DESERT

Desert
Online at http://desert.ut.ac.ir

Desert 22-2 (2017) 209-220

Responses of above and below-ground traits of wheat wild relative (*Aegilops tauschii*) and bread wheat (*Triticum aestivum* L.) to imposed moisture stress

S.S. Moosavi[a*], M. Nazari[a], M. Maleki[b]

[a] *Department of Agronomy and Plant Breeding, Faculty of Agriculture, Bu-Ali Sina University, Hamedan, Iran*
[b] *Department of Biotechnology, Institute of Science and High Technology and Environmental Science, Graduate University of Advanced Technology, Kerman, Iran*

Received: 6 May 2017; Received in revised form: 11 July 2017; Accepted: 13 August 2017

Abstract

The narrow genetic variation of bread wheat is one of the limitations to improve it for drought-tolerance. The research carried out to study the responses of different genotypes and traits to imposed moisture stress. The plant material comprised of 10 *Aegilops tauschii* accessions as well as a tolerant (BW2) and a susceptible (BW1) bread wheat cultivar. To assess the root and shoot-traits, two separate pot experiments were conducted, under normal and moisture stress conditions during 2013–14 and 2014–15 years. The majority of the traits were significantly affected by the genotypes (G), water treatments (WT), and G×WT interaction. The results revealed a high inter genus diversity for the all traits, except tillers number per plants. A19 accession was less affected by the imposed moisture stress, while A14 and A16 were the most affected ones. In addition, BW2 cultivar was more tolerant, with a greater yield, than BW1. Water use efficiency and seed weight per main spike were the most effective traits to improve grain yield. A high amount of water use efficiency, plant harvest index, spikelet number per spike, seed number per main spike, seed number per plant, biological yield per plant, and RWC, and a low amount of phenological traits (except grain filling period), excised leaf water retention, and root to shoot dry weight ratio were suggested for improvement of grain yield. Harvest index and biomass were two main-components of grain yield in the favorite (BW2 and A19) genotypes. A19 and BW2 may have value for breeding wheat better adapted to moisture stress conditions.

Keywords: Genetic; Diversity*;* Root; Traits; Moisture; Stress

1. Introduction

The human population will increase to over 8 billion by the year 2020 (Ashraf and Harris, 2005), therefore feeding the growing population will become a critical challenge in the worldwide (Sohail *et al.,* 2011). Wheat, as the most important crop, provides 20 percent of the calories and protein for the world's population food (Braun *et al.,* 2010, Graybosch and Peterson, 2010). This crop is planted under arid and semi-arid regions with insufficient water (Özturk *et al.,* 2014). Indeed, among the abiotic stress, one of the most widely limiting for crop production on a global basis is water stress (Tomar *et al.,* 2004). Beside, wheat is affected by moisture stress in around 50 percent of its planted areas (Rajaram, 2001).

Genetic diversity and selection are basic prerequisites to breed in crop plant (Falconer and Mackay, 1996). In spite of the wheat wild relatives containing a much wider range of resistance to moisture stress, the narrow genetic variation of bread wheat cultivars, is one of the major limitations to improve their drought tolerance. Therefore, to develop moisture stress-tolerant crops in any breeding program, it is necessary to identify the degree of tolerance among the crop genotypes or it′s wild relatives (Ashraf, 2010). For bread wheat, the genus *Aegilops* is closely related to genus *Triticum* (Van Slageren, 1994). *Ae. tauschii* is one of the

* Corresponding author. Tel.: +98 918 8526940
Fax: +98 81 34425402
E-mail address: s.moosavi@basu.ac.ir

most valuable species for wheat improvement among the more than 300 wild species in the tribe *Triticeae* (Sohail *et al.,* 2011). Interest has developed in recent years in exploiting *Aegilops spp.* as important genetic resources for wheat improvement (Farooq *et al.,* 1996, Zaharieva *et al.,* 2001). It has been proposed that *Triticum tauschii* (the diploid D-genome donor of hexaploid wheat), could be used as a source for exploiting genetic variation for resistance to water stress (Halloran, 1990). *Ae. tauschii* is a valuable source of resistance to environmental stresses and could therefore contribute to the wheat breeding biotic and abiotic programs (Colmer *et al.,* 2006). Indeed, the D- genome plays a key role in resistance to disease (Malik *et al.,* 2003), tolerance to environmental stress (Schachtman *et al.,* 1992), bread quality (Gupta and Mac-Ritchie, 1994), and grain yield increscent (Del Blanco *et al.,* 2000). For example, *Aegilops geniculata* Roth. has been pursued by Farooq (2004) as a potential source for improvement of salt tolerance in wheat. Therefore, a better understanding of the adaptive traits of this species may promote it′s use for wheat genetic improvement (Mguis *et al.,* 2013). Because of the extensive distribution of *Ae. tauschii* in the Middle Eastern (especially in Iran) and Central Asian continental areas possessing very arid habitats, it has been hypothesized that forms could have evolved in the species that possess drought tolerance superior to that of modern wheat (Reddy *et al.,* 1993). Naghavi and Mardi (2010), indicated that the genetic diversity within the DD genome of *Ae. tauschii* is much higher than DD genome of Iranian bread wheat. Generally, appropriate selection of the parents is essential to be used in crossing nurseries to enhance the genetic recombination for potential yield increase (Islam, 2004).

Phenological, morpho-physiological and root-related traits are valuable indices of moisture stress tolerance (Entz and Fowler, 1990), and they are extremely related to grain yield under normal and moisture stress conditions (Van Ginkel *et al.,* 1998). In other words, morphological traits can be used as suitable tools for the indirect analysis of genetic diversity (Kaur *et al.,* 2016). For example, different root-related traits are very important criteria to select for drought tolerances, as a remarkable and unknown genetic diversity resource (Sohail *et al.,* 2011).

Breeding wheat drought-tolerance requires a remarkable level of heritable variation among wheat genotypes or their wild relatives, which may serve as a rich source of appropriate genetic variation (Ashraf, 2010). The present study was done to assess genetic diversity and the responses of above and especially below-ground (as a valuable genetic resource) traits of 10 *Ae. tauschii* accessions and two bread wheat cultivars under different moisture conditions.

2. Materials and Methods

2.1. Plant material

Ten accessions of *Aegilops tauschii*, originating from different sites altitude and latitude of Iran, and two commercial bread wheat (*Triticum aestivum*) cultivars (Pishgam and Shahryar, drought-tolerant and susceptible respectively) were used (Table 1).

Table 1. The studied genotypes under two moisture conditions during 2013–14 and 2014–15

Acce. code	Explanations, site of origin (city, province, and country)
A11	*Aegilops tauschii*; Amol, Mazandaran, Iran
A12	*Aegilops tauschii*; Ahar**,** Eastern Azerbaijan, Iran
A13	*Aegilops tauschii*; Karaj, Alborz, Iran
A14	*Aegilops tauschii*; Astara, Gilan, Iran
A15	*Aegilops tauschii*; Moghan, Ardabil, Iran
A16	*Aegilops tauschii*; Chalous, Mazandaran, Iran
A17	*Aegilops tauschii*; Heyran, Ardabil, Iran
A18	*Aegilops tauschii*; Kooch, Esfahan, Iran
A19	*Aegilops tauschii*; Gilan, Gilan, Iran
A20	*Aegilops tauschii*; Doroud, Lorestan, Iran
BW1	*Triticum aestivum* var. Shahryar; relatively susceptible to drought stress, resistant to cold, brown rust, and yellow rust stresses; year of release 2002
BW2	*Triticum aestivum* var. Pishgam; resistant to terminal drought, cold, brown rust, and yellow rust stresses; year of release 2008

2.2. Growing conditions and statistical design

The experiment was conducted in a research-greenhouse at Bu-Ali Sina University (located in Hamedan province, west of Iran) during two successive years (2013–14 and 2014–15). The plant materials were grown in black plastic pots, with fifteen plants per each pot and after three weeks later, the seedlings were thinned to 10 bushes per each pot. In order to easy assessment of root- related traits, the black plastic pots of 40 cm of diameter and 80 cm of height were applied. Each pot was filled by 15 kg soil comprised of 50% agronomy-field soil (silty-loam), 25% sand, and 25% manure. Four notches have been created to the bottom of every pot to guarantee a good drainage. In each year, two separate experiments carried out based on a randomized complete block design with three replications under normal (95 percent soil field (pot) capacity: 95% S.F.C) and imposed moisture stress (45 percent soil field (pot) capacity: 45% S.F.C) conditions.

