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# Evaluation of End Drought Tolerance of 12 Wheat Genotypes by Stress Indices

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**Abstract:** Wheat is the world's most important crop and drought is a global problem. Wheat production is subjected to water deficit after pollination in Ardabil. An experiment was conducted for assessing tolerance of 12 bread wheat genotypes to terminal drought. Experimental design was split plot on the basis of RB in three repetitions. The main factor was normal irrigation and terminal drought conditions and the sub factor was genotypes. Six Drought tolerance indices calculated for grain yield of genotypes. Toos produced the highest grain yield in the both normal irrigation by 4 ton/ha and terminal drought by 3.92 ton/ha. MP, GMP, STI and MSTI had the highest correlation with yield in both conditions, selected as the best indices. TOL introduced Gascogen and Ruzi-84 as tolerant genotypes to drought. By plot diagram charting was places Toos, 4041, 4061, MV17/zrn and Sabalan on A region. These were tolerant to drought and were suitable for normal condition. Gobustan, Gascogen and Ruzi-84 were placed in D region and identified as sensitive to drought. Genotypes 4057, 4041 and Toos that were placed in one group of cluster analysis are the best genotypes which have higher yield in both stressed and non-stressed conditions than other genotypes. Principal components analysis showed that 99% of total changes justified by the first component (Yield with 77%) and the second component (tolerance indices with 22%). There was a good match for results of cluster analysis and principal components analysis.

**Key words:** Wheat · Drought stress · Tolerance indices

## INTRODUCTION

Yield of agricultural plants is affected by genetic structure of plant, environmental conditions and their converge effects. While all of alive and non-alive stresses are important factors to reduce production, drought stress is the most important factor to limit production of crops in agriculture systems at dry and semidry areas [1]. Iran was located on world's desert belt and identified as a dry and semidry area. Rainfall mean is about 250 Mm in country and this rat is one third (1/3) of the world's one, while it has 1.2 percent of worlds drought lands. On the other hand, of 18.5 million hectare of agricultural lands, 6.2 million hectare (33.5 %) is dedicated to dry cultivation. Of 1.2 million hectare of dry lands under cultivation, there is rainfall more than 400 Mm [2]. Long term statistics (40 years) show that rainfall in provinces like West-Azerbaijan, East-Azerbaijan, Khorasan, Ardabil, Zanjan and Hamadan is 301, 347, 386, 310,438 and 340 Mm, respectively, which primarily happened at fall, winter and early spring [3]. The more dry region, the high rainfall oscillations, so that rainless and more humid years was created from average to periodical rate. Therefore, we must select varieties for these areas which can produce cost-effective and stable yield at rainless years and also they were tolerant to drought and can utilize humidity which reserved in the soil at the most optimal conditions [4]. Even in the most weather conditions, irregular raining lead to limiting available water and thus to shorten plant growth [5]. Of 2.3 million hectare irrigated wheat in the country, about 900 thousand hectare of irrigated wheat varieties were cultivated at cold regions [6]. In these areas, farmers do not obtained optimal results in high-need varieties to irrigation due to lack of adequate water in spring and/or lack of enough irrigation as a result of consumption of irrigation water for summer agricultures, consequently the wheat agriculture suffered from drought stress in end of season [7]. So, evaluation of different traits like relative yield of genotypes under drought stress and non stress conditions is a starting point to identify drought tolerance and to select genotypes for reformation in dry regions [8]. Esmaeilzade [9] reported that yield

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mean, geometric mean and drought tolerance index have more efficiency to recognize tolerant wheat genotypes to drought stress than two other indices (tolerance sensitive and stress sensitive) and among them, the stress tolerance has more capability in distinction of groups. Zare Feizabadi and Ghodsi [10] reported that stress sensitive provided meaningful distinction between 20 wheat genotypes.

