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Evaluation of genetic diversity and traits relations in wheat cultivars under drought stress using advanced statistical methods

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ABSTRACT

In order to study of genetic diversity and classify physio-agronomic characters under normal irrigation and drought stress in wheat cultivars, 15 cultivars were evaluated in the research farm of University of Mahabad, Iran. According to stepwise regression some of traits entered to final model that as far to correlation coefficients and path analysis regarding, the biggest part of correlation coefficient and direct effect was achieved for number of grains per spike, number spikes per plant with grain yield under two conditions. These traits had the highest indirect effect on the grain yield mutually. So, screening for high value for these traits can bring increase in wheat grain yield under two conditions. Factor analysis detected three and four factors which explained 91.23 and 92.43 percent of the total variation in non-drought stress and drought stress conditions, respectively. In drought stress condition the first factor, second factor, third factor and fourth factors were named as yield component, physiological, biomass and growth, and yield factor respectively. Cluster analysis based on the three and four factors grouped cultivars into the two groups under normal and three groups under drought stress conditions. Generally, tolerant cultivars can be used for direct culture or as parents for create of variation in breeding programs.

Key words: correlation; drought stress; factor analysis; path analysis; physio-agronomic traits; wheat

IZVLEČEK

OVREDNOTENJE GENETSKE RAZNOLIKOSTI IN RAZMERIJ MED LASTNOSTMI PRI SORTAH KRUŠNE PŠENICE V RAZMERAH SUŠNEGA STRESA S STATISTIČNIMI METODAMI

Z namenom preučevanja genetske raznolikosti in razvrščanja fizioloških in agronomskih lastnosti je bilo v razmerah sušnega stresa in normalnega namakanja ovrednotenih 15 sort krušne pšenice na raziskovalnem polju University of Mahabad, Iran. S postopno regresijo so nekatere lastnosti vključili v končni model na osnovi koeficientov korelacije in standardiziranih koeficientov multiple regresije in ugotovili, da so imele največji neposredni učinek v obeh razmerah poskusa lastnosti kot so število zrn na klas, število klasov na rastlino in pridelek zrnja. Te lastnosti so imele hkrati tudi največji neposrednik učinek na pridelek zrnja. Iskanje sort z velimi vrednostmi teh lastnosti lahko poveča pridelek pšenice v obeh razmerah poskusa. Faktorska analiza je ugotovila tri, oziroma štiri faktorje, s katerimi lahko razložimo 91.23 in 92.43 odstotkov celukupne variabilnosti v razmerah brez suše in ob sušnem stresu. V razmerah sušnega stresa so prvi, drugi, tretji in četrti faktor poimenovani kot komponento pridelka, fiziološki parametri, biomasa in rast ter pridelek. Klasterska analiza je na osnovi treh in štirih faktorjev uvrstila sorte v dve skupini v normalnih razmerah in v tri skupine v razmerah sušnega stresa. V splošnem bi odporne sorte lahko gojili neposredno v prozvodnji ali jih uporabili kot starše pri ustvarjanju raznolikosti v žlahtniteljskih programih.

Ključne besede: korelacija; sušni stres; faktorska analiza, multipla regresija; fiziološko-agronomske lastnosti; krušna pšenica

1 INTRODUCTION

Common wheat (*Triticum aestivum* L.) as the most important cereal crop is cultivated throughout the major agro-climatic zones of the world (Baik and Ullrich, 2008). World's wheat production was about 735.23 million tons in 2016 (FAO, 2016). Drought stress is the most important factor limiting crops production in

