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Responses of above and below ground traits of 10 accessions of *Triticum boeoticum* to non-stress and imposed moisture stress conditions

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Abstract

Triticum boeoticum wild wheat is a remarkable gene pool to environmental stress resistance. It is one of the most valuable species of the Triticeae tribe for improving wheat cultivars to moisture-stress. This research was carried out to assess the changes and responses of different traits of 10 accessions of *Triticum boeoticum* under non-stress and imposed moisture stress conditions in 2015 and 2016. Most traits were significantly affected by accession (A), water treatments (WT), and A×WT interactions. The accessions showed a high-level of genetic diversity for all traits, except peduncle weight. The accessions Tb_5 and TB_3 with the highest amount of economic yield per plant (EYPP) and water use efficiency (WUE), were less affected by the imposed moisture stress, while accession Tb_6 with the maximum amount of water use (WU), main root length (MRL) and some phenological traits, were the most affected. The traits of WUE and main stem weight (MSTW) showed the highest and the traits of excised leaf water retention (ELWR), MRL and WU showed the lowest alignment with EYPP, respectively. The ability of producing assimilates (by increasing biological yield per plant and MSTW) and the ability of faster assimilates-remobilization into grains (by increasing harvest index and WUE), has been a neglected aspect of breeding wheat program under drought stress. In other words, the ability of a genotype to produce more assimilates and allocate it to grains (by increased BYPP and WUE, respectively) instead of belowground-traits, will result to increase EYPP. For example, the Tb_6 ecotype, due to the allocation of more assimilates to underground parts, had little grain yield. While the traits of WUE, BYPP, seed number per main spike, seed weight per main spike (SWPMS) and main spike weight (MSPW) showed a positive and significant (P<0.01) correlation to EYPP, the traits of ELWR, MRL, day to heading and day to anthesis, had a negative and significant (P<0.05) correlation with yield. Generally, a high amount of WUE, MSTW, SWPMS, MSPW and peduncle weight; with a low amount of ELWR, phenological traits (except grain filling period), MRL, WU, and root to shoot dry weight ratio (RDWSDW) were suggested for the improvement of grain yield. SWPMS and MSPW were two main-components of grain yield in the favorite accessions (Tb_5 and Tb_3). Tb_5 and Tb_3 may have value for breeding wheat better adapted to moisture stress conditions in future.

Keywords: Wheat; Wild relatives; Diversity; Root trait; Multivariate analysis

1. Introduction

Wheat (*Triticum aestivum* L.) is more important than other cereals due to its rich calories and protein contents. It is a constant diet for about one-third of the world's people (Abdel-Haleem *et al*., 2009). Although Iran has different climatic conditions, wheat is grown in all parts of the country and is considered the main food for the people. In 2014, about 221 million hectares of the cultivated lands were allocated to wheat cultivation and the harvested yield reached close to 730mill.tonnes of grain (F.A.O., 2014). Unfortunately, most of the

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wheat-cultivated lands are located in arid and semi-arid regions of the world with limited water availability. Indeed, long global warming period has led to reduction in rainfall, which increases evaporation and eventually leads to drought. Drought is one of the most important environmental stresses, which limits the production of crops in most parts of the world (Abedi *et al*., 2010). Recent climate changes in the world have exacerbated this situation (Anand *et a*l., 2003). Due to drought effects, the plant's yield is reduced to about 50% (Akpinar *et al*., 2013). Therefore, in these regions, the production of drought tolerant wheat cultivars is critical for food security (Budak *et al*., 2013). Several factors such as growth conditions, physiology, genotype, developmental stage, drought severity, and duration affect the plants response to drought stresses (Kantar *et al*., 2011; Akpinar *et al.*, 2012). The plants response to drought stress is shown by anatomical and physiological signs, such as stomatal closure and synthesis of compatible osmolytes and antioxidants (Ahuja, 2010; Ergen, 2009). Production of the resistant and tolerant cultivars is a principal goal in the plant breeding activities (Rashid *et al.*, 2003). A breeding activity that results in the increase of yield under water stress conditions modifies a high-performance cultivar under optimum conditions. Wild-wheat ancestors including *Aegilops tauschii* (2n=2x=14, DD), *T. urartu* (2n= 2x=14, AA) and *T. boeoticum* (2n=2x=14, AA) are more tolerant to drought stress (Valkoun, 2001; Mujeeb-Kazi *et al*, 2007; Sultan *et al*., 2012). Because these wheat species are highly resistant to drought stress, they are considered as a genetic source for improving the drought tolerance of wheat cultivars (Budak., 2013). Among abovementioned species *T. boeoticum*, is more tolerant to drought than other wheat relatives. This species is tolerant to different kinds of environmental stresses, such as salt (Munns *et al.*, 2013) and pathogenic infection (Chhuneja, 2013). Therefore, it can be concluded that *T. boeoticum* is a good gene pool for the improvement of modern wheat. Among different statistical methods, multivariate analysis is one of the most important methods for assessing genetic diversity (Mohammadi and Prasanna, 2003). The study was done to investigate the effect of imposed moisture stress on different above and below-ground traits and to identify the most tolerant genotype among 10 *T. boeoticum* accessions during two consecutive years.

2. Materials and Methods

2.1. Growing conditions and statistical design

This experiment was carried out in the greenhouse of Bu-Ali Sina University in Hamadan, Iran during 2 consecutive years, 2015 and 2016. The plant material included 10 accessions of wild wheat relatives (*T. boeoticum*). The plant samples were collected from different regions of Iran (Table 1). Black pots with a height of 80cm and diameter of 40cm were used. Pots were filled with 15kg of soil (50% salty-loam, 25% sandy and 25% manure) (Mossavi *et al*, 2017). 15 seeds were planted inside each pot and were thinned into 10 plants after three weeks. Two separate experiments were carried out in a randomized complete block design, with three replications and two conditions (non-stress and imposed moisture stress). Non-stress and moisture stress conditions were performed with 95% and 45% of pot capacity, respectively. During the first three weeks, all pots were irrigated with fresh water until they reached the field capacity. After that, when the seedlings had 4-6 leaves, moisture stress (45% pot capacity) was applied.

Table 1. The studied genotypes under non-stress and moisture stress conditions during 2015 and 2016 years

Accession code	Scientific name	Site of collection (city, province, country)
Tb_1	*T. boeoticum*	Dehsefid, Kermanshah, Iran.
Tb_2	*T. boeoticum*	Khoramabad road to Firouzabad, Lorestan, Iran.
Tb_3	*T. boeoticum*	150 Km before Mianeh from Ardabil, Iran.
Tb_4	*T. boeoticum*	Ravansar, Kermanshah, Iran.
Tb_5	*T. boeoticum*	1 Km before Zagheh from Droud, Lorestan, Iran.
Tb_6	*T. boeoticum*	20 Km after Sarvabad, road of Sanandaj to Marivan, Kurdistan, Iran.
Tb_7	*T. boeoticum*	10 Km before Norabad from Aleshtar, Lorestan, Iran.
Tb_8	*T. boeoticum*	Ahar, East-Azarbaijan, Iran.
Tb_9	*T. boeoticum*	10 Km after Ganji to Ghorveh, Kurdistan, Iran.
Tb_{10}	*T. boeoticum*	Ghorveh, Kurdistan, Iran.

