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Genetic diversity in spring wheat cultivars and relationships between traits under terminal drought stress

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ABSTRACT

For evaluation of the traits related to water deficit stress in 20 spring wheat (*Triticum aestivum* L.) cultivars and subsequently determination of the most tolerant and sensitive cultivars, an experiment was carried out in split plot based on randomized complete block design (RCBD) in the research farm of the University of Tabriz, Iran during 2010-2011 and 2011-2012 crop seasons. The first factor was different levels of water stress including water stress (no irrigation after booting stage) and well-watered conditions, and the second factor comprised 20 spring wheat cultivars. The results indicated that there was significant difference between cultivars and irrigation conditions related to nearly all the traits studied here. The mean comparison and cluster analysis of the cultivars showed that Marvdasht, Niknejhad, Moghan3, Darya and Kavir cultivars had the highest values, but Pishtaz, Bam, Sistan, Sepahan and Bahar cultivars had the lowest values for almost of all the traits. Generally, Kavir and Bahar cultivars were recognized as the most tolerant and susceptible cultivars under drought stress, respectively. According to stepwise regression, some traits entered into the final model, as the maximum amounts of correlation coefficient and direct effects were achieved for the number of spike per plant under two conditions. So, screening for higher values of this trait can bring an improvement in wheat grain yield under two conditions. Factor analysis detected three and four factors which explained 89.95 and 88.01 % of the total variation in non-stress and stress conditions, respectively. Under drought stress condition the factors of 1, 2, 3 and 4 named as root, yield and yield components, physiological, and biomass factors, respectively. These coefficients showed that cultivars with higher values of these factors had the highest values for the traits related to names of each factor.

Keywords: Cluster analysis, drought, factor analysis, path analysis, wheat.

ارزیابی تنوع ژنتیکی و ارتباط صفات در ارقام گندم بهاره در شرایط تنش خشکی

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چکیده

این آزمایش بصورت کرتهای خرد شده در قالب طرح بلوک‌های کامل تصادفی در مزرعه پژوهشی دانشگاه تبریز ایران انجام شد. نتایج نشان داد که تفاوت معنی‌داری بین ارقام و شرایط آبیاری مربوط به تقریباً همه صفات مورد مطالعه وجود دارد. مقایسه میانگین و تجزیه‌ای خوشه‌ای ارقام نشان داد که ارقام مرودشت، نیک‌نژاد، مغان۳، دریا و کویر دارای بالاترین ارزش‌ها، در حالی که رقم پیشتاز، بم، سیستان، سپاهان و بهار دارای کمترین ارزش برای تقریباً تمام صفات بودند. در مجموع، با توجه به نتایج این تحقیق ارقام کویر و بهار بترتیب بعنوان متحمل‌ترین و حساس‌ترین ارقام در شرایط تنش خشکی شناخته شدند. با توجه به رگرسیون گام به گام برخی از صفات وارد مدل نهایی شدند که بیشترین مقدار ضریب همبستگی و اثر مستقیم روی عملکرد دانه تحت دو هر شرایط شاهد و تنش خشکی برای تعداد سنبله در بوته بدست آمد. بنابراین، غربالگری برای مقدار بالای این صفت می‌تواند افزایش عملکرد گندم تحت دو شرایط را به ارمغان بیاورد. همچنین تجزیه عامل‌ها بترتیب سه و چهار عامل که به ترتیب ۸۹/۹۵ و ۸۸/۰۱ درصد از کل تنوع در شرایط شاهد و تنش خشکی را تبیین کردند، شناسایی کرد. تحت تنش خشکی عوامل ۱، ۲، ۳ و ٤ بنام عامل ریشه، عملکرد و اجزای عملکرد، عامل فیزیولوژی و عوامل بیولوژیک نامیده شدند. این ضرایب نشان داد که ارقام با ارزش بالاتر برای این عوامل بالاترین ارزش‌ها را برای صفات مربوطه به نام عوامل دارند.

واژه‌های کلیدی: تجزیه خوشه‌ای، تنش خشکی، تجزیه به عامل‌ها، تجزیه علیت، گندم.

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Introduction

Drought is a significant limiting factor for agricultural productivity and generally inhibits plant growth through reducing water absorption and consequently nutrient uptake. Decreased water availability generally results in a reduction in growth as well as final yield of crop plants. Plant drought tolerance is a highly complex trait that involves multiple genetic, physiological and biochemical mechanisms (Erdei *et al*., 2002).

Wheat is an important cereal crop and serves as a main and strategic food in many countries throughout the world. Water stress is recognized as an important factor that affects wheat growth and yield (Ashraf, 1998), however, various wheat species and cultivars within the species exhibit substantial differences in response to soil moisture (Rascio *et al*., 1992). Selection for yield under drought stress conditions is complicated by low heritability and large genotype-environment interactions (Golabadi, *et al*., 2005). Grain yield is a complex multi component character and is greatly influenced by various environmental conditions. Various morphological and physiological characters contribute to grain yield (Flexas, *et al*., 2007). Some morphological traits such as root length, spike number per m^2, grain number per spike, number of fertile tillers per plant, 1000-grain weight, peduncle length, spike weight, stem weight, awn length, and grain weight per spike affect wheat tolerance to the moisture shortage of the soil (Moustafa *et al*., 1996). Moreover, drought stress is a decrease of soil water potential, so plants reduce their osmotic potential for water absorption, mainly through congestion of soluble carbohydrates and proline content, as osmotic regulation would be taken place (Martin *et al*., 1993). Therefore, osmotic regulation will help the plant species to modulate cell development and growth under water stress circumstances (Pessarkli, 1999). It is reported that high relative water content (RWC) is a resistant mechanism to drought, and that higher values of RWC are the consequences of more osmotic regulation and/or less elasticity of tissue cell wall (Ritchie *et al*., 1990). In the previous study performed on 4 cultivars of bread wheat, the values of RWC and other physiological traits reduced by moisture stress (Siddique *et al*., 2000).

Environmental conditions and genotype interaction affected the relationships among plant characters. Toward a clear understanding of the type of plant traits, correlation and path coefficient analysis are logical steps (Kashif & Khaliq, 2004). Path analysis is a reliable statistical tool which is available for the breeders in better understanding of the cause involved in the associations between traits and partitioning the existing correlation into direct and indirect effects, through main variables (Lorencetti *et al.,* 2006). Path analysis has been widely used in crop breeding, not only to determine the nature of relationships between grain yield and its contributing components, but also to identify those components with significant effects on yield for potential use as selection criteria (Board *et al.,* 1997; Naghavi *et al.,* 2014). Meanwhile, factor analysis suggested by Walton (1972) has been widely used to identify growth and plant characters related to wheat (Moghaddam *et al.,* 1998; Naghavi *et al.,* 2015). This method basically reduces a large number of correlated variables to a small number of uncorrelated variables or factors. This method is a strong statistical approach which has been employed widely to 1) estimate the components of yield, 2) extract a subset of identical variables, 3) identify the basic concepts of multivariable data, 4) recognize applied and biological connections among the traits, 5) reduce a large number of correlative traits to a small number of factors and lastly 6) explain the correlation among the variables (Bramel *et al.,* 1984). Khayatnezhad *et al.* (2010), using factor analysis on durum wheat cultivars, showed that the importance of factor coefficients characteristics of total and fertile tillers, main spike length, 1000-seed weight, and yield selected genotypes is desirable for dry conditions. Also, Gholamin *et al.* (2010) indicated that the importance of factor coefficients characteristics of fertile tillers, grain weight, and seed weight and harvest index of selected genotypes is desirable for dry conditions.

In this way, the following objectives were pursued in the current study:1) detection of the most important traits on wheat grain yield under terminal drought stress; 2) identification of new variables for the interpretation of the traits; 3) grouping all the 20 wheat cultivars under environmentally two different conditions; 4) evaluation of the genetic diversity for drought adaptation among the studied cultivars under drought stress.