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agricultural systems in arid and semi-arid regions (Mollasadeghi et al., 2011). Drought stress is recognized as an important factor that affects the wheat growth and yield (Ashraf, 1998). Some morphological traits such as number of spike per m^2, number of grains per spike, number of fertile tillers per plant, 1000-grain mass, peduncle length, spike mass, stem mass and grain yield affect wheat tolerance to the moisture shortage in the soil (Plaut et al., 2004; Blum, 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 (Kahrizi et al., 2010). Also, environmental conditions and genotype interaction affect the relationships among plant characters. So, toward a clear understanding of the type of plant traits, correlation and path coefficient analysis are logical steps (Kashif and Khaliq, 2004). Path analysis is a tool that is available to the breeder for better understanding the cause involved in the associations between traits and to partition the existing correlation in to direct and indirect effects, through a main variables (Lorencetti et al., 2006). Generally, this method provides more information among variables than do correlation coefficients since this analysis provides the direct effects of specific yield components on yield, and indirect effects via other yield components (Garcia del Moral et al., 2003). Path analysis has been widely used in crop breeding to determine the nature of relationships between grain yield and its contributing components, and to identify those components with significant effect on yield for potential use as selection criteria (Board et al., 1997; Khalili et al., 2013; Naghavi et al., 2014). Different statistical techniques have been used in modeling crops yield, including correlation, regression, path analysis, factor analysis, factor components and cluster analysis (Mohamed, 1999). 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 method that has been used to estimate the components of yield, to extract a subset of identical variables, to identify the basic concepts of multivariable data, to recognize applied and biological connections among the traits, to reduce a large number of correlative traits to a few number of factors and to explain the correlation among the variables (Bramel et al., 1984). Cluster analysis can be used to identify variables which can be classified into main groups and subgroups based on similarity and dissimilarity. This technique is useful for parental selection in breeding programs (El-Deeb and Mohamed, 1999) and crop modeling (Jaynes et al., 2003). Naghavi et al. (2015) showed a negative correlation between plant height and grain yield. They attributed that to the lower number of grains/spike with the tallest wheat plants. Kumbhar et al. (1983) and Mohamed (1999) had shown that grain mass/spike, biological yield and number of spikes/m^2 were closely related to grain yield g/m^2. The differential relations of yield components to grain yield may be attributed to environmental effects on plant growth (Asseng et al., 2002). Khayatnezhad et al. (2010) using factor analysis in his studies on durum wheat cultivars showed that the importance of factor coefficients characteristics of total and fertile tillers, main spike length, 1000-seed mass, and yield selected genotypes is desirable for dry conditions. Also, Naghavi, et al., (2015) used the factor analysis to identify growth and morphological traits relevant to yield in wheat and introduced four factors which included yield components, morphological traits, spike length and the number of grain per plant.

Our objective was to determine the relationship between grain yield and related characters under normal irrigation and drought stress. Also, one of another goals in this study was founding the direct and indirect effects of morphological and agronomic traits on grain yield under two conditions. On the other hands, the another objectives of this investigation were evaluate the relations of different characters and also identifying effective factors in yield improvement in wheat cultivars and grouping of cultivars according to achieved factors under normal irrigation and drought stress.

2 MATERIALS AND METHODS

Fifteen cultivars of wheat such as Mahabad Landrace cultivar and Sardari, Zarin, Azar, Homa, Alamoot, Shahriyar, Mihan, Zare, Urum, Pishgam, Toos, Alvand, Navid, Sabalan were cultivated in a split plot basis of randomized complete block design with four replications under two different conditions (normal irrigation and no irrigation after booting stage) at Research Farm of University of Mahabad, Iran (latitude 36.46°N, longitude 45.43°E, Altitude 1385 m above sea level) during growing season of 2015-2016. The climate is characterized by mean annual precipitation of 330 mm; mean annual temperature of 12 °C. The experimental treatments consisted of irrigation levels as the main plot at second levels: irrigation after 70 mm evaporation from class A pan (without stress), irrigation after 150 mm evaporation from class A pan (water deficit stress) and fifteen cultivars of wheat as the sub plot were considered in this study. Each plot contained 4 rows with 25 cm apart and 1m in length. All plots were irrigated after sowing and subsequent irrigations in the beginning of stem elongation. Weeds were controlled by hand during crop growth and development.

Agronomic characteristics and physiological criteria including: plant height (cm), plant dry mass (g), specific leaf area (cm^2/g), relative water content (%), proline content, chlorophyll content (ChC) and osmotic potential (OP), spike length (cm), number of tillers per plant, number of fertile tillers per plant, number of spikes per plant, number of grains per spike, 1000-grains mass (g), grain yield (g), were measured after the physiological maturity in 10 selected plants of each experimental plot, randomly.

Physiological criteria were used for flag leaf measurement. Specific leaf area was calculated on the basis of this formula: special leaf area (cm^2g^{-1}) = (leaf area)/(leaf dry mass) (Arias, 2007). Moreover, relative water content (%) was determined according to method of Turner (1986). Also, proline contents ($mg.g^{-1}FM$) were measured by acid hydrin method. The chlorophyll content was determined using a chlorophyll meter (SPAD-502, Japan). Osmotic potential was measured by osmometer (Martinez et al. 2004); mode: Osmomat 010, Genotel. Morphological and growth traits such as the plant height (cm), plant dry mass (g), spike length (cm), number of tillers per plant, number of fertile tillers per plant, number of spikes per plant, number of grain in spike, 1000 grain mass (g) and grain yield (g) were measured at the end of growth stage. Finally, mean of data used for analysis and simple linear correlation coefficients were computed and these coefficients were subjected to path analysis as described by Dewey and Lu (1959) using SPSS software. Also, mean of data used for analysis and simple linear correlation coefficients were computed then factor analysis on the base of major factors analysis and varimax rotations was done on the data. The factors which had a root bigger than one were selected and were used to form factorial coefficients matrix (Sharma, 1985; Tadesse and Bekele, 2001). Also eigen values, percent variance, variance, and cumulative percentage share of each of the extracted factors were calculated. Finally cluster analysis was performed according to values for cultivars basis of factors. Analysis of data and drawing of dendrogram were performed with SPSS software.

