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Study on genetic variation and selection against tolerance to terminal drought stress in bread wheat genotypes using stress susceptibility and tolerance indices aimed at improving grain yield

Vahid Mollasadeghi and Samaneh Elyasi

Department of Agronomy and Plant Breeding, Ardabil Branch, Islamic Azad University, Ardabil, Iran.

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ABSTRACT

One of the most important wheat breeding strategies under Mediterranean climate is to achieve genotypes that are potentially capable of producing desirable yield while encountering water limitation during their flowering stage. With the aim to investigate such an important issue, we planted 12 bread wheat genotypes in research farm of Islamic Azad University, Ardabil Branch, as randomized complete blocks design (RCBD), during 2008-09 cropping year. This section of the study addresses traits such as plant height, day's number to heading, days number to anthesis, fertile tiller number, spike length, spike weight, grain number per spike, grain weight per spike, 1000 grain weight and grain yield. Estimating the phenotypic and genotypic coefficient for various traits revealed that the studied genotypes were genetically more variable in terms of traits such as plant height, spike length, grain number per spike and grain weight per spike, 1000 grain weight and days to heading than in terms of other traits. Cluster analysis divided the studied genotypes into two categories. Mean of square between the categories was significant for all traits except for grain yield, spike length and date of heading. The inheritability of yield components was higher than that of grain yield.

Introduction

Wheat farming is practiced under a vast expanse of climatic condition and geographical areas and due to its high adaptability to diverse climatic conditions, it dominates more arable land than any other plant species, not to mention it is considered as staple food for a great part of world's ever-increasing population (Kamali, 2008). Apart from its commercial importance, it is also an increasingly functional tool in political and international relations throughout the world. Although Iran boasts barely 1% of world population, it consumes roughly 2.5% of worldwide wheat production. Wheat is a strategic good like energy and considered one of the most important indices for agriculture (Akbari et al., 2010). Unfortunately, drought stress, as one of the most important and dominant environmental stresses, has been challenging its production and decreasing its yield in semiarid regions as well as in areas that suffer from drought stress. According to Ambrejeh, a region with an annual precipitation between 20 to 450mm should be referred to as semiarid (Rajaram and VanGinkel., 1996). Moreover, almost 32% of arable lands under wheat cultivation in developing countries experience one or more types of drought stress during growth season (Blum, 1988). Blum (1988) believes that environmental stresses occur on the field mainly as the result of limitation of such factors as water, nutrients and heat. Stress can range from very low to very high in intensity while its level of intensity associates with the amount of energy involved in changing processes within biological system.

According to Fischer and Maurer (1978) production of drought tolerant cultivars involves two stages. In first stage, cultivars are screened in an intensive and speedy process based on grain yield under water stress, whilst in the second stage the remaining samples are screened based on important morpho-physiological traits associated with yield and with traits effective on drought tolerance.

Ehdaei et al., (1988) argued that old wheat cultivars that are characteristically drought tolerant produce more yield than do the new short cultivars; nevertheless they have lower yield potential. Results from studies conducted by Slafer and Araus (1998) indicated that wherever crop production is in danger of terminal drought, the best strategy to increase harvest index and grain yield is to select cultivars and lines with high growth potential, which are capable of proceeding to reproductive stage from vegetative growth stage when the moisture is abundantly available in the soil. These cultivars or lines have ample time opportunity to use moisture reserve in the soil before the terminal drought can occur Genotypes may fall into four groups based on their response to stressed and non-stressed environmental conditions (Fernandez, 1992): Group A: genotypes producing good yield in both stressed and non-stressed environments.

Group B: genotypes producing good yield only in non-stressed environment.

Group C: genotypes producing good yield in stressed environment.

Group D: genotypes producing low yield in both stressed and non-stressed environments.

Various indices have been proposed for evaluating response of genotypes under various environmental conditions and for determining the tolerance and susceptibility of the genotypes. The best selection criterion is one that can distinguish group A from other three groups.

Tele:
E-mail addresses: vahidmolasadegi@ymail.com

Rosielle and Hamblin, in 1981, introduced Tolerance (TOL) and Mean Productivity (MP) indices. High values for TOL give an indication of genotype's susceptibility to stress; curiously, the selection of genotypes is done based on lower values of TOL and higher values of MP. It is possible to distinguish genotypes of group B from those of C by using MP and TOL indices and Fernandez (1992) classification. In 1978, Fischer and Maurer proposed Stress Susceptibility Index (SSI). Low SSI value indicates that yield variations of a given genotype is less under stressed condition than under non-stressed condition and this goes down to the higher stability of that genotype. It is possible to distinguish genotypes of groups B and C from those of other groups by using SSI index and Fernandez (1992) classification.