Materials and methods

Twenty cultivars of spring wheat (*Triticum aestivum* L.) listed in Table 1 were provided from Cereal Department of Seed and Plant Improvement Institute (SPII) of Karaj, Iran. They were assessed using a split plot on the basis of randomized complete block design with four replications, under two moisture levels during 2010-2011 and 2011-2012 growing season at the Research Farm of University of Tabriz, Iran (latitude 38.03°N, longitude 46.17°E, Altitude 1360 m above sea level). The climate is characterized by mean annual precipitation of 330 mm and mean annual temperature of 9.8 ˚C. All the plots were PVC pipe with 20 cm diagonal and 1.0 meter length that were filled with mix of loam soil and animal manure. Planting was performed by hand and after germination, three plants in each plot were grown. All the plots were irrigated after sowing and subsequent irrigations after booting stage were carried out only for I_1 (as control), and not for I_2 (as stress) as stopping irrigation. Weeds were controlled by hand during cropping season. Physiological criteria were determined based on flag leaf. Leaf temperature measurement was made using the infrared thermometer. The chlorophyll content was determined using a chlorophyll meter (SPAD-502, Japan). The chlorophyll fluorescence was measured by a chlorophyll fluorometer (Opti Science, OS-30MSA). Moreover, RWC (%) was determined according to method of Turner (1986). Also, Specific Leaf Area was calculated on the basis of this formula: Special Leaf Area (Cm^2g^{-1}) = (Leaf Area)/(Leaf Dry Weight) (Arias, 2007). Proline contents ($mg.g^{-1}FW$) were measured by Acid Hydrin method (Mc Manus *et al.* 2000). The pressure chamber method was used for measuring the leaf water potential (Boyer, 1967). Osmotic potential was measured by Osmometer (Martinez *et al.* 2004); mode: Osmomat 010, Genotel. Morphological and growth traits such as plant height (cm), plant dry weight (g), number of tiller in plant, spike length (cm), number of fertile tiller in plant, number of root, length of root (cm), volume of root (ml), root dry weight (g), root diameter (mm), number of spike per plant, number of grain in spike, 1000-grain weight (g) and grain yield (g) were measured at the end of growth stage.

Finally, mean of data were utilized for path analysis as described by Dewey & Lu (1959) using SPSS software. Also, factor analysis on the basis of major factors and varimax rotations was conducted for all the data. The factors with *Eigen* values greater than one were selected and used subsequently to form factorial coefficients matrix (Sharma, 1985). Moreover, Eigen values, percent variance, variance, and cumulative percentage share of each extracted factors were calculated. All the data were analyzed using MSTATC and SPSS softwares. Statgraphics and Excel softwares were also applied to draw dendrogram and related figures, respectively.

Table 1. Cultivars of spring wheat used for drought tolerance assessment

No	Cultivar	No	Cultivar
1	Mahdavi	11	Sivand
2	Pishtaz	12	Pars
3	Bam	13	Bahar
4	Sistan	14	BC Roshan
5	Zagros	15	Kavir
6	Marvdasht	16	Niknejhad
7	Sepahan	17	Darya
8	Aflak	18	Morvarid
9	Arta	19	Roshan
10	Arg	20	Moghan3

Results and discussion

Analysis of variance, comparison of means and cluster analysis

According to the combined analysis of variance, there were significant differences among cultivars, excepting chlorophyll fluorescence, which suggested the significant genetic diversity (Table 2). Moreover, a significant difference under stress levels was observed, as well. Cultivars×stress interaction was significant for florescence of chlorophyll, chlorophyll index, special leaf area, proline content, number of grain per spike, 1000 grain weight and grain yield (Table 2), suggesting different reactions of genotypes under different stress levels. Further, the results showed significant differences between years for almost all the traits studied here.

Means for physiological traits of wheat cultivars are shown in Table 3 and Figure 1. Leaf temperature increased and chlorophyll index reduced under stress conditions. Among the wheat cultivars, the unfavorable magnitudes of leaf temperature and chlorophyll index were recorded for Bahar and Sepahan, while Darya, Marvdasht, Moghan 3 and Kavir had the minimum quantities of leaf temperature and Kavir, BC Roshan and Darya exhibited the maximum values of chlorophyll index. On the other hand, only temperature had negative and significant correlation with grain yield under two conditions (Table 4). There are reports about decrease of chlorophyll index under drought stress conditions (Ghaffari *et al.*, 2012). But resistant cultivars to drought and thermal stress conditions had high chlorophyll content (Sairam &Siravastava, 2002). Winter *et al.* (1988) also found significant differences in leaf temperature between drought stressed plants and irrigatedones, but not among the wheat cultivars. It has been also indicated that the plants with lower leaf temperature may harbor higher photosynthetic rate. On the other hand, the lower photosynthetic rate in plants acclimated to a higher temperature, might be owing to the increased respiration (Jones, 1983).

Under control condition related to chlorophyll fluorescence, Moghan3, Marvdasht and Darya cultivars had the maximum values, while the minimum rate belonged to the Arg, Morvarid and Pars cultivars. The three cultivars of Bahar, Pars and Pishtaz, and Zagros, Marvdasht and Niknejhad cultivars had the minimum and the maximum amounts of chlorophyll fluorescence under stress conditions, respectively. Chlorophyll fluorescence analysis is a sensitive indicator to measure tolerance domain of the photosynthetic apparatus to environmental stresses (Maxwell & Johnson, 2000). The pattern of changes in fluorescence chlorophyll observed in this study are supported by the change patterns reported by many investigations under drought conditions (Zlatev &Yordanov, 2004).

RWC is one of the most important physiological traits which are commonly reduced under drought stress. In our experiment, the minimum ratio of RWC recorded for BC Roshan, Arg and Niknejhad cultivars. On the other hand, the maximum ratio of RWC recorded for Sepahan, Moghan3 and Kavir. Water deficit conditions cause water losses within the plant and result in a decrement in RWC. Therefore, RWC is widely used as one of the most reliable indicator to define the sensitivity and tolerance of plants against water deficit (Sanchez-Rodriguez *et al.,* 2010). Decline in RWC ratio has been reported in many studies (Ahmadi *et al.,* 2012; Farshadfar *et al.*, 2012) and generally are in agreement with the results of this study.

Under control conditions, Sivand, Marvdasht and Darya had the maximum values of SLA, while the minimum amount of SLA belonged to the Arg, Morvarid and Pars cultivars. Bahar, Pars and Pishtaz cultivars and Zagros, Marvdasht and Niknejhad cultivars showed the minimum and maximum amounts under stress conditions, respectively. On the other hand, the results showed negative and significant correlation between SLA and grain yield under drought stress (Table 4). The current increase in SLA under water deficit condition may be due to the loss of weight rather than decrease in leaf area under water deficit. Araus *et al.* (1997) indicated an increase in SLA under water deficit conditions, probably reflects adaptation to drought conditions. Also, a diminution in SLA-DW could indicate transient dry matter deposition and/or increased cell wall thickness (Lu & Neumann, 1999).

The least values of Proline content were observed for Sepahan, Bahar and Sistan cultivars, while the highest values of this metrics were obtained for Marvdasht, Niknejhad and Moghan3 under control condition. But, Bahar, Roshan and Sistan had the minimum and Marvdasht, Darya and Kavir had the maximum amounts of Proline content under stress conditions. Increase in the ratio of Proline content under drought stress has been reported in many investigations (Bayoumi *et al.*, 2008; Sanchez-Rodriguez *et al.,* 2010). Meanwhile, Bayoumi *et al.* (2008) reported that tolerant genotypes had more proline content rather than sensitive genotypes under drought stress.

Drought stress reduced the Leaf Water Potential from -1.65 Mpa in control plants to -1.94 MPa in stressed plants. This was in agreement with the results obtained by the other researchers (Moustafa *et al.*, 1996). Other investigators (Musick *et al.*, 1994) also reported that drought resistant cultivars had lower ψs values as compared with the susceptible ones. For Leaf Water Potential and Osmotic Potential, Kavir, Darya and Marvdasht had the maximum values, Pishtaz, Sepahan and Bam possessed the lowest ratio for Leaf Water Potential and Pishtaz, Sepahan and Bahar had unfavorable values for Osmotic Potential. Moreover, simple correlations under two conditions showed positive and negative correlations between Leaf Water Potential plus Osmotic Potential and grain yield, respectively (Table 4).

Plant height ranged from 47.3 cm (Sivand) to 57.1 cm (Roshan), while the range for plant dry weight varied from 13.5 g (Pars) to 15.6 g (Roshan) under average circumstances. Moreover, the results showed positive and significant correlations between plant height and plant dry weight under control and stress conditions (Table 4). The maximum values for number of tiller were recorded for Kavir, Moghan3, Darya and Marvdasht, while the highest values for number of fertile tiller belonged to Kavir, Darya, and Marvdasht cultivars. On the other hand, the lowest number of tiller and number of fertile tiller belonged to Sepahan, Bam and Bahar cultivars. These results were in keeping with the results of simple correlation between morphological traits (Table 4). The decrease in plant height under drought stress condition could be due to a diminution in relative turgidity and dehydration of protoplasm which is associated with loss of turgor and reduced cell division and cell expansion (Bayoumi *et al.*, 2008). Inamullah *et al.* (1999) observed that plant height and other morphological traits in wheat varieties reduced significantly under water stress when it was compared with irrigated.

Kavir, Darya and Moghan3 had the maximum amounts for root number, root length, root volume, root dry weight and root Diamer. On the other hand, in addition to the Bahar and Sepahan that were showed the minimum amount of root traits for all of traits; Bam for root number, root volume and root diamer; Sistan for root length and Pishtaz for root dry weight were showed the lowest amounts (Table 3). According to the simple correlations, there were somesignificant and positive correlations between root traits under control and drought stress (Table 4). Different genotypes exhibited various responses versus water stress (Taiz & Zeiger, 1991), and Xue *et al.* (2003) showed that the apparent resistance against drought in some genotypes could be due to differences in root growth. On the other hand, Paleg & Aspinall (1999) indicated that drought resistant wheat species are such that they have a large proportion of their total mass as roots and also a deep rooting habit coupled with high numbers of seminal roots.

