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Investigation of relationship between yield and yield components of wheat under drought stress using multivariate analysis

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Abstract

In order to evaluate effects of drought stress on yield and some relevant traits of bread wheat cultivars, current study was carried out in the research field of Islamic Azad University of Karaj during 2006-2007. The irrigation schemes scheduled as main plots included the following: (T_1) 40% moisture depletion throughout the growing season (control); (T_2) 60% moisture depletion throughout the growing season; (T_3) 80% moisture depletion throughout the growing season; (T_4) no irrigation at stem elongation and continuing with adequate irrigation to the end; (T_5) no irrigation from stem elongation to the end of the growing season; (T_6) no irrigation at flowering and continuing with adequate irrigation to the end; (T_7) no irrigation from flowering to the end of the growing season; and (T_8) no irrigation from milk stage to the end; and 2 wheat cultivars [Marvdasht (V_1), Chamran (V_2)] as sub-plots. The simple correlation results showed that seed yield has a positive, significant correlation with the biomass, Harvest index, Plant height, 1000 grain weight and Spike numbers per square meter. According to results of principal component analysis an increase in the number of components was associated with a decrease in eigenvalues and its maximum at three factors which all together accounted for 70.87% of the total variation of grain yield.

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Introduction

Wheat (Triticum spp.) has been the world's most important food crop since the dawn of agriculture about10 000 years ago (Lev-Yadun *et al.*, 2000). Abiotic stresses (e.g., drought, heat, and salinity) are the major cause of grain yield loss, upward of 50% (Boyer, 1982). In the mean time drought is by far the most important environmental stress in agriculture and many efforts have been made to improve crop productivity under water-limiting conditions (Cattivelli *et al.,* 2008). Understanding plants respond to drought stress can play a main role in stabilizing crop responses under this condition. Several multivariate statistical techniques have been used in investigation on crops yield, including correlation, principle components and cluster analysis, etc. For example cluster analysis can be used to identify variables which can be classified into main groups and subgroups based on similarity and dissimilarity and principal components used to exploration and simplifying complex data sets (Leila and Al-khatibn, 2005). These methods can help to find relationship between wheat grain yield and its components under. Shahryari *et al.* (2008) after the study on 42 genotypes of bread wheat under drought stress reported that there was a positively significant correlation between grain yield with 1000 grain weight and total number of tillers per plant. Wong *et al*, (2010) during a study on sorgum reported that principal component analysis revealed 94% of variation in 10 varieties of sorghum.

Our objectives were to determine the relationship between yield and yield components to estimate effective traits on yield under drought stress in difference stages multivariate analysis methods.

Materials and methods

Description of the project site

The field study was conducted at Research Field of Islamic Azad University, Karaj Branch, Mahdasht, Karaj, Iran (35°45'N, 51°06'E, 1313 m) during 2006 and 2007. The location has a semi-arid climate with mean annual rainfall of 275 mm. The soil is clay loam with a pH of 7.6 and its salinity in 0-30 cm of soil profile is 5.55 dS m^{-1}.

Experiment design and treatments

A split-plot experiment was used based on completely randomized block design with four replications. The following irrigation schedules were used: the main plot (T_1) at 40% moisture depletion throughout the growing season (control); (T_2) 60% moisture depletion throughout the growing season; (T_3) 80% moisture depletion throughout the growing season; (T_4) no irrigation at stem elongation followed by adequate irrigation to the end of the season; (T_5) no irrigation from stem elongation to the end of the season; (T_6) no irrigation at flowering followed by adequate irrigation to the end of the season; (T_7) no irrigation from flowering to the end; and (T_8) no irrigation from milk stage (70 in Zadoks scale) to the end. Wheat cultivars including two Iranian [Marvdasht (V_1), Chamran (V_2)] were sown with a plant density of 500 plant m^2 with 15-cm row spacing.