In 1992, Fernandez introduced Stress Tolerance Index (STI). Genotypes with higher stability based on this index, have higher STI values. Thus, it is expectedly feasible to distinguish genotypes of group A from those of other groups by using this index. Narayan and Misra (1989) after conducting an experiment to investigate drought tolerance of wheat varieties in both stressed and non-stressed conditions found that SSI had a positively significant correlation with yield under non-stressed condition (r = 0.71**). Ehdaei et al., (1988) in a study on some landraces and advanced vernal wheat varieties under stressed environment aiming to investigate responses to these stresses concluded that landraces had no difference with advanced varieties in terms of mean susceptibility index. They also reported a negative correlation as much as r = -0.84** between SSI and grain yield under stressed condition. In this experiment, SSI and Yp (grain yield under non-stressed condition) did not produce any significant correlation. Nourmand Moayyed (1997) in a study conducted to investigate the variation of qualitative traits and to determine the best drought tolerance indices for bread wheat, reported that the correlation between SSI and Yp (grain yield under non-stressed condition) was positively significant (r = 0.43**), whereas the correlation between SSI and Ys (yield under stressed condition) was negatively significant (r = -0.56**). Study on correlations between indices of drought tolerance and yield under both stressed and non-stressed conditions showed that Geometric Mean Productivity (GMP) and STI are efficient indices.

Therefore, it is highly important to investigate the genetic variation of the varieties and lines of this plant in breeding programs. Results from an experiment conducted by Heydari et al. (2006) in order to examine the genetic variation of various traits in 157 replication haploid lines of bread wheat, suggested that these lines were of more genetic variation in terms of traits such as last internode length, number of fertile spike per unit area, plant height, grain number and grain yield per main spike than other ones including volumetric weight of grain, days number to maturity, days number to heading and anthesis. Golabadi et al. (2003) after studying the genetic variation of 300 Durum wheat genotypes reported that these genotypes vary significantly in terms of traits such as grain yield, harvest index and spike number per unit area. Additionally, in their study grain yield had a positively significant correlation with harvest index, biological yield, days number to maturity, grain number per spike and grain weight per spike. Mahfouzi et al. (2004) after examining breeding methods to increase wheat yield in cold and arid areas of Iran reported that genetic variation among genotypes may contribute to the grain yield increase in arid areas.

This aim of this study is four-fold:

1-To investigate the genetic variation of the study wheat with respect to morphological and phonological traits so that by identifying their far and near groups, the obtained results can be used for proper crossing.

2-To identify the response of bread wheat genotypes to terminal drought stress

3-To identify the best evaluation index or indices

4-To identify stress tolerant genotypes.

Materials And Methods

The field experiment for first year was conducted on 12 wheat genotypes during 2008-09 cropping year in order to select wheat genotypes and identify their near and far groups. Domestic and foreign commercial varieties (source: Agricultural Research Station) were used in this experiment as listed in Table 1. Furthermore, this research was conducted as RCBD, with three replications, at research farm of agriculture faculty of Islamic Azad University, Ardabil branch. The cultivations to prepare the farm included plow following the harvest of previous crop, one time disking, two times cultivating with perpendicular levelers, application of fertilizer and furrowing. The amount of seed usage was determined based on 450 seed per m^2 for each variety. Irrigation was done in flooding manner. Weeds were controlled manually. All the samples were taken randomly and from competing plants on the middle rows, and measurement was done on traits such as plant height, fertile tiller number, spike length, spike weight, grain number per spike, grain weight per spike, 1000 grain weight, grain yield, date of heading and date of anthesis. This study was conducted in order to investigate terminal drought tolerance in bread wheat genotypes at research station of Islamic Azad University, Ardabil Branch, located at Hasan-barough (5km west of Ardabil) in 2008-09 and 2009-10 cropping years. Six bread wheat genotypes including three genotypes namely Gascogne, Sabalan, 4057 were provided by natural resource and agricultural research center of Ardabil Province and three others namely Ruzi-84, Gobustan and Saratovskaya-29 by agricultural institute of Azerbaijan Republic, which were evaluated under non-stressed and terminal drought stress conditions based on RCBD with three replications. Each experimental plot included 3, 3 meters long rows recurring 20cm from each other. Amount of seed usage was determined based on 450 seeds per 1m2 and on weight of 1000 grains for each variety, which were sown in late October. Irrigation was done traditionally, which included two autumnal and three vernal irrigations. It should be mentioned that after applying stress, there was no effective rainfall in either of the years. After maturity and harvest of the crop, grain yield of the varieties was measured under both conditions (non-stressed and stressed) and the resulting data was subjected to combined analysis of variance based on statistical standards of the design for both experimental conditions in order to identify the effects of year and genotypes as well as the interaction of "genotype × year".