The mean grain yield, 1000 grain weight and number of grains in spike for experiments are shown in Figure 1, and number of spike per plant in Table 3. All the characters in Table 3 were reduced under stress condition, but the reduction in 1000 grain weight was greater than the number of grain in spike. The highest number of spike per plant was achieved for Kavir, Marvdasht and Moghan3, while Sepahan, Bam and Bahar had the lowest amounts (Table 3). The results showed negative and significant correlations between number of grains in spike and 1000 grain weight under two conditions (Table 4). So, an increase in 1000 grain weight may cause a reduction in the number of grains in spike (Figure 1). Number of grains in spike ranged from 24.9 (Marvdasht) under drought stress to 37.6 (Pishtaz) under control condition, while the range for 1000 grain weight varied from 30.3 g under drought stress (Sistan) to 45.5 g (Darya) under stress condition. All the cultivars differed significantly in respect to grain yield under non-stress conditions and under stress conditions ($p<0.01$). This emphasized the different responses of cultivars to drought conditions. In control condition related to this trait, Niknejhad, Kavir and Moghan3 cultivars had the maximum values, while the minimum amounts belonged to Bam, Sepahan and Bahar cultivars. Bahar, Sivand and Pars cultivars and also the cultivars of Moghan3, Darya and Kavir had the minimum and the maximum amounts of grain yield under stress conditions, respectively. Further, under non-stress condition, grain yield had a positive and significant correlation only with the number of spike per plant, while there was a significant positive correlation between grain yield and number of spike per plant, 1000 grain weight and significant negative correlation between grain yield and number of grains in spike (Table 4). Giunta *et al.* (1993) and Pour Aboughadareh *et al.* (2013) reported mean decreased in grain yield under drought stress. Tompkins *et al.* (1991)

reported the significant suppressive effect of water stress on number of grains per spike. Other research such as Passioura (1997) also reported a positive significant correlation between grain yield and 1000-grain weight. Also, Moghaddam *et al.* (1997) reported negative correlation between number of grain per spike and 1000-grain weight.

According to cluster analysis, all the cultivars were divided into three and four major groups under control and drought stress conditions, respectively. In control condition (Figure 2), in the second group Pishtaz, Sepahan and Bahar had lower mean values than overall mean regarding all the traits, excepting chlorophyll fluorescence and RWC. Also, Moghan3, Marvdasht and Darya constituted the third group by the highest mean values for the most of traits, excepting SLA, plant height, plant dry weight and number of grain per spike. The rest cultivars had average amounts. According to Figure 3, Arg, BC Roshan, Aflak, Mahdavi, Arta, Zagros, Morvarid, and Roshan cultivars were placed in the first group under stress condition. This group had the maximum values for chlorophyll index, plant height and the minimum values for RWC. Pishtaz, Bam, Sistan, Sepahan and Bahar constituted the second cluster. These cultivars were characterized by the lowest amounts of all the traits, excepting RWC, plant height, plant dry weight, number of fertile tiller and number of grain in spike. Although, this group had not the lowest grain yield, low grain yield was recorded. The third cluster included Marvdasht, Niknejhad, Moghan3, Kavir and Darya cultivars with the maximum amounts for almost all the traits, except for RWC, chlorophyll index, height and number of grain in spike. Sivand and Pars were placed in the fourth group with the minimum values for height, plant dry weight, number of fertile tiller, number of spike per plant and grain yield. On the other hand, the highest RWC ratio belonged to this cluster.

Table 2. Analysis of variance for yield and other traits in spring wheat cultivars under different moisture levels

Source of Variation	d.f.	Men Squares										
		†Tem (^{0}C)	CF	CI	RWC (%)	SLA (cm^2.gr^{-1})	PC (mg.gr^{-1} FW)	LWP (MPa)	OP (MPa)	PH (cm)	PDW (g)	SpL (cm)
Year (Y)	1	68.450**	0.026**	51.28**	191.991**	0.0000001	2.259**	1.148**	0.971**	722.402**	37.813**	217.47**
Replication (Year)	6	0.567	0.000006	0.258	0.354	86.614	0.009	0.004	0.001	0.303	0.002	0.055
Stress (S)	1	610.513**	0.033**	208.174**	79.089*	1100.932**	8.636**	6.807**	14.302**	7566.05**	250.632**	349.448**
Y×S	1	2.45	0.000000028	0.001	4.065	0.0000001	0.000013	0.0000078	0.0000028	0.002	0.113	0.000125
Error	6	0.890	0.0000048	0.279	0.457	91.907	0.007	0.003	0.002	0.561	0.009	0.022
Genotype (G)	19	4.168**	0.000322	2.968**	35.367**	2190.274**	0.483**	0.1**	0.23**	86.855**	4.274**	10.123**
G×Y	19	0.568	0.000187	0.705	25.039**	0.0000001	0.02	0.012	0.019	42.598	1.838	1.447*
G×S	19	0.499	0.000345*	1.932	13.835	2221.465**	0.104**	0.033	0.014	26.866	1.91	0.436
G×S×Y	19	0.187	0.000086	0.296	14.36	0.0000001	0.018	0.005	0.008	35.86	1.756	0.246
Error	228	1.776	0.00021	1.186	11.991	159.484	0.016	0.031	0.069	40.945	1.916	0.876
CV (%)		5.22	1.99	2.65	4.46	7.69	2.43	9.83	20.47	12.57	9.61	9.97

†Tem, CF, CI, RWC, SLA, PC, LWP, OP, PH, PDW, SpL indicate Temperature, Chlorophyll Fluorescence, Chlorophyll Index, Relative Water Content, Special Leaf Area, Proline Content, Leaf Water Potential, Osmotic Potential, Plant Height, Plant Dry Weight, Spike Length, respectively. Also, * and ** were significant at 5 % and 1 % probability levels, respectively.

Continued table 2. Analysis of variance for yield and other traits in spring wheat cultivars under different moisture levels

Source of Variation	d.f.	Mean Squares										
		†RN (no.)	RL (cm)	RV (ml)	RDW (g)	RD (mm)	NT (no.)	NFT (no.)	NSp (no.)	NGSp (no.)	1000-GW (g)	GY (g)
Year (Y)	1	70.313	257.045**	135.07**	1.307	2.297**	109.278**	105.8**	105.8**	257.403**	252.938**	345.975**
Replication(Year)	6	26.079	.304	.127	.213	.047	.52	.465	.315	40.461**	22.272	.851
Stress(S)	1	4712.45**	3476.885**	2443.708**	202.585**	47.625**	444.153**	437.113**	437.113**	747.253**	4334.304**	2146.42**
Y×S	1	.05	.004	.000031	.001	.00007	.078	.0000001	.0000001	166.753**	.053	.502
Error	6	6.317	.004	.122	.047	.046	4.249**	4.415**	4.131**	47.186**	26.42*	6.115**
Genotype (G)	19	124.931**	85.582**	22.084*	1.693*	.561**	13.64**	13.835**	14.527**	108.495**	64.452**	17.112**
G×Y	19	26.576	15.03	3.457	.415	.064	1.153	1.03	1.03	13.416	13.576	2.006
G×S	19	24.437	13.463	6.059	.675	.171	1.449	1.382	1.422	60.279**	34.054**	3.9*
G×S×Y	19	6.155	4.151	2.147	.147	.046	1.058	.862	.862	23.161*	10.596	1.388
Error	228	23.501	14.374	11.553	1.008	.259	1.099	1.119	1.183	12.583	11.537	1.999
CV (%)		23.19	13.19	21.01	34.90	30.93	14.05	16.45	17.01	10.91	9.08	17.83

†RN, RL, RV, RDW, RD, NT, NFT, NSp, NGSp, 1000-GW and GY indicate Root Number, Root Length, Root Volume, Root Dry Weight, Root Diamer, Number of Tiller in plant, Number of Fertile Tiller, Number of Spike per plant, Number of Grain in Spike, 1000Grain Weight and Grain Yield, respectively. Also, * and ** were significant at 5 % and 1 % probability levels, respectively.

