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Investigation of late-season drought stress effects on ecophysiological traits and grain yield in barley lines using different statistical methods

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Abstract

In order to evaluate the relationships between ecophysiological traits and understand the direct and indirect their effects on grain yield, six advanced barley lines (MB-87-10, MB-87-14, MB-87-19, MBD-87-13, MBD-87-15 and MBD-87-16) and two checks (Nosrat and Uosef) were used in a randomized complete block design (RCBD) with three replications under normal and terminal drought stress conditions in 2012-2013 at Experimental Farm of Islam Abad, Kermanshah, Iran. The results of the present study showed that drought stress significantly ($P<0.01$) influenced on measured traits including plant height, spike length, number of grains per panicle, number of spikes per square meter, 1000 seed weight and grain yield. Also biological yield, harvest index and stem diameter significantly ($P<0.01$) decreased under terminal drought stress condition. Line MB-87-19 and MBD-87-15 had the highest and lowest grain yield, respectively. Stepwise multiple regression analysis revealed that the statistical model was fitted. The results of path analysis in normal condition indicated that days to heeding (0.78), flag leaf length(0.245) and plant height (0.201) had the highest positive direct effects on grain yield and days to maturity (-0.29) the highest negative direct effect. In terminal drought stress conditions, days to maturity (0.54), days to heeding (0.33) and plant height (0.139) had the highest positive direct effects on grain yield and flag leaf length (-0.068) the highest negative direct effect. According to these results, days to heeding, flag leaf length and plant height in normal condition and days to maturity, days to heeding and plant height in terminal drought stress condition can be used as selection indices in breeding programs.

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Introduction

Barley is a member of cereals and is being used as food and feed crop and the fourth most produced cereal worldwide is a major feed grain crop and one of the most important cereal crop grown in Kermanshah Province (Aghaei *et al.*, 2010). In agronomic and breeding studies, correlation coefficients are generally employed to determine the relation of seed yield with yield components (Anjum *et al.,* 2011; Farshadfar *et al.,* 2013). However, correlation coefficients mostly bring forth the interrelations of independent components. In plant production, the barley cultivars grain yield is a function of many parameters which have interrelations among themselves and affect the grain yield directly or indirectly. For this reason, as a tool, the correlation coefficients become insufficient in using yield components for selection criteria to improve grain yields. It is reasonable to know whether any yield component has a direct or an indirect effect on yield, so that the selection studies can be carried out successfully (Golestani and Assad, 1998; Blum, 2005). Here, the path analysis brings a solution to this problem and is used to determine the direct or indirect effect of any yield component on grain yield in relation to the other yield components. Many researches were done on wheat breeding in which both correlation and path analysis methods were simultaneously used (Dong *et al.,* 2008: Hasheminasab *et al.,* 2013); however, few studies were on barley. Some researchers reported a positive and significant correlation between plant height and grain yield (Blum, 2005; Jabbari *et al.*, 2010; Drikvand *et al.*, 2011). In many studies, it has been reported that seed number/spike has a positive effect on grain yield (Jabbari *et al.*, 2010; Drikvand *et al.*, 2011; Birol and Necmettin, 2011). Different statistical methods and multivariate analysis have been used in evaluating and modelling wheat growth and development, including simple correlation, multivariate regression, path analysis and principal component analysis (Hasheminasab *et al.*, 2012, 2013), but some of them have been used to evaluate the relationship between grain yield and ecophysiological traits related to drought tolerance. Therefore, the main objective of this study was to evaluate the effects of late-season drought stress on ecophysiological characteristics and grain yield in barley lines using multivariate statistical methods.

Materials and methods

Plant material and experimental conditions

This experiment was conducted at Experimental Farm of Islam Abad, Kermanshah, Iran. This place is in 34 degree and 8 minutes of latitude, 26 degree and 47 minutes of longitude and also had 1346 m height of sea surface and annual average rainfall is 538 mm. Two separate experiments were conducted in a randomized complete block design with three replications using six advanced barley lines (MB-87-10, MB-87-14, MB-87-19, MBD-87-13, MBD-87-15 and MBD-87-16) and two checks (Nosrat and Uosef) in both stress and non-stress conditions. Every one of the experiments was in the same conditions and the only existing difference among them was stopping the irrigation in one of the experiments at blooming stage till complete maturity stage. Seeds were hand-sown 3 to 5 cm deep on October 28 in 2012-2013 growing season. Individual plot consisted of 4 rows, 2.4 m long and spaced 5 cm apart and 60 cm between rows. The experiments were conducted as fertilizer broadcast were 200 kg ha-1 of ammonium phosphate, 150 kg/ha (the hole of phosphate and 1/3 of ammonium applied prior to planting plus an additional 130 kg ha-1 of ammonium at the two stage of growth raw rating and early heading. Weeds were also hand weeded four times during the season.

