humic substances, as natural biological origin fertilizers have mitigation activity on plants facing the biotic and abiotic stresses. This experiment was conducted by a split plot on the basis of completely randomized block design (RB) in Ardabil in 2008 to 2009 farmer year. Main factor was stressed and non stressed conditions; and sub factor was genotypes. Gascogne, Toos, 4057 and 4041 were the most tolerant genotypes against stress from mean productivity (MP), geometric mean productivity (GMP) and stress susceptibility index (STI) indices; and had highest yield in this research. Gascogen, Sabalan and 4057 genotypes had the low susceptibility against stress by stress susceptibility index (SSI). On the basis of stress tolerance (TOL), genotypes 4041 and Toos had a high tolerance to drought stress. In non-stress condition, there were significantly positive correlations between yield and MP, GMP, STI and TOL. And, in the stress condition, correlation of yield with GMP and STI were significantly positive. Correlation of yield with SSI was negative and significant for stress condition. Cluster analysis was placed 4041 and Toos genotypes in a group which were the best genotypes of this research. These two genotypes had the high yield relative to others in the both conditions of stress and non stress. Principle components analysis showed that yield component was justified 64% of the changes; tolerance indices component 30% of the changes.

Key words: Wheat, stress, humic fertilizer, tolerance indices.

INTRODUCTION

Drought stress is the most important factor limiting crops production in agricultural systems in arid and semi arid regions. Of 2.3 million ha of irrigated wheat in the country, in a range of about 900 thousand ha 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). Forty-year long-term statistics show that rainfall in Ardabil province is 310 mm that mainly is happening in the fall, winter and early spring

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Abbreviations: RB, Randomized block design; **MP,** mean productivity; **GMP,** geometric mean productivity; **STI,** stress susceptibility index; **TOL,** stress tolerance; **SSI,** stress susceptibility index.

Table 1. List of study genotypes of wheat in this investigation.

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

(Anonymous, 2004).

Continuing occurrence of drought in recent years and particularly drought conditions in 2007 to 2008 agricultural years that affected the vast area of the country has loop the repeated alarm for agricultural productions and production stability. Therefore, necessity of more attention to sustainable solutions in all research fields and performing operations to reduce the effects of this factor is very important. 2007 to 2008 farming years is one of the clear years that experienced effect of this phenomenon on different dry and irrigated crops as well (Agaeisarbarze et al., 2009).

Fischer and Maurer (1978) offered stress susceptibility index (SSI) for the assessment of stress tolerant varieties. Rosielle and Hamblin (1984) used stress tolerance (TOL) and mean productivity (MP) for selection of stress tolerant cultivars. It is better to use TOL index when the yield increasing in stressed condition is considered. If yield increasing is considered in both stressed and non stressed conditions, it is better to use MP index. Fernandez (1992) divided genotypes reaction into four groups based on their yield in stressed and non-stressed environments: Group A are genotypes that have high yield in both conditions; group B are genotypes that have high yield under non-stressed conditions; group C are genotypes that have a good yield in stressed conditions, and group D are genotypes that have lower yield in both conditions. He was offered stress tolerance index (STI) and geometric mean productivity (GMP) for selecting genotypes that have optimum yield in both stressed and non-stressed conditions.

Sio-se et al. (2006) had stated that selection of cultivars based on TOL index lead to reducing yield in non-stressed conditions. They mentioned SSI index as appropriate for the reforming in low intensity stresses, and indices MP, GMP and STI are appropriate for the stresses of high intensity. Humic materials are the result of decomposition of organic materials, and they are natural organic compounds that are containing 50 to 90% of peat, lignite, sapropel organic matter and nonliving organic matter in soil and water ecosystems. Scientists believe that the following principal ways of its action could be proposed: organism development, hormone-like activity, nutrient carriers, catalysts of biochemical reactions and antioxidant activity (Kulikova et al., 2005). It was known that potassium humate increases plant tolerance against alive and non-alive stresses (Shahryari et al., 2008).

Shahryari et al. (2011a) concluded a significant difference for both grain yield and biological traits in terms of "irrigation levels × humic fertilizer levels" effect. So their investigated genotypes had significant difference in terms of grain yield and genotypes had genetic variation in terms of this trait.