The experimental field received 100 kg P_2O_5/h in the form of triple superphosphate, applied during deep plough in autumn. Nitrogen fertilizer was applied at a rate of 150 kg N/h in the form of urea, the first half of which was supplied during planting and the remaining half in stem elongation stage. Each genotype was planted at 7 lines with a length of 4 m and a width of 15 cm, with a distance of 1 m between the main plots, 0.5 m between the sub-plots and 3 m between replications. In order to apply drought stress chalk blocks were used to constantly control the moisture in the plots, which were regulated with the soil moisture calibration curve as shown in Figure 1. All the plots were irrigated using an installed pipeline system. The first irrigation was scheduled on 13th November just after planting and then irrigation was carried out according to defined treatment protocols.

Crop sampling and data analysis

Measurements of the four traits under study, plant height (cm), peduncle length, and the number of fertile and infertile spikelet, were carried out on 10 normal plants randomly selected from the two middle rows of each plot. In other to evaluate grain yield, 1000-seed weight (g), biomass (g), harvest index (%), spike numbers in m^2 and number of seeds per spike, two middle rows of each plot were harvested. Data analysis was done using SAS (9.1) software and means were compared using Duncan's multiple range tests at 0.05 probability level. Before statistical analysis, all data were passed normality test and were transformed were needed.

Results

Variance analysis

The results indicated that all measured traits were affected significantly by drought stress treatment (Table 1) so that the most grain yield was observed in control treatment and the lowest grain yield in T7 treatment and T2 to T8 treatments have exhibited respectively 15.7, 37.8, 13, 61, 45, 62 and 43% yield reduce in proportion to the control (results not reported here). Baloch *et al,* (2012) reported that drought stress during boot and anthrsis stages of wheat cultivars lead to significant variability for tillers/plant, seeds/spike, grain yield/plant and 1000-grain weigh . On the other hand, treatment of variety had significant effect on the harvest index, 1000 grain weight, number of seed per spike, plant height, length of peduncle, fertile and infertile spikelet numbers.

Table 1. Analysis of variance for grain yield and yield competitions for two wheat varieties sown under seven drought stress and normal conditions.

S.O.V S.O.V	df	Grain yield	biomass	Harvest index	1000 grain weight	number of seed spike-1	Spike numbers m-2	Plant height	length of peduncle	fertile spikelet numbers	infertile spikelet numbers
Replication	3	77.48	34.04^{ns}	80.75^{*}	151.05^{**}	10.62^{ns}	141012.2^{**}	96.3^{**}	29.2^{ns}	3.28^{**}	0.17^{ns}
Drought stress (A)	7	122.09^{**}	105.5^{**}	255.30^{**}	440.05^{**}	14.30^{*}	76694.5^{**}	278.1^{**}	147.2^{**}	1.47^{**}	0.55^{**}
Error	21	10.91	7.14	43.8	34.22	8.27	32154.4	9.2	45.2	0.79	0.25
variety (B)	1	25.76^{ns}	0.0043^{ns}	383.8^{**}	335.8^{**}	48.30^{**}	1344.1^{ns}	196.8^{**}	346.4^{**}	25.5^{**}	19.06^{**}
A*B	7	16.66^{ns}	3.33^{ns}	81.08^{**}	25.7^{ns}	10.20^{ns}	7583.2^{ns}	46.3^{**}	36.7^{ns}	2.9^{**}	0.39^{**}
Error	24	11.11	12.6	22.0	21.5	5.4	5.0	6.2	17.4	0.34	0.09
C.V	-	16.20	121.8	12.9	15.67	9.20	18.5	3.08	15.5	3.5	13.2

ns, *and **means non-significant, significant at 5 and 1% levels of probability, respectively

Interaction effect of drought stress and varieties were signified for harvest index, plant height and fertile and infertile spikelet numbers traits and consequently it is expected the varieties indicate different reactions to these traits.