Table 3. Comparison of means for stress levels and cultivars using Duncan method

Levels of stress	†Tem (^{0}C)	CI	RWC (%)	LWP (MPa)	OP (MPa)	PH (cm)	PDW (g)	SpL (cm)
I1 (control)	24.17a	41.93a	78.07a	-1.65a	-1.07b	55.75a	15.29a	10.43a
I2 (stress)	26.93b	40.32b	77.07b	-1.94b	-1.49a	46.02b	13.52b	8.34b
Cultivars								
Mahdavi	25.44abcde	41.26abcd	75.77de	-1.80bcde	-1.26abcd	54.57ab	15.06ab	9.24cdef
Pishtaz	26.19de	40.53cde	78.78abc	-1.89de	-1.15cd	50.28bcd	14.21bcd	8.44gh
Bam	26.06cde	40.66bcde	78.49abcd	-1.91e	-1.18cd	52.62abcd	15.05ab	8.78efgh
Sistan	26.19de	40.92abcde	77.28bcde	-1.82cde	-1.15cd	49.33bcd	14.08bcd	8.68fgh
Zagros	25.50abcde	41.37abc	76.46cde	-1.78bcde	-1.28abcd	51.23bcd	14.60abcd	9.31cdef
Marvdasht	24.75ab	41.43abc	78.13bcde	-1.69abc	-1.47a	52.02bcd	14.83abc	10.48ab
Sepahan	26.375e	40.43de	78.91abc	-1.90e	-1.11cd	48.98cd	14.11bcd	8.34gh
Aflak	25.44abcde	41.46ab	76.91bcde	-1.76abcde	-1.31abc	50.78bcd	14.54abcd	9.46cde
Arta	25.81bcde	41.08abcd	77.27bcde	-1.81cde	-1.24bcd	51.41bcd	14.53abcd	9.01defg
Arg	25.44abcde	41.24abcd	75.31e	-1.82cde	-1.27abcd	51.26bcd	14.62abcd	9.43cdef
Sivand	25.69abcde	41.29abcd	77.40bcde	-1.80bcde	-1.28abcd	47.31d	13.59d	9.23cdef
Pars	25.50abcde	41.09abcd	78.89abc	-1.83cde	-1.24bcd	47.49d	13.48d	8.94efgh
Bahar	26.25e	40.11e	77.03bcde	-1.87de	-1.08d	47.87cd	13.71cd	8.25h
BC Roshan	25.38abcde	41.58ab	75.26e	-1.74abcd	-1.33abc	53.14abc	14.78abc	9.77cd
Kavir	24.94abc	41.83a	81.03a	-1.62a	-1.48a	50.34bcd	14.29bcd	11.07a
Niknejhad	25.06abcd	41.09abcd	75.60de	-1.76abcde	-1.42ab	50.19bcd	14.03bcd	9.96bc
Darya	24.63a	41.5ab	77.56bcde	-1.66ab	-1.47a	50.11bcd	14.13bcd	10.58ab
Morvarid	25.69abcde	41.26abcd	77.94bcde	-1.79bcde	-1.30abcd	51.29bcd	14.54abcd	9.32cdef
Roshan	25.75abcde	40.88bcde	77.91bcde	-1.86de	-1.22bcd	57.06a	15.55a	8.94efgh
Moghan3	24.94abc	41.49ab	79.54ab	-1.71abc	-1.43ab	50.47bcd	14.38bcd	10.56ab

†Tem, CI, RWC, LWP, OP, PH, PDW and SpL indicate Temperature, Chlorophyll Index, Relative Water Content, Leaf Water Potential, Osmotic Potential, Plant Height, Plant Dry Weight and Spike Length, respectively. Also, different letter between cultivars showed significant at 5 % probability level.

Continued table 3. Comparison of means for stress levels and cultivars using Duncan method

Levels of stress	†RN (no.)	RL (cm)	RV (ml)	RDW (g)	RD (mm)	NT (no.)	NFT (no.)	NSp (no.)
I1 (control)	17.07b	25.45b	13.42b	2.08b	1.26b	8.64a	7.60a	7.56a
I2 (stress)	24.74a	32.04a	18.95a	3.67a	2.03a	6.28b	5.26b	5.23b
Cultivars								
Mahdavi	20.81def	29.54bcedf	16.12abcdef	2.89abc	1.65abcde	7.88bcd	6.81bcde	6.81bcd
Pishtaz	18.50efg	26.48fghi	15.23cdef	2.49bc	1.51cde	6.56fgh	5.56ghi	5.56ef
Bam	16.69g	26.30ghi	15.01def	2.55abc	1.47de	6.38gh	5.38hi	5.13f
Sistan	18.44efg	26.01ghi	15.20cdef	2.57abc	1.48de	6.50fgh	5.50ghi	5.50ef
Zagros	20.25defg	28.98cdefg	15.74abcdef	2.83abc	1.58bcde	7.56de	6.56ef	6.56d
Marvdasht	23.25abcd	31.24abcd	17.58abcde	3.27ab	1.83abcde	8.63ab	7.63ab	7.63ab
Sepahan	17.00fg	25.41hi	14.63f	2.35c	1.40e	6.25gh	5.38hi	5.38f
Aflak	22.06bcde	28.68cdefg	16.15abcdef	3.02abc	1.63abcde	7.75cd	6.75cde	6.75bcd
Arta	19.69defg	27.56efghi	15.35bcdef	2.73abc	1.51cde	7.31def	6.31efg	6.31de
Arg	20.19defg	28.26defgh	15.46abcdef	2.77abc	1.51cde	7.69cde	6.69de	6.69cd
Sivand	21.25cde	28.98cdefg	15.75abcdef	2.91abc	1.58bcde	7.06defg	5.69gh	5.56ef
Pars	21.81bcde	28.50defg	15.76abcdef	2.80abc	1.57bcde	6.88efg	5.88fgh	5.63ef
Bahar	16.63g	24.63i	14.83ef	2.36c	1.42de	5.88h	4.75i	4.75f
BC Roshan	20.19defg	28.99cdefg	16.68abcdef	3.10abc	1.69abcde	7.75cd	6.75cde	6.75bcd
Kavir	26.44a	32.79a	18.32a	3.37a	1.99ab	8.88a	7.94a	7.94a
Niknejhad	23.44abcd	31.26abcd	17.78abcd	3.26ab	1.85abcd	8.50abc	7.50abcd	7.50abc
Darya	25.31ab	32.25ab	18.23ab	3.37a	2.03a	8.63ab	7.63ab	7.50abc
Morvarid	21.50bcde	29.88abcde	16.20abcdef	2.88abc	1.68abcde	7.81bcd	6.81bcde	6.81bcd
Roshan	19.75defg	27.54efghi	15.68abcdef	2.72abc	1.61bcde	6.56fgh	5.56ghi	5.56ef
Moghan3	24.94abc	31.67abc	17.96abc	3.31ab	1.93abc	8.75a	7.56abc	7.56abc

†RN, RL, RV, RDW, RDNT, NFT and NSp indicate Root Number, Root Length, Root Volume, Root Dry Weight, Root Diamer, Number of Tiller per plant, Number of Fertile Tiller and Number of Spike per plant, respectively. Also, different letter between cultivars showed significant at 5 % level.