The indices were used as follow to evaluate the genotypes in terms of their tolerance against drought:

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

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

where, Ypi and Ysi are grain yield of each genotype under non-stressed and stressed conditions, respectively; whereas Yp and Ys are mean yield of genotypes under non-stressed and stressed conditions, respectively.

Simple correlation coefficients between grain yield (under both conditions) and the indices were estimated, while statistical calculations were conducted using SPSS-16, Minitab-15 and MSTAT-C software.

Results And Discussion

Results from analysis of variance (Table 2) showed that the mean squares of genotype were significant for all traits except for fertile tiller number and date of anthesis, which represents a significant difference between genotypes in terms of all traits other than mentioned ones. There was a significant difference between the blocks in terms of traits such as plant height, number of fertile tiller, spike weight, grain weight per spike and weight of 1000 grain, thus blocking has been positively effective on decreasing unevenness.

Mean comparison for the studied traits showed (Table 3) that the wheat genotypes varied significantly in terms of grain yield, at 5% probability level. Results from mean comparison for grain yield (Table 3) showed that genotype 4057 (4.377 ton/ha) produced the highest grain yield, whereas Saratovskaya-29 (3.093 ton/ha) had the lowest value among the genotypes for this trait. Calderini et al. (1999) argued that the increase in grain yield, as observed most recently, has been mainly due to increased grain number per spike, whilst this component of yield has proved more efficient than grain weight. Although both source and sink have limiting effect on the yield, it is well established that sink has been comparatively more limiting, even in new lines of wheat.

The genotypes varied significantly in terms of weight of 1000 grain and Sardari (74.35gr) has had the highest mean value for this trait compared to all other wheat genotypes. Irrigation during grain filling increases grain weight through increasing photosynthetic materials and remobilizing them into the grain. In contrast, unavailability of sufficient humidity during this sensitive period leads to a dramatic reduction of weight of 1000 grain (Sinha, 1987; Takami et al., 1990; Wardella et al., 1994; Richie et al., 1990; and Mollasadeghi, 2010). Results showed that grain number per spike as well as increased grain weight had a positive correlation with productivity. Thus, high grain number per spike and high grain weight per spike have been effective on increasing grain yield of the genotypes.

Based on forgoing discussion it is safe to say that selection for traits such as grain number per spike, grain weight per spike and weight of 1000 grain can prove efficient in improving grain yield. Therefore, 4057, Ruzi-84 and Tous, which produced the highest grain yield among the genotypes, also had higher value for grain number per spike and grain weight per spike than other genotypes.

Simple correlation coefficients between the studied traits (Table 4) showed that grain yield had not a significant relation with any of the studied traits. Palta et al. (1994) and Ozturk and Aydin (2004) reported a positively significant correlation between grain yield and weight of 1000 grain, whereas Misra et al. (1995) and Mollasadeghi (2010) reported a negative correlation between them. Currently, efforts of the breeders are directed towards achieving an optimal version of these components for yield enhancement; however, since these traits are influenced by various environmental conditions and by the genotypes, consequently inconsistent reports are given on correlation between these traits. In addition, grain number per spike had a positively significant correlation with grain weight per spike and spike weight ($P < 0.01$), whereas it had a negatively significant correlation with weight of 1000 grains, at 1% probability level. Golparvar (2000) in his study to evaluate bread wheat genotypes under drought stress conditions concluded that the highest reduction under drought stress condition happened in grain number per spike.

Moreover, the relation between grain weight per spike and weight of 1000 grain in main spike ($r = -0.609^*$) was negatively significant and this suggests that the correlation between the main components of the yield is not always positive; curiously, decrease in one of the components leads to increase in another. There was a negative correlation between grain yield and plant height and this might be due to bred cultivars in the study as being dwarf, which are potentially high yielding cultivars, i.e. lower height leads to early anthesis. Sandho (1977), Ehdaei and Waines (1988), Abedi (1998), Danaei et al. (2000) and Mollasadeghi (2010) reported a negative correlation between the plant height and grain yield of wheat cultivars, however Bennet (1992) obtained a positive correlation between plant height and grain yield of a numbers of genotypes. Therefore, it may be concluded that the relation between plant height and grain yield depends upon the genotype and environmental conditions.