Simple correlation

Simple correlation between grain yield and some related traits for 2 varieties of wheat in the7 levels of drought stress and non-stress conditions was calculated (Table 2). Referring to these results, seed yield has a positive, significant correlation with the biomass (0.871), Harvest index (0.672), Plant height (0.520), 1000 grain weight (0.467) and Spike numbers per square meter (0.338). Singh *et al.* (2010) reported that seed yield of bread wheat has a positive, significant correlation with the biomass.. The differential relations of yield components to grain yield may be attributed to environmental effects on plant growth (Asseng *et al.*, 2002). Biomass has a positive, significant correlation with the plant height (0.587), 1000 grain weight (0.394) and spike numbers per square meter (0.369), harvest index (0.251) and length of peduncle (0.250). Harvest index has a positive, significant correlation with the 1000 grain weight (0.387). Also 1000 grain weight has a positive, significant correlation with the plant height (0.420) and infertile spikelet numbers (0.293) Singh *et al.* (2010) reported that this trait highly significant and positive correlation with plant height and ear length. Number of seed per spike has a positive, significant correlation with the fertile spikelet numbers (0.489) and length of peduncle (0.426) and a negative, significant correlation with the infertile spikelet numbers (-0.451). Spike numbers per square has a positive, significant correlation with the meter plant height (0.593) and length of peduncle (0.316). Plant height has just a positive, significant correlation with the length of peduncle (0.420). Length of peduncle has a positive, significant correlation with the fertile spikelet numbers (0.340) and a negative, significant correlation with the infertile spikelet numbers (-0.389) and finally fertile spikelet numbers has a negative significant correlation with the infertile spikelet numbers (-0.761).

Table 2. A matrix of simple correlation coefficients (r) for the estimated two varieties of wheat in different drought stress and non stress conditions.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Grain yield (1)	1									
Biomass (2)	0.871^{**}	1								
Harvest index (3)	0.672^{**}	0.251^{*}	1							
1000 grain weight (4)	0.467^{**}	0.394^{**}	0.387^{**}	1						
number of seed spike-1 (5)	0.057^{ns}	0.018^{ns}	0.031^{ns}	-0.011_{ns}	1					
Spike numbers m-2 (6)	0.338^{**}	0.369^{**}	0.184^{ns}	-0.113^{ns}	-0.007^{ns}	1				
Plant height (7)	0.520^{**}	0.587^{**}	0.221^{ns}	0.420^{**}	0.061^{ns}	0.593^{**}	1			
Length of peduncle (8)	0.182^{ns}	0.250^{*}	0.004^{ns}	-0.005^{ns}	0.426^{**}	0.316^{**}	0.420^{**}	1		
Fertile spikelet numbers (9)	-0.020^{ns}	0.052^{ns}	-0.131^{ns}	-0.092^{ns}	0.489^{**}	0.008^{ns}	-0.018^{ns}	0.340^{**}	1	
Infertile spikelet numbers (10)	0.119^{ns}	0.015^{ns}	0.215^{ns}	0.293^{*}	-0.451^{**}	0.056^{ns}	-0.024^{ns}	-0.389^{**}	0.761^{**}	1

* and **: means that is significant at 5%, 1% level of probability. ns: Not significant.

Principal component analysis

The principal components analysis is a multivariate statistical technique for exploration and simplifying complex data sets. The ability of this procedure to transform a number of possibly correlated variables into a smaller number of variables called principal components has been demonstrated by Everitt and Dunn (1992). According to results of principal component analysis (Table 3 and Figure 2) an increase in the number of components was associated with a decrease in eigenvalues. This trend reached its maximum at three factors which all together accounted for 70.87% of the total variation of grain yield so that PC1 accounted for about 32.89% of the variation in grain yield; PC2 for 25.42% and PC3 for 12.56%. Similar results were reported by Leilah and Al-Khateeb (2005). They found in a study on wheat that three main components which all together accounted for 74.4% of the total variation of grain yield. The results showed that PC1 correlated moderately well with biomass, plant height, and harvest index. So, the PC2 correlated moderately with the number of seed per spike, and fertile spikelet numbers and a negative correlation with infertile spikelet numbers. The next component (PC3) contained 1000 grain weight and, harvest index.