Fernandez [11], Mozaffari [12] also introduced STI and GMP as drought tolerance indices. Fernandez [11] had divided genotypes reaction on the basis of their yields into 4 categories under stressed and non-stressed conditions: group A are genotypes which have high yield in both of conditions; group B are genotypes which have a high yield under non-stressed conditions; group C including genotypes which have a good yield under stressed conditions and finally group D are genotypes which have a low yield in both conditions. He believed the most suitable standard to select about stress, is a standard which can recognize group A from other groups. Rosielle and Hamblin [13] presented tolerance index (TOL) and mean of proficiency (MP). High amounts of tolerance indicated sensitivity of more genotypes to drought and also the lower tolerance, the better. Rosielle and Hmblin [14] used from TOL and MP to choose stress tolerance varieties. It is better to use from TOL, when the yield increasing under stressed condition was considered. If the yield increasing was considered in both conditions (stressed and non-stressed ), It's better to use from MP index. MP can not separate genotypes of group A from Group B and selection process had performed on the basis of high amounts of MP. Fischer and Maurer [15] proposed stress sensitive index (SSI) to evaluate stress tolerance varieties. Choosing according to this index cause to selection of low yield genotypes under normal conditions, but also lead to selection of high yield genotypes under drought stress conditions. This index can not separate group A from C. Fernandez [11] presented stress tolerance index (STI). High amounts of STI for one genotypes means higher drought tolerance and more drought potential yield of that genotype. This index can not separate group A from C and B. He presented another index as called geometry mean (GMP) which has less sensitivity to yield under normal and stressed conditions.GMP has high ability to separate group A from other groups in comparison with MP. According to *Fernandez* [11], indices which have high correlation with grain yield under both conditions (stressed and normal), selected as the best indices. Sio-se Mardeh *et al.* [16] expressed that SSI is suitable index to reform under low stresses, if STI, GMP and MP suggested for high stresses. They also explain that selection of varieties on the basis of TOL cause to reducing yield under non-stressed conditions, SSI is suitable for reformation under low stresses, but MP, GMP and STI are suitable indices for high stresses. This research was conducted to select wheat genotypes in comparison with drought tolerance in end of season in Ardabil. The purpose of this project is to identify the best drought tolerance index to evaluate sensitivity rate and drought tolerance of different genotypes of wheat.

## MATERIALS AND METHODS

In order to choose end-season drought tolerance genotype (s) in Ardabil at fall cultivation, 9 genotypes produced from agronomic research and natural references center of *Ardabil* and 3 genotypes produced from *Azerbaijan*. Seeds of each genotype were cultivated on the basis of one-thousand grain and 450-grain weight in square meter in research farm of Islamic Azad university of Ardabil. Experimental form was split plot on the basis of random blocks (RB) in three repetitions. The main factor was irrigation levels and the sub-factor is related to genotypes. Irrigation levels were: normal irrigation and drought stress. There is no two times irrigation process for drought after anthesis. According to weather statistics, the rainfall was 242.3 Mm during agricultural season, the minimum of temperature was -1.5°C on February and the maximum was 25.01°C on August [17]. For statistical calculations, we used from softwares like Minitab-15, SPSS-16 and MSTAT-C. In order to determine drought tolerance genotypes, indices MP, GMP, STI, TOL, SSI and MSTI were calculated by following relations:

$MP = (Y_{Pi} + Y_{Si}) / 2$ $GMP = vY_{Pi} \times Y_{si}$ $STI = (Y_{Pi} \times Y_{Si})/Y_p^2$

$TOL = (Y_{Pi} - Y_{Si})$ $SSI = (1-(Y_{si}/Y_{pi})) / SI; SI = 1- (Y_s/Y_p)$

$MSTI = K_1( STI ); K_1=Y_{pi}^2/Y_p$

In above relations, YPi, YSi, Ys and Yp refer to grain yield of each genotype under non-stressed conditions, grain yield under stressed conditions, mean yield of genotypes under stressed condition and mean yield of genotypes under non-stressed condition, respectively. Then, the simple correlations between these indices were calculated and ear analysis conducted by minimum variance of Ward way on the basis of standardized average of drought tolerance indices.