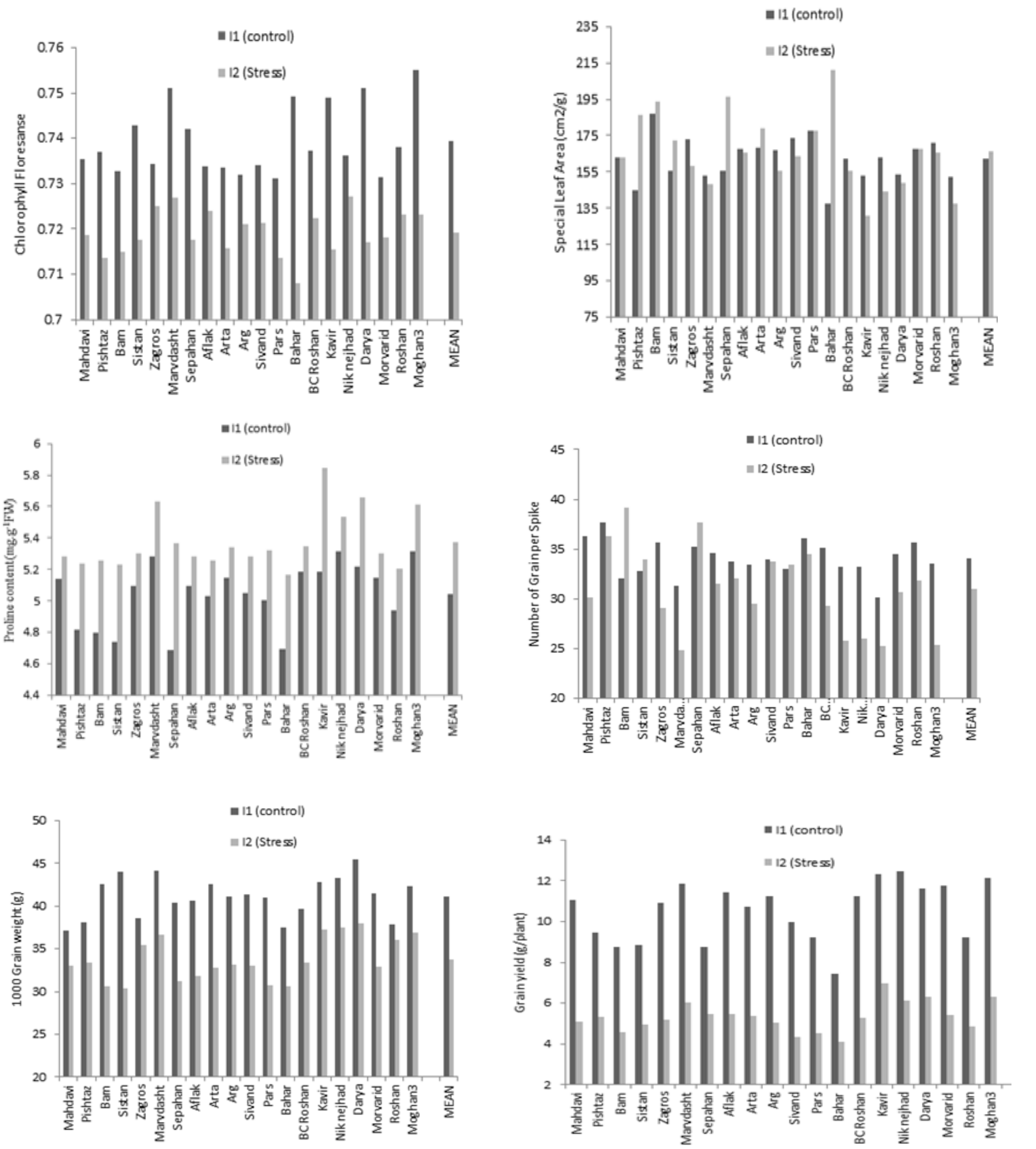

Figure 1. Comparison of spring wheat cultivars for traits with significant cultivar×stress interaction under control and stress conditions

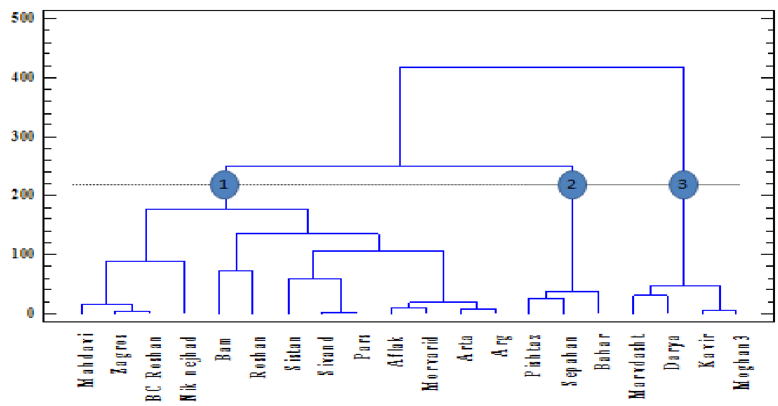

Figure 2. Dendrogram based on all the studied traits under control condition with Ward method and Discriminant analysis cutting

Table 4. Correlation coefficients between studied traits for wheat cultivars under normal irrigation (below of main diamer) and drought stress (above of main diamer)

	†Tem	CF	CI	RWC	SLA	PC	LWP	OP	PH	PDW	SpL	RN	RL	RV	RDW	RD	NT	NFT	NSp	NGSp	1000-GW	GY
1	1	-.582**	-.502*	-0.029	.858**	-.746**	-.859**	.943**	-0.34	-.504*	-.907**	-.850**	-.943**	-.908**	-.946**	-.873**	-.791**	-.769**	-.754**	.833**	-.759**	-.669**
2	-.531*	1	0.353	-0.230	-.654**	0.265	0.337	-.522*	.446*	.558*	.478*	0.386	.525*	.473*	.566**	0.352	0.429	0.413	0.409	-.549*	.542*	0.357
3	-.893**	.558*	1	-0.371	-.481*	0.074	.697**	-0.367	0.244	0.317	.453*	.466*	.471*	0.277	.509*	0.238	0.232	0.210	0.201	-0.288	0.089	0.121
4	-0.083	.496*	0.25	1	0.036	0.305	-0.083	-0.080	-0.182	0.065	0.012	0.256	0.129	.618**	-0.027	0.209	0.073	.705**	.609**	0.107	0.155	.551*
5	0.147	-.730**	-0.183	-0.237	1	-.754**	-.799**	.872**	-.462*	-.609**	-.920**	-.789**	-.905**	-.852**	-.889**	-.805**	-.856**	-.837**	-.830**	.889**	-.809**	-.738**
6	-.831**	0.136	.816**	-0.137	0.080	1	.646**	-.862**	0.183	0.345	.883**	.756**	.821**	.903**	.805**	.933**	.920**	.913**	.892**	-.757**	.756**	.885**
7	-.844**	.723**	.904**	0.284	-0.409	.654**	1	-.851**	0.387	.530*	.884**	.823**	.875**	.817**	.894**	.812**	.740**	.722**	.703**	-.713**	.628**	.654**
8	.918**	-0.385	-.946**	-0.095	0.021	-.916**	-.844**	1	-0.367	-.542*	-.964**	-.869**	-.956**	-.992**	-.983**	-.970**	-.909**	-.893**	-.869**	.862**	-.811**	-.816**
9	0.106	-0.23	-0.231	-0.08	0.389	-0.123	-0.306	0.162	1	.960**	0.384	0.138	0.345	0.355	0.39	0.289	0.356	0.383	0.388	-.460*	.587**	0.413
10	0.110	-0.182	-0.218	-0.013	0.339	-0.128	-0.280	0.167	.866**	1	.553*	0.314	.515*	.526*	.558*	.462*	.516*	.536*	.532*	-.582**	.704**	.565**
11	-.922**	.598**	.951**	0.305	-0.199	.820**	.890**	-.936**	-0.151	-0.132	1	.843**	.952**	.957**	.969**	.948**	.932**	.915**	.890**	.878**	.806**	.822**
12	-.897**	.516*	.929**	0.128	-0.231	.833**	.811**	-.911**	-0.291	-0.316	.894**	1	.897**	.849**	.870**	.852**	.782**	.766**	.764**	-.734**	.646**	.727**
13	-.891**	.454*	.918**	0.100	-0.21	.860**	.796**	-.929**	-0.229	-0.25	.888**	.981**	1	.935**	.957**	.920**	.878**	.858**	.835**	-.849**	.771**	.762**
14	-.838**	.600**	.853**	0.162	-0.316	.650**	.792**	-.787**	-0.155	-0.22	.815**	.907**	.896**	1	.962**	.983**	.933**	.923**	.901**	-.864**	.823**	.860**
15	-.842**	.503*	.855**	0.067	-0.208	.698**	.788**	-.822**	-0.173	-0.248	.786**	.900**	.880**	.956**	1	.929**	.885**	.868**	.844**	-.853**	.763**	.779**
16	-.780**	.468*	.775**	0.003	-0.242	.659**	.670**	-.733**	-0.031	-0.113	.729**	.856**	.865**	.960**	.902**	1	.925**	.913**	.885**	-.814**	.801**	.861**
17	-.824**	0.115	.807**	-0.11	0.084	.987**	.634**	-.902**	-0.122	-0.112	.811**	.822**	.855**	.630**	.664**	.648**	1	.996**	.986**	-.880**	.777**	.927**
18	-.803**	0.089	.793**	-0.117	0.098	.969**	.621**	-.890**	-0.102	-0.087	.799**	.785**	.832**	.592**	.610**	.616**	.989**	1	.993**	-.877**	.769**	.939**
19	-.780**	0.097	.784**	-0.113	0.073	.965**	.619**	-.877**	-0.073	-0.042	.794**	.766**	.819**	.573**	.582**	.600**	.984**	.993**	1	-.893**	.768**	.938**
20	.524*	-0.308	-.481*	-0.108	-0.192	-0.368	-.468*	.515*	0.203	0.178	.532*	-0.405	-0.331	-0.265	-0.292	-0.165	-0.365	-0.379	-0.336	1	-.843**	-.803**
21	-0.420	0.326	.505*	0.173	0.045	0.355	.499*	-.490*	-0.393	-0.338	.511*	0.400	0.335	0.250	0.241	0.147	0.351	0.374	0.352	-.916**	1	.821**
22	-.732**	0.125	.793**	0.250	0.011	.941**	.641**	-.858**	0.398	-0.123	.788**	.756**	.806**	.564**	.557*	.580**	.957**	.968**	.983**	-0.322	0.41	1

†Tem, CF, CI, RWC , LWP, OP, PH, PDW, SpL, RN, RL, RV, RDW, RD, NT, NFT, NSp, NGSp, 1000-GW and GY indicate Temperature, Chlorophyll Florescence, Chlorophyll Index, Relative Water Content, Leaf Water Potential, Osmotic Potential, Plant Height, Plant Dry Weight and Spike Length, Root Number, Root Length, Root Volume, Root Dry Weight, Root Diamer, Number of Tiller per plant, Number of Fertile Tiller, Number of Spike per plant, Number of Grain in Spike, 1000Grain Weight and Grain Yield, respectively.