Shahryari et al. (2011b) investigated response of six wheat genotypes to humic fertilizer against terminal drought. They expressed that applied humic fertilizer reduced average grain yield differences between stressed and non-stressed conditions from 1.0 to 0.1 ton/ha. In another research for determining effect of humic fertilizer on wheat under drought condition, Mollasadeghi et al. (2011) showed that humic fertilizer decreased stress intensity by 12%.

The study was carried out to select wheat genotypes to deal with end-season drought tolerance in Ardabil region in the presence of humic fertilizer (potassium humate) by use of multivariate statistics.

MATERIALS AND METHODS

In selecting genotype or genotypes, tolerant to end-season drought in Ardabil region treated liquid humic fertilizer (potassium humate) derived from peat (containing 33.23 g/L humic acid and 9.02 g/L fulvic acid) in the autumn planting, nine genotypes were prepared from Agriculture and Natural Resources Research Center of Ardabil province and three genotypes (Ruzi-84, Gobustan and Saratovskaya-29) were prepared from Azerbaijan (Table 1). Seeds of each genotype were cultivated based on 450 seed per square meter in Research Farm of Islamic Azad University, Ardabil in 2008 to 2009 farming year. The form of experimental design was split plot based on completely randomized block design (RB) in three replications. The main factor was environmental conditions and sub factor was genotypes. Environmental conditions were: normal irrigation (none stressed) with humic fertilizer and drought stress with humic fertilizer. Two times irrigation was not conducted after anthesis for drought. Humic liquid fertilizer solution was prepared based on 220 ml in 10 L of water for one ton seeds and were used for the pre-treatment of wheat seeds prior to planting. In order to spraying at different growth stages, humic liquid fertilizer was prepared and used based on 400 ml in 50 L of water for one hectare of wheat cultivation. Solution spraying was done at the tillering, shoot and grain filling stages on the aerial plant parts. During experiment, any type of fertilizer or poison was not used. In order to identify drought tolerant genotypes, indices including mean productivity (MP), geometric mean productivity (GMP), stress tolerance index (STI), tolerance index (TOL), stress susceptibility index (SSI) and modified stress tolerance index (MSTI) were calculated using the following relations. Stress susceptibility index (SSI) was presented by Fischer and Maurer (1978) and is calculated with the following formula:

Table 2. ANOVA for yield in two different environments (stressed and non stressed).

Source of variation	df	Mean of square	
		Non-stressed condition with humic fertilizer	Stressed condition with humic fertilizer
Replication	2	0.472	0.939 *
Genotypes	11	0.843 **	0.613 **
Error	22	0.273	0.165
C. V (%)		12.34	11.54

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

$SI=1-(Ys/ Yp)$

$SSI= (1-(Y_{si} / Y_{pi})) /SI$

Mean productivity index (MP) and tolerance index (TOL) were presented by Rosielle and Hamblin (1984). It is noteworthy that the selection of stress tolerant genotypes is based on low values of TOL and high values of MP. Using TOL and MP indices, it is possible to separate genotypes groups B and C of Fernandez from each other (Rosielle and Hamblin, 1984). MP and TOL are calculated as follow:

$MP= (Y_{pi} + Y_{si})/2$

$TOL= (Y_{pi} - Y_{si})$

It was presented by Fernandez (1992) which is able to identify the genotypes group A. Genotype with high STI has high drought tolerance and yield potential. This index is calculated as follow:

$STI= (Y_{pi} \times Y_{si}) / Y_p^2$

It was presented by Fernandez and is expressed as follow (Fernandez, 1992):

$GMP= \sqrt{} Y_{pi} \times Y_{si}$

From the aforementioned relations, Y_{Pi} is the grain yield of each genotype in non-stressed condition with humic fertilizer; Y_{Si} is the grain yield in stressed condition with humic fertilizer; Y_s is the average yield of genotypes in stressed conditions with humic fertilizer and Y_p is the average yield of genotypes in non-stressed conditions with humic fertilizer.