## RESULTS AND DISCUSSIONS

In this project, the stress intensity (SI) is equal to 20%. It is essential to say that this index is just calculable to measuring drought stress intensity in experiment and it has no efficiency to measuring stress intensity in varieties [15]. Achieved results from calculation of drought tolerance and drought sensitive indices (Table 1) show that MP,GMP,MSTI and STI which their high amounts indicated stress tolerance, introduced Toos,4041 and 4057 with yields 3.92,3.53 and 3.39 Ton/ha respectively as stress tolerance genotypes. Genotype MV-17 with yield 3.25 Ton/ha identified as tolerant varieties. These indices had identified Saratovskaya-29 and Saysonz with yields 2.27 and 2.73 Ton/ha, respectively as the most critical genotypes under drought stress conditions. Stress sensitive index (SSI) which its numerical low amounts(less than one) indicated high tolerance of variety to stress [18] and TOL and SSI indices which their lower amounts indicating relative tolerance to stress, had identified Toos and 4041(with yields3.92 and 3.53 Ton/ha, respectively) as tolerant genotypes, as well as they identified Gascogen and Ruzi-84 (with yields 2.47 and 2.87 Ton/ha, respectively) as drought sensitive genotypes. Mp, GMP, MSTI, STI and SSI indices identified genotype 4047 as a tolerant genotype, but TOL index introduced it as a sensitive variety. Evaluation of genotypes by SSI, had divided experimental materials just on the basis of stress tolerance and stress sensitive, that is we can determine tolerant and sensitive genotypes regardless of their yield potential by this index [19]. Stress sensitive index evaluated on the basis of proportion of each variety yield under stressed to non-stressed condition in comparison with this proportion in total varieties. Thus, two varieties with low/high yield can have equal SSI rate in both conditions, so selection process on the basis of this index cause to reformers to mistake [20]. According to investigators [11, 21 and 22], the best index to select varieties, is stress tolerance one (STI), as it can separate varieties which has a have a high yield in both stressed and non-stressed conditions (group A) from two groups of varieties which have just relatively yield under non-stressed (group B) or stressed (group C) conditions. Achieved results from correlation between drought tolerance and yield indices (Table 2) can be applied to select the best genotypes and indices as a suitable standard. Yield in normal condition show positive and meaningful correlation with mean proficiency (r = 0.850**), geometric mean (r = 0.821**), stress tolerance (r = 0.809**) and metamorphosed stress tolerance (r = 0.923**) in probability level of 1%. These results are compatible with Roiselle and Hamblin [13] and Mohammadi *et al.* [23]. They show that in a majority of comparative experiments, the correlation yield

Table 1: Estimation of sensitivity rate of 12 wheat genotypes by different drought tolerance indices under normal and stressed conditions

| Number | Genotyoe | YPi | YSi | MP | GMP | STI | TOL | SSI | MSTI |
|---|---|---|---|---|---|---|---|---|---|
| 1 | Gascogne | 3.87 | 2.47 | 3.17 | 3.09 | 0.67 | 1.41 | 1.86 | 0.70 |
| 2 | Sabalan | 3.80 | 3.16 | 3.48 | 3.46 | 0.84 | 0.64 | 0.86 | 0.84 |
| 3 | 4057 | 4.38 | 3.39 | 3.88 | 3.85 | 1.03 | 0.98 | 1.15 | 1.38 |
| 4 | Ruzi-84 | 4 | 2.87 | 3.44 | 3.38 | 0.8 | 1.13 | 1.45 | 0.89 |
| 5 | Gobustan | 3.73 | 2.75 | 3.24 | 3.20 | 0.71 | 0.97 | 1.34 | 0.69 |
| 6 | Saratovskaya-29 | 3.09 | 2.27 | 2.68 | 2.64 | 0.49 | 0.82 | 1.36 | 0.32 |
| 7 | MV17/Zrn | 3.62 | 3.25 | 3.44 | 3.43 | 0.82 | 0.37 | 0.52 | 0.75 |
| 8 | Sardari | 3.92 | 3.09 | 3.51 | 3.48 | 0.84 | 0.83 | 1.09 | 0.9 |
| 9 | 4061 | 3.67 | 3.16 | 3.42 | 3.40 | 0.81 | 0.51 | 0.71 | 0.76 |
| 10 | 4041 | 3.88 | 3.53 | 3.70 | 3.70 | 0.95 | 0.35 | 0.46 | 1 |
| 11 | Sissons | 3.64 | 2.73 | 3.10 | 3.07 | 0.66 | 0.73 | 1.08 | 0.55 |
| 12 | Toos | 4 | 3.92 | 3.96 | 3.96 | 1.09 | 0.08 | 0.1 | 1.22 |