2.2. Measurement of the traits

In this experiment, 32 above and below-ground traits were measured in both non-stress and moisture stress conditions. Leaf relative water content (RWC) and excised leaf water retention (ELWR) was determined according to the standard method proposed by Mguis *et al.* (2013). For each pot in each stage of irrigation, used water was recorded, and the total water use (WU) was measured as the sum of water use during the plant growth. After physiological maturity, the plants were harvested from the surface of the soil, the roots washed, and the characters related to root and grain yield were measured. The grain filling period was calculated by subtracting between 'days to anthesis' and 'days to heading'.

The grain yield is obtained by the weight of the harvested seeds per plant. To determine the total biomass, at the time of maturity, all plants in the pot were harvested from the soil surface and the total weight of the harvested plants werre measured.

Root area (RA) and root diameter (RD) were calculated with the following formula:

$$RA = 2\sqrt{MRL.MRV.\pi} \quad (1)$$

$$RD = \sqrt{4.RFW / \pi.MRL} \quad (2)$$

(Alizade, 2006)

Where MRL, MRV and RFW are main root length, main root volume, and root fresh weight respectively.

2.3. Statistical analysis

To study the diversity of genotypes based on important agro morphological traits, various statistical methods were used. Principal component analysis (PCA) and correlation analysis is performed using Minitab v. 16 software. Combined analysis of variance and mean comparison were calculated by SAS v. 9.1 packages (SAS Institute Inc., 2004).

Table 2. The information of 32 measured traits during 2015 and 2016 years

Character/unit	Abbreviation	Character/unit	Abbreviation
Days to heading	DTH	Main stem weight (g)	MSTW
Days to anthesis	DTA	1000-grain weight (g)	TKW
Days to maturity	DTM	Economical yield per plant (g)	EYPP
Grain filling period	GFP	Biological yield per plant (g)	BYPP (SDW)
Chlorophyll content (%)	SPAD	Plant harvest index (%)	PHI
Plant height (cm)	PH	Leaf area index (cm2)	LAI
Peduncle length (cm)	PEL	Relative water content (%)	RWC
Leaf number per plant	LN	Excised leaf water retention (%)	ELWR
Tillers number per plant	TN	Water use (l)	WU
Fertile spikes number per plant	NFS	Water use efficiency (g/l)	WUE
Spikelet number per spike	SNPS	Main root length (cm)	MRL
Seed number per main spike	SNPMS	Main root volume (cm3)	MRV
Seed number per plant	SNPP	Root dry weight (g)	RDW
Main spike weight (g)	MSPW	Root area (cm2)	RA
Seed weight per main spike (g)	SWPMS	Root to shoot dry weight ratio	RDWSDW
Peduncle weight (g)	PEW	Root diameter (cm)	RD

3. Results and Discussion

The results show that although the effect of year was not significant for most of the traits, but this effect was significant for some traits such as DTH, LN, TN, SNPS, SNPP, MSTW, PHI, MRL, RDWSDW, and RA (Table 3). It is probably due to the controlled conditions of the experiment in the greenhouse during the two consecutive years. Moosavi *et al*. (2017) and Mguis *et al*. (2008) reported similar results in greenhouse experiments during two years.

The effect of accession was significant for all traits, expect PEW (Table 3). This indicated a high level of genetic diversity among the studied accessions. Therefore, this germplasm may be a valuable gene pool for selection to improve wheat cultivars to moisture-stress. Amini *et al*. (2015) stated that genetic diversity is an effective parameter for the selection of high yield tolerant genotypes and better understanding of the physiological mechanisms. Pour-Aboughadareh *et al*. (2016) concluded that there is significant difference between *T. boeoticum* for all traits, which indicates a remarkable genetic diversity among the studied accessions. In another research (Misbah *et al*., 2015) a remarkable genetic variation was reported among the wheat genotypes under both normal and moisture stress conditions. Mguis *et al.* (2008) showed a high degree of variation for morphological, phenological, and yield related characters.

Accession by water- treatment interaction was significant for some traits, including EYPP, which indicated a different reaction of accessions to different moisture conditions. In other words, it may be inferred that while an accession is suitable for selection in non-stress conditions, another is suitable for selection under moisture stress conditions.

Mean comparison of traits were done for accessions (Table 4) and between two water treatments (Table 5). The results (Table 4) showed that there was a significant difference among accession for all traits (P<0.05). While drought- tolerant accession namely Tb_5 has the highest EYPP in germplasm, Tb_1 and Tb_9 had the lowest EYPP under non-stress and moisture-stress conditions. The correlation results (Table 7) indicated that while the traits of WUE, BYPP, SNPS, SWPMS and MSPW showed a positive and significant (P<0.01) correlation with EYPP, the traits of ELWR, MRL, DTH and DTA, had a negative and significant (P<0.05) correlation with EYPP. In fact, the suitable and tolerant accessions Tb_5 and Tb_3 had the maximum amount of first group of the mentioned above-traits, while the susceptible-accession Tb_6 had a maximum amount of the second group traits. Indeed, a high amount of WUE, MSTW, SWPMS, MSPW and peduncle weight, and a low amount of ELWR, phenological traits (except grain filling period), MRL, WU and root to shoot dry weight ratio (RDWSDW) were suggested for the improvement of the germplasm grain yield.

In fact, the above results were in accordance to the correlation results. In other words, unlike the traits of WUE ($r=0.089^{**}$), BYPP ($r=0.72^{**}$), SNPMS ($r=0.070^{**}$), SWPMS ($r=0.60^{**}$) and MSPW ($r=0.59^{**}$), that showed a positive and significant (P<0.01) correlation with EYPP, the traits of ELWR ($r=-0.57^{*}$), MRL ($r=-0.53^{*}$), DTH ($r=-0.43^{*}$) and DTA ($r=-0.41^{*}$), had a negative and significant (P<0.05) correlation with the yield (Table 7).

Sinha and Sharma (1979), observed a positive correlation between grain yield and the three main components of grain yield, namely number of seeds per spike, number of spikes per plant, and TKW. The desirable and tolerant accession (Tb_5 and Tb_3) had more TKW and SNPMS than sensitive accessions (Table 4). TKW and number of spikes are two important components in grain yield evaluation (Gounzales *et al*., 2007). Thousand-grain weight is one of the important components of yield, and has a positive relationship with the indicated yield (Komeili, 2007). In a study conducted on wheat yield under drought stress, Golabadi *et al*. (2008) showed a positive and significant correlation between grain yield and 1000-grain weight. Plant yield can be increased by the increase in dry matter, the contribution of economic yield (plant harvest index), and the number of days to maturity and plant height. Khansari *et al.* (2015) observed that the increase in these traits lead to an increase in the yield. The results showed that the plant height had a negative correlation with grain yields, which was in accordance to the study of Modares *et al*. (2003).

The present findings revealed that WUE is the most important yield related trait. It was related to SNPMS ($r=0.88^{**}$), SWPM ($r=0.87^{**}$), MSPW ($r=0.85^{**}$), TKW ($r=0.78^{**}$) and GFP ($r=0.69^{**}$). A conspicuous result was that WUE had a significant negative relationship with all phenological traits, except for GFP. In fact, it is an important strategy for selection of accession to improve grain yield under both moisture conditions, especially in moisture stress. So that, the tolerant and favorite accessions Tb_5 and Tb_3 had a high mount of SNPMS, SWPM, MSPW, TKW and GFP, and a low value of ELWR, DTH and DTA. Indeed, increased WUE under both conditions, especially under moisture stress, not only resulted in a reduced vegetarian growth, but also increased SNPMS, SWPM, MSPW, TKW and GFP and reduced DTH and DTA. In other words, an increase in GFP and sink-capacity (SNPMS, SWPMS, MSPW, and TKW) and a decrease in root related traits resulted in BY partitioning changes. Therefore, we proposed a neglected strategy namely selection of high amounts of GFP, SNPMS and TKW, simultaneously. Therefore, the traits of SNPMS, SWPMS, MSPW, and TKW can to be selected for further improvement of wheat EYPP.