Estimating the phenotypic and genotypic coefficients (Table 5) revealed a high genetic variation for traits such as plant height, spike length, grain number per spike, and grain weight per spike, 1000 grain weight and date of heading. Contrarily, date of anthesis, grain yield, fertile tiller number and spike length of genotypes were of less genetic variation. Results from this investigation were consistent with the findings of Heidari et al. (2006). They reported that the phenological traits of the replication haploid lines of bread wheat are less variable than other traits.

General inheritability of grain yield was less than that of yield components (Table 5). This shows that the environmental factors are more effective on grain yield than on its components. This has also been declared by Heidari et al. (2006) and Garavandi and Kahrizi (2010). Farzi and Shekari Mostaelli Beglu (2010) found that the highest rate of general inheritability belong to peduncle's length and peduncle's weight (87% and 81%, respectively), whereas the lowest rate of inheritability belongs to plant weight (31%) and harvest index. In addition, in their experiment they estimated the general inheritability rate of grain yield trait to be 65% which is in contrast with results of this investigation.

Shahryari et al. (2011) in their study to examine the genetic diversity among 18 bread wheat genotypes in terms of phenological and morphological traits, demonstrated that the genotypes were genetically more diverse in terms of traits such as plant height, weight of 1000 grains, grain number per spike, spike length, spike weight, peduncle length, peduncle weight and grain yield than in terms of other traits.

Cluster analysis was used in this study to categorize the genotypes with respect to plant height, spike length, spike weight, grain number, grain weight, 1000 grain weight, grain yield and date of heading (Fig. 1). Based on the analysis the genotypes fell into two categories. The categorization was verified 100% by analysis of discriminate function. Mean of squares obtained from cluster analysis were significant for traits such as plant height, spike weight, grain number per spike, grain weight, 1000 grain number at 1% probability level, whereas at 5% probability level it was significant only for spike length. Groups produced from cluster analysis were not of significant differences in terms of grain yield, spike length and date of heading (Table 6). Genotypes such as Gascogne, Sabalan, 4057, Ruzi-84, Gobustan, MV17/zrn, 4041, 4061, Sissons and Toos were placed in category 1. These genotypes had the highest values for all the traits except for 1000 grain number and plant height, which had medium values. Genotypes of category 2 had the highest value for plant height and 1000 grain weight. This group included Saratovskaya-29 and Sardari.

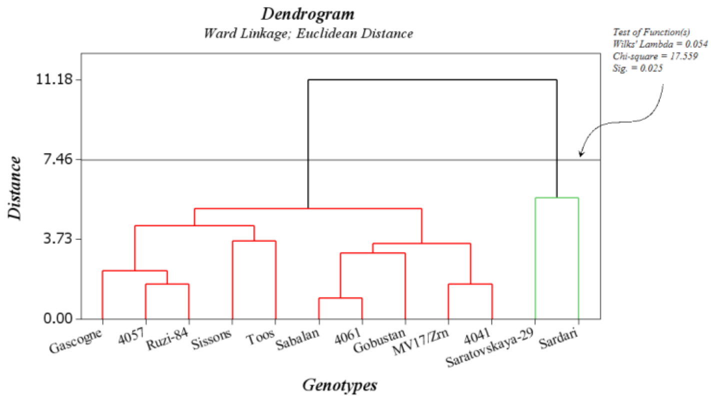

Fig. 1 : Dendrogram resulting from cluster analysis of bread wheat genotypes on phonological and morphological traits

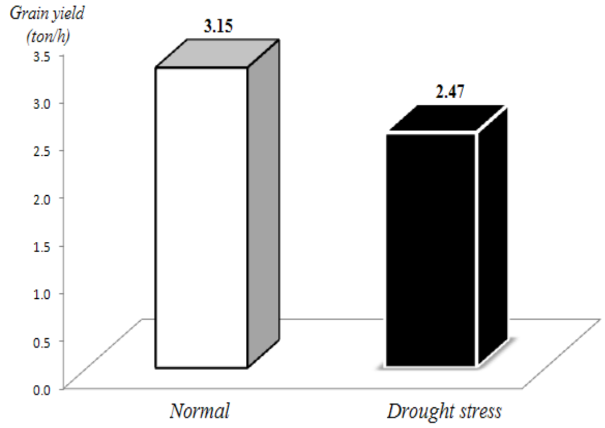

Fig. 2: mean yield of the genotypes under normal irrigation and drought stress conditions in 2008-09 and 2009-10 cropping years