MP is calculated based on arithmetic average so because of presence of the relatively more intense differences between Ysi and Ypi, MP values have an oblique, while the geometric mean shows lower sensitivity to relatively more intense differences between Ypi and Ysi. So in separation of genotypes, in group A from three other groups, GMP is more appropriate index than MP. For statistical calculations, software such as SPSS-18, Minitab-15, Snagit-8 and MSTAT-C were used.

RESULTS AND DISCUSSION

ANOVA result showed the significant difference (at probability level of 1%) between yield of genotypes in both environments (stressed and non stressed environments) (Table 2). This means existence of genetic variation between studied genotypes. In other words, there were differences for genetic potential of yield trait.

Mean comparisons (Table 3) showed Toos had the highest (5.14 ton/ha) and Sabalan had the lowest (3.35 ton/ha) grain yield in none stressed condition. But in the stressed condition, Gascogne (4.28 ton/ha) had the highest and Saratovskaya-29 had the lowest (2.85 ton/ha) grain yield.

Results obtained from calculation of drought tolerance and drought sensitivity indices (Table 4) showed that genotypes Gascogne, Toos, 4057 and 4041 are the most tolerant ones to low-water stress in this experiment for STI, GMP and MP. These genotypes also had higher yield. Gascogne, Sabalan and 4057 genotypes had less sensitivity to water deficit based on the SSI index. Based on TOL index, genotypes Toos and 4041 had more tolerance to water deficit stress. Ehdaei et al. (1988) concluded that none of the under-study cultivars had high capability in yield and low SSI simultaneously, but the results obtained in this experiment are not compatible with other researchers.

Correlation between drought tolerance and yield indices can be used as a good criterion for selecting the best genotypes and indices. Yield in normal conditions with humic fertilizer with mean productivity (r = 0.860**), geometric mean productivity (r = 0.759**), stress tolerance index (r = 0.860**), tolerance index (r = 0.706*) and the modified stress tolerance (r = 0.968**) showed positive and significant correlation at probability levels of5 and 1%. The results are compatible with Rosielle and Hamblin (1984). They showed that in most yield comparison experiments, correlation between MP and YP; and MP and YS was positive. Yield in stressed conditions with humic fertilizer with mean productivity (r = 0.796 **) and stress tolerance index (r = 0.794 **) showed positive and significant correlation at probability level of 1%. But at probability level of 5% with stress susceptibility index (r = -0.511 *), it had negative and significant correlation.

Cluster analysis (Figure 1) placed 12 genotypes evaluated in two groups. Variance analysis between groups (Table 5) revealed that in terms of most parameters, the most significant difference between groups exist at probability levels of 5 and 1%. This confirmed the grouping. To distinguish characteristics

Table 3. Mean comparisons of grin yield for studied wheat genotypes.

Genotype	Grain yield (kg/ha)	
	Non-stressed condition with humic fertilizer	Stressed condition with humic fertilizer
Gascogne	3.73[c]	4.28[a]
Sabalan	3.35[c]	3.83[abcd]
4057	3.97[bc]	3.98[abc]
Ruzi-84	3.84[c]	3.14[de]
Gobustan	3.39[c]	3.29[cde]
Saratovskaya-29	3.65[c]	2.85[e]
MV17/Zrn	4.13[bc]	3.46[bcde]
Sardari	3.91[bc]	3.09[de]
4061	3.74[c]	3.14[de]
4041	4.79[ab]	3.76[abcd]
Sissons	3.70[c]	3.45[bcde]
Toos	5.14[a]	4.07[ab]

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

Table 4. Estimation of rate of tolerance and sensitivity of wheat genotypes with relevant indices.