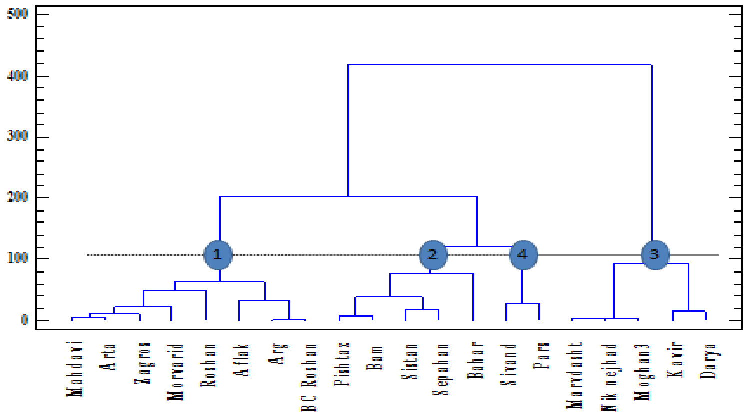

Figure 3. Dendrogram based on all the studied traits under stress condition with Ward method and Discriminant analysis cutting

Path analysis

In order to explain the achieved results from simple correlations in a better manner and determine the most important traits that affect the grain yield, stepwise regression and path analysis were applied. Path analysis describes correlations to identify direct and indirect effects for entered traits into the regression model. Path coefficient analysis was conducted by considering yield-related traits as predictor variables and grain yield as the response variable. In the control condition, comparison of the direct and indirect effects between grain yield and some related traits were calculated (Table 6, 7). In this sense, grain yield was positively correlated with number of spike per plant, number of fertile tiller, root volume, RWC and plant dry weight, and the amount of correlation coefficient for RWC was lower than other traits under drought stress (Table 7). According to the results and as regards to amounts of direct effects traits under normal irrigation, the best traits for selection of plant with high grain yield were chlorophyll index, number of spike per plant and root length, because these traits had high direct effect and high correlation coefficient with grain yield under normal irrigation (Table 5, 6). Under drought stress condition, number of spike per plant, number of fertile tiller, root volume, relative water content and plant dry weight were entered to final regression model (Table 5). All of these traits showed a positive significant correlation with grain yield (Table 7). Traits number of spike per plant, root volume and number of fertile tiller per plant were showed moderate direct effect on grain yield under drought stress however results revealed that these traits with indirect effects via other traits, high positive correlations on grain yield were peresented. Also, RWC was showed the lowest direct effect on grain yield that in total with consider RWC indirect effects via other traits on grain yield, was showed moderate positive correlation on grain yield (Table 7). The most amounts of correlation coefficient and direct effect on grain yield under drought stress was achieved for number of spike per plant, number of fertile tiller per plant and root volume. Generally, number of spike per plant was the best criterion for improving grain yield in wheat under normal irrigation and drought stress conditions. So, screening of high amounts for this trait can bring a growth in wheat grain yield under two conditions. Khalili *et al.* (2013) used path analysis to assess the effects of the most important yield components on grain yield. Also, Naghavi *et al.* (2014), using path analysis in wheat found that the number fertile tiller and number spike per plant had significant positive, direct effects on grain yield under drought stress conditions, as well as well-watered conditions. Also, Simane *et al.* (1993), using path analysis, found that the grain weight and number of spike had significant positive and direct effects on grain yield under moisture stress and control conditions.

Table 5. Results of stepwise regression for grain yield as the response and other characters as predictors in non-stress and water deficit stress conditions

Stress conditions	Model	Unstandardized Coefficients		Standardized Coefficients	R^2	Adjusted R^2
		β	Std. E.	*β*		
Non-stress		-4.144	0.578			
	Chlorophyll Index	0.066	0.007	**0.328**		
	Number of Spike per plant	0.072	0.009	**0.688**	0.632	0.621
	Root length	-0.067	0.014	**0.380**		
	Proline Content	0.069	0.016	**-0.411**		
Water stress deficit	Constant (α)	-1.712	0.428			
	Number of Spike per plant	0.065	0.011	**0.307**		
	Number of Fertile Tiller	0.052	0.008	**0.207**	0.657	0.649
	Root Volume	0.063	0.013	**0.301**		
	Relative Water Content	0.049	0.017	**0.125**		
	Plant Dry Weight	0.056	0.005	**0.254**		

Table 6. Path analysis of grain yield with related traits in cultivars of wheat under normal conditions

Variables added to the model	Indirect effect via				
	†ChI	NSp	RL	PC	Correlation coefficient with grain yield
ChI	**0.328**	0.539	0.349	-0.335	0.793
NSp	0.257	**0.688**	0.311	-0.397	0.983
RL	0.301	0.563	**0.380**	-0.353	0.806
PC	0.268	0.664	0.327	**-0.411**	0.941
Residual					0.098

†ChI, NSp, RLand PC indicate Chlorophyll Index, Number of Spike per plant, Root Length and Proline Content, respectively. Also, values in main diagonal are direct effects.

Table 7. Path analysis of grain yield with related traits in cultivars of wheat under drought stress

Variables added to the model	Indirect effect via					
	†NSp	NFT	RV	RWC	PDW	Correlation coefficient with grain yield
NSp	**0.307**	0.206	0.271	0.076	0.135	0.938
NFT	0.305	**0.207**	0.270	0.088	0.136	0.939
RV	0.277	0.187	**0.301**	0.077	0.134	0.860
RWC	0.187	0.146	0.186	**0.125**	0.017	0.551
PDW	0.163	0.111	0.158	0.008	**0.254**	0.565
Residual						0.099

†NSp, NFT, RV, RWC and PDW indicate Number of Spike per plant, Number of Fertile Tiller, Root Volume, Relative water content and Plant Dry Weight, respectively. Also, values in main diagonal are direct effects.

Factor analysis

Study the correlation coefficient among different characters makes it possible to decide more precisely about selected indirect selection indices and removing ineffective characters. Further, since coefficients of correlation may individually not provide thorough information about the relations of different traits and given the various advantages of multivariate statistical analyses for deep understanding of data structure, factor analysis was used in the current study. By means of varimax rotation which maximizes the variance among the factors, the factors which justify more percentage of variations among the characters are more importance and must be accordingly studied. So, the effective characters on each factor are identified and the factors are named according to the most effective characters (Sharma, 1985; Talebi *et al*,. 2009). In factor analysis by means of major factors analysis and on the basis of Eigen value larger than 1.0, under normal and stress conditions, three factors were identified under normal irrigation and four factors were identified under drought stress and they altogether justified 89.95 and 88.01 % of total variation among the characters, respectively (Table 8 and 9). Under normal condition, the first factor which made 48.95 % of the total variation comprised the spike length, number tiller per plant, number fertile tiller per plant, number spike per plant, number grain per spike, 1000 grain weight and grain yield. So, this factor was named as grain yield and component yield factor. Factor 2, which accounted 24.06 % of the total variation, composed plant height and plant dry weight, root number, root length, root volume, root dry weight and root dimer and thus this factor was called as biological yield factor. Factor 3, which accounted 13.96 % of the total variation, included leaf temperature, chlorophyll florescence, chlorophyll index, RWC, SLA, proline content, leaf water potential and osmotic potential. Because these traits were related to physiology, so this factor was named as physiological factor. Under drought stress condition, the first factor justified 33.45 % of total variation which included root number, root length, root volume, root dry weight and root dimer. Therefore, this factor was identified as component root factor. The second factor composed spike length, number tiller per plant, number fertile tiller per plant, number spike per plant, number grain per spike, 1000 grain weight and grain yield explained 22.93 % of total variation. Thus this factor called as yield and components yield factor. Factor 3, which accounted 17.67 % of the total variation, included leaf temperature, chlorophyll florescence, chlorophyll index, RWC, SLA, proline content, leaf water potential and osmotic potential. So, this factor named as physiological factor. Factor 4, which accounted 13.96 % of the total variation, consisted of plant height and plant dry weight and subsequently called as biomass factor.

These coefficients showed that cultivars with higher values of these factors had the highest values of these traits related to the names of factors. In general, factor analysis shows which grain yield components were associated with which physiological, agronomical characters and root traits. Naghavi *et al.* (2015) used factor analysis to reduce number of variables in wheat cultivars and reported four (root, growth and grain yield, grain traits, biomass) and two (grain yield and biomass) factors under normal and drought stress, respectively. Gupta *et al.* (1999) studied 17 traits of 40 lines of advanced generations of wheat as well as 11 controls, and factor analysis reduced these grain quality and yield-related traits to 5 major factors of maturity, spike attributes, grain attributes, protein quality and tillering. In the another study on bread wheat cultivars, Dawari & Luthra (1991) revealed that harvest index, grain number per spike and spike length were the main yield components and that the selection in terms of these features could improve the yield. Also, Golparvar *et al.* (2002) and Damania & Jackson (1986) reported plant height and plant dry weight as one of the main factors under drought stress.