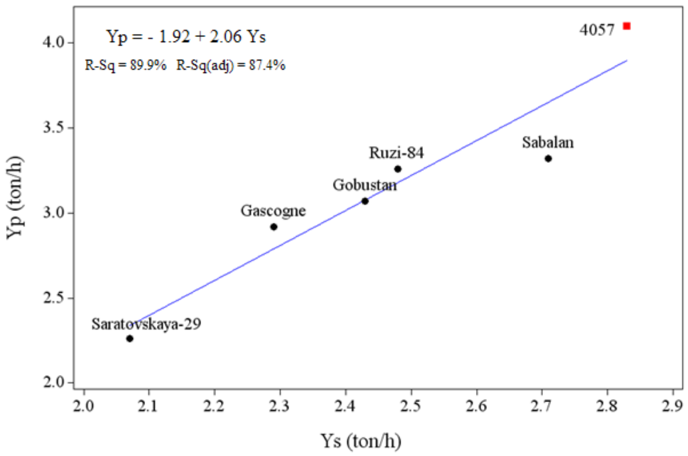

Fig. 3 : classification of genotypes based on grain yield under non-stressed (Yp) and terminal drought stress (Ys) conditions

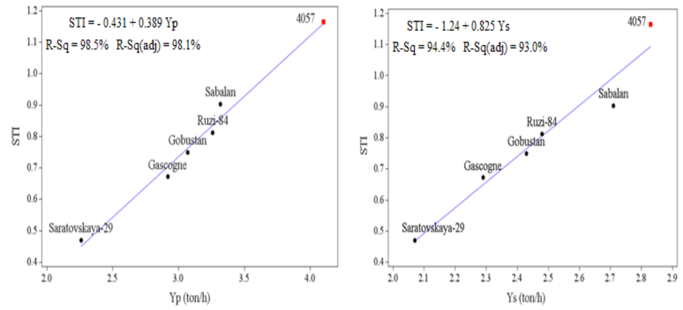

Fig. 4 : Variations of STI and grain yield under non-stressed and terminal drought stress conditions in various wheat genotypes

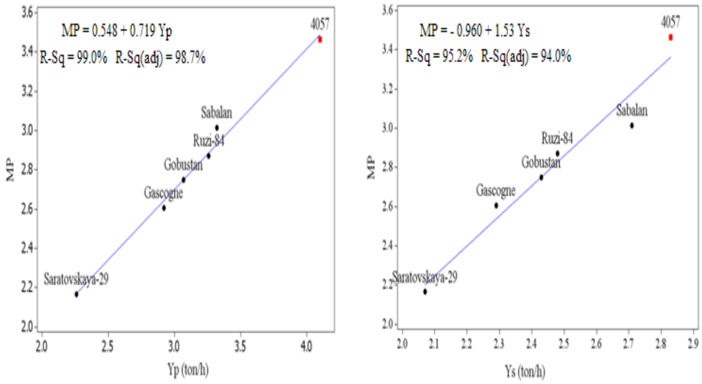

Fig. 5 : Variations of MP index and grain yield under non-stressed and terminal drought stress conditions in various wheat genotypes

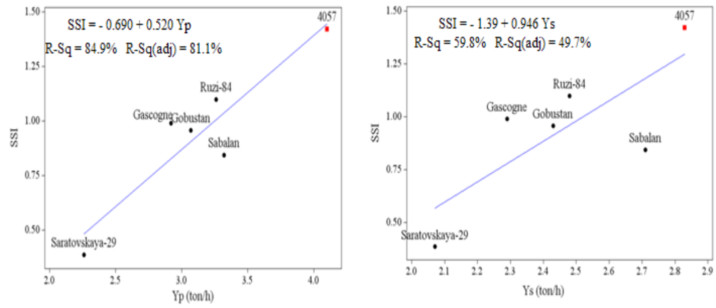

Fig. 6 : Variations of SSI and grain yield under non-stressed and terminal drought stress conditions in various wheat genotypes

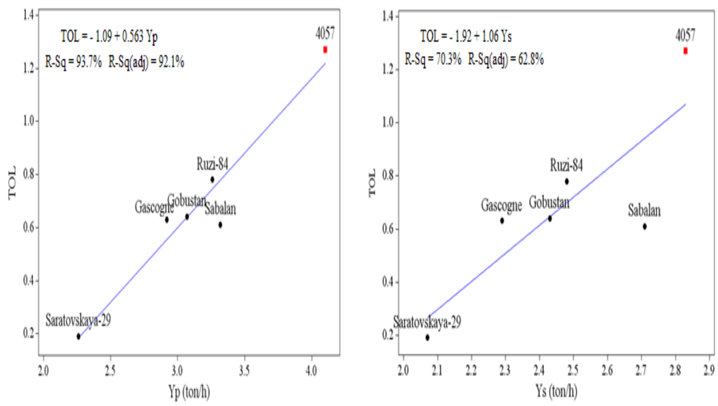

Fig. 7 : Variations of TOL and grain yield under non-stressed and terminal drought stress conditions in various wheat genotypes