Therefore, WUE, MSTW, SWPMS, MSPW, and PEW, were suggested as the most effective traits on grain yield improvement. Indeed, an increase in single spike weight has mainly improved the grain yield of the wild wheat accessions. Sohail *et al*. (2011), revealed that *Ae. tauschii* accessions used water more efficiently than the synthetic wheat lines under well-watered conditions, but exhibited a greater reduction in average WUE under drought conditions. Previous studies (Austin et al., 1989; Slafer, 1994) revealed a positive and significant correlation between grain number (m^{-2}) and grain yield. In the present study, the traits of SNPMS, SNPS, SNPP and NFS were recognized as the most important components of grain number (m^{-2}). Therefore, an increase in the above components will result in an increase in grain number (m^{-2}) and lead to a grain yield improvement.

EYPP is one of the most important components of aboveground biomass. Therefore, a genotype that has the ability to allocate more of assimilates to its aboveground parts, may be able to produce more grain yield under stress conditions, which is desirable.

In tolerant accessions (Tb_5 and Tb_3), the ratio of root to shoot dry weight has decreased (Table 5). In other words, tolerant and desirable accessions (Tb_5 and Tb_3), in addition to high amount of BYPP, allocate more of their photosynthetic materials to grains. In a research (Moosavi *et al*., 2017) the root to shoot ratio was suggested as a good criteria for the selection of drought tolerant genotypes.

The imposed moisture stress reduced all traits except GFP, SPAD and ELWR (Table 5). For example, the EYPP under moisture stress was about half the EYPP under non-stress conditions.

It is noteworthy that, the accessions have reduced DTH and DTA according to escape mechanism under moisture stress condition, while increasing GFP. Indeed, reducing DTH and DTA and increasing GFP is a valuable mechanism to produce grain yield and to survive adverse environmental conditions. Therefore, increased GFP and decreased DTH and DTA are an intelligent methodology for the selection of drought-tolerant genotypes. In fact, drought escape leads to a reduction in the biological yield. Wortmann (1998) and Kilic *et al*. (2010) showed that drought escape is associated with a reduced yield. Kilic *et al.* (2010) reported that DTH, GFP, DTM, PH, number of spikes per m^{-2}, PEL, spike length, number of grains per spike. and TKW of genotypes were reduced under drought stresses and the chlorophyll content was increased. They also showed that an increase in the grain filling period and higher chlorophyll content lead to an increased genotype yield under drought stresses. Royo *et al.* (2000) concluded that drought stress, especially in the late stages of growth, reduces the grain filling period and TKW. Their results were consistent with the results of Fallahi (2012) and Farshadfar (2011).

Table 3. ANOVA summery of 32 different traits of 10 *T. boeoticum* accession subjected to non-stress and moisture stress conditions during 2015 and 2016 years

Characters	Sources of variation			
	Year	Accession (A)	Water Treatment. (WT)	A × WT
Phenological traits				
Days to heading	602.04**	1366.50**	398.08**	401.11**
Days to anthesis	56.38$^{n.s}$	1051.80**	369.11**	380.51**
Days to maturity	124.80$^{n.s}$	628.40**	89.90$^{n.s}$	457.81**
Grain filling period	259.40$^{n.s}$	513.30**	44.40$^{n.s}$	711.71**
Morpho-physiological trait				
Chlorophyll concentration	72.80$^{n.s}$	27.90*	1.21$^{n.s}$	29.50**
Plant height	125.80$^{n.s}$	306.70**	24.05$^{n.s}$	82.71$^{n.s}$
Peduncle length	3.50$^{n.s}$	41.07**	11.51$^{n.s}$	10.80$^{n.s}$
Leaf number per plant	1011.08**	1585.40**	1.90$^{n.s}$	543.41**
Tillers number per plant	152.10**	77.90**	0.73$^{n.s}$	46.71**
Fertile spikes number per plant	8.70$^{n.s}$	32.20**	0.41$^{n.s}$	5.20**
Spikelet number per spike	159.60**	41.09**	24.41$^{n.s}$	48.71**
Seed number per main spike	14.70$^{n.s}$	40.30**	1.51$^{n.s}$	29.91**
Seed number per plant	91.30**	11177.01**	3359.01**	2305·01**
Main spike weight	0.01$^{n.s}$	0.04**	0.06*	0.01**
Seed weight per main spike	0.01$^{n.s}$	0.03**	0.06$^{n.s}$	0.01**
Peduncle weight	0.003$^{n.s}$	0.010$^{n.s}$	0.009$^{n.s}$	0.001$^{n.s}$
Main stem weight	0.10*	0.21**	0.07$^{n.s}$	0.05**
1000-grain weight	91.40$^{n.s}$	71.30**	158.30*	12.41$^{n.s}$
Economical yield per plant	0.10$^{n.s}$	1.50**	1.80**	0.45**
Biological yield per plant	0.02$^{n.s}$	47.08**	6.04$^{n.s}$	3.50$^{n.s}$
Plant harvest index	167.70*	213.30**	12.60$^{n.s}$	125.61**
Leaf area index	396.90$^{n.s}$	985.10**	1890.01**	1259.01**
Relative water content	657.60$^{n.s}$	499.71**	832.10$^{n.s}$	222.41**
Excised leaf water retention	936.60$^{n.s}$	85158.01**	11093.01*	64272.01**
Water use	450875.01$^{n.s}$	6608605.01**	184479262.01**	3621429.01*
Water use efficiency	0.03$^{n.s}$	0.10**	0.01$^{n.s}$	0.02$^{n.s}$
Root-related traits				
Main root length	508.40**	36.20**	53.01*	22.10$^{n.s}$
Main root volume	0.10$^{n.s}$	34.81**	30.02**	12.10**
Root dry weight	2.20$^{n.s}$	1.91**	0.57$^{n.s}$	0.79**
Root area	27.20**	37.81**	56.80**	14.40**
Root to shoot dry weight ratio	2.90**	1.81**	0.08$^{n.s}$	0.95**
Root diameter	0.01$^{n.s}$	0.09**	0.01$^{n.s}$	0.01**
Degree of freedom	1	9	1	9

ns, *and ** indicate not-significant and significant at 5% and 1% probability levels respectively

Pour-Aboughadareh (2016) concluded that all yield-components had a positive and significant relationship with grain yield, except for the number of fertile tillers. Other researchers such as Garcia-Del-Moral *et al*. (1985), Gholparvar *et al*. (2009), Shiri *et al*. (2010) and Singh *et al*. (1973) reported a positive and significant correlation between grain yield and seed number per spike, grain weight, main spike length, and number of fertile tillers. An increase in the weight of spike, weight of 1000 seeds, and the number of seeds per spike, leads to an increase in the grain yield (Moosavi *et al.,* 2017; Armenian *et al.,* 2010). John Mohammadi *et al.* (2014) and Nouri *et al*. (2017) reported a positive and significant correlation between grain yield and the traits of spikelet number, grain length, and 1000-grain weight.