During the first-three weeks, the pots watered daily with tap water while adding the necessary volume to bring soil to field capacity. After the first-three weeks, moisture stress treatment (45% S.F.C.) started when the seedling had approximately 4-6 leaves.

2.3. Measurement of the traits

In each normal and moisture stress experiments, 31 traits related to phenology, morpho-physiology, root-characters, and grain yield-related were measured (Table 2).
Root area (RA), was calculated with the following formula:

$$RA = 2\sqrt{MRL \times MRV \times \pi} \quad \text{(Alizade, 2006)} \qquad (1)$$

Where in MRL and MRV are "main root length" and "main root volume" respectively. ELWR and RWC were calculated according to Mguis *et al.* (2013).

Table 2. The information of 31 measured traits during 2013–14 and 2014–15 growing seasons

Character	Abbreviation	Character	Abbreviation
Days to heading	DTH	Main stem weight (g)	MSTW
Days to anthesis	DTA	1000-grain weight (g)	TGW
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 (cm^2)	LAI
Peduncle length (cm)	PEL	Relative water content (%)	RWC
Leaves number	LN	Excised leaf water retention (%)	ELWR
Tillers number per plants	TN	Water use (l)	WU
Fertile spikes number per plants	FSNPP	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 (cm^3)	MRV
Seed number per plant	SNPP	Root dry weight (g)	RDW
Main spike weight (g)	MSW	Root area (cm^2)	RA
Seed weight per main spike (g)	SWPMS	Root to shoot dry weight ratio	RDWSDW
Peduncle weight (g)	PEW	-	-

2.4. Statistical analysis

Combined analysis of variance, mean comparison and correlation analysis were computed by SAS v. 9.1 packages (SAS Institute Inc., 2004). Combined Analysis of variance was performed using GLM procedure (Mguis *et al*., 2008) and below model;

$$X = Y + BLOCK(Y) + WT + Y \times WT + BLOCK \times WT(Y) + G + T \times G + WT \times G + Y \times WT \times G + BLOCK \times G(Y, WT) \quad (2)$$

In above model, X= a measured data, Y= year, WT= water treatment and G= genotype effect. While the year effect was treated as random effect, genotype and water treatment were treated as a fixed effect. Data sets were transformed before GLM if distribution of residuals was not normal. The principal component analysis (PCA) was performed on the two years combined means using Minitab v. 16 software (Minitab 16 statistical software, 2010).

3. Results and Discussion

Analysis of variance showed no significant differences between obtained data of the 2 years of experimentation, except SPAD and water use (Table 3). Indeed, because of same environmental factors (humidity, light, temperature, etc.) and controlled conditions during the 2 years of experimentation, the effect of year was not significant for the majority of the traits. Mguis *et al.* (2008) revealed no significant differences between data during the 2 years of glasshouse experimentation.

The results of ANOVA (Table 3) indicated that genotype effect was significant for all phenological traits, 21 out of 22 morpho-physiological traits and all the root-related characters, except main root volume. The obtained result indicating a high level of genetic diversity in the germplasm. Indeed, the studied gemplasm could be a remarkable gene pool for breeding programs in the future. Sohail *et al.* (2011) reported a high degree of variation for most morpho-physiological traits in the *Ae. tauschii* and synthetic wheat lines under different moisture conditions. So that, they suggested that under normal moisture conditions, highly significant differences were observed in all the studied morpho-physiological traits except for root-shoot ratio, and partitioning of dry mater to roots. However, under moisture stress, root-shoot ratio, and partitioning of dry mater to roots were significantly differed. Mguis *et al.* (2008) suggested that a high degree of variation of morphological, phenological and yield characters mainly related to geo-graphical origin.

The analysis of variance has been pursued then by the mean comparison of the traits, among the genotypes (Table 4) and between water treatments (Table 5). The means of all traits, except tillers number per plants and main root volume, showed significant difference ($P<0.05$) between inter and intra-genus (Table 4). Pishgam, the drought-tolerant cultivar, had the highest economic yield in the germplasm. Indeed, it's productivity was significantly greater than Shahryar cultivar (2.34^{a} and 1.38^{b} g/plant respectively). While A19 had the maximum economic yield (1.22^{bc} g/plant) among *Aegilops* accessions. A17, A16, and A14 (0.11^{e}, 0.23^{e}, and 0.34^{de} g/plant respectively) showed minimum grain yield altogether in both normal and moisture stress conditions (Table 4).

Table 3. ANOVA summery of 31 different traits of 12 wheat genotypes subjected to normal and moisture stress conditions during 2013–14 and 2014–15 growing seasons

Characters	Abbreviation	Sources of variation			
		Year	Genotype (G)	Water Tr. (WT)	G × WT
Phenological traits					
Days to heading	DTH	110.2^{ns}	13022.7^{***}	815.1^{*}	875.2^{***}
Days to anthesis	DTA	98.1^{ns}	12825.7^{***}	603.7^{ns}	933.3^{***}
Days to maturity	DTM	83.1^{ns}	11288.2^{***}	2213.5^{**}	614.1^{***}
Grain filling period	GFP	18^{ns}	1309.3^{*}	121.5^{ns}	656.2^{***}
Morpho-Physiological traits					
Chlorophyll concentration	SPAD	0.1^{*}	43^{*}	1096^{***}	15.2^{ns}
Plant height	PH	25.2^{ns}	1528.4^{***}	2859.9^{***}	43.7^{ns}
Peduncle length	PEL	3.1^{ns}	254.8^{***}	159.9^{**}	6.3^{ns}
Leaves number	LN	2.1^{ns}	134.5^{*}	32.3^{ns}	130.9^{*}
Tillers number per plants	TN	0.01^{ns}	2.8^{ns}	3.5^{*}	6.8^{*}
Fertile spikes number per plants	FSNPP	0.05^{ns}	14.8^{**}	46.5^{*}	2.2^{ns}
Spikelet number per spike	SNPS	2.3^{ns}	119.7^{***}	19.2^{*}	9.9^{**}
Seed number per main spike	SNPMS	3.1^{ns}	368.8^{***}	5.8^{ns}	9.3^{ns}
Seed number per plant	SNPP	5.1^{ns}	793.8^{**}	2579^{**}	155.5^{*}
Main spike weight	MSW	0.004^{ns}	2.9^{***}	0.3^{**}	0.02^{ns}
Seed weight per main spike	SWPMS	0.001^{ns}	1.1^{***}	0.1^{**}	0.1^{***}
Peduncle weight	PEW	0.001^{ns}	0.2^{***}	0.03^{*}	0.01^{**}
Main stem weight	MSTW	0.001^{ns}	2.6^{***}	1.1^{ns}	0.2^{ns}
1000-grain weight	TGW	13.3^{ns}	1145.1^{**}	2486.9^{**}	255.2^{*}
Economical yield per plant	EYPP	0.01^{ns}	2.2^{***}	5.5^{**}	0.2^{ns}
Biological yield per plant (SDW)	BYPP	1.01^{ns}	71.8^{**}	141^{*}	15.4^{ns}
Plant harvest index	PHI	1.1^{ns}	125.3^{*}	120.1^{**}	52.7^{ns}
Leaf area index	LAI	2^{ns}	159.5^{***}	8.2^{ns}	23.4^{***}
Relative water content	RWC	3.3^{ns}	410.9^{*}	2128.7^{**}	186.1^{ns}
Excised leaf water retention	ELWR	128^{ns}	2426361.8^{*}	1182312.4^{ns}	661228.5^{ns}
Water use	WU	789^{*}	24183380.2^{**}	1160610011^{**}	3028273^{*}
Water use efficiency	WUE	$.0001^{ns}$	0.003^{***}	0.0^{ns}	0.0^{ns}
Root-related traits					
Main root length	MRL	0.01^{ns}	76.7^{*}	164.7^{*}	102.5^{*}
Main root volume	MRV	0.001^{ns}	12.5^{ns}	114.3^{*}	20.9^{ns}
Root dry weight	RDW	0.001^{ns}	2.5^{*}	11.1^{*}	3.6^{ns}
Root area	RA	2.03^{ns}	166.4^{*}	2103.8^{*}	601.1^{*}
Root to shoot dry weight ratio	RDWSDW	0.006^{ns}	0.24^{*}	0.62^{**}	0.13^{*}
Degree of freedom (df)		1	11	1	11