Number	Genotype	YPi	YSi	MP	GMP	STI	TOL	SSI	MSTI
1	Gascogne	3.73	4.28	4.00	3.99	1.03	0.00	0.00	0.92
2	Sabalan	3.34	3.83	3.59	1.67	0.83	0.00	0.00	0.59
3	4057	3.97	3.98	3.98	3.97	1.02	0.00	0.00	1.03
4	Ruzi-84	3.84	3.14	3.49	3.47	0.78	0.71	1.77	0.74
5	Gobustan	3.39	3.29	3.34	3.33	0.72	0.10	0.30	0.53
6	Saratovskaya-29	3.65	2.85	3.25	3.22	0.67	0.80	2.10	0.57
7	MV17/Zrn	4.13	3.46	3.80	3.78	0.92	0.68	1.56	1.01
8	Sardari	3.91	3.09	3.50	3.47	0.78	0.82	2.02	0.77
9	4061	3.74	3.14	3.44	3.42	0.76	0.60	1.55	0.68
10	4041	4.79	3.76	4.28	4.24	0.16	1.03	2.07	1.72
11	Sissons	3.70	3.45	3.58	3.43	0.82	0.25	0.66	0.73
12	Toos	5.14	3.07	4.61	4.57	1.35	1.06	1.99	2.29

Y_{Pi}, Grain yield of each genotype in non-stressed condition with humic fertilizer; Y_{Si}, grain yield in stressed condition with humic fertilizer; SSI, stress susceptibility index; MP, mean productivity; GMP, geometric mean productivity; TOL, tolerance index; STI, stress tolerance index; MSTI, modified stress tolerance index.

of each group of traits of each cluster mean and the mean total was calculated for each parameter (Table 5).

Characteristics of each cluster in terms of all indices were as follows; the first group included genotypes Saissons, Gobustan, Gascogne, Sabalan and 4057 that ranked in second; the second group consists of genotypes Ruzi - 84, MV17/zrn, Saratovskaya - 29, 4041, Toos, 4061 and Sardari was ranked first. Genotypes 4041 and Toos in terms of stress + humate; and non-stress + humate had the high yield than other genotypes.

Latent roots and vector specific genotypes studied (Table 6) showed that 64% of the first vector shows the changes, and this component has a positive correlation with the YP, YS, MP, GMP, SSI, MSTI and TOL; so the first component, component yield can be named. In other words, 12 genotype distribution in the three clusters based on two main factors I and II (Figure 2) were performed. In this figure, component yield had the important role in differentiating the groups found. This component had important role to distinguish groups for MP, GMP, SSI and MSTI. The second component involved 30% of the changes; and shows a high positive correlation with STI and TOL, so this component can be named the tolerance index. With different literature it can be said that the second component of the index TOL, STI in differentiated groups have important role.