Table 2: Correlation between drought tolerance indices with grain yield under normal irrigation and drought stress conditions

| | YPi | YSi | MP | GMP | STI | TOL | SSI |
|---|---|---|---|---|---|---|---|
| Ysi | 0.602* | 1 | | | | | |
| MP | 0.850** | 0.923** | 1 | | | | |
| GMP | 0.821** | 0.950** | 0.998** | 1 | | | |
| STI | 0.809** | 0.954** | 0.995** | 0.998** | 1 | | |
| TOL | 0.106 | -0.730** | -0.434 | -0.480 | -0.495 | 1 | |
| SSI | -0.092 | -0.850** | -0.603* | -0.643* | -0.654* | 0.979** | 1 |
| MSTI | 0.923** | 0.825** | 0.961** | 0.950** | 0.995** | -0.238 | -0.415 |

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

between MP and Yp and also MP and Ys is positive. Yield under stressed conditions show positive and meaningful correlation with mean proficiency (r = 0.932**), geometric mean (r = 0.950**), stress tolerance index (r = 0.954**) and metamorphosed stress tolerance (r = 0.825**) in probability level of 1%; but it show negative and meaningful correlation with stress sensitive (r = -0.850**) and tolerance index (r = -0.730**) in probability level of 1%. Khalilzade and Karbalaei Khiavi [21], Farshadfar *et al.* [24] and Choukan *et al.* [18] believed that the best suitable index to select stress tolerance varieties, is index in which there is relatively high correlation with grain yield in both stressed and non-stressed conditions. Therefore, by evaluation of correlation rate between grain yield and stress tolerance in both conditions, it can be possible to identify most suitable index. Since mean proficiency (MP), geometry mean of proficiency (GMP), metamorphosed stress tolerance index (MSTI) and Fernandez index show high correlation in both normal irrigation and drought stress conditions, introduced as major indices. Farshadfar *et al.* [24] in a research about pea reported that all of indices show positive and meaningful correlation with yield under non-stressed condition and also they expressed that TOL has a negative and unmeaningful correlation with yield under stressed condition. Fernandez [11] in a three years study in normal and low-water stress conditions realize that there is a meaningful correlation between grain yield and stress sensitive indices. Also, results of this project is compatible with Nourmand Mo'aeid *et al.* [25]. They reported there is positive and meaningful correlation between STI and GMP indices with wheat yield. Shafazade *et al.* [26] in study of wheat genotypes, reported positive and meaningful correlation between yield in non-stressed condition and MP,GMP and STI and also they expressed that there is positive and meaningful correlation between yield in non-stressed condition and all drought tolerance and drought sensitive indices. They suggested that existence of positive and meaningful correlation between indices and yield in both conditions (stressed and non-stressed) means these indices are suitable to evaluate drought tolerance of genotypes. Bahmaram *et al.* [27] in their reports about evaluation of drought tolerance of spring varieties expressed that STI can be better applied to evaluate drought tolerance of varieties than TOL and SSI. Results of this research are compatible with Taghizade *et al.* [28] They realized that among under-study indices, MP, GMP and STI indices have a positive and meaningful correlation with yield in both conditions, while evaluation of drought tolerance references in lentil genotypes in Ardabil. Baldini *et al.* (quoted as Fernandez, [11]) in a research, realized that there is no relation between stress sensitive index (SSI) and grain yield. Choukan *et al.* (quoted as Fath Bahri *et al.*, [18]) by evaluation of some drought tolerance indices in some genotypes of spring barley, reported meaningful correlation between STI with MP and GMP in both stressed and non-stressed conditions. Rosielle and Hamblin [14] showed that in a majority of comparative experiments, the correlation yield between MP an Yp and also MP and Ys are positive. According to their reports, selection on the basis of MP generally cause to increasing yield in both normal and stressed conditions. Fernandez [11] declared that sensitivity of GMP index is less than different amounts of Yp and Ys, while MP index which is on the basis of computation mean, has up-curve, as there is relatively high difference between Yp and Ys, thus GMP has the highest capability to separate major genotypes in comparison with MP. Correlation between drought tolerance and yield indices (Table 2) can be applied as a suitable standard to select better genotypes and indices. In order to grouping genotypes, we used from ear analysis by the Ward way on the basis of standardized mean of evaluated drought tolerance indices during both stressed and normal conditions and 12 under-study genotypes were placed on three groups (Figure 1). Results of unbalanced variance analysis between groups indicating the highest meaningful difference between groups (intergroup) and minimum difference is inside of the groups (intra-group). In order to distinguish characteristics of each group about under-study traits, we calculated average of each ear and total average for each parameter (Table 3) which attributes of each ear is as follow:

- First group including genotypes like Gobustan, Gascogen, Saysonz and saratovskaya-29 which rank among second just for purpose of TOL and SSI indices in both normal irrigation and drought stress conditions.
- Second group including genotypes like Sabaln,Sardari,4057,4041,4061,MV-17,Ruzi-84 and Toos which rank among first just for purpose of STI, GMP, MP, Ys, Yp and MSTI in both stressed and normal conditions and also it has a high yield in both stressed and normal conditions, as well as it rank among second for purpose of TOL and SSI indices.

Table 3: Mean, total mean deviation and standard deviation of mean in ear analysis for tolerance indices of wheat genotypes under normal irrigation and drought stress conditions

| | | Indices | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Cluster | | Yp | Ys | MP | GMP | STI | TOL | SSI | MSTI |
| Group 1 | $\bar{x}$ | 3.537 | 2.555 | 3.047 | 3 | 0.632 | 0.982 | 1.41 | 0.565 |
| | $\bar{x}_4-\bar{x}$ | 0.343 | 0.229 | 0.252 | 0.247 | 0.097 | 0.302 | 0.326 | 0.177 |
| | $S_e$ | 0.172 | 0.114 | 0.126 | 0.123 | 0.49 | 0.151 | 0.163 | 0.088 |
| Group 2 | $\bar{x}$ | 3.909 | 3.296 | 3.604 | 3.582 | 0.897 | 0.611 | 0.792 | 0.967 |
| | $\bar{x}_h-\bar{x}$ | 0.237 | 0.319 | 0.215 | 0.224 | 0.112 | 0.353 | 0.435 | 0.224 |
| | $S_e$ | 0.084 | 0.113 | 0.076 | 0.079 | 0.039 | 0.125 | 0.154 | 0.079 |

Meaning ful in probability level of 5 and 1% and unmeaning ful, respectively

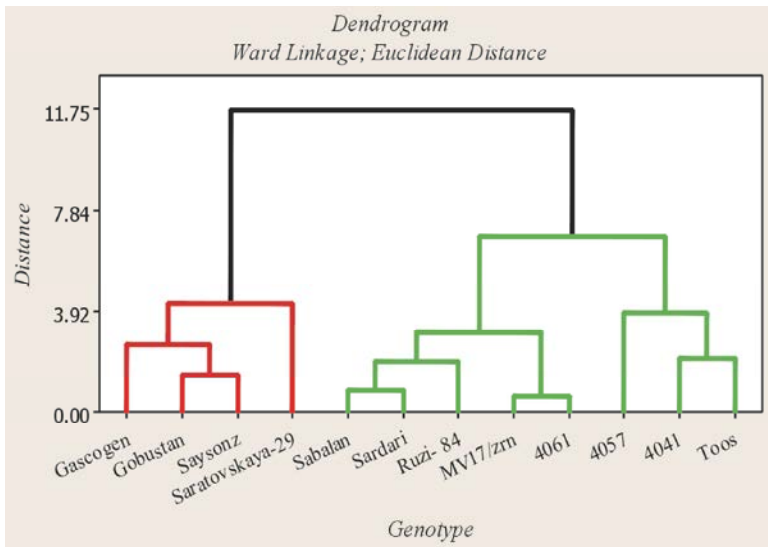


Fig. 1: Achieved dendrogram form ear analysis by the minimum variance of ward way on the basis of drought tolerance indices of 12 wheat genotypes under normal irrigation and drought stress conditions