3 RESULTS AND DISCUSSION

3.1 Analysis of variance

The results of analysis of variance (Table 1) showed high significant differences ($P<0.01$) between of cultivars for all traits, except SLA and OP which was significant in probability level $P<0.05$. Also difference between normal irrigation and drought stress was significant for all of traits. This indicates that the magnitude of differences in cultivars was sufficient to select them against drought. Also, results indicated that there is a high variation for all traits which revealed the presence of genetic diversity for these attributes in the materials. Therefore, these traits have good potential for selection of the most tolerant and most sensitive cultivars for using in cross together and create genetically variation or using of direct culture for tolerant cultivars.

At the study of Garavandi and Kahrizi (2010), in which 20 bread wheat genotypes were evaluated, grain yield, spike number per square meter, number of seed per spike, spike density and awn length had the heights genetic diversity in compare with other traits. Kutlu and Kinaci, (2010) reported similar results for agro-morphological traits and grain yield in both stress and non-stress conditions. Also, Farshadfar (2012) showed significant difference among wheat genotypes in term of physiological traits under stress and non-stress.

Table 1: Analysis of variance for yield and other traits in wheat cultivars under different irrigation treatment

Source of Variation	df	Mean of Squares						
		†PH	PDM	SLA	RWC	PC	ChC	OP
Replication (R)	3	0.956	0.004	35.906	0.430	0.163	0.298	0.055
Stress (S)	1	421.98**	236.982**	702.76**	45.83**	3.739**	19.837**	0.629**
Error a	3	0.409	0.008	246.317	0.003	0.104	0.049	0.053
Genotype (G)	14	98.764**	5.278**	184.91**	69.724**	3.089**	13.656**	0.873**
G×S	14	24.891	1.073	310.189*	11.897	1.932*	0.985	5.167**
Error b	84	30.670	1.853	118.872	13.096	0.458	1.005	0.198
CV (%)		11.58	8.46	11.76	9.98	12.09	11.65	13.96

†PH, PDM, SLA, RWC, PC, ChI and OP indicate plant height, plant dry mass, specific leaf area, relative water content, proline content, chlorophyll content and osmotic potential respectively. Also, * and ** were significant at 5 % and 1 % probability levels.

Table 1: continued

Source of Variation	df	Mean of Squares						
		†SpL	NT	NFT	NSp	NGSp	1000-GM	GY
Replication (R)	3	0.061	0.550	0.499	0.329	43.871*	23.987	0.873
Stress (S)	1	353.894**	451.159**	490.461**	543.134**	556.092**	3984.930**	2196.561**
Error a	3	0.054	2.129	1.128	2.094	18.186	28.44	4.457
Genotype (G)	14	11.873**	15.905**	16.047**	18.947**	110.857**	65.192**	18.903**
G×S	14	0.436	1.198	1.209	1.762	11.940	8.093	2.320
Error b	84	0.936	1.122	1.432	1.875	12.945	9.670	2.406
CV (%)		10.55	13.08	17.49	18.21	13.44	10.55	18.98

†SpL, NT, NFT, NSp, NGSp, 1000-GM and GY indicate spike length, number of tillers per plant, number of fertile tillers, number of spikes per plant, number of grains per spike, 1000 grain mass and grain yield respectively. Also, * and ** were significant at 5 % and 1 % probability levels.

3.2 Correlation analysis

According to the results of the correlation, significant positive correlation was found between grain yield and spike length, number of tillers per plant, number of fertile tillers, under both conditions (Table 2). Moreover of these traits plant dry mass, relative water content, proline content, chlorophyll content, number of spikes per plant and number of grains per spike had significant positive correlation with grain yield under drought stress (Table 2). Also, significant negative correlation was found between grain yield and plant height, specific leaf area and osmotic potential under drought stress condition (Table 2).

Maximum of amount of correlation coefficients between studied traits with grain yield was achieved for number of grains per plant and number of spikes per plant under normal irrigation and drought stress. On the other hands, a negative significant correlation was found between 1000-seed mass and number of grains per spike under two irrigation conditions. Plant height was positively correlated with plant dry mass under both conditions. Also, correlation analysis showed physiological traits values were positive significantly correlated together under two conditions. Further, number of tillers with number of fertile tillers and number of spikes per plant had significant positive correlation under normal irrigation and drought stress. Also, spike length showed positive and significant correlation with number of grains per spike under normal irrigation and drought stress.