In most cases, the objective of genetic improvement in wheat plant is to obtain a strong correlation between grain yield and the harvest index. The harvest index indicates grain yield to the biological yield ratio. Therefore, if photosynthetic organs are sufficient, the grain yield will increase with an increase in the harvest index. At the end of the plant growth period, significant amount of photosynthetic material that were produced during the growth period enter the seeds (Navabpour *et al*., 2013). Rezaei *et al*. (1996) used the relationship between grain yield and the harvest index as a criterion for the selection of high yielding lines in wheat. Calderini *et al* (1995) believes that grain yield improvement can be achieved by the reduction of plant height. This improvement results in the transfer of material from the vegetative part to the reproductive sector. Neboti *et al*. (2010) and Naghdipour *et al*., (2013) showed a negative correlation between grain yield and plant propagation, which is similar to our results. In order to investigate the relationship between genotypes and traits, the data obtained from normal and under drought stress were combined and analyzed by the principal component analysis. The results (Table 6) showed that the three main components explained 82% of the total data variance. The first component with 47% of the total variation had a positive and significant relationship with EYPP. Therefore, this component was called the ‘grain yield component’, and a greater amount of this component is more favorable. The second component with 23% of the total variation had a negative relationship with EYPP. Therefore, a high and low amount of first and second components, namely area IV, was desired and desirable, respectively. Therefore, bi-plot results (Figure 1) revealed that accessions Tb_5 and Tb_3 are desirable genotypes, while accession Tb_6 is undesirable. In fact, the favorite accession had a high value of the traits of SNPS, WUE, LAI, PHI, SPAD, SWPMS, MSTW, TKW, SNPMS, PH, PEL, TN, and MSPW. Therefore, an increase in these traits lead to an increase in grain yield. Unlike the above traits, a decrease in the traits of DTH, DTP, DTM, WU, ELWR, RDW, and MRL are proposed for yield improvement. The accessions Tb_5 and Tb_3 with the highest amount of EYPP and WUE, were less affected by the imposed moisture stress, while accession Tb_6 with the maximum amount of WU, MRL and phenological traits (DTH and DTA), was the most affected. The traits of WUE and MSTW showed the highest alignment with EYPP. Yet, the traits of ELWR, MRL and WU showed the lowest alignment with EYPP. A high potential for storage of assimilates (for example, by a high level of MSTW) and the ability of their remobilization into grains, has been a neglected aspect in the previous breeding programs. Generally, the ability of a genotype to allocate more assimilates to grains instead of belowground traits (for example, due to a higher WUE and lower RDWSDW) will increase grain yield. Unlike the Tb5 and Tb3 ecotypes, the Tb6 ecotype had very little grain yield due to the high amount of WU and wider belowground sections. According to Blum (1996), shortening the period of growth and development leads to a better appearance in the genotype (in terms of yield and stability) under stress conditions.

In the studies of Ahmadi *et al.* (2005), Abolhassani *et al*. (2006), Hasani *et al*. (2007) and Moosavi *et al*. (2017), the first and second components justify the highest percentage of variation in the indices. Principle analysis has been used to evaluate the diversity and selection of desirable genotypes by Ghafoor (2003), Hamayoon *et al*. (2011), Shiv *et al*. (2012), and Moosavi *et al*. (2017). Bi-Plot can be an efficient multivariate method for detecting favorite ecotype and traits (Shiri and Bahrampour, 2015).

Table 4. Mean comparison of 10 *T. boeoticum* accession subjected to non-stress and moisture stress conditions during 2015 and 2016 years

Characters abbreviation	Tb_1	Tb_2	Tb_3	Tb_4	Tb_5	Tb_6	Tb_7	Tb_8	Tb_9	Tb_{10}
DTH	141^{b}	120^{f}	135^{cd}	113^{g}	130^{e}	148^{a}	131^{ed}	150^{a}	135^{cd}	135^{c}
DTA	150^{c}	133^{g}	143de	125^{h}	138^{f}	154^{b}	143de	160^{a}	141^{e}	146^{d}
DTM	184^{cbd}	178^{d}	184^{bcd}	181^{bcd}	182^{bcd}	187^{b}	181^{bcd}	197^{a}	186^{bc}	180^{cd}
GFP	35de	45.8^{b}	40.5^{bc}	54.1^{a}	43.9^{b}	32^{e}	38^{cd}	38^{cd}	44.5^{b}	34.4^{de}
SPAD	46.9^{bc}	50.5^{a}	49.1^{abc}	48.9^{abc}	48.8^{abc}	47.0^{bc}	49.7^{ab}	47.4^{abc}	45.8^{c}	46.8^{bc}
PH	59.1^{bc}	66.7^{a}	61.9^{ab}	64.1^{ab}	64.0^{ab}	53.3^{cd}	55.1^{cd}	58.6^{bc}	51.6^{d}	59^{bc}
PEL	20.7^{bc}	23.6^{ab}	23.1^{ab}	25.5^{a}	23.8^{ab}	21.4^{bc}	22.3^{abc}	19.4^{c}	21.9^{bc}	23.9^{ab}
LN	29.5^{c}	27.4^{c}	37.1^{b}	19.9^{d}	38.5^{b}	36.3^{b}	22.6^{d}	68.7^{a}	29.6^{c}	20.4^{d}
TN	5.2^{de}	6.2^{cd}	7.9^{b}	4.4^{e}	7.7^{b}	6.5^{c}	5.1^{de}	14.1^{a}	5.2^{de}	4.1^{e}
NFS	4.1^{cdef}	4.3^{cde}	4.9^{cd}	3.8^{def}	6.4^{b}	9.1^{a}	4.3^{cde}	5.1^{c}	3.4^{ef}	3.1^{f}
SNPS	16.7^{bc}	15.4^{cd}	15.9^{cd}	14.1^{d}	18.6^{b}	16^{cd}	16.1^{cd}	20.7^{a}	14.4^{cd}	15.2^{cd}
SNPMS	14.7^{c}	14.5^{c}	14.6^{c}	11.9^{d}	17.2^{ab}	15.04^{bc}	14.1^{cd}	18.2^{a}	14.9^{bc}	12.5^{cd}
SNPP	47.1^{de}	56.3^{d}	72.8^{c}	41.6^{e}	105.1^{b}	148.1^{a}	67.4^{c}	111.0^{b}	46.8^{de}	44.1^{e}
MSPW	0.29^{cd}	0.34^{bc}	0.44^{a}	0.31^{bcd}	0.44^{a}	0.32^{bcd}	0.35^{bc}	0.36^{b}	0.31^{bcd}	0.26^{d}
SWPMS	0.27^{cd}	0.33^{bc}	0.40^{a}	0.29^{bcd}	0.40^{a}	0.30^{bcd}	0.31^{bc}	0.35^{ab}	0.27^{cd}	0.24^{d}
PEW	0.12^{ab}	0.14^{ab}	0.20^{a}	0.13^{ab}	0.18^{ab}	0.21^{a}	0.15^{ab}	0.16^{ab}	0.11^{b}	0.10^{b}
MSTW	0.42^{cd}	0.56^{bc}	0.83^{a}	0.56^{bc}	0.67^{b}	0.56^{bc}	0.47^{cd}	0.64^{b}	0.35^{d}	0.43^{cd}
TKW	19.1^{cde}	22.1^{abc}	22.9^{ab}	23.9^{a}	22.1^{abc}	17.1^{e}	22.3^{ab}	16.5^{e}	18.4^{de}	20.5^{bcd}
EYPP	0.7^{e}	0.9^{cde}	1.3^{b}	0.8^{de}	1.9^{a}	1.4^{b}	1.1^{bcd}	1.2^{bc}	0.7^{e}	0.9^{cde}
BYPP	3.5^{b}	4.6^{b}	7.1^{a}	3.7^{b}	7.4^{a}	8.3^{a}	3.8^{b}	8.1^{a}	3.3^{b}	3.4^{b}
PHI	22.3^{b}	23.2^{b}	16.9^{c}	24.3^{ab}	26.5^{ab}	16.4^{c}	28.9^{a}	15.5^{c}	23.9^{ab}	25.7^{ab}
LAI	41.8^{d}	50.6^{c}	63.3^{ab}	50.9^{c}	40.9^{d}	57.7^{b}	50.6^{c}	66.4^{a}	46.7^{cd}	41.1^{d}
RWC	63.3^{cd}	61.1^{d}	71.2^{b}	68.7^{bc}	63.4^{cd}	69.1^{bc}	61.6^{d}	82.4^{a}	64.7^{cd}	61.7^{d}
ELWR	504de	474^{ef}	576^{bc}	588^{bc}	435^{f}	466^{ef}	471^{ef}	541^{cd}	706^{a}	615^{b}
WU	12428^{ab}	11014^{d}	11414^{bcd}	11314^{cd}	11014^{d}	13371^{a}	11414^{bcd}	11275^{cd}	12114^{bc}	11914^{bcd}
WUE	0.02^{d}	0.03^{c}	0.04^{b}	0.03^{cd}	0.06^{a}	0.03^{cd}	0.03^{bc}	0.04^{bc}	0.02^{d}	0.03^{cd}
MRL	24.0^{a}	23.4^{a}	21.2^{ab}	19.5^{b}	20.6^{ab}	23.5^{a}	22.3^{ab}	23.5^{a}	22.7^{ab}	23.2^{a}
MRV	3.6^{d}	2.8^{de}	5.2^{c}	1.8^{f}	3.6^{d}	7.9^{a}	3.1^{de}	6.3^{b}	2.2^{ef}	2.5^{ef}
RDW	1.20^{b}	0.81^{c}	1.35^{b}	0.54^{cd}	0.80^{c}	1.72^{a}	1.36^{b}	1.42^{b}	0.49^{d}	0.77^{cd}
RA	8.5^{bc}	6.9^{de}	9.3^{b}	5.3^{f}	7.9^{cd}	11.6^{a}	7.2^{cde}	10.7^{a}	6.4^{ef}	6.7^{de}
RDWSDW	0.60^{bcd}	0.29^{e}	0.74^{bc}	0.33^{de}	0.47^{cde}	1.75^{a}	0.76^{b}	1.75^{a}	0.55^{bcde}	0.55^{bcde}
RD	0.3^{bc}	0.2^{c}	0.4^{a}	0.2^{c}	0.3^{b}	0.4^{a}	0.2^{bc}	0.4^{a}	0.2^{c}	0.2^{bc}