Cluster analysis

The analysis drought stress treatment and wheat varieties (Figure 3) and grain yield and some related traits of wheat (Figure 4) through the average linkage method of cluster analysis has been shown. According to Figure 3 and hypothetical discriminate line, varieties in different drought levels were classified into four groups when clustering for the varieties × drought stress levels interaction effects of all ten traits. In the first group there were two varieties in non stress condition. Varieties of Marvdash and Chmran in 60% moisture depletion, during growing season (T_3) and varieties of Chamran in 80% moisture depletion, during growing season, (T_4) were classified into second group. In the third group there were varieties under short period of drought stress (except variety of Chamran in 80% moisture depletion, during growing season (T3V2)) and in the last group varieties there were varieties without irrigation from stem elongation to the end, and without irrigation from flowering to the end. On the other hand according to Figure 4 cluster 1 included grain yield/ h (y1), while cluster 2 included infertile spikelet numbers (y10), fertile spikelet numbers (y9), harvest index (y3), number of seed spike^{-1}(y5), 1000 grain weight (y4) and length of peduncle (y8). Cluster 3 included plant height (7). Cluster 4 included spike numbers m^{-2} (6) and the last cluster included biomass.

Table 3. Eigenvalue of the correlation matrix for the estimated variables of wheat under drought and normal conditions using the principal component procedure.

	Princ 1	Princ 2	Princ 3	Princ 4	Princ 5	Princ 6	Princ 7
Y1	0.499790	-0.063572	0.185132	0.170419	-.283626	-.258578	-.066369
Y2	0.463464	0.015652	0.001191	-0.236813	-.438069	-.439017	0.058823
Y3	0.322817	-0.163160	0.330847	0.675992	0.103523	0.293112	-.240758
Y4	0.307969	0.182865	0.460144	-0.476454	0.282206	0.339580	0.085974
Y5	0.058420	0.435999	0.285313	0.200029	0.445400	-.370897	0.574307
Y6	0.303490	0.073994	-.0624770	0.298530	-.004062	0.247688	0.336484
Y7	0.438854	0.069225	-.279628	-0.310099	0.195856	0.322606	0.109892
Y8	0.212768	0.402504	-.190586	-0.068379	0.454577	-.229711	-.646731
Y9	-0.001129	0.522851	0.222298	-0.015844	-.317415	0.364084	0.113006
Y10	0.054508	-0.547638	-.094129	0.026148	0.305197	-.225520	0.201549
Eigenvalue	3.28918289	2.54207377	1.25577838	0.80874924	0.74947248	0.50790528	0.44571270
Proportion	0.3289	0.2542	0.1256	0.0809	0.0749	0.0508	0.0446
Cumulative	0.3289	0.5831	0.7087	0.7896	0.8645	0.9153	0.9599

(y1) grain yield, (y2) biomass, (y3) harvest index, (y4) 1000 grain weight, (y5) number of seed spike^{-1}, (y6) Spike numbers m^{-2} , (y7) Plant height, (y8) length of peduncle, (y9) fertile spikelet numbers and (y10) infertile spikelet numbers.

Discussion

Totally our results showed that there were significant interaction effects between drought stress and variety in some traits (harvest index, plant height, fertile spikelet numbers, infertile spikelet numbers), therefore this drought stress levels in each variety will have different effect. Simple correlation showed that there was a significant positive relationship between biomass with harvest index and plant height. This subject showed that the biomass had a powerful correlation with vegetative and reproductive production of wheat. Harvest index showed a significant positive relationship with 1000 grain weight, the therefore relationship of harvest index and grain weight was more than the number of grain in each plant. Also there was a significant positive relationship between 1000 grain weight and plant height. One of the possible reasons of this issue is that there is much light absorption in the higher plants therefore they have more current photosynthesis during seed filling period. Totally the differential relations of yield components to grain yield may be attributed to environmental effects on plant growth (Asseng *et al.*, 2002).

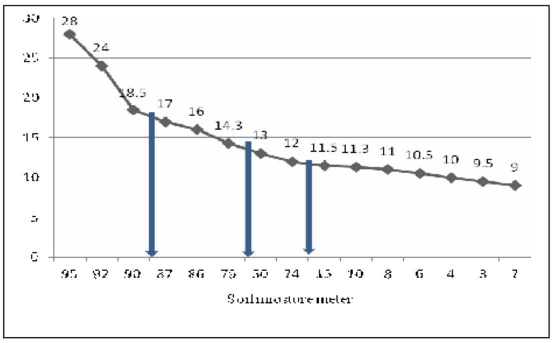

Fig. 1. Soil moisture curve and changes of electrical conductivity of gypsum blocks.