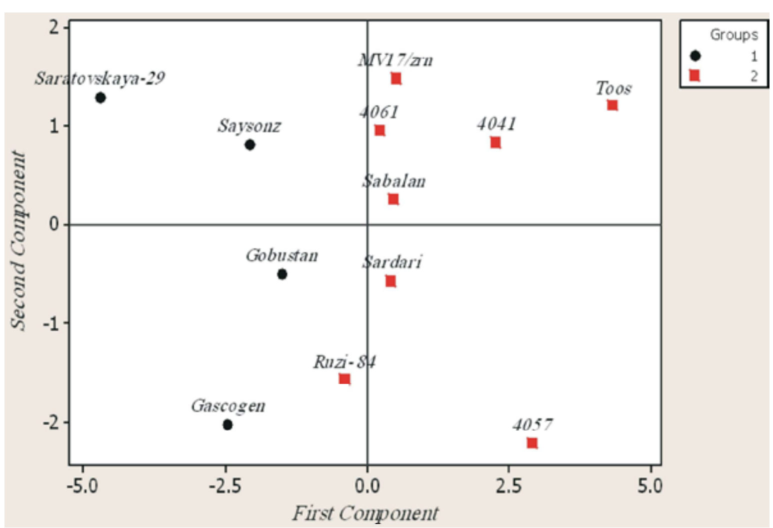


Fig. 2: Dispersion of under-study genotypes according to first and second components of principal components over drought tolerance indices of 12 wheat genotypes under normal irrigation and drought stress conditions

Table 4: Vectors and special amounts, relative and cumulative variance for three main components from principal components over drought tolerance indices of 12 wheat genotypes under normal irrigation and drought stress conditions

| | Special vectors of component | | |
|---|---|---|---|
| Tolerant indices | 1 | 2 | 3 |
| Yp | 0.755 | 0.654 | -0.338 |
| YS | 0.977 | -0.210 | -0.136 |
| MP | 0.987 | 0.157 | -0.277 |
| GMP | 0.994 | 0.106 | -0.238 |
| STI | 0.996 | 0.009 | 0.128 |
| TOL | -0.571 | 0.820 | -0.149 |
| SSI | -0.720 | 0.693 | 0.109 |
| MSTI | 0.924 | 0.357 | 0.827 |
| Special amount | 6.185 | 1.796 | 0.0271 |
| Relative variance | 0.772 | 0.224 | 0.003 |
| Cumulative variance | 0.772 | 0.996 | 1.000 |

Table 4 shows static roots and special vector of under-study genotypes about three first components and first vector shows 77% of varieties and with respect to which GMP, MP, Ys, Yp and MSTI indices have the highest positive coefficient to providing this component, so selection process selected high-yield genotypes on the basis of first component, thus this component can be called as yield component. Diffusion 12 genotypes in two ears presented in figure 2 on the basis of two main components (first and second).In this figure, first component (yield component) play important role in distinction of groups in both normal and stressed conditioned for purpose of yield. Also, this component had a major role in distinction of groups in the MSTI, SSI, GMP and MP indices, so that genotypes in the right of diagram were tolerant and productive and genotypes in the left were sensitive and low productive (Figure 2).Second component had justified 22% of the rest total variations and shows positive and high correlation with STI, TOL and Yp. Therefore, we can call this component as tolerant index. As such, second component play an important role in distinction of groups in normal condition for purpose of yield, as well as distinction of STI and TOL, so we can say the first component separated high and low yield genotypes from each other and the second component separated tolerant and sensitive genotypes from each other (Table 4). First and second main components had justified 99% of total variations (Table 4). In stressed and non-stressed conditions and by charting of 3D (3-dimension) diagram about yield of varieties in both conditions, as well as about STI and GMP indices, it was obvious that genotypes which are located in group A, had high STI and GMP and introduced these two indices as the best. By plot diagram had divided into four categories named A,B,C and Don the basis of two first components and genotypes which are placed on A region, have the high yield under drought stress and normal irrigation and also drought tolerance conditions. On the other hand, genotypes which are placed on D region have the lowest yield in both conditions and also they are sensitive. Indices that have a high correlation with yield under drought stress and normal irrigation conditions, introduced as major indices, in addition they placed on between yield under drought stress and normal irrigation.

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