For each row, values with the same letter indicate no-significant differences at 5%

Table 5. Mean comparison of water treatments (non-stress and moisture stress conditions) on 10 *T. boeoticum* accession by paired T test during 2015 and 2016 years

Characters	Normal condition	Stress condition	Characters	Normal condition	Stress condition
DTH	141.1^{a}	127.1^{b}	MSTW	0.6^{a}	0.4^{b}
DTA	149.0^{a}	137.0^{b}	TKW	23.3^{a}	18^{b}
DTM	185.1^{a}	183.1^{a}	EYPP	1.5^{a}	0.7^{b}
GFP	35.5^{b}	45.5^{a}	BYPP	6.5^{a}	4.1^{b}
SPAD	45.6^{b}	50.4^{a}	PHI	23.1^{a}	21.9^{a}
PH	61.9^{a}	56.8^{a}	LAI	64.4^{a}	37.7^{b}
PEL	24.7^{a}	20.5^{b}	RWC	71.1^{a}	62.1^{b}
LN	32.4^{a}	32.6^{a}	ELWR	459.1^{b}	615^{a}
TN	6.4^{a}	6.7^{a}	WU	15004.1^{a}	8324^{b}
NFS	5.3^{a}	4.4^{b}	WUE	0.1^{a}	0.1^{a}
SNPS	17.7^{a}	14.8^{b}	MRL	23.9^{a}	20.7^{b}
SNPMS	15.7^{a}	13.7^{b}	MRV	5.5^{a}	2.3^{b}
SNPP	89.7^{a}	57.1^{b}	RDW	1.4^{a}	0.6^{b}
MSPW	0.4^{a}	0.2^{b}	RA	10.1^{a}	6.1^{b}
SWPMS	0.4^{a}	0.2^{b}	RDWSDW	0.9^{a}	0.6^{b}
PEW	0.2^{a}	0.1^{b}	RD	0.3^{a}	0.2^{b}

For each row, values with the same letter indicate no-significant differences at 5%

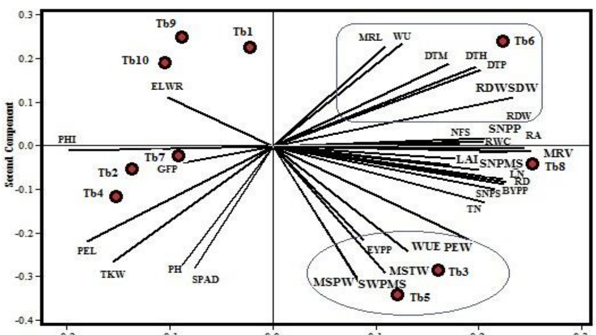

Fig. 1. Bi-plot of first and second components for 32 different traits of 10 *T. boeoticum* accession (Tb_1-Tb_{10}) subjected to non-stress and moisture stress conditions during 2015 and 2016 years

Table 6. Principal component analysis of 10 *T. boeoticum* accession subjected to normal and moisture stress conditions during 2015 and 2016 years

Trait	PC1	PC2	PC3	Trait	PC1	PC2	PC3
DTH	0.196	0.188	0.108	MSTW	0.107	-0.300	0.138
DTA	0.199	0.180	0.122	TKW	-0.156	-0.271	0.069
DTM	0.172	0.192	-0.231	EYPP	0.143	-0.132	-0.347
GFP	-0.084	-0.041	-0.359	BYPP	0.226	-0.087	-0.193
SPAD	-0.075	-0.287	0.002	PHI	-0.196	-0.003	-0.187
PH	-0.087	-0.276	-0.076	LAI	0.171	-0.054	0.042
PEL	-0.179	-0.221	0.017	RWC	0.190	-0.035	0.149
LN	0.220	-0.076	0.159	ELWR	-0.103	0.108	0.238
TN	0.203	-0.132	0.188	WU	0.128	0.239	-0.258
NFS	0.184	0.010	-0.348	WUE	0.132	-0.240	-0.215
SNPS	0.214	-0.093	0.002	MRL	0.106	0.233	0.177
SNPMS	0.208	-0.052	-0.047	MRV	0.250	-0.016	0.038
SNPP	0.207	0.015	-0.298	RDW	0.203	0.016	0.189
MSPW	0.084	-0.322	0.058	RA	0.242	-0.008	0.117
SWPMS	0.086	-0.324	0.071	RDWSDW	0.233	0.111	0.019
PEW	0.190	-0.220	-0.037	RD	0.225	-0.087	0.101
Cumulative variation (%)	47.0	70.3	82.4				