The analysis of correlation of different traits with grain yield can help to make decision about the relative importance of these traits and their merits as selection criteria (Dokuyucu and Akkaya, 1999). Various studies show that grain yield of wheat is significantly correlated with 1000-grain mass, the number of fertile tillers or spikes per plant and the number of spikelets per spike (Mohiuddin and Cory, 1980; Shanahan et al., 1985). Moghaddam et al. (1998) reported that yield, 1000-grain mass, and number of spikes per plant were correlated. In most of the previous studies, similar have been reported between yield and related characters such as, number of spikes, number of spikelets and 1000-grain mass (Sharma and Rao, 1989; Subhani and Khaliq, 1994). In the studies conducted by Sinha and Sharma (1979) and Belay et al. (1993), yield was positively correlated with yield components, with either positive or negative correlation between yield and plant height. Moghaddam et al. (1997) reported negative correlation between number of grains per spike and 1000-grain mass. Further, Passioura (1997) and Leilah and Al-Khateeb (2005) reported that grain yield of wheat has a positive correlation with number of spikes/m^2, 1000-grain mass, harvest index and biomass. Also, Fatemi Rika et al. (2013) reported significant correlation among grain yield, fertile tillers number, thousand grain mass, straw yield, plant biomass and harvest index under two conditions. Some of researches showed positive significant correlation between grain yield and number of spikes per plant (Kahrizi et al., 2010, Naghavi et al. 2015).

Table 2: Coefficient correlation between studied traits with grain yield under normal irrigation (under main diagonal) and under drought stress (above main diagonal)

	†PH	PDM	SLA	RWC	PC	ChC	OP	SpL	NT	NFT	NSp	NGSp	1000-GM	GY
PH	1	0.96**	0.40	-0.33	-0.34	-0.40	-0.41	0.32	-0.39	0.36	0.23	0.43	-0.41	-0.51*
PDM	0.90**	1	-0.52*	0.32	0.60**	0.69**	-0.29	-0.28	0.39	0.32	0.24	0.77**	-0.67**	0.60**
SLA	0.37	-0.28	1	-0.17	-0.40	-0.41	0.40	-0.40	0.30	0.20	0.37	-0.68**	0.60**	-0.73**
RWC	-0.11	0.29	-0.09	1	0.66**	0.60**	-0.30	0.79**	0.80**	0.82**	0.84**	0.32	0.53*	0.94**
PC	-0.20	0.26	-0.20	.58**	1	0.75**	-0.61**	0.76**	0.61**	0.76**	0.61**	-0.23	0.31	0.84**
ChC	-0.19	0.28	-0.28	0.38	0.65**	1	-0.63**	0.67**	0.76**	0.90**	0.74**	-0.80**	0.83**	0.71**
OP	-0.23	-0.08	0.26	-0.37	-0.64**	-0.40	1	-0.53*	-0.30	-0.43	-0.61**	-0.32	0.41	-0.65**
SpL	0.25	-0.10	-0.19	0.60**	0.66**	0.39	-0.33	1	0.76**	0.77**	0.87**	0.88**	0.75**	0.73**
NT	-0.20	0.15	0.32	0.63**	0.63**	0.36	-0.35	0.64**	1	0.88**	0.80**	-0.60**	0.60**	0.79**
NFT	0.28	0.12	0.29	0.61**	0.59**	0.31	-0.23	0.60**	0.60**	1	0.84**	-0.54*	0.65**	0.95**
NSp	0.10	0.08	0.28	0.62**	0.42	0.35	-0.31	0.60**	0.61**	0.63**	1	0.52*	0.69**	0.93**
NGSp	0.40	0.21	-0.40	-0.40	-0.30	-0.19	-0.23	0.53*	-0.28	-0.26	-0.22	1	-0.69**	0.98**
1000-GM	-0.39	-0.30	0.38	0.23	0.28	0.44	0.27	0.53*	0.30	0.25	0.29	-0.52*	1	-0.19
GY	-0.30	-0.12	-0.16	0.31	0.36	0.48	-0.11	0.59**	0.74**	0.54*	0.42	0.41	-0.21	1

† PH, PDM, SLA, RWC, PC, ChC, OP, SpL, NT, NFT, NSp, NGSp, 1000-GM and GY indicate plant height, plant dry mass, specific leaf area, relative water content, proline content, chlorophyll content, osmotic potential, spike length, number of tillers per plant, number fertile tillers, number of spikes per plant, number of grains per spike, 1000 grain mass and grain yield respectively. Also, * and ** were significant at 5 % and 1 % probability levels.