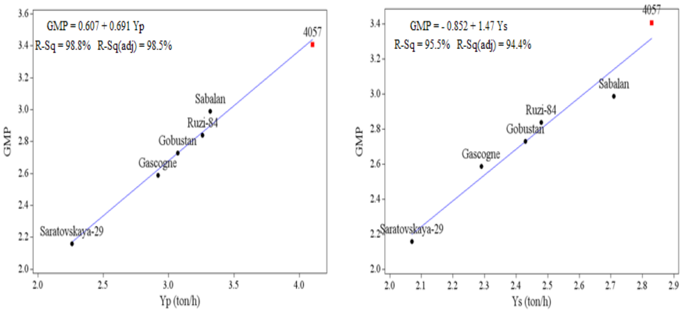

Fig. 8 : Variations of GMP index and grain yield under non-stressed and terminal drought stress conditions in various wheat genotypes

Table 7 shows the results of combined analysis of variance on grain yield under normal and drought stress conditions for 2008-09 and 2009-10 cropping years. Year proved significantly effective under both normal irrigation and drought stress conditions. Interaction of “genotype × year” was insignificant under both normal irrigation and drought stress. Effect of genotypes was significant under normal irrigation condition at 1% probability level, and this rightly suggests that there was a significant difference between the genotypes and they have varied in their genetic potential of responding to increased grain yield. However, this was not the case under drought stress condition.

Ahmadi et al., (2000), Parvizi Almani et al., (1997), Aflatouni and Daneshvar (1993), Abdemishani and Jafari Shabestari (1988) and Ehdaei (1995) in their study have reported the effect of genotype as significant under drought stress condition.

Interaction of “genotype × year” was not found significant under either normal irrigation or drought stress and this suggests that the genotypes did not produce different responses during the years of study and mean grain yield did not vary by year. Mean yield of the genotypes was 3.15ton/ha under normal irrigation in both years, whereas it was 2.47ton/ha under stressed condition, i.e. stress has decreased grain yield by 21.59% (Fig. 2). Under non-stressed conditions, genotypes such as 4057 (4.087ton/ha) and Ruzi-84 (3.225ton/ha) had the highest and lowest yields, respectively, whereas under terminal drought stress condition, 4057 (2.83ton/ha) and Sabalan (2.71ton/ha) had the highest and lowest yields, respectively (Table 8).

Table 8 not only contains the mean grain yield (under two conditions), but also 5 indices which have been calculated to estimate drought tolerance of the genotypes. Fig. 3 shows the classification of genotypes based on grain yield under both non-stressed and terminal drought stress conditions. In addition, Figures 3-6 show how the grain yield varies by indices (under both experimental conditions). Based on values of MP, GMP and STI for genotypes, selection based on this criterion leads to selection of high yielding genotypes under both conditions. Other authors also reported this characteristic for the mentioned indices (Rosielle and Hamblin, 1981 and Nourmand Moayyed, 1997). Genotype 4057 was designated as the best genotype in terms of indices such as MP, GMP and STI (Table 8 and Figs. 4, 5 and 8). This genotype produced the highest yields both under non-stressed (4.10ton/ha) and stressed (2.83ton/ha) conditions. Genotypes such as Sardari and Ruzi-84, which had higher yield under non-stressed and stressed conditions, produced higher values for MP, GMP and STI than others (Table 8 and Figs. 4, 5 and 8). Study on TOL suggests that genotypes with high yield did not exhibit an optimal tolerance against humidity stress, for instance genotypes such as Saratovskaya-29 had the highest tolerance to drought (minimum TOL) followed by Ruzi-84, however they didn’t produce an efficient yield under non-stressed condition. Saratovskaya-29 also was the best genotype in terms of SSI (Fig. 6). In contrast, genotypes such as 4057 and Ruzi-84, which produced optimal yield under both conditions, did not produce efficient TOL and SSI (Table 8 and Figs. 3, 6 and 7).