4. Conclusion

The present study revealed a high intra-genus genetic diversity with a significant accession-water treatment interaction. It indicated a different responsibility of accessions to imposed moisture stress. For example, the accessions Tb_5 and Tb_3, with a highest amount of EYPP and WUE, were less affected by the imposed moisture stress, while accession Tb_6, with a maximum amount of WU, MRL and phenological traits (except GFP), were the most affected. Tb_5 and Tb_3 were proposed as desirable drought-tolerant parents for future hybrid programs. Therefore, the current genetic material is a valuable gene pool for breeding programs under moisture stress conditions. In our study, tolerant and susceptible genotypes were well separated using WUE and ELWR. A high and low amount of WUE and ELWR were respectively suggested for moisture stress-tolerant genotype. Under these circumstances, a high amount of WUE, MSTW, SWPMS, MSPW, and peduncle weight, and a low amount of ELWR, phenological traits (except GFP), MRL, WU, and RDWSDW had been suggested for the improvement of the germplasm grain yield. In fact, a high level of SNPMS, SWPM, MSPW, TKW, and GFP, will lead to the improvement of WUE and the plant harvest index. Finally, the traits of WUE and seed number per main spike were remarkably proposed to develop desirable progenies in selection programs of wheat. The grain-filling period, as a phonological trait, had a big effect on grain yield improvement in favorite Tb_5 and Tb_3 accessions. The traits of WUE and MSTW showed the highest, and the traits of ELWR, MRL, and WU showed the lowest alignment with EYPP, respectively. The ability of production and storage of assimilates (for example, by a high level of MSTW and biological yield) and the ability of faster assimilates-remobilization into grains (by a high levels of WUE and harvest index), has been a neglected aspect in breeding of grain yield in previous breeding programs. In other words, the ability of a genotype to allocate more assimilates to grains instead of below-ground traits, due to a higher WUE, will increase grain yield. Unlike accessions Tb_5 and Tb_3, accession Tb_6, with a high WU, and due to its allocation of more assimilates in its below-ground parts, had a very low EYPP.

Generally, a high amount of WUE, MSTW, SWPMS, MSPW, GFP, and PEW, and a low amount of ELWR, DTH, DTA, DTM, MRL, WU, and RDWSDW were suggested for the improvement of grain yield. SWPMS and MSPW were two main components of grain yield in the favorite (Tb_5 and Tb_3) accessions. Tb_5 and Tb_3 may have value for breeding wheat that is better adapted to moisture stress conditions.

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Conflict of Interest

The authors declare no conflict of interest.

Table 7. Combined correlations among different traits of 10 *T. boeoticum* accession subjected to non-stress and moisture stress conditions during 2015 and 2016 years

	DTH	DTA	DTM	GFP	PH	PEL	TN	LN	SPAD	LAI	RWC	ELWR	MSPW	SNPS	SWPMS
DTP	0.99**														
DTM	0.83**	0.82**													
GFP	-0.90**	- 0.91**	- 0.52												
PH	0.50	0.52	0.31	-0.57*											
PEL	-0.57*	- 0.56*	- 0.65*	0.35	0.16										
TN	0.69**	0.68**	0.51	-0.67**	0.44	-0.35									
LN	0.79**	0.78**	0.63*	-0.72**	0.45	-0.46	0.98**								
SPAD	-0.77**	- 0.74**	-0.78**	0.55	-0.10	0.57	-0.31	-0.48							
LAI	0.12	0.13	0.32	0.04	-0.07	-0.33	0.48	0.42	0.03						
RWC	0.11	0.01	0.22	0.01	-0.26	-0.24	0.60*	0.55	-0.16	0.72**					
ELWR	0.07	0.03	-0.07	-0.11	-0.01	0.13	-0.08	-0.05	-0.38	-0.05	0.06				
MSPW	-0.88**	- 0.89**	-0.73**	0.82**	-0.75**	0.27	-0.51	-0.60*	0.63*	0.04	0.15	-0.15			
SNPS	0.83**	0.83**	0.67**	-0.77**	0.55	-0.45	0.87**	0.92**	-0.47	0.17	0.29	-0.27	-0.68		
SWPMS	-0.84**	- 0.84**	-0.69**	0.77**	-0.73**	0.34	-0.43	-0.52	0.64*	0.03	0.20	-0.26	0.96**	-0.60*	
SNPMS	-0.70**	- 0.72**	-0.53	0.72**	-0.78**	0.01	-0.29	-0.35	0.47	0.12	0.31	-0.27	0.93**	-0.43	0.91**
MSTW	0.05	0.06	-0.09	-0.17	0.35	0.22	0.61**	0.49	0.31	0.52	0.51	-0.11	0.02	0.38	0.10
PEW	-0.01	- 0.01	0.06	0.06	0.01	-0.21	0.49	0.40	0.30	0.71**	0.54	-0.35	0.22	0.33	0.22
NFS	0.55	0.54	0.81**	-0.23	0.28	-0.60*	0.45	0.53	-0.40	0.38	0.21	-0.47	-0.41	0.67	-0.40
BYPP	0.16	0.14	0.38	0.06	-0.02	-0.42	0.48	0.47	-0.06	0.62*	0.57*	-0.41	0.11	0.46	0.09
EYPP	-0.41	- 0.43	-0.13	0.54	-0.36	0.02	-0.12	-0.15	0.35	0.18	0.21	-0.57*	0.59*	0.50	0.60*
TKW	-0.94**	- 0.94**	-0.82**	0.83**	-0.66**	0.48	-0.60*	-0.71**	0.73**	-0.07	0.02	-0.15	0.96**	-0.76**	0.96**
SNPP	0.53	0.52	0.77**	-0.23	0.17	-0.60*	0.52	0.58*	-0.40	0.43	0.34	-0.47	-0.33	0.69**	-0.31
MRL	0.85	0.85**	0.64*	-0.81**	0.49	-0.67**	0.55	0.64*	-0.64*	0.06	-0.05	0.14	-0.77	0.66**	-0.84
MRV	0.59*	0.60*	0.63*	-0.44	0.12	-0.66*	0.78**	0.79**	-0.32	0.71**	0.63*	-0.34	-0.28	0.72**	-0.23
WU	0.84**	0.83**	0.97**	-0.56*	0.38	-0.61*	0.40	0.54	-0.80**	0.23	0.05	0.001	-0.79**	0.61*	-0.79**
PHI	-0.81**	- 0.81**	-0.71**	0.71**	-0.57*	0.51	-0.80**	-0.85**	0.57*	-0.50	-0.39	-0.22	0.73**	-0.74**	0.75**
WUE	-0.69**	- 0.70**	-0.51	0.69**	-0.53	0.24 4	-0.22	-0.31	0.60*	0.11	0.25	-0.45	0.85**	-0.29	0.87**
RA	0.73**	0.74**	0.64*	-0.64*	0.28	-0.70**	0.84**	0.87**	-0.40	0.59*	0.51	-0.23	-0.45	0.81**	-0.43
RD	0.67**	0.67**	0.60*	-0.60*	0.36	-0.48	0.82**	0.82**	-0.36	0.63*	0.56	-0.12	-0.43	0.76**	-0.39
RDWSDW	0.75**	0.75**	0.80**	-0.54	0.08	-0.74**	0.73**	0.78**	-0.62*	0.60*	0.60*	-0.10	-0.47	0.72**	-0.46
RDW	0.77**	0.80**	0.60*	-0.77**	0.33	-0.64*	0.77**	0.78**	-0.39	0.48	0.36	-0.19	-0.56	0.77**	-0.54
TRAITS	SNPMS	MSTW	PEW	NFS	BYPP	EYPP	TKW	SNPP	MRL	MRV	WU	PHI	WUE	RA	RDW
MSTW	0.04														
PEW	0.34	0.77**													
NFS	-0.17	0.12	0.45												
BYPP	0.33	0.48	0.81**	0.75**											
EYPP	0.70**	0.23	0.58*	0.40	0.72**										
TKW	0.82**	0.02	0.09	-0.55	-0.09	0.48									
SNPP	-0.06	0.15	0.50	0.97**	0.83**	0.47	-0.49								
MRL	-0.61*	-0.12	-0.11	0.39	0.06	-0.53	-0.87**	0.36							
MRV	-0.04	0.48	0.65*	0.70**	0.75**	0.19	-0.44	0.75**	0.46						
WU	-0.63*	-0.19	-0.06	0.75**	0.28	-0.21	-0.86**	0.70	0.70**	0.53					
PHI	0.59*	-0.38	-0.29	-0.51	-0.35	0.39	0.83**	-0.47	-0.78**	-0.70**	-0.69**				
WUE	0.88**	0.27	0.50	-0.02	0.48	0.89**	0.78**	0.08	-0.73**	-0.02	-0.61*	0.60*			
RA	-0.22	0.45	0.55	0.64*	0.61*	-0.03	-0.60*	0.67**	0.67**	0.95**	0.57*	-0.82**	-0.23		
RDW	-0.40	0.36	0.40	0.51	0.39	-0.22	-0.65*	0.52	0.73**	0.84**	0.57*	-0.79**	-0.40	0.93**	
RDWSDW	-0.23	0.18	0.38	0.69**	0.60*	0.005	-0.63*	0.77**	0.61*	0.88**	0.74**	-0.74**	-0.26	0.87**	0.83**