3.3 Path analysis

Path analysis was used to describe correlation to identify direct and indirect effects for entered traits into 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, comparing the direct and indirect effects between grain yield and some related traits were calculated (Table 3, 4). In this state, grain yield was positively correlated with chlorophyll content, number spikes per plant, number of grains per spike and negative correlation with 1000 grain mass and amount of correlation coefficient for 1000 grain mass was less rather than other traits (Table 4). According to this results and as regards to amounts of direct effects traits under normal irrigation the best of traits for selection of plant with high grain yield were chlorophyll content, number spikes per plant and number of grains per spike, because these traits had high direct effect and high correlation coefficient with grain yield under normal irrigation (Table 3, 4).

On the other hands, under drought stress condition, number of grains per spike, relative water content, number of spikes per plant, proline content and 1000 grain mass were entered to final regression model (Table 3). All of these traits showed a positive significant correlation with grain yield except of 1000 grain mass (Table 5). Under drought stress, traits such as number of grains per spike, number of spikes per plant and relative water content showed average direct effect on grain yield and these results showed that these traits act via other traits, cumulative effects with high positive correlations on grain yield was expressed. On the other hands, 1000 grain mass showed good direct effect on grain yield under drought stress but their effect via indirect effect of other traits decreased their correlation with grain yield (Table 5). The biggest part of correlation and direct effect on grain yield under drought stress was achieved for number of grains per spike, proline content and number of spikes per plant.

Generally, number of grains per spike and number of spikes per plant were the best criterion for improving grain yield in wheat under normal irrigation and drought stress conditions. So, screening for high amount for these traits can bring increase in wheat grain yield under two conditions. Naghavi et al., (2014), using path analysis in wheat found that the number of spikes per plant and number of fertile tillers had significant positive, direct effects on grain yield under drought stress conditions, as well as well-watered conditions. On the other hands, Baranwal et al., (2012) revealed that number of grains per spike, spike length and 1000-grain mass exhibited the maximum positive direct effect on grain yield. Also, Sheron et al., (1986) observed that yield components such as number of grains per spike and number of spikes per plant with plant height and spike length were directly related to grain yield.

Table 3: Results of stepwise regression analysis for grain yield as the response to other characters as predictors in non-stress and water deficit stress conditions

Stress conditions	Model	t-values	Unstandardized Coefficients		Standardized Coefficients	R^2	Adjusted R^2
			β	Std. E.	β		
Non-stress	Constant (α)	-0.955	-4.343	0.855			
	Number of Grains per Spike	0.112	0.064	0.009	**0.434**		
	Chlorophyll Content	0.094	0.070	0.008	**0.576**	0.598	0.583
	1000 Grain Mass	-0.112	-0.062	0.012	**-0.367**		
	Number of Spikes per plant	0.128	0.063	0.012	**0.432**		
Water stress deficit	Constant (α)	-0.124	-1.932	0.543			
	Number of Spikes per plant	0.118	0.063	0.014	**0.387**		
	Number of Grains per Spike	0.099	0.065	0.006	**0.437**		
	1000 Grain Mass	-0.139	-0.073	0.013	**-0.543**	0.634	0.622
	Relative water content	0.102	0.061	0.014	**0.365**		
	Proline Content	0.125	0.074	0.003	**0.643**		

† NGSp, ChC, 1000GM and NSp indicate number of grains per spike, chlorophyll content, 1000 grain mass and number of spikes per plant, respectively. Also, values in main diagonal are direct effects.

Table 4: Path analysis of grain yield with related traits in cultivars of wheat under irrigation conditions

variables added to the model	indirect effect via				
	†NGSp	ChC	1000GM	NSp	Correlation coefficient with grain yield
NGSp	**0.434**	-0.111	0.189	-0.096	0.412
ChC	-0.083	**0.576**	-0.162	0.149	0.477
1000GW	-0.224	0.254	**-0.367**	0.124	-0.210
NSp	-0.097	0.199	-0.105	**0.432**	0.423

† NGSp, ChC, 1000GM and NSp indicate number of grains per spike, chlorophyll content, 1000 grain mass and number of spikes per plant, respectively. Also, values in main diagonal are direct effects.

Table 5: Path analysis of grain yield with related traits in cultivars of wheat under drought stress

variables added to the model	indirect effect via					Correlation coefficient with grain yield
	†NSp	NGSp	1000-GM	RWC	PC	
NSp	**0.387**	0.229	-0.373	0.307	0.393	0.931
NGSp	0.202	**0.437**	0.374	0.118	-0.149	0.978
1000-GM	0.266	-0.301	**-0.543**	0.195	0.201	-0.193
RWC	0.326	0.141	-0.290	**0.365**	0.421	0.942
PC	0.237	-0.101	-0.169	0.239	**0.643**	0.840

† NSp, NGSp, 1000-GM, RWC and PC indicate number of spikes per plant, number of grains per spike, 1000 grain mass, relative water content and proline content, respectively. Also, values in main diagonal are direct effects.