^{ns}, *, ** and *** indicate not-significant and significant at 5%, 1%, 0.01% probability levels respectively.

The results (Table 4 and Figure 1) revealed that the favorite genotypes had a high level of WUE, PHI, MSW, MSTW, PEW, PH, PEL, SNPS, SNPMS, TGW, BYPP, LAI, SNPP, and RWC, while they included a low amount of the traits of DTM, DTA, WU, DTH, ELWR, RDWSDW, and LN. In other words, increasing the first group traits will result in grain yield improvement, while decreasing the second group namely DTM, DTA, WU, DTH, ELWR, RDWSDW, and LN is favorite and suggestible.

Table 4. Mean comparison of 12 wheat genotypes subjected to normal and moisture stress conditions during 2013–14 and 2014–15 growing seasons

Characters abbreviation	A11	A12	A13	A14	A15	A16	A17	A18	A19	A20	BW1	BW2
DTH	175^{bcd}	150^{cd}	179^{bcd}	215^{ab}	188^{bc}	252^{a}	251^{a}	205^{b}	140^{de}	158^{cd}	95^{f}	106^{ef}
DTA	189^{cdef}	163^{ef}	197^{cde}	229^{abc}	214^{bcd}	265^{a}	256^{ab}	221^{abc}	153^{fg}	174^{def}	107^{h}	118^{gh}
DTM	265^{ab}	233^{bc}	233^{bc}	267^{ab}	265^{ab}	288^{a}	288^{a}	249^{b}	202^{c}	265^{ab}	158^{d}	163^{d}
GFP	752^{ab}	59.3^{abc}	35.7^{c}	38.4^{bc}	51^{abc}	23^{c}	31.8^{c}	27.7^{c}	48.7^{abc}	84.3^{a}	51.3^{abc}	44.6^{bc}
SPAD	44.3^{abc}	45^{ac}	43.1^{bc}	45.1^{abc}	41.3^{cd}	41.9^{cd}	43.5^{bc}	37.6^{d}	48.5^{a}	41.7^{cd}	43.6^{abc}	47.4^{ab}
PH	30.8^{cde}	38.4^{c}	35.8^{c}	24^{e}	27.1^{de}	23.5^{e}	24.2^{e}	31.1^{cde}	37.8^{c}	35.4^{cd}	65.1^{b}	74.5^{a}
PEL	5.9^{cdef}	7.9^{cde}	8.7^{c}	5.2^{def}	4.7^{ef}	5.1^{def}	4.5^{f}	7.6^{cdef}	12.8^{b}	8.3^{cd}	24.8^{a}	22.8^{a}
LN	18.1^{abc}	26.8^{abc}	26.5^{abc}	28.3^{abc}	30.1^{ab}	32.5^{a}	22.2^{abc}	27.2^{abc}	15.5^{bc}	22.2^{abc}	20.1^{abc}	13.4^{c}
FSNPP	5.4^{abc}	5.5^{abc}	3.7^{cde}	4.2^{cde}	6.4^{a}	2.5^{de}	2.3^{e}	6.2^{ab}	4.9^{abc}	4.3^{bcd}	2.3^{e}	2.3^{e}
SNPS	5.4^{b}	5.1^{b}	4.1^{b}	5.5^{b}	6.8^{b}	4.8^{b}	4.8^{b}	4.1^{b}	5.1^{b}	5.1^{b}	17.1^{a}	15.8^{a}
SNPMS	5.4^{c}	5.1^{c}	4.1^{c}	5.5^{c}	6.8^{c}	4.8^{c}	4.8^{c}	4.1^{c}	5.1^{c}	5.1^{c}	19.6^{b}	29.4^{a}
SNPP	28.1^{bcd}	25.3^{bcde}	14.8^{def}	22.1^{bcdef}	39.1^{ab}	10.3^{ef}	7.5^{f}	25.1^{bcde}	21.5^{cdef}	19.9^{def}	37.5^{abc}	49.4^{a}
MSW	0.08^{d}	0.22^{cd}	0.16^{cd}	0.07^{d}	0.09^{d}	0.08^{d}	0.08^{d}	0.14^{cd}	0.30^{c}	0.24^{cd}	1.60^{b}	2.20^{a}
SWPMS	0.08^{c}	0.22^{c}	0.16^{c}	0.07^{c}	0.09^{c}	0.08^{c}	0.08^{c}	0.14^{c}	0.30^{c}	0.24^{c}	0.90^{b}	1.50^{a}
PEW	0.03^{b}	0.06^{b}	0.04^{b}	0.03^{b}	0.02^{b}	0.03^{b}	0.03^{b}	0.04^{b}	0.08^{b}	0.06^{b}	0.50^{a}	0.60^{a}
MSTW	0.17^{b}	0.25^{b}	0.21^{b}	0.2^{b}	0.12^{b}	0.15^{b}	0.2^{b}	0.16^{b}	0.32^{b}	0.3^{b}	1.6^{a}	2.08^{a}
TGW	15.2^{ef}	34.2^{abcde}	31.6^{bcde}	13.4^{ef}	8.04^{f}	18.2^{def}	20.5^{def}	29^{bcde}	53^{a}	39.5^{abc}	36^{abcd}	49.2^{ab}
EYPP	0.42^{de}	0.93^{bcd}	0.51^{de}	0.34^{de}	0.43^{de}	0.23^{e}	0.11^{e}	0.69^{cde}	1.22^{bc}	0.7^{bcde}	1.38^{b}	2.34^{a}
BYPP	7.9^{b}	7.47^{b}	4.48^{b}	7.16^{b}	6.66^{b}	4.77^{b}	4.71^{b}	7.35^{b}	8.73^{b}	6.57^{b}	16.52^{a}	14.5^{a}
PHI	5^{bc}	12.9^{abc}	12.9^{abc}	4.3^{bc}	6.3^{bc}	5.3^{bc}	2.9^{c}	11.3^{abc}	16.7^{a}	11.4^{abc}	13.3^{ab}	18.1^{a}
LAI	1.8^{b}	1.5^{b}	1.6^{b}	1.3^{b}	1.5^{b}	1.5^{b}	2.3^{b}	2.4^{b}	2.3^{b}	1.3^{b}	17.2^{a}	14.5^{a}
RWC	81.4^{ab}	66.7^{bc}	68^{bc}	65^{bc}	75.7^{ab}	54^{c}	69.8^{bc}	72^{abc}	77.1^{ab}	66.9^{bc}	83.5^{ab}	89.3^{a}
ELWR	1582^{bc}	1013^{bcd}	996^{bcd}	2239^{a}	924^{bcd}	1793^{ab}	1888^{ab}	890^{bcd}	514^{cd}	1358^{bc}	232^{d}	210.4^{d}
WU	15191^{b}	13441^{bcd}	13441^{cd}	14741^{b}	15191^{b}	17441^{a}	18475^{a}	13841^{bc}	11941^{cde}	14841^{b}	11591^{de}	10991^{e}
WUE	0.010^{def}	0.020^{cd}	0.010^{def}	0.006^{ef}	0.01^{def}	0.006^{ef}	0.000^{f}	0.020^{cde}	0.030^{bc}	0.020^{ed}	0.050^{b}	0.080^{a}
MRL	43.02^{a}	36.5^{a}	38.4^{a}	42.7^{a}	36.9^{a}	42.9^{a}	38.9^{a}	45.2^{a}	32.4^{b}	39.2^{a}	34.7^{b}	38.4^{a}
RDW	2.94^{b}	3.20^{b}	2.90^{b}	5.15^{a}	3.70^{a}	4.30^{a}	2.76^{b}	3.53^{a}	3.27^{a}	3.53^{a}	3.54^{a}	4.12^{a}
RA	65.15^{b}	63.3^{b}	61.7^{b}	81.1^{a}	65.6^{b}	73.9^{a}	64.2^{b}	71.9^{a}	68.3^{a}	64.7^{b}	62.1^{b}	75.7^{a}
RDWSDW	0.35^{c}	0.50^{abc}	0.69^{abc}	0.89^{ab}	0.60^{abc}	1.01^{a}	0.72^{abc}	0.49^{abc}	0.49^{bc}	0.60^{abc}	0.24^{c}	0.32^{c}