Principle component analysis showed that in PC1 effective traits on dry matter reservation and mobilization, have more important, but in PC2 effective traits on seed number (the number of seed per spike, fertile spikelet number and infertile spikelet number) are more efficacious. Also in PC3 effective traits on seed weight (1000 grain weight and harvest index) are important.

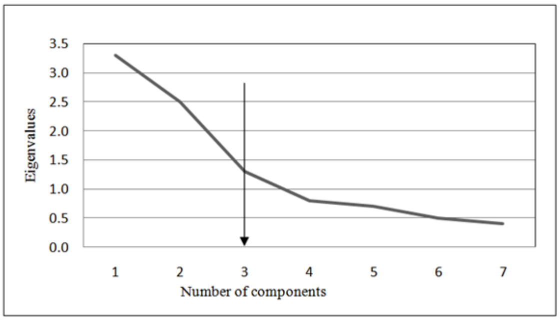

Fig. 2. Scree plot showing eigenvalues in response to number of components for the estimated variables of Wheat under drought and normal conditions.

As it was expected the cluster analysis showed that the control treatment placed in a different class in comparison with the others. On the other hand both of the varieties which had been used in this study, placed in one class in control condition (Figure 3), this result showed that these varieties for purposes of yield and yield components are genetically homogenic. According to the results that displayed in figure 3, negative effects from drought stress in flowering stage was more than severs drought stresses during lifetime of plants. This subject might prove that plants are more tolerable against continuous drought stress (even sever stress) than drought stress at sensitive stages (as an illustration in flowering stage). This is maybe because of adaptive response to water stress during lifetime. Some of the adaptive responses to water deficit are physiological and morphological changes, such as changes in plant structure, growth rate, tissue osmotic potential and stomatal conductance (Larcher, 1995).

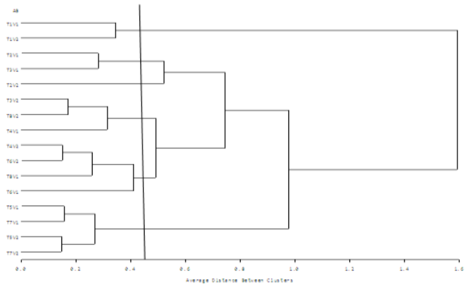

Fig. 3. Similarity levels of the estimated ten wheat characters 8levels of drought treatment and two wheat varieties using the average linkage method of cluster analysis (varieties* irrigation schemes).

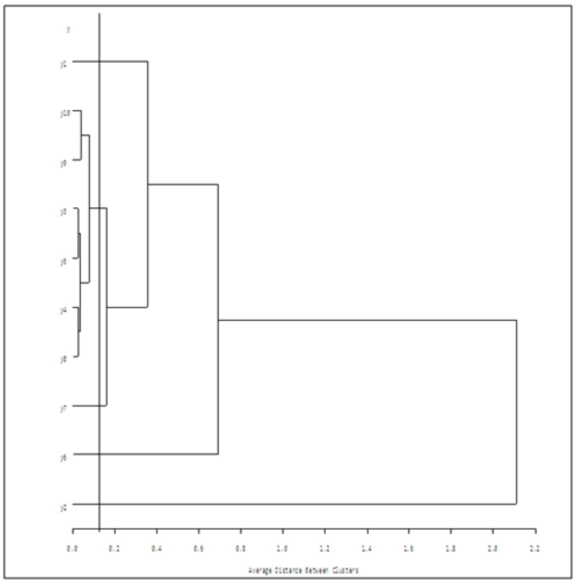

Fig. 4. Similarity levels of the grain yield and some related traits for two wheat varieties in 8 levels of drought treatment using the average linkage method of cluster analysis (grain yield and yield components)

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