References

Abd-el-Haleem, S.H.M., M. A. Reham, S.M.S. Mohamed, 2009. Genetic analysis and RAPD Polymorphism in some Durum Wheat Genotypes. Global Biotechnology and Biochemistry, 4; 1-9.

Abid, M., A. Shafaqat, Q. Lei Kang, Z. Rizwan, T. Zhongwei, J. Dong, L. John, D. Tingbo, 2018. Physiological and biochemical changes during drought and recovery periods at tillering and jointing stages in wheat (*Triticum aestivum*. L). Scientific Reports, 8; 40-56.

Abedi, T., H. Pakniyat, 2010. Antioxidant Enzyme Changes in Response to Drought Stress in Ten Cultivars of Oilseed Rape (*Brassica napus* L.). Czech Journal of Genetics and Plant Breeding, 46; 27–34.

Abolhasani, K., G. Saeidi, 2006. Evaluation of drought tolerance in safflower based on tolerant and susceptibility indices to water stress. Water and Soil Science, 10; 407-418.

Abuja, I., C.H. Devos, A. M. Bones, 2010. Plant molecular stress responses face climate change. Trend in Plant Science, 15; 664-674.

Ahmadi, A., M. Saeedi A. Zalli, 2005. Drought resistance and its relation with yield, leaf area and crop growth rate during reproductive stage in bread wheat genotypes with different breeding backgrounds. Journal of Agricultural Sciences and Natural Resources, 12; 82-90.

Akpinar, B. A., B. Avsar, S. J. Lucas, H. Budak, 2012. Plant abiotic stress signaling. Plant Signal Behavior, 7; 1450–1455.

Akpinar, B.A., S.J. Lucas, H. Budak, 2013. Genomics approaches for crop improvement against abiotic stress. The Scientific World Journal. Article ID, 361921; 1-9.

Alizadeh, A., 2006. Soil water plant relationship. 2nd ed. The Astane-Ghodse of Razavi Press.

Amini, A., R. Amirnia, H. Gazvini, 2015. Evaluation of relationship between physiological and agronomic traits related to salinity tolerance in bread wheat (*Triticum aestivum* L.) genotypes. Journal of Agricultural Sciences of Iran, 17; 329-348.

Anand, A., H. N. Trick, B. S. Gill, S. Muthukrishnan, 2003. Stable transgene expression and random gene silencing in wheat. Plant Biotechnology Journal, 1; 241 –251.

Arminian, A., S. Houshmand, B. Shiran, 2010. Evaluation the relationship between grain yield and some of its related traits in a doubled-haploid bread wheat population. Electronic Journal of Crop Production, 3; 21-38.

Austin, R.B., M.A. Ford, C.L. Morgan, 1989. Genetic improvement in the yield of winter wheat: A further evaluation. Journal of Agricultural Science, 112; 295–301.

Budak, H., B. A. Akpinar, T.Unver, M.Turktas, 2013. Proteome changes in wild and modern wheat leaves upon drought stress by two-dimensional electrophoresis and nano LC-ESI-MS/MS. Plant Molecular and Biology, 83; 89–103.

Budak, H., M. Kantar, K.K. Yucebilgili, 2013. Drought tolerance in modern and wild wheat. The Scientific World Journal, Article ID, 548246; 1 –16.

Blum, A., 1996. Crop responses to drought and the interpretation of adaptation. Plant Growth Regulation, 20; 135-140.

Calderini, D.F., M. F. Dreccer, G. A. Slafer, 1995. Genetic improvement in wheat yield and associated traits, examination of previous results and the latest trends. Plant Breeding, 114; 108-112.

Chhuneja, P., K. Kumar, D. Stirnweis, S. Hurni, B. Keller, H. S. Dhaliwal, 2012. Identification and mapping of two powdery mildew resistance genes in *Triticum boeoticum L.* Theoretical and Applied Genetics, 124; 1051 –1058.

Dehshiri, M.R., T. Bahrampour, 2015. Genotype environment interaction analysis using GGE biplot in grain maize (Zea *mayse* L.*)* hybrids under different irrigation conditions. Cereal Research, 5; 83-94.

Ergen, N. Z., H. Budak, 2009. Sequencing over 13000 expressed sequence tags from six subtractive cDNA libraries of wild and modern wheat's following slow drought stress. Plant Cell Environment, 32; 220–236.

FAO, 2014. Statistical Database. Food and Agriculture Organization of the United Nations, Rome, Italy (http//www.apps.fao.org).

Farshadfar, E., M. Farshadfar, F. Farshadfar, 2011. Screening agronomic, physiological and metabolite indicators of drought tolerance in bread wheat (*Triticum aestivum* L.). American Journal of Scientific Research, 38; 88-96.

Fallahi, H. A., J. Alat Jafar Bay, F. Seyyedi, 2012. Evaluation of drought tolerance in Durum wheat genotypes using drought tolerance indices. Seed and Plant Improvement Journal, 27; 15-22.

Garcia Del Moral, L.F., J.M. Ramos, L. Recalde, 1985. Relationships between vegetative growth, grain yield and grain protein content in six barley cultivars. Canadian Journal of Plant Science, 65; 523-532.

Ghafoor, A., Z. Ahmad, N.I. Hashmi, M. Bashir, 2003. Genetic diversity based on agronomic traits and SDS-PAGE markers in relation to geographic pattern of blackgram (*Vigna mungo* L.). Journal of Genetics and Breeding, 57; 5-14.

Gholparvar, A.R., M.R. Ghanadha, A. A. Zali, A. Ahmadi, E.M. Harvan, 2009. Factor analysis of morphological and Morpho-physiological traits in bread wheat (T*riticum aestivum* .L) genotypes under drought and non-drought stress conditions. Pajouhesh and Sazandegi, 72; 52-59.

Gonzalez, A., I. Martin, L. Ayerbe, 2007. Response of barley genotypes to terminal soil moisture stress: phonology, growth and yield. Australian Journal of Agricultural Research, 58; 29-37.