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

In addition, the correlation result (Table 7) confirmed the above-obtained results. So that, the correlation result indicated a high and positive association between economic yield/plant and WUE, PHI, MSW, MSTW, PEW, PH, PEL, SNPS, SNPMS, TGW, BYPP, LAI, SNPP, and RWC. Therefore, according to the results, any attempt for increasing the above-mentioned traits maybe lead to direct or indirect grain yield improvement. Meanwhile, a negative and significant correlation was detected between economic yield/plant and the traits of DTM, DTA, WU, DTH, ELWR, RDWSDW, and LN respectively (Table 7). Totally, reduction in phenological traits namely DTM, DTH, and DTA (except GFP) was leaded to improve grain yield by escape mechanism under moisture stress conditions.

Therefore, main spike weight, main stem weight, spikelet number per spike, seed number per plant, water use efficiency, plant harvest index, and biological yield were suggested as the major effective traits on grain yield improvement. Indeed, increasing the above-mentioned traits have been leaded to increase of grain yield in new wheat cultivars, while increasing single spike weight, has been mainly improved the grain yield of the wild wheat accessions. Sohail *et al.* (2011), revealed that synthetic wheat lines had higher averages than the *Ae. tauschii* lines for shoot dry weight, total dry weight, root-shoot ratio, partitioning of dry mater to roots and WUE, which indicates their ability to use water more efficiently for biomass production under drought conditions. Indeed, the *Ae. tauschii* accessions used water more efficiently than the synthetic wheat lines under well-watered conditions, but exhibited a greater reduction in their average WUE under drought conditions (Sohail *et al.*, 2011).

In reality, some previous studies (Austin *et al.*, 1989; Slafer, 1994) revealed a positive and significant correlation between grain number m^{-2} and grain yield. Indeed, in our research, the traits of spikelet number per spike, seed number per main spike, and seed number per plant were recognized as the most important components of grain number m^{-2}. Therefore, increasing in the above components will result in increasing grain number m^{-2} and it lead to grain yield improvement. In another research (Navabpour *et al.*, 2013), the traits of spike number per plant, 1000-grain weight, spike weight, grain number per spike and leaf area index were the best suitable traits for indirect grain selection. Leilah and Al-Khateeb (2005), explained that spike length, spikes number m^{-2}, grain weight per spike, harvest index and biological yield were the most important traits respectively.

Table 5. Mean comparison of water treatments (normal and moisture stress conditions) on 12 wheat genotypes by paired T test during 2013–14 and 2014–15 growing seasons

Characters	Normal condition	Stress condition	Characters	Normal condition	Stress condition
DTH	181.533 [a]	173.179[b]	MSTW	0.631 [a]	0.371 [a]
DTA	195.167 [a]	187.929 [a]	TGW	36.179 [a]	22.910 [b]
DTM	245.032 [a]	234.625[b]	EYPP	1.117 [a]	0.503 [b]
GFP	47.429 [a]	45.107 [a]	BYPP	9.825 [a]	6.639 [b]
SPAD	39.502 [b]	47.494 [a]	PHI	11.671 [a]	8.657 [b]
PH	44.162 [a]	31.356 [b]	LAI	4.371 [a]	3.950 [a]
PEL	11.650 [a]	8.036 [b]	RWC	78.358 [a]	67.816 [b]
LN	24.214 [a]	22.931 [a]	ELWR	1016.701 [a]	1215.701 [a]
TN	3.419 [b]	3.968 [a]	WU	18226.701 [a]	10060.601 [b]
FSNPP	5.064 [a]	3.450 [b]	WUE	0.027 [a]	0.022 [a]
SNPS	7.490 [a]	6.543 [b]	MRL	40.578 [a]	37.258 [b]
SNPMS	8.634 [a]	8.186 [a]	MRV	11.123 [a]	8.258 [b]
SNPP	32.601 [a]	19.936 [b]	RDW	4.032 [a]	3.115 [b]
MSW	0.527 [a]	0.406 [b]	RA	74.008 [a]	61.470 [b]
SWPMS	0.386 [a]	0.279 [b]	RDW/MSDW	0.472 [b]	0.666 [a]
PEW	0.160 [a]	0.110 [b]			

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

Table 6. Principal component analysis of 12 wheat genotypes subjected to normal and moisture stress conditions during 2013–14 and 2014–15 growing seasons

Characters	PC1	PC2	PC3
DTH	-0.189	-0.118	0.112
DTA	-0.192	-0.116	0.093
DTM	-0.202	-0.046	0.033
GFP	0.037	0.183	-0.159
SPAD	0.105	-0.046	-0.132
PH	0.206	-0.002	0.072
PEL	0.204	0.009	0.083
LN	-0.150	-0.023	0.059
TN	0.043	-0.056	-0.053
FSNPP	-0.066	0.088	-0.407
SNPS	0.188	-0.065	0.199
SNPMS	0.191	-0.123	0.144
SNPP	0.162	-0.072	-0.065
MSW	0.200	-0.077	0.137
SWPMS	0.201	-0.078	0.097
PEW	0.200	-0.072	0.155
MSTW	0.199	-0.078	0.157
TGW	0.151	0.111	-0.204
EYPP	0.203	-0.030	-0.105
BYPP	0.194	-0.051	0.071
PHI	0.172	0.092	-0.213
LAI	0.188	-0.031	0.230
RWC	0.169	0.040	-0.016
ELWR	-0.176	-0.144	0.085
WU	-0.183	-0.058	0.197
WUE	0.204	-0.049	-0.062
MRL	-0.105	-0.199	0.082
MRV	0.087	-0.261	-0.276
RDW	-0.000	-0.331	-0.098
RA	-0.002	-0.365	-0.179
RDW/MSDW	-0.157	-0.127	-0.012
Percent of variation (%)	56.10	16.10	8.000
Cumulative variation (%)	56.10	72.20	80.200