3.4 Factor analysis

Since coefficients of correlation may singly 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 have had more importance and must be studied. So, the effective characters on each factor are identified and the factors are named according to the most effective characters (Tadesse and Bekele, 2001). In factor analysis by means of major factors analysis and on base of specific numbers larger than 1, under normal and stress conditions three factors were identified under normal irrigation and four factors were identified under drought stress and they all together justify 91.23 and 92.43 percent of existent variation among the characters, respectively (Table 6 and 7).

Under normal condition the first factor which made 50.43 % of the total variation was composed of the spike length, number of tillers per plant, number of fertile tillers per plant, number of spikes per plant, number of grains per spike, 1000 grain mass and grain yield. So, first factor was named as grain yield and yield components factor. Factor 2, which accounted 25.67 % of the total variation, was composed of plant height and plant dry mass and thus this factor was called as biomass factor. Factor 3, which accounted 15.13 % of the total variation, included specific leaf area, relative water content, proline content, chlorophyll content and osmotic potential. Because these traits were related to physiology so, this factor was named as physiological factor. On the other hand, under drought stress condition the first factor justified 36.23 % of total variation which included number of spikes per plant, number of grains per spike, 1000 grain mass. Therefore, this factor was identified as yield components factor. The second factor was composed of specific leaf area, relative water content, proline content, chlorophyll content and osmotic potential explained 24.18 % of total variation. Thus this factor was called as physiological factor. Factor 3, which accounted 18.26 % of the total variation, included plant height and plant dry mass. So, this factor was named as biomass factor. Factor 4, which accounted 13.76 % of the total variation was composed of spike length, number of tillers per plant, number of fertile tillers per plant and grain yield and thus this factor was called as growth and grain yield factor. These results showed that cultivars with the highest values of these factors had the highest values for associated traits to those factors. In general, factor analysis showed which from the factors under normal and drought stress condition, yield components factor with description of high amount from total variation was common that it showed importance of related traits to it.

Naghavi et al. (2015) used factor analysis to reduce variables in wheat cultivars and they reported four factors (growth and grain yield, grain traits, biomass and root) and two factors (grain yield and biomass) under normal and drought stress, respectively. Khayatnezhad et al. (2010) on durum wheat cultivars showed that the importance of factor coefficients characteristics of growth traits (fertile tillers and main spike length), 1000-seed mass and yield selected genotypes is desirable under drought stress. Also, Gholamin et al. (2010) showed the importance of factor coefficients related to biomass and yield components for selection of desirable genotypes under dry conditions. In other studies on bread wheat cultivars, Dawari and Luthra (1991) revealed that number of grains per spike, spike length and harvest index were the main yield components and that the selection in terms of them could improve the yield.

Table 6: Factor analysis for agro-morphological traits in wheat cultivars under normal irrigation

Traits	1	2	3	Communalities
†PH	-0.159	0.608	-0.015	0.877
PDM	0.395	0.642	0.204	0.901
SLA	-0.412	-0.003	0.508	0.887
RWC	0.305	0.199	0.621	0.931
PC	0.278	0.251	0.748	0.922
ChC	0.290	0.198	0.814	0.909
OP	-0.343	-0.078	0.567	0.912
SpL	0.902	0.204	0.312	0.941
NT	0.936	0.229	0.235	0.949
NFT	0.909	0.301	0.109	0.907
NSp	0.907	0.278	0.205	0.919
NGSp	0.831	0.290	-0.346	0.859
1000-GM	0.649	0.389	0.223	0.894
GY	0.908	0.335	0.309	0.885
Eigen values	9.71	4.98	2.33	
Proportional variance	50.43	25.67	15.13	
Cumulative variance	50.43	76.10	91.23	

† PH, PDM, SLA, RWC, PC, ChC, OP, SpL, NT, NFT, NSp, NGSp, 1000-GM and GY indicate plant height, plant dry mass, specific leaf area, relative water content, proline content, chlorophyll content, osmotic potential, spike length, number of tillers per plant, number of fertile tillers, number of spikes per plant, number of grains per spike, 1000 grain mass and grain yield respectively.