Golabadi, M., A. Arzani, M. Maibody, 2006. Assessment of drought tolerance in segregating populations in durum wheat. African Journal of Agriculture Research, 1; 162-171.

Hasani, S., H. Pirdashti, R. Mesbah, N. Babaian Jolodar, 2007. Evaluation of drought tolerance indices in yield of six cultivars of Virginia tobacco *(Nicotiana tabacum.* L). Seed and Plant Improvement Journal, 24; 129-144.

Hamayoon, R., H. Khan, N. L. Shahenshah, I. Munir, M. Arif, I. A. Khalil, A. Z. Khan, 2011. Performance of chickpea genotypes under two different environmental conditions. African Journal of Biotechnology, 10; 1534- 1544.

Janmohammadi, M., N. Sabaghnia, M. Nouraein, 2014. Path analysis of grain yield and yield components and some agronomic traits in bread wheat. Acta Universitatis Agriculturae ET Silviculturae Mendelianae Brunensis, 62; 945-952.

Khansari,V. A., H. Sabouri, A. Byabani, A. Gholizadeh, H. A. Falahi, M. Zarei, 2016. Study of correlation and causality analysis of agronomic traits in wheat- wheat and sugar beet-wheat rotations. Journal of Applied Eco-physiological Plant Research. 2:145-156.

Kilic, H., T. Yağbasanlar, 2010. The effect of drought stress on grain yield, yield components and some quality traits of durum wheat (*Triticum turgidum* ssp. durum) cultivars. Notulate Botanicae Horti Agrobotanici, 38; 164-170.

Komeili, H., H. RashedMohassel, M. Ghodsi, A. ZareFaizabad, 2007. Evaluation of drought tolerance in wheat new genotypes under water stress conditions. Journal of Agricultural Research, 2; 314-301.

Mguis, K. h., A. Albouchi, M. Abassi, A. Khadhri, M. Ykoubi-Tej, A. Mahjoub, N. Ben Brahim, Z. Ouerghi, 2013. Responses of leaf growth and gas exchanges to salt stress during reproductive stage in wild wheat relative Aegilops geniculata Roth and wheat *(Triticum durum*). Acta Physiologiae Plantarum, 35; 1453–1461.

Misbah, S., G. Shabbir, A. Rasheed, A. Gul kazi, T. Mahmood, A. Mujeeb-Kazi, 2015. Performance of diverse wheat genetic stocks under moisture stress condition. Pakistan Journal of Botany, 47; 21-26.

Mohammadi, S.A., B.M. Prasanna, 2003. Analysis of genetic diversity in crop plants: salient statistical tools and considerations. Crop Science, 43; 1235 – 1248.

Moosavi, S. S., M. Nazari, M. Maleki, 2017. Responses of above and below-ground traits of wheat wild relative (*Aegilops tauschii*) and bread wheat (*Triticum aestivum* L.) to imposed moisture stress. Desert, 22; 209-220.

Modarese Sanavi, S., A, Sorosh Zade, 2003. The effects of row spacing and seeding rate on yield and yield components of wheat promising lines M-75-10. Journal of Agricultural Sciences and Natural Resources, 10; 83-97.

Mujeeb-Kazi, A., A. Gul, I. Ahmad, M. Farooq, S. Rizwan, H. Bux, 2007. Aegilops tauschii, as a spot blotch (*Cochliobolus sativus*) resistance source for bread wheat improvement. Pakistan Journal of Botany, 39; 1207–1216.

Munns .R., R. A. James, B. Xu, A. Athman, S.J. Conn, C. Jordans, 2012. Wheat grain yield on saline soils is improved by an ancestral Na+ transporter gene. Nature Biotechnology, 30; 360–173.

Nabovati, S., M. Aghaee Sarbarzeh, R. Choukan, F. Ghanavati, G. Najafian, 2010. Genetic variation in agronomic characteristics and grain quality traits of durum wheat genotypes. Seed and Plant Improvement Journal, 26; 331-350.

Naghdipour, A., M. Khodarahmi, A. Pourshahbazi, M. Esmailzadeh, 2011. Factor analysis for grain yield and other traits in durum wheat. Journal of Agronomy and Plan Breeding, 7; 84-96.

Navabpour, S., G. Kazemi, 2013. Study the relations between grain yield and related traits in wheat by path analysis. Crop Production Publication, 6; 191-203.

Noori, A., A. A. Mehrabi, H. Safari, 2017. Study of correlation and path coefficient analysis of agronomic traits and grain yield for *Aegilops cylindrical* accessions under non-stress and drought stress conditions in Ilam. Journal of Crop Breeding, 9; 76-84.

Pour Aboughadareh, A. A., S. S. Alavikia, M. Moghaddam, A. A. Mehrabi, M. A. Mazinani, 2016. Diversity of Agro-Morphological traits in populations of einkorn wheat (*Triticum boeoticum* and *Triticum urartu*) under normal and water deficit stress conditions. Journal of Crop Breeding, 8; 37-46.

Rashid, A., Q. Saleem, A. Nazir, H. S. Kazım, 2003. Yield potential and stability of nine wheat varieties under water stress conditions. International Journal of Agriculture and Biology, 5; 7-9.

Rezaei, A., 1996. The relationship between flour quality and high molecular weight of glotenin sub unit in wheat. Iranian Agriculture Science, 1; 11 -21.

Royo, C., M. Abaza, R. Blanco, L.F. Garcia Del Moral, 2000. Triticale grain growth and morphometry as affected by drought stress, late sowing and simulated drought stress. Australian Journal of Plant Physiology, 27; 1051 -1059.

Shiri, M., A. A. Mehrabi, F. A. Shahriyari, A. R. Bagherii, 2010. Evaluation of genetic diversity of wild einkorn wheats in west and North West Iran using SSR markers. Journal of Applied Biology, 8; 125-136.

Singh, M., R. K. Singh, 1973. Correlation and path coefficient analysis in barley. Indian Journal of Agricultural Sciences, 43; 455-458.

Shiv, S., M.A. Iquebal, N. P. Singh, R.K. Solanki, 2012. Genetic diversity studies in chickpea (*Cicer arietinum* L.) germplasm. Journal of Food Legumes, 25; 31–36.

Sinha, G.C.P., N. N. Sharma, 1979. Correlation, regression and path analysis studies in wheat varieties. Indian Journal of Agronomy, 25; 225-229.

Slafer, G.A., E.H. Satorre, F.H. Andrade, 1994. Increases in grain yield in bread wheat from breeding and associated physiological changes. In: Slafer, G. A. (Ed.), Genetic Improvement of Field Crops. Marcel Dekker, Inc., New York, pp. 1–68.

Sohail, Q., T. Inoue, H. Tanaka, A.E Eltayeb, Y. Matsuoka, H. Tsujimoto, 2011. Applicability of drought tolerance traits to breeding of hexaploid wheat. Breeding Science, 61; 347-357.

Sultan. M., L. Hui, L. J. Yang, Z.H Xian, 2012. Assessment of drought tolerance of some *Triticum L.* species through physiological indices. Czech Journal of Genetics and Plant Breeding, 48; 178–184.

Valkoun. J. J., 2001. Wheat pre-breeding using wild progenitors. Euphytica, 119; 17–23.

Wortmann, C. S., 1998. An adaptation breeding strategy for water definite in bean developed with application of the DSSAT 3 dry Bean Model. African Crop Science Journal, 6; 215-225.