According to the result (Table 4, Table 7, and Figure 1), harvest index, WUE, and biological yield were suggested as remarkable characters in increasing the yield of the favorite genotypes (namely Pishgam and A19). Indeed, seed weight per main spike is an important part of plant harvest index. As also, because of correlation among water use efficiency, spike weight and harvest index (Sadras, 1990), with increasing spike weight, grain yield will increase. Slafer (1994) reported that harvest index and biomass are two main-components of grain yield. Indeed, in spite of that, harvest index has been improved during wheat breeding programs, but it may be increase to it's potential amount (namely 62%). Besides, there are a positive and significant correlation between water use efficiency (WUE) and harvest index (Sadras, 1990). Indeed, because of improving grain yield is not easy by increasing harvest index in the future, therefore Wallace and Zobel (1992) suggested increasing biomass in order to improvement of grain yield. Arminian *et al.* (2010) suggested that grain yield was significantly correlated with biomass, harvest weight and grain yield. *Ae. tauschii* accessions from West Asian countries and Iran produced higher total dry weight than their corresponding synthetic wheat (SW) lines. Although the *Ae. tauschii* accessions from China produced the highest total dry weight under well-watered conditions, their corresponding SW lines produced far less TDW.

There was a positive and significant correlation between economic and biological yield per plant (r=0.7*). So that, increscent biomass has obtained by increasing solar use and absorption per unit area (Slafer 1994). In other words, the genotypes with greater biomass, especially with a high levels of maim stem weight and peduncle weight, have better source to sink transition in limited environmental resources and therefore the plant grain yield will improve. Munir *et al.* (2007) reported that seeds number plant^{-1}, seeds weight plant^{-1} and 1000-grain weight (TGW) had a positive and significant correlation with grain yield. In a research (Arminian *et al.*, 2010), seeds number per spike and TGW were suggested as the most effective traits for grain yield improvement. As well as, in another research (Moosavi *et al.* 2014), was attributed an opposed behavior and ontogeny relationships between seed number and TSW. Moosavi *et al.* (2013), reported that harvest index, biomass and RWC were the most important traits for indirect grain yield selection.

The results (Table 7) showed a positive and significant correlation between TGW and grain yield (r=0.8**). In other words, the majority of genotypes with a greater TGW, they had a high grain yield. In reality, the new improved cultivars with increasing WUE in their terminal growing period, can improve TGW and grain yield. Slafer (1990) reported that, new wheat cultivars have had more assimilate transfer rate from sink to source about 1 month before flowering time, so that it leads to increase TGW in them.

Thousand-grain weight was reported by many researchers as a character with the most closely related to grain yield, therefore it has been often used in selecting high yielding wheat cultivars (Deyong, 2011; Leilah and Al-Khateeb, 2005).

The results (Table 7) indicated that plant height had a positive and significant ($p<0.01$) correlation with grain yield. Law and Worland (1978) reported a direct and significant correlation between plant height and grain yield. index, 1000-grain weight and grain filling rate, while Ranjbar *et al.* (2015) reveled a negative and significant correlation between 1000-grain Indeed, the better solar distribution in the plant canopy leads to the above relationship. However, increasing plant height is not always favorite (Slafer, 1994).

The expression of 22 traits was significantly ($P <0.05$) affected by the water treatment (Table 3). This included 2 out of 4 phenological traits (DTH and DTM), 16 out of 22 morpho-physiological traits (SPAD, PH, PEL, TN, FSNPP, SNPS, SNPP, MSW, SWPMS, PEW, TGW, EYPP, EYPP, PHI, RWC, and WU), and all of the root-related traits. Indeed, the majority of the traits were affected by the increasing levels of moisture stress.

During the vegetative phase, moisture stress leaded to decreasing plant height, peduncle length, peduncle weight, main stem weight, water use, main root length, main root volume, and root dry weight (Table 5). On the other hand, during the reproductive phase, water treatment accelerated emergence of heading and maturity and it reduced the traits of fertile spike number per plant, seed number per spike, seed number per plant, seed weight per main spike, 1000-grain weight, and finally economic yield per plant was decreased (Table 5). The moisture stress exercised a depressive effect very marked on the output in grains that passes from 1.117 g/plant for normal to 0.503 g/plant for moisture stress, with a reduction of 54.96% (Table 5). So that, all studied traits decreased progressively with the acuteness of the moisture stress, except root to shoot dry weight ratio, tillers number per plants, and chlorophyll concentration. Indeed, reduction of root to shoot dry weight ratio is efficient character in selection for drought-tolerant genotypes. Mguis *et al.* (2008) reported that during the reproductive phase, salinity treatment accelerated spikes emergence and flowering time and reduced sizes and spikes number.

At the normal, the phenological traits occur later than moisture stress conditions (Table 5). Indeed, the germplasm matured after 245 days in normal, but in the stress conditions, they matured after 234 days. As expected, the reduction of the growing period was accompanied by a significant reduction in yield-components, biomass, and grain production (Table 4). Malik *et al.* (2003) provided that abiotic stress tolerance in wild relative might be related to constitutive genome (high tolerance associated with D genome) and with geographical origin. In fact, at the bread wheat variety and the 10 *Ae. tauschii* accessions, the drought appears by a depressive effect on the growth apparent since the first days of installation of the drought constraint. This was observed in other research (Colmer *et al.,* 2006). Growth of wheat cultivar and the 10 *Ae. tauschii* accessions decreased with increasing moisture stress, as indicated by PH, PEL, PEW, FSNPP, SNPS, SNPP, MSW, SWPMS, TGW, BYPP, PHI, MRL, MRV, RDW, RA, and finally EYPP. Colmer *et al.* (2006) reported that abiotic stress, for example salt, drought, etc, generally appears by a weak growth, a reduction of the surface and the leaves number, an acceleration of senescence of the mature leaves. In addition, Cramer and Quarrie (2002) in maize, noted that salt stress, look like drought stress, reduced the development of the aboveground parts by inhibition of the apparition of new leaves. In reality, the reduction of plants growth with lowering moisture in this study reflects the increased metabolic energy cost and reduced carbon gain, which are associated with abiotic stress adaptation. Indeed, stress will result in reduction of photosynthetic rate per unit of leaf area. These plants lost biomass continuously, this was a result of tillers survived, flowered and produced a few small but non-viable grains (Yasir *et al.,* 2013). The depressing action of the drought on the growth and on the output was demonstrated on a large number of species. Morphological symptoms are inductions of injurious effects of drought stress. The adverse effects can be known only by critical comparison with plants control. Drought may directly or indirectly inhibit cell division and enlargement in the plant's growing point. Reduced shoot growth caused by drought originates in growing tissues; not in mature photosynthetic tissues. As a result, leaves and stems of the affected plants appear stunted. Chloride induces elongation of the palisade cells, which leads to leaves becoming succulent. Moisture stress accelerates phenological development induces early flowering in wheat cultivars and 10 *Ae. tauschii* accessions, reduce plant height and peduncle length, reduce biomass, increase root to shoot ratio. As a result, grain yield is reduced. This is attributed to the reduced FSNPP, SNPS, SNPP, SWPMS, TGW. The results have been mentioned in wheat (Maas and Grieve, 1990) and in Triticale (Yakoubi, 2001).