Grain yield and ecophysiological characteristics

Eight plant samples were randomly chosen from middle part of each row and were signed by labels and the border parts were left out. Then, the labelled plant samples were measured for the following traits: plant height, seed number spike, days to heeding, days to maturity, 1000 seed weight and grain yield were recorded for each plot or the mean of 10 randomly selected plants in the centre rows of each plot. The omission of outer rows eliminated potential border effects. Grain yield was measured by harvesting 1 m of the central part of each plot at physiological maturity. The plants of specific area were cut from crown with sickle and weighed and biomass was calculated. Number of clusters in a square was counted. Using 10 spikes, number of spikelet per spike and number of grains per spike were counts and calculated that selected randomly. The average weight of grain obtained after selecting 1000 grains that were weighted selected from 10 samples with 100 entries randomly.

Statistical analysis of data

The measurement data of the studied traits across two environment conditions were analyzed by the statistical methods including descriptive statistics, simple correlation coefficients, stepwise multiple linear regression and path analysis using SAS 9.2, Path 2 and SPSS 20 software's.

Results and discussion

Simple correlation analysis

The results of correlation analysis among grain yield and other traits showed that the plant height (r= 0.65**), flag leaf length (r= 0.489**), seed number spike (r= 0.539**), days to heeding (r= 0.701**) and days to maturity (r= 0.759**) had the highest significant positive correlation with grain yield (Table 1). This result was agreement with the finding of Jabbari *et al.* (2010) and Drikvand *et al.* (2011). The relationship of grain yield with other characters is shown in table 1.

Table 1. Pearson's correlation coefficients between measured traits.

Variables	GY	PLH	FLL	SNS	DH	DM	TKW
GY	1						
PLH	0.650**	1					
FLL	0.489**	0.343*	1				
SNS	0.539**	0.715**	0.253	1			
DH	0.701**	0.590**	0.321*	0.706**	1		
DM	0.759**	0.637**	0.612**	0.611**	0.480**	1	
TKW	0.025	-0.334*	0.174	-0.407**	-0.178	0.029	1

* and ** significant at 5 and 1% levels probability, respectively; plant height (PLH); flag leaf length (FLL); seed number/spike (SNS); days to heading (DH); days to maturity (DM); thousand kernel weight (TKW); grain yield(GY).

Table 2. Correlation coefficients direct and sums of the indirect effects and percentages of direct and indirect effects of some yield components on grain yield in normal and terminal drought stress conditions.

Variables	Correlation coefficient	P value	Direct effects	Sums of indirect effects	% direct effects	% indirect effects
Normal Condition						
PLH	0.476	0.000	0.209	0.27	43.1	56.9
FLL	0.365	0.000	0.239	0.13	63.5	35.5
SNS	0.228	0.000	-0.23	0.46	33.5	66.5
DH	0.704	0.000	0.75	-0.02	96.2	2.6
DM	0.238	0.000	-0.26	0.52	35.1	64.9
TKW	-0.241	0.000	-0.22	-0.03	89.0	11.0
		Terminal Drought Stress Condition				
PLH	0.577	0.000	0.141	0.43	24.9	75.1
FLL	0.447	0.000	-0.069	0.52	11.8	88.2
SNS	0.567	0.000	-0.157	0.72	17.8	82.2
DH	0.585	0.000	0.340	0.21	62.8	35.1
DM	0.712	0.000	0.530	0.14	79.1	19.9
TKW	-0.325	0.000	-0.143	-0.18	44.0	56.0

Path-coefficient analysis

Stepwise regression analysis indicated that thousand kernel weight and seed number/spike were the most important yield components. Path-coefficient analysis showed that in normal condition days to heeding (0.75), flag leaf length (0.239) and plant height (0.209) had the highest positive direct effects on grain yield and days to maturity (-0.26) had the highest negative direct effect on grain yield (Table 2). This result was agreement with those reported by Nikkhah *et al.* (2010). Under terminal drought stress condition, days to maturity (0.53), days to heeding (0.34) and plant height (0.141) had the highest positive direct effects on grain yield and also flag leaf length (-0.157) had the highest negative direct effect on grain yield (Table 2). The indirect effects of other components are shown in Table 3. According to these results, days to heeding, flag leaf length and plant height in normal conditions and days to maturity, days to heeding and plant height in stress conditions can be used as selection indicators in breeding programs.