Table 8. Factor analysis for studied traits in wheat cultivars under normal irrigation

Traits	1	2	3	Communalities
†Tem	-0.210	0.119	0.609	0.903
CF	0.298	0.298	0.698	0.890
CI	-0.389	-0.013	0.711	0.907
RWC	-0.212	-0.076	0.609	0.909
SLA	-0.325	-0.089	0.519	0.899
PC	0.314	0.245	0.745	0.881
LWP	0.215	0.126	0.729	0.903
OP	0.303	0.102	0.703	0.911
PH	-0.298	0.705	0.303	0.901
PDW	0.244	0.829	0.389	0.929
SpL	0.812	0.094	0.224	0.903
RN	0.313	0.712	0.198	0.893
RL	0.376	0.857	0.235	0.923
RV	0.401	0.699	-0.304	0.887
RDW	0.398	0.708	0.297	0.895
RD	0.119	0.835	0.325	0.906
NT	0.729	0.323	0.298	0.894
NFT	0.819	0.286	0.217	0.909
NSp	0.907	0.278	-0.307	0.895
NGSp	0.678	0.356	0.290	0.883
1000-GW	0.911	0.308	0.298	0.890
GY	0.915	0.324	0.224	0.912
KMO				0.81
Eigen values	9.55	5.05	2.46	
Proportional variance	48.95	24.06	16.94	
Cumulative variance	48.95	73.01	89.95	

†Tem, CF, CI, RWC , SLA, PC, LWP, OP, PH, PDW, SpL, RN, RL, RV, RDW, RD, NT, NFT, NSp, NGSp, 1000-GW and GY indicate Temperature, Chlorophyll Index, Chlorophyll Florescence, Relative Water Content, Leaf Water Potential, Osmotic Potential, Plant Height, Plant Dry Weight and Spike Length, Root Number, Root Length, Root Volume, Root Dry Weight, Root Diamer, Number of Tiller in plant, Number of Fertile Tiller, Number of Spike per plant, Number of Grain in Spike, 1000Grain Weight and Grain Yield, respectively.

Table 9. Factor analysis for studied traits in wheat cultivars under drought stress

Traits	1	2	3	4	Communalities
†Tem	-0.126	0.202	0.646	-0.207	0.918
CF	0.095	0.278	0.738	0.298	0.890
CI	-0.249	0.390	-0.512	0.303	0.885
RWC	-0.120	-0.278	0.778	-0.106	0.912
SLA	-0.189	-0.165	0.673	0.298	0.888
PC	0.109	0.211	0.768	0.276	0.912
LWP	0.245	0.276	0.709	0.309	0.889
OP	0.312	0.309	0.838	0.209	0.903
PH	-0.306	0.246	0.129	0.645	0.905
PDW	0.289	0.203	0.107	0.684	0.901
SpL	0.297	0.643	0.280	0.311	0.905
RN	0.711	0.304	0.196	0.297	0.912
RL	0.727	0.334	0.278	0.387	0.901
RV	0.818	0.199	0.256	0.217	0.890
RDW	0.807	0.238	0.305	0.364	0.883
RD	0.790	0.198	0.208	0.359	0.901
NT	0.269	0.598	0.199	0.302	0.883
NFT	0.399	0.812	0.298	0.256	0.903
NSp	0.280	0.745	0.209	0.289	0.912
NGSp	0.398	0.737	0.307	0.406	0.899
1000-GW	0.279	0.663	0.297	0.401	0.901
GY	0.401	0.612	0.307	0.328	0.915
KMO					0.74
Eigen values	4.51	4.08	2.55	2.11	
Proportional variance	33.45	22.93	17.67	13.96	
Cumulative variance	33.45	56.38	74.05	88.01	

†Tem, CF, CI, RWC, SLA, PC, LWP, OP, PH, PDW, SpL, RN, RL, RV, RDW, RD, NT, NFT, NSp, NGSp, 1000-GW and GY indicate Temperature, Chlorophyll Index, Chlorophyll Florescence, Relative Water Content, Leaf Water Potential, Osmotic Potential, Plant Height, Plant Dry Weight and Spike Length, Root Number, Root Length, Root Volume, Root Dry Weight, Root Diamer, Number of Tiller in plant, Number of Fertile Tiller, Number of Spike per plant, Number of Grain in Spike, 1000Grain Weight and Grain Yield, respectively.

Conclusions

Considering cluster analysis and selection according to the values of suitable traits under water deficit stress, it can be concluded that the cultivars of Marvdasht, Niknejhad, Moghan3, Kavir and Darya had the highest values for the most traits studied rather than overall mean, and can be accordinly introduced as the most tolerant drought cultivars. Also, another cluster included Pishtaz, Bam, Sistan, Sepahan and Bahar cultivars, had the lowest values for the most traits studied rather than overall mean and couldn't adopt themselves to environmental conditions, so we can name them as the sensitive drought cultivars. The other cultivars exhibited moderate paatern. Therefore, we can suggest cultivars of tolerant for direct cultivation or we can use these cultivars by mating with cultivars of sensitive group for genetic diversity. Further, according to comparison of mean, and cluster analysis, Kavir and Bahar cultivars were tolerant and susceptible cultivars under drought stress, respectively. On the other hand, according to stepwise regression, the maximum amounts of correlation coefficient and direct effect were achieved for number of spike per plant under two conditions. So, screening for higher amounts of this trait can bring an increment in wheat grain yield under two conditions. Lastly, factor analysis detected three and four factors which explained 89.95 and 88.01 % of the total variation in non-drought stress and drought stress conditions, respectively.

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REFERENCES

1. Ahmadi, M., Farshadfar, E. & Veisi, S. (2012). Evaluation of genetic diversity in bread landrace of bread wheat under irrigated and rainfed conditions. *International Journal of Agriculture and Crop Sciences*, 4(21), 1627-1636.
2. Allard, R. W. (1960). *Principles of plant breeding.* (1st ed.). John Wiley and Sons, Inc., New York. 63p.
3. Araus, J. L., Ceccarelli, S. & Grando, S. (1997). Relationship between leaf structure and carbon isotope discrimination in field-grown barley. *Plant Physiology and Biochemistry,* 35, 533-541.
4. Arias, D. (2007).Calibration of LAI-2000 to estimate leaf area indexand assessment of its relationship with stand productivity in six native and introduced tree species in costarica. *Forest Ecology and Management,* 1, 24785-193.
5. Ashraf, M. Y. (1998). Yield and yield component response of wheat (*Trittium aestivum* L.) genotypes grown under different soil water deficit conditions. *ActaAgronomica Hungrica,* 46, 45-51.
6. Bayoumi, T. Y., Eid, M. H. & Metwali, M. M. (2008). Application of physiological and biochemical indices as a screening technique for drought tolerance in wheat genotypes. *African Journal of Biotechnology,* 7, 2341-2352.
7. Board, J. E., Kang, M. S. & Harville, B. G. (1997). Path analyses identify indirect selection criteria for yield of late-planted soybean. *Crop Science,* 37, 879-884.
8. Boyer, J. S. (1967). Leaf water potentials measured with a pressure chamber. *Plant Physiology,* 42,133-137.