Genotype × water treatment interactions were also detected for 16 traits (Table 3), indicating variable performance of different genotypes in different moisture conditions.

Principal component analysis (PCA) was performed on data from the combined normal and moisture stress treatment data sets (Table 6). The first-three principal components explained 80.2 percent of the observed variation. The PC1 and PC2 mainly distinguish the traits in different groups. The PC1 accounted for 56.10 percent of the variation and showed the largest negative loading values with all of the phenological traits, except grain filling period, and the largest positive loading values with all of the biological yield, economical yield, and yield-component (Table 6). Therefore, this factor was known as "yield and yield-components factor". Presence of positive and negative correlation trends between the components and the variables are interpreted by positive and negative loading values. The PC2 accounted for 28.68 percent of the observed variation, and showed the largest negative loading values with root-related traits (Table 6). In spite of high amount of first factor, but the medium or low amount of second factor was suggested.

Therefore, the area between first and forth bigot areas were the best suitable bipolt parts (Figure 1). Ivandic *et al.* (2000), showed that the first-three components explain 88.8% of the observed variation. They introduced first component as yield- related traits. In another study under rain-fed conditions (Janmohammadi *et al.,* 2014), the first and second PCA explained 28% and 13% of total variation of agro-morphological traits.

In addition, the PC3 accounted for 8 percent of the observed variation. The most effective trait in the third component was fertile spikes number per plant. The traits with the largest impact on the components showed the highest rate of variation and hence can be used for grouping populations, effectively. So that, the genotype-by-trait (GT) biplot is a statistical tool for evaluating cultivars based on multiple traits and for identifying lines that are superior. Entries identified for agro-morphological and physiological traits hence could be candidates for use as parents in a breeding program (Yan and Rajcan, 2002). The correlation coefficient between any two traits is approximated by the cosine of the angle between their vectors (Yan and Rajcan, 2002). The plot currently shows the relationship among the traits that had relatively large loading on both PC1 and PC2 axes. By plotting the PCAs that are considered to be important, plants close to the ideal plant would be selected (Yan and Rajcan, 2002). Therefore, using the biplot diagram (Figure 1) Pishgam cultivar (BW2), from bread wheat group, and Gilan (A19), from *Ae. tauschii* accessions, with the longest favorite vectors are those that have extreme values for more suitable traits, were identified as tolerant to moisture stress. Among *Ae. tauschii* accessions, A14 and A16 were detected as sensitive to moisture stress. In addition, the means comparison results (Table 4) revealed that very high variability existed between *Ae. tauschii* accession namely between A19, A14 and A16 for most of the traits. Two bread wheat cultivars (BW1 and BW2) and accession from A19 were characterized with the highest amounts of leaf chlorophyll concentration, plant height, peduncle length, spikelet number per spike, seed number per main spike, main spike weight, seed weight per main spike, peduncle weight, main stem weight, 1000-grain weight, economical yield per plant, biological yield per plant, plant harvest index, water use efficiency, leaf area index and relative water content. *Ae. tauschii* accessions from A14 and A16 were characterized with the highest amounts of days to heading, days to anthesis, days to maturity, water use, excised leaf water retention, ratio of root to shoot dry weight (Table 4, Figure 1). The PCA and factor analysis revealed that which morphological trait were associated with yield components (Hailegiorgis *et al.*, 2011; Janmohammadi *et al.*, 2014).

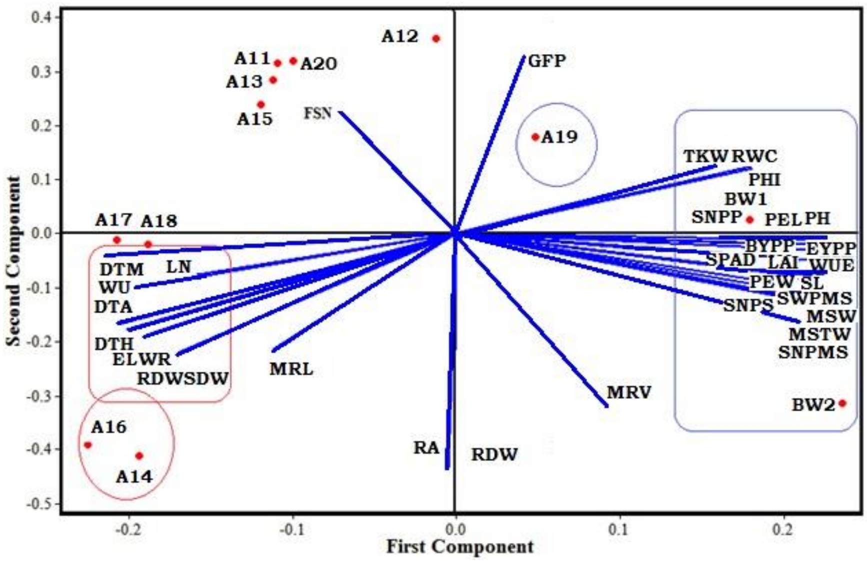

Fig. 1. Bi-plot of first and second components for 31 different traits (Table 2) of 12 wheat genotypes subjected to normal and moisture stress conditions in 2014–2015 growing season. A11- A20: ten *Ae. tauschii* accessions, BW1 and BW2: Shahriar and Pishgam cultivars respectively. Accessions in the oval are tolerant (A19) and susceptible (A16 and A14) to moisture stress respectively. Bw2 is more drought-tolerant with greater yield than Bw1

Relationships among traits of economic importance affect the breeding strategies along with selection procedure. If all breeding objectives were positively correlated, selection would not be difficult than selecting for a single trait. If all breeding objectives were either positively correlated or independently inherited, selection would not be too difficult either (Mohammadi and Amri, 2011). Correlation analysis helps to determination effective traits in order to indirect selection superior genotypes. The analysis of correlation among different traits with grain yield can indicate the relative importance of these traits and their merits as selection criteria (Agrama, 1996). Correlation of economical yield per plant (EYPP) with all of the phenological traits was negative and highly significant except GFP, and highly significant with all of the morpho-physiological traits except SPAD, FSNPP, and TN. In addition, correlation coefficient of EYPP was highly significant and negative with leaves number, excised ELWR and WU in morpho-physiological traits. Linked genes control the above correlations for many phenological and morpho-physiological traits, probably resulting from that many of the traits (Deyong, 2011). In addition, EYPP had a significant negative correlation with ratio of root to shoot dry weight (RDWSDW) in root-related traits. However, the correlations between another root-related traits and economical yield were not significant; such a result indicates that the economical yield is affected by the combination of root-related traits. The present investigation revealed that water use efficiency had a strong relation with economical yield per plant, suggesting the need for more emphasis on these components for increasing the grain yield in wheat.