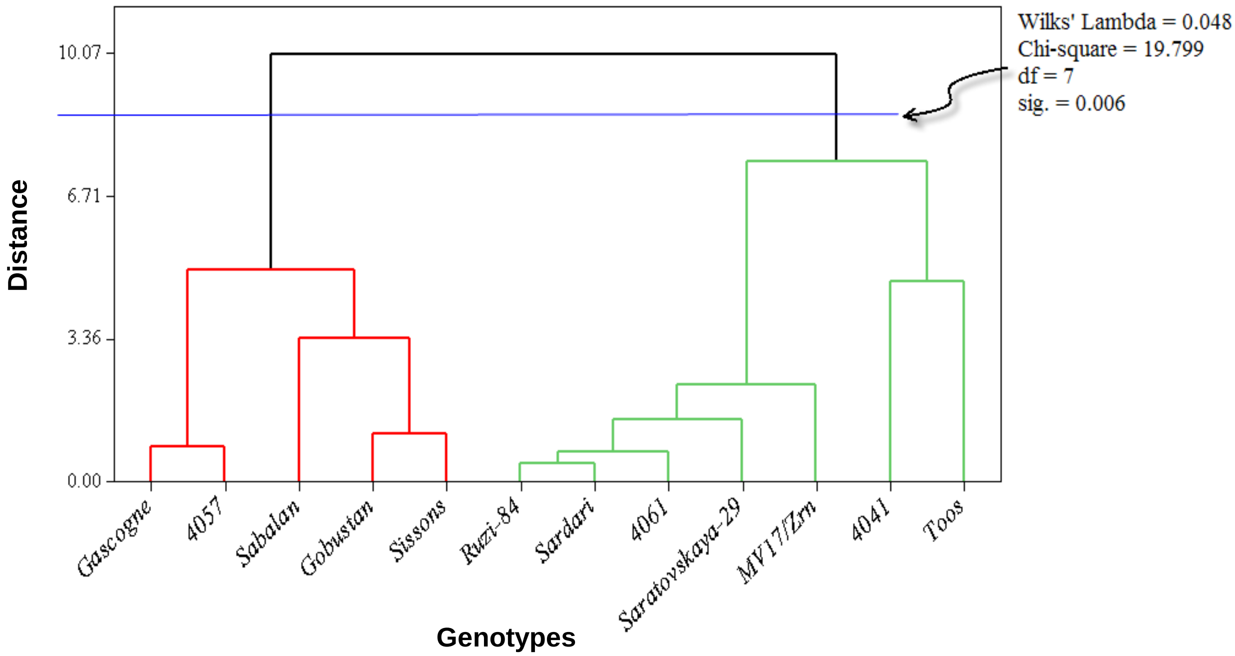

Figure 1. Genotype dendrogram cluster analysis based on indices of drought tolerance.

Table 5. Mean, total mean deviation and standard deviation of mean in cluster analysis for tolerance indices of wheat genotypes.

Cluster		Indices							
		Yp	Ys	MP	GMP	STI	TOL	SSI	MSTI
Group 1	$\bar{x}$	3.74	3.451	3.597	3.375	0.833	0.395	0.996	0.757
	$\bar{x}_h - \bar{x}_{..}$	0.244	0.449	0.254	0.654	0.121	0.335	0.886	0.178
	S_e	0.077	0.142	0.08	0.206	0.038	0.112	0.28	0.056
Group 2	$\bar{x}$	4.96	3.915	4.445	4.405	1.255	1.045	2.03	2.005
	$\bar{x}_h - \bar{x}_{..}$	0.247	0.219	0.233	0.266	0.134	0.021	0.56	0.403
	S_e	0.175	0.155	0.465	0.165	0.095	0.015	0.04	0.285
F		**	ns	**	*	**	*	ns	**

* and ** Significantly at p < 0.05 and < 0.01, respectively. Yp, Average yield of genotypes in non-stressed conditions with humic fertilizer; Ys, average yield of genotypes in stressed conditions with humic fertilizer; SSI, stress susceptibility index; MP, mean productivity; GMP, geometric mean productivity; TOL, tolerance index; STI, stress tolerance index; MSTI, modified stress tolerance index.

Results of this research are in accordance with Rosielle and Hamblin (1984), Mohammadi et al. (2006), Mollasadeghi et al. (2011 a, b, c). So, Fernandez (1992) reported significant correlations between stress sensitivity indices and grain yield in a three years experiment. Also, findings of this study are in accordance with Nourmand-Mo'eid et al. (2001). They reported significantly positive correlation of STI and GMP with wheat yield. So, Haghparast (1995), Nikkhah (1999) and Shafazadeh et al. (2004) in their study of wheat genotypes revealed high significantly positive correlations between Ys with MP, GMP and STI; and positively significant correlation between Yp and all of calculated stress sensitivity and tolerance indices. They expressed such as correlations

Table 6. Vectors and special amounts, relative and cumulative variance for three main components from principal components over drought tolerance indices of 12 wheat genotypes.

Tolerant indices	*1	2	3
Yp	0.976	0.191	0.071
YS	0.551	-0.82	0.138
SSI	0.94	-0.328	0.128
MP	0.788	0.105	-0.923
GMP	0.941	-0.327	0.129
TOL	0.562	0.814	0.205
STI	0.392	0.911	0.128
MSTI	0.985	-0.002	0.178
Special amount	5.078	2.727	0.4303
Relative variance	0.636	0.303	0.054
Cumulative variance	0.636	0.939	0.993

*Special vectors of component. Yp, Average yield of genotypes in non-stressed conditions with humic fertilizer; Ys, average yield of genotypes in stressed conditions with humic fertilizer; SSI, stress susceptibility index; MP, mean productivity; GMP, geometric mean productivity; TOL, tolerance index; STI, stress tolerance index; MSTI, modified stress tolerance index.