9. Bramel, P. J., Hinnz, P. N., Green, D. E. & Shibles, R. M. (1984).Use of principal factor analysis in the study of three stem termination types of soybean. *Euphytica*, 33, 387-400.
10. Comstock, R. R. & Robinson, H. F. (1952). Genetic parameters, their estimation and significance. In: Proceeding of *6th international Grassland Congress*. Wash., D.C., U.S.A. 1, 298-307.
11. Damania, A. B. & Jackson, M. T. (1986).An application of factor analysis to morphological data of wheat and barley landraces from the Bheri River.*Valley Nepol Research*, 5, 25-30.
12. Dawari, N. H. & Luthra, O. P. (1991). Character association studies under high and low environments in wheat (*Triticum aestivum* L.). *Indian Journal of Agricultural Research*, 25, 515-518.
13. Dewey, D. R. & Lu, K. H. (1959). Correlation and path-coefficient analysis of components of crested Wheat grass seed production. *Agronomy Journal*, 51, 515-518.
14. Erdei, L., Tari, I., Csisza´r, J., Pe´csva´radi, A., Horva´th, F., Szabo, M., Ordog, M., Cseuz, L., Zhiponova, M., Szilak, L. & Gyorgyey, L. (2002). Osmotic stress responses of wheat species and cultivars differing in drought tolerance: some interesting genes (advices for gene hunting). *Acta Biology Szegediensis*, 46, 63-65.
15. Farshadfar, E., Farshadfar, M. & Dabiri, S. (2012). Comparison between effective selection criteria of drought tolerance in bread wheat landraces of Iran. *Annualsof Biology Research*, 3(7), 3381-3389.
16. Flexas, J., Ribas-Carbo, M., Diaz-Esoejo, N., Galmes, J. & Medrano, H. (2007). Mesophyll conductance to CO2: current knowledge and future prospects. *Plant, Cell and Environment*, 31(5), 602-621.
17. Ghaffari, M., Toorchi, M., Valizadeh, M. & Shakiba, M. R. (2012). Morpho-physiological screening sunflower inbred lines under drought stress condition. *Turkish Journal of Field Crops*, 17(2), 185-195.
18. Gholamin, R., Zaeifizadeh, M. & Khayatnezhad, M. (2010). Factor analysis for performance and other characteristics in durum wheat under drought stress and without stress. *Middle-East Journal of Scientific Research*, 6(6), 599-603.
19. Giunta, F., Motzo, R. & Deidda, M. (1993). Effect of drought on yield and yield components of durum wheat and triticale in Mediterranean environment. *Field Crops Research*, 33(4), 399-409.
20. Golabadi, M., Arzani, A. & Maibody, S. M. M. (2005). Evaluation of variation among durum wheat F3 families for grain yield and its components under normal and water-stress field conditions. *Czech Journal of Genetics andPlant Breeding*, 41, 263-267.
21. Golparvar, A. R., Ghannadha, M. R., Zalli, A. A. & Ahmadi, A. (2002). Evaluation of some morphological traits as selection criteria for improvement of bread wheat. *Iranian Journal of Agricultural Sciences*, 4(3), 202-207. (in Farsi)
22. Gupta, A. K., Mittal, R. K. & Ziauddin, A. (1999). Association and factor analysis in spring wheat. *Annals of Agricultural Research*, 20, 481-485.
23. Inamullah, Z. A., Swati, A. & Siraj-u-Din, L. (1999). Evaluation of lines for drought tolerance in wheat (*Triticum aestivum* L.). *Scientific Khyber*, 12(2), 39-48.
24. Jones, H.G. (1983). *Plants and microclimate: A quantitative approach to environmental plant physiology*. (1st ed.).Cambridge University Press, Cambridge, London. 89p.
25. Kashif, M. & Khaliq, I. (2004). Heritability, correlation and path analysis for some metric traits in wheat. *International Journal of Agricultural Biology*, 6, 138-142.
26. Khalili, M., Pour Aboughadareh, A. R., Naghavi M. R. & Naseri Rad, H. (2013). Path analysis of the relationships between seed yield and some of morphological traits in safflower (*Carthamus tinctorius* L.) under normal irrigated and rainfed conditions. *Technical Journal of Engineering Applied Science*, 3(15), 1692-1696.

27. Khayatnezhad, M., Zaefizadeh, M., Gholamin, R., Jamaati Somarin, S. & Zabihi Mahmoodabad, R. (2010). Study of morphological traits of wheat cultivars through factor analysis. *American-Eurasian Journal of Agriculture and Environmental Science*, 9(5), 460-464.
28. Lorencetti, C., de Carvalho, F. I. F., de Oliveira,A. C., Valério,I. P., Hartwig,I., Benin, G. & Schmidt, D. A. M. (2006). Applicability of phenotypic and canonic correlations and path coefficients in the selection of oat genotypes. *Science of Agriculture (Piracicaba brazillian),* 63, 11-19.
29. Lu, Z. & Neumann, P. M. (1999). Low cell-wall extensibility can limit maximum leaf growth rates in rice. *Crop Science,* 39, 126-130.
30. Martin, M., Micell, F., Morgan, J. A., Scalet, M. & Zerbi, G. (1993). Synthesis of osmotically active substances in winter wheat leaves as related to drought resistance of different genotypes. *Journal of Agronomy and Crop Science,* 171, 176-184.
31. Martinez, J. P., Lutls, S., Schanck, A. & Bajji, M. (2004). Is osmotic adjustment required for water stress resistance in the Mediterranean shrub *Atriplex halmius* L.? *Plant Physiology,* 161, 1041-1051.
32. Maxwell, K. & Johnson, G. N. (2000). Chlorophyll fluorescence: a practical guide. *Journal of Experimental Botany,* 51, 659-668.
33. Mc Manus, M. T., Bieleski, R. L., Caradus L. R. & Barker, D. J. (2000). Pinitoal accumulation in mature leaves of white clover in response to a water deficit. *Environmental and Experimental Botany,* 43, 11-18.
34. Moghaddam, M., Ehdaie, B. & Waines, J. G. (1997). Genetic variation and interrelationships of agronomic characters in landraces of bread wheat from southeastern Iran. *Euphytica,* 95, 361-369.
35. Moghaddam, M., Ehdaie, B. & Waines, J. G. (1998). Genetic variation for interrelationships among agronomic traits in landraces of bread wheat from Southwestern Iran. *Journal of Genetics and Breeding,* 52, 73-81.
36. Moustafa, M. A., Boersma, L. & Kronstad, W. E. (1996). Response of four spring wheat cultivars to drought stress. *Crop Science,* 36, 982-986.
37. Musick, J. T., Jones, O. R., Stewart, B. A. & Dusek, D. A. (1994). Water-yield relationships for irrigated and dryland wheat in the U.S. southern plains. *Agronomy Journal,* 86, 980-986.
38. Naghavi, M. R., Moghaddam, M., Toorchi, M. & Shakiba, M. R. (2014). Evaluation of the relationship between morphological and agronomic traits with grain yield in spring wheat cultivars under drought stress. *International Journal of Biosciences,* 5(3), 88-93.
39. Naghavi, M. R., Toorchi, M., Moghaddam, M. & Shakiba, M. R. (2015). Evaluation of diversity and traits correlation in spring wheat cultivars under drought stress. *Notulae Scientia Biologicae,* 7(3), 349-354.
40. Passioura, J. B. (1997). Grain yield, harvest index and water use of wheat. *Journal of the Australian Institute of Agricultural Science,* 43, 117-120.
41. Pessarkli, M. (1999). *Hand book of plant and crop stress*. (2nd ed.).Marcel Dekker Inc. University of Arizona, USA.97p.
42. Pour Aboughadareh A. R., Naghavi, M. R. & Khalili, M. (2013). Water deficit stress tolerance in some of barley genotypes and landraces under field conditions. *Notulae Scientia Biologicae,* 5, 249-255.
43. Rascio, A., Plantani, C., Difonza, N. & Wittemer, G. (1992). Bound water in durum wheat under drought stress. *Plant Physiology,* 98, 909-912.
44. Ritchie, S. W., Nguyan, H. T. & Holaday, A. S. (1990). Leaf water content and gas exchange parameters of two wheat genotypes differing in drought resistance. *Crop Science,* 30, 105-111.

45. Sairam, R. K. & Siravastava, G. C. (2002). Changes in antioxidant activity in subcellular fractions of tolerant and susceptible wheat genotypes in response to long term salt stress. *Plant Science,* 162, 897-907.
46. Sanchez-Rodriguez, E., Rubio-Wilhelmi, M., Cervilla, L. M., Blasco, B., Rios, J. J., Rosales, L., Romero, M. A. & Ruiz, J. M. (2010). Genotypic differences in some physiological parameters symptomatic for oxidative stress under moderate drought in tomato plants. *Plant Science,* 178, 30-40.
47. Sharma, S. K. (1985). Factor analysis of berry and its seed characteristics in potato. *Plant Genetic and Breeding,* 37, 77-82.
48. Siddique, M. R., Hamid, B. A. & Islam, M. S. (2000). Drought stress effects on water relations of wheat. *Botanical Bulletin of the Academia Sinica (Taipei),* 41, 35-39.
49. Simane, B., Struik, P. C., Nachit, M. M. & Peacock, J. (1993). Ontogenetic analysis of yield components and yield stability of durum wheat in water-limited environments. *Euphytica,* 71, 211-219.
50. Taiz, L. & Zeiger, E. (1991). *Plant Physiology*. The Benjamin/Cummings Publishing Company, Inc. 559p.
51. Talebi, R., Fayaz, F. & Naji, A. M. (2009). Effective selection criteria for assessing drought stress tolerance in durum wheat (*Triticum durum* Desf). *Genetics and Applied Plant Physiology,* 35(1-2), 64-74.
52. Tompkins, D. K., Fowler, D. B. & Wright, A. T. (1991). Water use by no till winter wheat influence of seed rate and row spacing. *Agronomy Journal,* 1,766-769.
53. Turner, N. C. (1986). Crop water deficit: A decade of progress. *Advances in Agronomy,* 39, 1-51.
54. Walton, P. D. (1972). Factor analysis of yield in spring wheat (*Triticum aestivum*). *Crop Science,* 12, 731-733.
55. Winter, S. R., Musick, J. T. & Porter, K. B. (1988). Evaluations of screening techniques for breeding drought-resistant winter wheat. *Crop Science,* 28, 512-516.
56. Xue, Q., Zhu, Z., Musick, J. T., Stewart, B. A. & Dusek, D. A. (2003). Root growth and water uptake in winter wheat under deficit irrigation. *Plant and Soil,* 257, 151-161.
57. Zlatev, Z. & Yordanov, I. T. (2004). Effect of soil drought on photosynthesis and chlorophyll fluorescence in bean plants. *Bulgarian Journal of Plant Physiology,* 30, 3-18.