Table 3. Path coefficient (direct and indirect effects) of the measured traits on grain yield under normal and terminal drought stress conditions.

Normal Condition						
Effects	PLH	FLL	SNS	DH	DM	TKW
Direct	0.201	0.245	-0.230	0.780	-0.290	-0.220
In direct by PLH		0.016	-0.142	0.431	-0.164	0.130
In direct by FLL	0.014		0.059	0.184	-0.079	-0.048
In direct by SNS	0.126	-0.060		0.392	-0.157	0.157
In direct by DH	0.122	0.060	-0.125		-0.146	0.069
In direct by DM	0.120	0.066	-0.129	0.376		0.084
In direct by TKW	-0.124	0.052	0.168	-0.232	0.109	
Terminal Drought Stress Condition						
	PLH	FLL	SNS	DH	DM	TKW
Direct	0.139	-0.068	-0.157	0.330	0.540	-0.143
In direct by PLH		-0.027	-0.110	0.195	0.318	0.058
In direct by FLL	0.057		-0.065	0.102	0.418	0.004
In direct by SNS	0.100	-0.028		0.298	0.286	0.068
In direct by DH	0.074	-0.019	-0.123		0.242	0.031
In direct by DM	0.080	-0.051	-0.079	0.161		0.030
In direct by TKW	-0.058	0.002	0.075	-0.083	-0.118	

Analysis of variance (ANOVA)

The results of ANOVA showed that Line MB-87-19 had the highest of yield (with an average yield of 68.62 kg/ha) and MBD-87-15 with an average yield of 46.47 kg per hectare had the lowest of yield (Table 4). In normal irrigation condition, mean comparison the interaction effects showed that Uosef with the 1000 seed weight of 43 gram is the best genotype for desired attribute (Table 4). In terms of grain yield, a significant difference was observed in the study between genotypes within probability level of %1. Also, the interaction effect varieties and irrigation was significant in five percent (5%) level of probability indicating the interaction of genotype and environment that influence on performance components and performance and performance is changed. This result is consistent with finding of other researchers (Bakhshi Khanigi *et al.*, 2006; Fardad and Azeem, 1995). So can be stated considering that yield is a quantitative attribute and is under the influence of environmental conditions, creates differences in the performance of in environmental conditions (normal and stress). One of the basic problems of farmers is to supply enough water for late fall crops because of crop growth coinciding with the summer crops. Therefore, selection will be useful for genotypes which to give acceptable performance both normal and stress conditions. Genotypes, in this respect, in addition to yield under normal condition, have potential for all traits associated with performance and can introduced as ideal genotypes under stress conditions. A team of plant breeders has proposed its stability and yield under stress conditions as the resistant varieties selection indicator. Of course, it should be kept in mind that high yield under stress conditions may not be indicative of a genotype drought resistance, individually; because the drought escape nature or the genotype ability should also be considered. Selection for high yield under non stress conditions can improve plant performance under stress conditions. But, selection for tolerance in stress conditions often leads to a decrease in yield during planting in non-stress conditions. Selection, in some cases, in non-stress conditions for high yield somewhat indirectly could be increase yield under drought stress.

Table 4. Mean comparison of the traits measured in terminal drought stress condition.

Genotype	SPR	EPR	PLH (cm)	TKW (gr)	YLD (kg/ha)
Nosrat	51 a	311.7 ab	101 a	42.3 abcd	6552 ab
MB-87-10	48 bcd	309.3 ab	94 ab	36.0 ef	6124 abcd
MB-87-14	53 ab	287.7 ab	100 ab	39.0 bcdef	5897 acde
MB-87-19	51 abc	303.7 a	92 ab	41.0 abcde	6862 a
MBD-87-13	46 cdefg	319 a	92 b	42.7 abc	5632 bcde
MBD-87-15	47 bcde	221 bc	98 ab	43.0 ab	4647 ef
MBD-87-16	45 bcdef	306 ab	96 b	43.0 ab	5168 cdef
Uosef	49 bcd	277.7 ab	98.5 ab	43.0 a	6661 abc

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