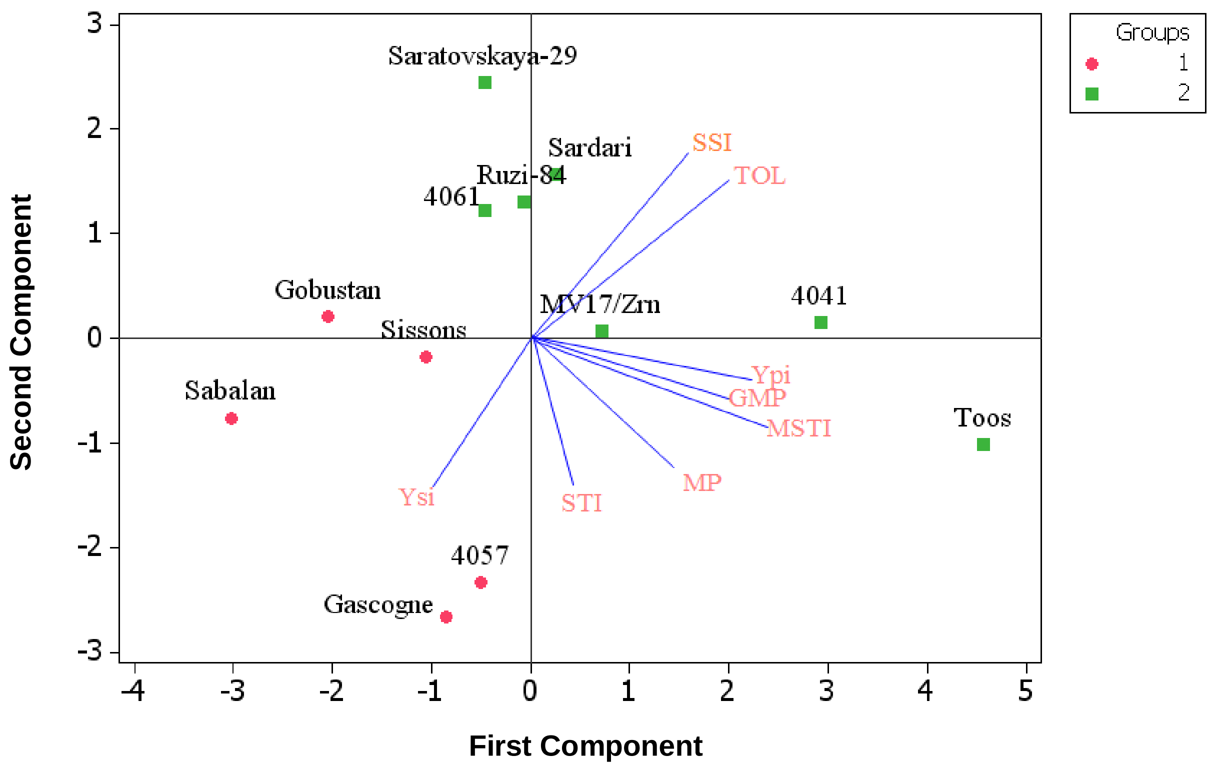

Figure 2. Distribution of genotypes based on both the first and second components.

proves the suitability of indices for assessment of genotypes for drought tolerance.

So it can be said that the first component genotypes with high and low yield and the second component separated genotypes to tolerant and sensitive. The third component, the remaining five percent of all changes can be justified. In general, the main components of the first, second and third 99% of the changes were justified and removes other components effect change very small.

It can be concluded that in the presence of humic fertilizer, Gascogne, Toos, 4057 and 4041 were the most tolerant genotypes against end-season drought of

Ardabil; and had the highest yield. Gascogen, Sabalan and 4057 genotypes had the low susceptibility against stress. However, 4041 and Toos were the best genotypes that had the high yield relative to others in both conditions of stressed and none stressed environments. Principle components analysis showed that yield component was justified by 64% of the changes; tolerance indices component 30% of the changes. Results of this investigation are recommendable for future wheat breeding programs in the presence of humic fertilizer for increasing of grain yield against end-season drought of Ardabil region.

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