Table 7. Combined correlations between different traits of 12 wheat genotypes subjected to normal and moisture stress conditions during 2013–14 and 2014–15 growing seasons

Traits	SPAD	PH	PEL	LN	TN	FSNPP	SNPS	SNPMS	SNPP	MSW	SWPMS	PEW	MSTW	TGW	EYPP
PH	0.4														
PEL	0.4	0.9**													
LN	-0.7*	-0.6*	-0.6*												
TN	-0.2	0.1	0.2	0.2											
FSNPP	-0.3	-0.4	-0.4	0.3	0.1										
SNPS	0.3	0.9**	0.9**	-0.5	0.3	-0.5									
SNPMS	0.4	0.9**	0.9**	-0.6*	0.2	-0.5	0.9**								
SNPP	0.2	0.7**	0.7*	-0.4	0.4	0.1	0.8**	0.8**							
MSW	0.4	0.9**	0.9**	-.06*	0.2	-0.5	0.9**	0.9**	0.7**						
SWPMS	0.4	0.9**	0.9**	-0.6*	0.2	-0.5	0.9**	0.9**	0.7**	0.9**					
PEW	0.4	0.9**	0.9**	-0.6*	0.2	-0.5	0.9**	0.9**	0.7*	0.9**	0.9**				
MSTW	0.4	0.9**	0.9**	-0.6*	0.2	-0.5	0.9**	0.9**	0.7*	0.9**	0.9**	0.9**			
TGW	0.5	0.7*	0.7*	-0.6*	-0.1	-0.2	0.4	0.5	0.2	0.6	0.6*	0.5	0.5		
EYPP	0.5	0.9**	0.9**	-0.7*	0.1	-0.2	0.8**	0.8**	0.7*	0.9**	0.9**	0.9**	0.9**	0.8**	
BYPP	0.3	0.9**	0.9**	-0.7*	0.4	-0.3	0.9**	0.9**	0.8**	0.9**	0.9**	0.9**	0.9**	0.5	0.8**
PHI	0.4	0.8**	0.8**	-0.6*	0.04	-0.1	0.5	0.6*	0.5	0.7*	0.7*	0.6*	0.6*	0.9**	0.9**
LAI	0.3	0.9**	0.9**	-0.5	0.3	-0.5	0.9**	0.9**	0.7*	0.9**	0.9**	0.9**	0.9**	0.4	0.8**
RWC	0.4	0.7**	0.7*	-0.8**	0.1	0.01	0.7*	0.7*	0.8**	0.7**	0.7*	0.7*	0.7*	0.4	0.7*
ELWR	-0.2	-0.8**	-0.8**	0.5	-0.3	-0.01	-0.6*	-0.6*	-0.7*	-0.7*	-0.7*	-0.7*	-0.7*	-0.7*	-0.8**
WU	-0.4	-0.8**	-0.8**	0.6*	-0.1	-0.03	-0.6*	-0.6*	-0.7*	-0.7*	-0.7*	-0.7*	-0.7*	-0.8**	-0.9**
WUE	0.5	0.9**	0.9**	-0.7**	0.2	-0.3	0.8**	0.9**	0.7**	0.9**	0.9**	0.9**	0.9**	0.8**	0.9**
DTH	-0.5	-0.8**	-0.8**	0.6*	-0.1	0.02	-0.7*	-0.7*	-0.7*	-0.7*	-0.8**	-0.7*	-0.7*	-0.7*	-0.8**
DTA	-0.5	-0.9**	-0.9**	0.7*	-0.1	0.1	-0.7*	-0.7*	-0.7*	-0.8**	-0.8**	-0.8**	-0.8**	-0.7*	-0.9**
DTM	-0.5	-0.9**	-0.9**	0.6*	-0.2	0.2	-0.8**	-0.8**	-0.7*	-0.9**	-0.9**	-0.9**	-0.9**	-0.7*	-0.9**
GFP	0.2	0.2	0.06	-03	-0.3	0.3	0.05	-0.01	0.3	0.01	0.03	0.01	0.01	0.2	0.2
MRL	-0.6*	-0.4	-0.5	0.4	-0.2	0.2	-0.4	-0.3	-0.2	-0.3	-0.3	-0.3	-0.3	-0.5	-0.4
MRV	0.6*	0.3	0.4	-0.4	0.3	-0.1	0.3	0.4	0.3	0.4	0.4	0.4	0.4	0.3	0.5
RDW	0.1	-0.01	0.01	0.3	0.3	-0.1	0.2	0.2	0.2	0.1	0.1	0.1	0.1	-0.2	0.05
RA	0.1	-0.03	-0.03	0.02	0.1	-0.05	0.01	0.2	0.1	0.1	0.1	0.1	0.01	-0.1	0.1
RDWSDW	-0.1	-0.7*	-0.7*	0.6*	-0.1	-0.1	-0.6*	-0.6*	-0.8**	-0.6*	-0.6*	-0.6*	-0.6*	-0.4	-0.7*
Traits	BYPP	PHI	LAI	RWC	ELWR	WU	WUE	DTH	DTA	DTM	GFP	MRL	MRV	RDW	RA
PHI	0.6*														
LAI	0.9**	0.5													
RWC	0.7*	0.5	0.7*												
ELWR	-0.7*	-0.9**	-0.7*	-0.7*											
WU	-0.7*	-0.9**	-0.6*	-0.7*	0.9**										
WUE	0.8**	0.9**	0.8**	0.7*	-0.8**	-0.8**									
DTH	-0.8**	-0.8**	-0.7*	-0.8**	0.8**	0.9**	-0.8**								
DTA	-0.8**	-0.8**	-0.7*	-0.8**	0.8**	0.9**	-0.8**	0.9**							
DTM	-0.9**	-0.9**	-0.8**	-0.7*	0.9**	0.9**	-0.9**	0.9**	0.9**						
GFP	0.1	0.2	-0.1	0.3	-0.1	-0.2	0.1	-0.5	-0.5	-0.1					
MRL	-0.3	-0.5	-0.3	-0.4	0.6*	0.5	-0.4	0.6*	0.6*	0.6	-0.3				
MRV	0.4	0.3	0.3	0.2	-0.1	-0.4	0.5	-0.2	-0.2	-0.4	-0.2	-0.2			
RDW	0.2	-0.1	0.1	-0.3	0.3	0.1	0.1	0.2	0.2	0.1	-0.3	0.3	0.7*		
RA	0.1	-0.1	-0.04	-0.2	0.3	0.01	0.1	0.3	0.3	0.1	-0.5	0.5	0.8**	0.8**	
RDWSDW	-0.7*	-0.5	-0.7*	-0.9**	0.7*	0. 7*	-0.7*	0.8**	0.8**	0.7*	-0.5	0.2	0.1	0.4	0.4

F-probabilities are indicated by symbols: * significant differences at P < 0.05 and ** significant differences at P < 0.01

4. Conclusion

The present study revealed a very high inter-genus diversity among the genotypes with different response to imposed moisture stress. For example, Gilan accession was less affected by the imposed moisture stress than all the *Aegilops* accessions. Indeed, Gilan and Pishgam were proposed as efficient parents in the future hybrid programs. Therefore, the current genetic material is a valuable genetic resource for future breeding programs under moisture stress conditions. In our study, tolerant and susceptible genotypes were separated using RWC and ELWR very well. So that, high and low amount of RWC and ELWR were respectively suggested for tolerant genotype. Under these circumstances, selection should be made for increased water use efficiency and a high level of RWC. Simultaneously, a high level of seed number per spike, seed number per plant and finally seed number m^{-2}, will lead to increase potential harvest index. Finally, the traits of WUE and seed number per plant and per main spike were remarkably proposed to develop desirable progenies in selection programs of wheat. Meanwhile, grain-filling period, as a phonological trait, had a big effect on grain yield improvement in favorite A19 accession.

Acknowledgements

We are grateful to greenhouse management of Bu-Ali Sina University and Graduate University of Advanced Technology, Kerman, Iran. The study was supported by Bu-Ali Sina University (Hamedan, Iran) Grant No. 941-94 (Grant code: 4096).

References

Agrama, H.A.S., 1996. Sequential path analysis of grain yield and its components in maize. Plant Breed, 115; 343-346.

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

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

Ashraf, M., 2010. Inducing drought tolerance in plants: Recent advances. Biotechnology Advances, 28; 169-183.