Correlation coefficients of indices with grain yield under terminal drought stress and non-stressed conditions have been given in Table 9. Correlation coefficient between grain yield under stressed condition (Ys) and grain yield under non-stressed condition (Yp) was positively significant (r = 0.948**). Yield under stressed condition (Ys) was positively and significantly correlated with indices such as MP, GMP, TOL and STI, at 5 and 1% probability levels; however it produced a positively insignificant correlation with SSI. Furthermore, Grain yield under non-stressed condition (Yp) produced a positively significant correlation with all the indices (Table 9). MP index tends to increase yield potential, while in most of the yield tests the correlation between MP and Ys was positive (Rosielle and Hamblin, 1981). MP index produced the highest correlation coefficient with grain yield under non-stressed condition, followed by STI and then GMP indices. In contrast, under stressed condition GMP had the highest correlation coefficient with grain yield, followed by MP and then STI indices. Results from this study are consistent with those reported by other authors (Fernandez, 1992; Nourmand Moayyed, 1997 and Ahmadi, 1999).

Based on Table 8 and Figs. 4, 5 and 8 all the genotypes were classified in one group with respect to mean productivity (MP), geometric mean productivity (GMP) and stress tolerance index (STI). Furthermore, these indices produced a positively significant correlation with grain yield under both non-stressed and drought stress conditions. Thus, the abovementioned three indices are efficient for evaluation of drought tolerance of genotypes.

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

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

Table 2: ANOVA for measured traits in bread wheat genotypes

Source	df	Mean of Squares									
		Plant height	Fertile tiller number	Spike length	Spike weight	Seed number per spike	Grain weight per spike	1000 grain yield	Grain yield	Days number to heading	Days number to anthesis
Replication	2	516.38**	4.7**	0.189	0.364**	0.985	14.943**	55.5**	0.633	2.111	0.985
Genotypes	11	296.8**	0.985	0.382*	0.216**	93.5**	11.796*	152.4**	0.622*	19.179**	0.985
Error	22	20.979	0.533	0.177	0.05	10.351	2.713	8.429	0.486	1.596	4.121
C. V %		2.25	13.13	20.26	8.59	17.07	16.48	32.28	28.49	0.79	0.53

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

Table 3: Mean comparison of the measured traits for under-study wheat genotypes by Duncan way in probability level of 5 percent

Genotypes	Characters							
	Plant height	Spike length	Spike weight	Seed number per spike	Grain weight per spike	1000 grain yield	Grain yield	Days number to heading
Gascogne	61.57 e	7.48 bc	1.957 a	31.77 ab	18.5 a	58.27 bc	3.873 ab	202 b
Sabalan	70.77 cd	8.33 a	1.68 abc	28.73 bc	15.8 abc	54.60 cd	3.797 ab	200 b
4057	73.23 cd	7.67 abc	1.91 a	30.13 bc	16.97 ab	56.53 bc	4.377 a	201 b
Ruzi-84	72.47 cd	7.4 bc	1.777 ab	29.17 bc	16.73 ab	57.48 bc	4.003 ab	200.33 b
Gobustan	81.8 b	7.77 abc	1.59 abc	24.97 cd	15 bc	60.16 b	3.927 ab	200 b
Saratovskaya-29	100.06 a	7.13 c	1.303 cd	22.8 d	13.03 cd	57.24 bc	3.093 b	207 a
MV17/Zrn	70.17 cd	7.63 abc	1.47 bc	32.6 ab	16.6 ab	51.15 de	3.623 ab	200.67 b
Sardari	77.4 bc	7.77 abc	1.037 d	15.4 e	11.43 e	74.35 a	3.927 ab	200 b
4061	66.17 de	8.2 ab	1.65 abc	29.63 bc	15.13 bc	51.12 de	3.67 ab	200.33 b
4041	68.67 cde	7.43 bc	1.62 abc	31.77 ab	15.27 bc	48.07 e	3.877 ab	201.67 b
Sissons	66.47 de	7.53 abc	1.887 ab	36.67 a	17.93 ab	48.82 e	3.46 ab	202.3 b
Toos	70.3 cd	8.1 ab	1.803 ab	32.8 ab	16.5 ab	50.23 de	4.003 ab	207 a
Mean	73.25	7.69	1.64	28.86	15.74	55.67	3.78	201.86