Table 7: Factor analysis for agro-morphological traits in wheat cultivars under drought stress

Traits	1	2	3	4	Communalities
†PH	-0.034	-0.173	0.798	0.309	0.893
PDM	0.128	0.109	0.856	0.356	0.904
SLA	-0.325	0.656	-0.105	-0.267	0.899
RWC	0.304	0.890	0.187	0.197	0.889
PC	0.250	0.776	0.298	0.258	0.910
ChC	0.318	0.809	0.167	0.102	0.875
OP	-0.201	0.656	0.095	-0.219	0.876
SpL	0.373	0.232	0.184	0.687	0.924
NT	0.315	0.207	0.390	0.898	0.897
NFT	0.309	0.203	0.167	0.783	0.901
NSp	0.898	0.307	0.249	0.401	0.899
NGSp	0.786	0.150	0.193	0.308	0.932
1000-GM	0.843	0.209	0.295	0.411	0.902
GY	0.256	0.247	0.145	0.913	0.882
Eigen values	4.53	4.13	2.46	2.02	
Proportional variance	36.23	24.18	18.26	13.76	
Cumulative variance	36.23	60.41	78.67	92.43	

† PH, PDM, SLA, RWC, PC, ChC, OP, SpL, NT, NFT, NSp, NGSp, 1000-GM and GY indicate plant height, plant dry mass, specific leaf area, relative water content, proline content, chlorophyll content, osmotic potential, spike length, number of tillers per plant, number of fertile tillers, number of spikes per plant, number of grains per spike, 1000 grain mass and grain yield respectively.

3.5 Cluster analysis based on extracted factors

According to the importance of all the studied traits and regarding to the correlation among traits that was effective in different factors, cultivars grouped on the basis of all factors under normal irrigation (Figure 1) and drought stress (Figure 2). According to the impact of factor coefficients cultivars were grouped according to tolerance and sensitivity under drought stress (Table 8 and 9). Cluster analysis with cutting of discriminant analysis based on the three and four factors under two conditions, cultivars grouped into the two and three groups under normal irrigation and drought stress respectively (Figure 1 and 2).

Under normal irrigation, 9 cultivars such as Urum, Sabalan, Zarin, Sardari, Alvand, Azar, Homa, Pishgam and Mahabad landrace were classified in the first cluster, forming group1. Cultivars in this cluster are linked with the highest rate to first to third factors (Table 8, Figure 1). So, these cultivars have high values for physiological traits, biomass traits and grain yield and yield components. Second group comprises 6 cultivars such as Toos, Mihan, Alamoot, Navid, Shahriyar and Zare. Cultivars of this cluster showed the lowest values for first to third factor. So, these cultivars have the lowest values for grain yield and yield components and other traits (Table 8).

On the other hands, under drought stress in the first group were placed 6 cultivars such as Pishgam, Toos, Alamoot, Homa, Mahabad landrace and Mihan. These cultivars showed average values of all factors and so cultivars of this group were named semi tolerant (semi-sensitive) (Table 9, Figure 2). Also, the second group was comprised of 3 cultivars such as Navid, Zare and Shahriyar which showed the lowest values for factor 1 to 4, so these cultivars had the lowest values of physiological traits, biomass, yield components and grain yield (Table 9). Further, third group included Sabalan, Urum, Azar, Sardari, Zarin and Alvand cultivars with the highest values for all of the traits according to factor 1 to 4 (Table 9). Generally cluster 3 and 2 were the most tolerant and the most sensitive cultivars under drought stress (Figure 2). So, cultivars of these clusters with inter-cross can be used to increase grain yield in breeding programs.

Table 8: The average of traits for achieved groups from cluster analysis based on factor analysis in 15 wheat cultivars under normal irrigation

Clusters	Factor 1	Factor 2	Factor 3
1	125.549	126.749	129.729
2	113.738	108.396	118.639

Table 9: The average of traits for achieved groups from cluster analysis based on factor analysis in 15 wheat cultivars under drought stress

Clusters	Factor 1	Factor 2	Factor 3	Factor 4
1	45.745	47.498	9.094	42.375
2	38.709	42.439	5.984	37.630
3	48.230	56.264	13.395	44.629