Ashraf, M., P.J.C. Harris, 2005. A-biotic stresses: plant resistance through breeding and molecular approaches. 1sd ed. Food Products Press. Oxford, London.

Braun, H.J., G. Atlin, T. Payne, 2010. Multi-location testing as a tool to identify plant response to global climate change. Cereal Research Communications, 24;155-161.

Colmer, T.D., J. Flowers, R. Munns, 2006. Use of wild relatives to improve salt tolerance in wheat. Journal of Experimental Botany, 57; 1059-1078.

Del-Blanco, I.A., S. Rajaram, W.S. Kronstad, M.P. Reynolds, 2000. Physiological performance of synthetic hexaploid wheat derived populations. Crop Science, 40; 1257-1263.

Deyong, Z., 2011. Analysis among main agronomic traits of spring wheat (*Triticum aestivum*) in Qinghai Tibet Plateau. Bulgarian Journal of Agricultural Sciences, 17; 615-622.

Entz, M.H., D.B. Fowler, 1990. Differential agronomic response of winter wheat cultivars to pre-anthesis environmental stress. Crop Science, 30; 1119-1123.

Falconer D.S., T.F.C. Mackay, 1996. Introduction to quantitative genetics. 4th ed. Longman New York.

Farooq, S., T.M. Shah, M. Asghar, 1996. Intergeneric hybridization for wheat improvement: v. production of and metaphase 1 chromosome analysis in F1 hybrids of wheat (*Triticum aestivum*) with *Aegilops ovata* L. Cereal Research Communications, 24; 155-161.

Graybosch, R.A., C.J. Peterson, 2010. Genetic improvement in winter wheat yields in the Great Plains of North America, 1959-2008. Crop Science, 50; 1882-1890.

Gupta, R.B., F. Mac-Ritchie, 1994. Allelic variation at gluteninsununit and gliadin loci, Glu-1, Glu-3 and Gli-1, of common wheats. II. Biochemical basis of the allelic effects on drought properties. Journal of Cereal Sciences, 19; 19-29.

Hailegiorgis, D., M. Mesfin, T. Genet, 2011. Genetic divergence analysis on some bread wheat genotypes grown in Ethiopia. Journal of Central European Agriculture, 12; 344-352.

Hajabbasi, M.A., 2001. Tillage effects on soil compactness and wheat root morphology. Journal of Agricultural Sciences and Technology, 3; 67-77.

Islam, M.R., 2004. Genetic diversity in irrigated rice. Pakistan Journal of Biotechnology Sciences, 2; 226-29.

Kaur, G., A. Joshi, D. Jain, R. Choudhary, D. Vyas, 2016. Diversity analysis of green gram (*Vignara diata* (L.) Wilczek) through morphological and molecular markers. Turkish Journal of Agriculture and Forestry, 40; 229-240.

Leilah, A.A., S.A. Al-Khateeb, 2005. Statistical analysis of wheat yield under drought conditions. Journal of Arid Environments, 61; 483-496.

Malik, R., C.M. Smith, T.L. Harvey, G.L. Brownguedira, 2003. Genetic mapping of wheat curl mite resistance genes Cmc3 and Cmc4 in common wheat. Crop Science, 43; 644-650.

Mguis, Kh., 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* Desf.). Acta Physiologiae Plantarum, 35; 1453–1461.

Mguis, Kh., N. Ben Brahim, A. Albouchi, M. Yakkoubi-Tej, A. Mahjoub, Z. Ouerghi, 2008. Phenotypic responses of the wild wheat relative *Aegilops geniculata* Roth and wheat (*Triticum durum* Desf.) to experimentally imposed salt stress. Genetic Resources and Crop Evolution, 55; 665–674.

Mohammadi, R., A. Amri, 2011. Graphic analysis of trait relations and genotype evaluation in durum wheat. Journal of Crop Improvement, 25; 680-696.

Moosavi S.S., F. Kian-Ersi, M.R. Abdollahi, 2013. Application of multivariate statistical methods in detection of effective traits on bread wheat yield under moisture stress conditions. Cereal Research, 3; 119-130.

Moosavi, S.S., M. Zahedi-No, M. Chaichi, M.R. Abdollahi, 2014. Assessment of diversity and identifying of effective traits on grain yield of barely under non-stress and terminal moisture stress conditions. Cereal Research, 4; 67-85.

Munir M, M.A. Chowdhry, T.A. Malik, 2007. Correlation studies among yield and its components in bread wheat under drought conditions. International Journal of Agriculture and Biotechnology, 9; 287-90.

Naghavi, M.R., M. Mardi, 2010. Characterization of genetic variation among accessions of *Aegilops tauschii*. AsPac. Journal of Molecular Microbiology and Biotechnology, 18; 93-96.

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

Özturk, A., S. Bayram, K. Haliloglu, M. Aydin, O. Caglar, S. Bulut, 2014. Characterization for drought resistance at early stages of wheat genotypes based on survival, coleoptile length, and seedling vigor. Turkish Journal of Agriculture and Forestry, 38; 824-837.

Rajaram, S., 2001. Prospects and promise of wheat breeding in the 21st century. Euphytica, 119; 3-15.

Ranjbar, A., A.R. Sepaskhah, S. Emadi, 2015. Relationships between wheat yield, yield components and physico-chemical properties of soil under rain-fed conditions. International Journal of Plant Production 9; 433-465.

Reddy, N, M..E. Nicolas, G.M. Halloran, 1993. Evaluating *Triticum tauschii* as a source of drought tolerance for wheat. Protocols of Tenth Australian Plant Breeding Conference, 2; 99-100.

Sadras V.O., 1990. Transpiration, transpiration efficiency and harvest index in sunflower (*Helianthus Annuus* L.). Diss. University of Melbourne.

Schachtman, D.P., E.S. Lagudah, R. Munns, 1992. The expression of salt tolerance from *Triticum tauschii* in hexaploid wheat. Theory and Applied Genetics, 84; 714-719.

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.

Tomar, S.M.S., G.T. Kumar, 2004. Seedling survival as a selection criterion for drought tolerance in wheat. Plant Breeding, 123; 392–394.

Van Ginkel, M., D.S. Calhoun, G. Gebeyeho, A. Mirenda, C. Tainyou, R. Pargas Lara, R.M. Trethowan, K. Saure, J. Crossa, S. Rajaram, 1998. Plant traits related to yield of wheat in early, late or continuous drought conditions. Euphytica, 100; 109-121.

Van Slageren, M.W., 1994. Wild wheats: a monograph of *Aegilops* L. and Amblyopyrum (Jaub. etSpach) Eig (Poaceae). Agricultural University, Wageningen – International Center for Agricultural Research in Dry Areas, Aleppo, Syria.

Wallace, D.H., R.W. Zobel, 1992. Efficient genetic gain in yield requires selection and use of parent of genotypes with the highest rates of biomass accumulation. Abstracts Supplement of the First International Crop Science Congress, Ames, IA, pp. 12.

Yan, W., I.R. Rajcan, 2002. Biplot analysis of test sites and trait relations of soybean in Ontario. Canadian Journal of Plant Science, 42;11–20.

Yasir, T.A., D. Min, X. Chen, A.G. Condon, Y.G. Hu, 2013. The association of carbon isotope discrimination with gas exchange parameters and yield traits in Chinese bread wheat cultivars under two water regimes. Agricultural Water Management, 119; 111-120.

Zaharieva, M, E. Gaulin, M. Havaux, E. Acevedo, P. Monneveux, 2001. Drought and heat response in the wild wheat relative *Aegilops geniculata* Roth: potential interest for wheat improvement. Crop Science, 41;1321-1329.