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

Table 4: Simple correlation coefficients between the evaluated traits

	Plant height	Fertile tiller number	Spike length	Spike weight	Seed number per spike	Grain weight per spike	1000 grain yield	Grain yield	Days number to heading
Fertile tiller number	0.47	1							
Spike length	-0.393	-0.422	1						
Spike weight	-0.596*	-0.370	0.069	1					
Seed number per spike	-0.623*	-0.409	0.043	0.823**	1				
Grain weight per spike	-0.660*	-0.401	-0.015	0.926**	0.892**	1			
1000 grain yield	0.349	0.432	-0.08	-0.593*	-0.883**	-0.609*	1		
Grain yield	-0.497	-0.381	0.250	0.372	0.076	0.265	0.162	1	
Days number to heading	0.018	0.316	-0.345	0.432	0.396	0.360	-0.363	-0.118	1
Days number to anthesis	0.417	0.360	-0.247	0.022	0.116	-0.034	-0.270	-0.367	0.798**

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

Table 5: Mean characteristics, scope changes, the coefficients of variation and heritability of general ability traits in bread wheat genotypes

	Plant height	**fertile tiller number**	**Spike length**	**spike weight**	**Seed number per spike**	**Grain weight per spike**	**1000 grain yield**	**Grain yield**	**days number to heading**	**days number to anthesis**
Mean	73.36	2.033	7.69	1.64	28.87	15.74	55.66	3.79	192.167	**201.81**
Rang	56.50	4.40	2.20	1.54	30.70	11.40	33.49	2.64	11	**8**
PCV	17.21	42.85	6.87	22.24	24.96	17.11	16.11	19.63	1.68	**1.06**
GCV	16.03	23.38	4.16	17.57	22.33	13.41	15.24	6.88	1.54	**0.34**
h^2	86.84	29.78	36.67	62.41	80.06	61.40	89.51	12.27	84.62	**15.24**

Table 6 : Comparison of groups given from cluster analysis for different traits

Traits	Means	
	The first group	The Second group
Plant height	70.16 b	88.74 a
Spike length	7.74 a	7.45 b
spike weight	1.74 a	1.17 b
Seed number per spike	30.82 a	19.10 b
Grain weight per spike	16.44 a	12.23 b
1000 grain yield	64.53 b	65.80 a
Grain yield	3.84 a	3.51 b
days number to heading	192.16 a	192.17 b
Differences between averages of each column which have common characters are not significant at probability level of 5%.		

Table 7: Combined analysis of variance for grain yield in normal and drought stress condition in different Year in 2008-2009 & 2009-2010 seasons

S.O.V	d.f	MS	
		Normal	Drought stress
Year	1	15.748**	4.403**
Rep / Year	4	0.657	1.113
Genotype	5	2.135**	0.456ns
Genotype × Year	20	0.357ns	0.131ns
Error	36	0.296	0.396
C.V.%			
ns and *, ** : Not significant and significant 5 , 1% probability levels, respectively.			

Table 8: Estimates of stress tolerance of wheat genotypes based on mean yield of two years under non-stress and post anthesis drought stress conditions

Genotypes	Yp	R	Ys	R	MP	R	GMP	R	TOL	R	SSI	R	STI	R
1	2.92	5	2.29	5	2.61	5	2.59	5	0.63	3	0.99	4	0.67	5
2	3.32	2	2.71	2	3.02	2	2.99	2	0.61	2	0.84	2	0.90	2
3	4.10	1	2.83	1	3.47	1	3.41	1	1.27	6	1.42	6	1.17	1
4	3.26	3	2.48	3	2.87	3	2.84	3	0.78	5	1.10	5	0.81	3
5	3.07	4	2.43	4	2.75	4	2.73	4	0.64	4	0.96	3	0.75	4
6	2.26	6	2.07	6	2.17	6	2.16	6	0.19	1	0.39	1	0.47	6
Mean	3.15	-	2.47	-	2.81	-	2.79	-	0.69	-	0.95	-	0.8	-

Yp: Yield in normal condition	Ys: Yield in stress condition
SSI : Stress Susceptibility Index	STI :Stress Tolerance Index
TOL : Tolerance	MP : Mean Productivity
GMP : Geometric Mean Productivity	R : Rank

Table 9: Correlation coefficient between tolerance and susceptibility indices, Yp and Ys in 6 genotypes in two years under non-stress and post anthesis drought stress conditions

	Yp	Ys	MP	GMP	TOL	SSI
Ys	0.948**	1				
MP	0.995**	0.976**	1			
GMP	0.994**	0.977**	1**	1		
TOL	0.968**	0.838*	0.938**	0.935**	1	
SSI	0.923**	0.776	0.887*	0.885**	0.972**	1
STI	0.992**	0.974**	0.997**	0.997**	0.935**	0.868*
ns and *, ** : Not significant and significant 5 , 1% probability levels, respectively.						

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