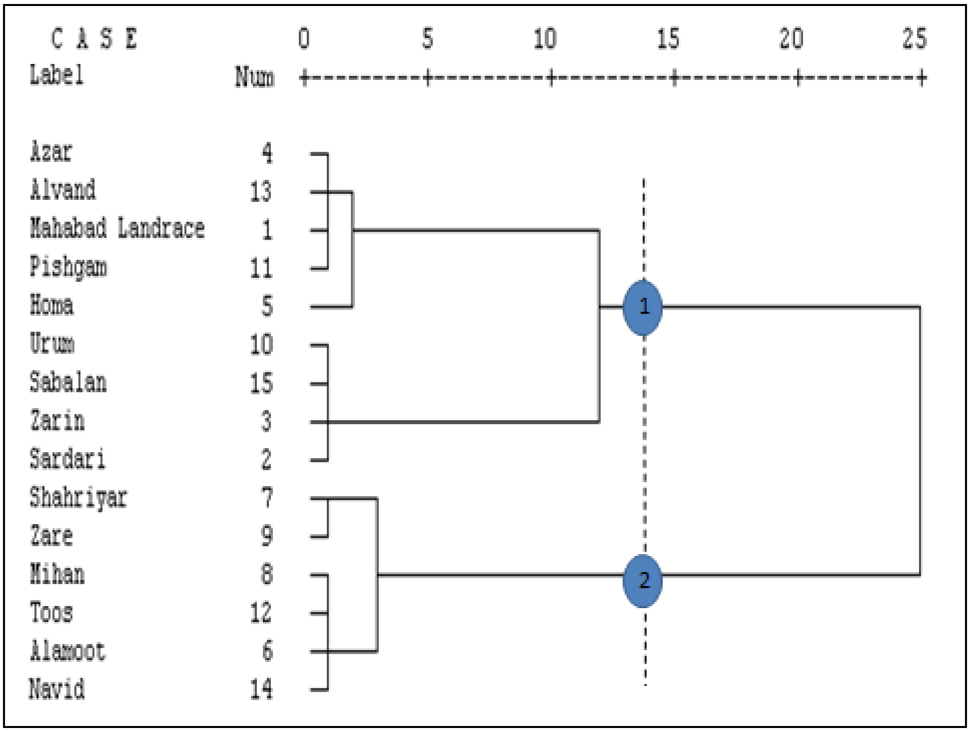

Figure1: Dendrogram for factors coefficient and cutting of discriminant analysis under normal irrigation

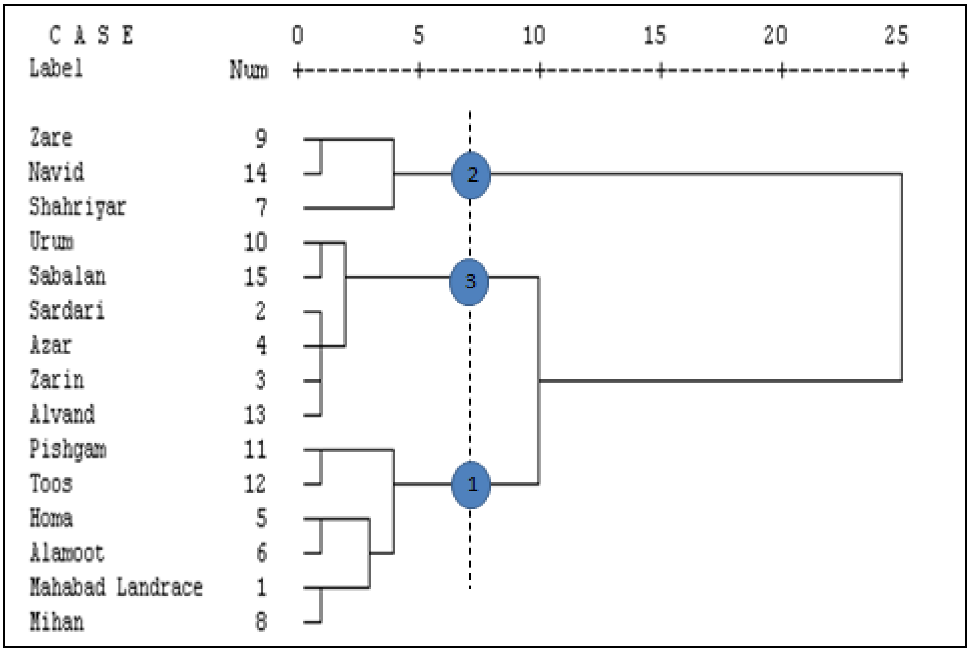

Figure 2: Dendrogram for factors coefficient and cutting of discriminant analysis under drought stress

4 CONCLUSIONS

Considering to our results, number of grains per spike and number of spikes per plant were the best criterion for improving grain yield in wheat under normal irrigation and drought stress conditions. So, screening for high values of these traits can bring increase in wheat grain yield under two conditions. Factor analysis detected three and four factors which explained 91.23 and 92.43 percent of the total variation in non-drought stress and drought stress conditions, respectively. In normal condition the first, second and third factor were identified as yield and yield components, biomass and physiological factors, respectively. While, under drought stress condition the first factor, second, third and fourth factors were named as yield components, physiological, biomass factor, growth and yield factor. Generally by cluster analysis with factors values was known "Sabalan, Urum, Azar, Sardari, Zarin, Alvand "and "Navid, Zare, Shahriyar" cultivars as the most tolerant and sensitive cultivars, respectively. Also, for further selection and breeding, parents may be selected from those clusters which had significant genetic distance for crossing in order to obtain genetic recombination and transgressed segregation in the subsequent generations. Also, it is suggested that in arid and semi-arid regions tolerant cultivars used directly.

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