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Investigation of traits correlations and path analysis of barley (*Hordeum Vulgare* L.) seed yield under terminal drought-stress conditions

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Abstract

In order to evaluate most important traits affecting grain yield of ten barley genotypes under stress and non-stress conditions, a field experiment was conducted similarly in 2010-2011, at University research farm of Karaj Azad Islamic (35⁰ 43´ N latitude, 50⁰ 56´ E longitude, 1160 m altitude). The experiments were laid out in split plot using randomized complete block design with four replications. Main plots were in two levels; full irrigation and drought stress (terminal irrigation at ear appearance). Ten barley genotypes also used as sub plot treatments. There were significant correlation among grain yield, fertile tillers number, days to maturity, thousand grain weight, straw yield, biomass and harvest index also inoculated days to heading negatively in two conditions. Results of stepwise regression revealed that 4 traits: fertile tillers number, harvest index, Biomass and straw yield (in the irrigated condition) could explain almost 98 percent of grain yield trait variation. Results of path analysis showed that inoculated biomass had the most direct effect (1.73) on grain in stress condition. Based on obtained results it can be suggested these traits: fertile tillers number, biomass and straw yield in stress and non-stress conditions.

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Introduction

Barley is the fourth most important cereal crop and was cultivated successfully in a wide range of climate. Barley contains beta glucon which reduces blood plasma cholesterol and provides natural care for heart (Singh, 2012). This crop is potent for growing under drought and saline condition. (Nessa *et al.,* 1998). Drought is major cause of yield reduction in the world today. Breeding crops with improved drought tolerance is one approach to alleviate this problem (khaiti, 2012). Environment strongly affects yield and its components; more ever, correlation studies in barley (Rassmuosn and Cannel, 1970) and durum wheat (Garcia *et al.,* 2003) provide additional evidence of important effect that environmental variation has on the relationships among yield components. Drought stress may cause a reduction in all the yield components, but particularly in the number of fertile spike per unit area and in the number of grain per spike (Giunta *et al.*, 1993; Simane *et al.,* 1993; Abayomi and wright, 1999), while kernel weight is negatively influenced by high temperatures and drought during ripening (Chmielewski and Kohn, 2000).

Yield is a complex character and is dependent of a number of components studies on the correlation of component characters and their relative contribution are of immense value in the selection of superior genotypes (singh, 2012). Toward a clear understanding of the type of plant traits, correlation and path coefficient analysis are logical steps (kashif and khaliq, 2004). The components of grain yield are altered by adverse growing conditions as the effects of certain environmental factors on crop growth and yield differ depending upon the developmental when the so conditions occur. Path-coefficient analysis was used to investigate the main processes influencing rain yield and its formation under Mediterranean condition (Garcia del Moral *et al.,* 2005). 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 variable (Lorencetti *et al.,* 2006). Grain yield can be analyzed in terms of three primary yield components (number of spikes per unit land area, product of number plants per land area and number of spike per plant, number of grains per spike and mean grain weight). These components develop sequentially, with later-developing components under control of earlier developing ones (Hamid and Grafius, 1978; Garcia del moral *et al.,* 1991; Dofing and knight, 1992).

The study of characters association provides information about the estimates of interrelationship of various yield components in manifestation of yield. Path analysis focused direct and indirect effect of component traits on yield (singh *et al.,* 2010). Simple correlation may not provide a clear picture of the importance of each component in determining grain yield. Path coefficient analysis divides the correlation coefficients into direct and indirect effects. Its allow the separation of the direct influence of each yield component on grain yield from the indirect effects caused by the mutual relationships among yield components themselves (Garcia del Moral *et al.,* 2005). Path coefficient analysis provides means to quantify the interrelationship of different yield components and indicate whether the influence is directly reflected in the yield or take some other path ways to produce an effect. Path analysis was used for different crops to determine the direct and indirect effects of yield components (Khaliq *et al.,* 2004; Yasin and Singh, 2010, Yagdi, 2009).

Totally, based on prior studies on multivariate analysis, we can say that these methods gain accurate information about relationships of yield components and these data are valuable for understanding the reasons of plant responses to different conditions.

Our objectives were to determine the correlation between yield and yield components and direct and indirect effects of these traits on grain yield to estimate effective traits on grain yield of barley varieties for using of them in breeding programs.

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 2010 and 2011. The location has a semi-arid climate with mean annual rainfall of 251.2 mm. The soil is clay loam with a pH of 7.4 and its salinity in 0-30 cm of soil profile is 3.33 dS m^{-1}.

Experiment design and treatments

A split-plot experiment was used based on completely randomized block design with four replications. The main plot was included: 40% moisture depletion throughout the growing season (control) and no irrigation at stem elongation followed by adequate irrigation to the end of the season and sub plots was 10 barley cultivars including 10 [Zar jo, Kavir, Gohar jo, Reihan, Torkaman, Karoon, Valfajr, Dasht, Nosrat and Yoosef propertises of these varieties was explained in Table 1]. Rain fall and mean temperature of the field research was shown in Table 2.

Each genotype was planted at 8 lines with a length of 4 m and a width of 15 cm, with a distance of 3 m between the main plots, 0.5 m between the sub-plots. All varieties were sown with a plant density of 350 plant m^2.

The experimental field received 200 kg P_2O_5/h in the form of Ammonium superphosphate, applied during deep plough in autumn. Nitrogen fertilizer was applied at a rate of 135 kg N/h in the form of urea, during planting and 90 kg N/h in flowering stage.

Crop Sampling and Data Analysis

In other to evaluate grain yield three middle rows of each plot were harvested (1.35 M^2 in each plot). Other measured traits included: plant height, number of seed per spike, number of unfilled seeds, number of spike per m^2 ,1000-seed weight, grain weight of each spike, straw weight, spike weight per m^2, biomass, grain yield and harvest index. Data analysis was done using SAS (9.1) software and PATH 2 software. Before statistical analysis, all data were passed normality test and were transformed were needed.

Results and discussion

According to the results of correlation coefficients between measured traits which have been raised in normal and drought stress, presented in Table 7 and 8, the grain yield exhibited a positive correlation with number of fertile tiller, straw yield, biomass and harvest index. Also in drought condition, grain yield showed a positive correlation with length of peduncle. On the other hand, there was a negative correlation between grain yield and Days to heading in both of conditions which namely that early varieties had less grain yield than late varieties. There was a positive correlation between number of grain in spike and main spike weight and grain weight in spike. Also was fond a negative correlation between leaf area index with number of grain in spike, grain weight in spike and main spike weight in normal condition (Table 7). Leilah and Al-Khateeb (2005) reported that grain yield of wheat are a positive correlation with plant height, number of spikes/m2, 100-grain weight, weight of grain/spike, harvest index and biomass. Also there was a positive correlation between biomass with plant height and length of peduncle in terminal drought condition (Table 8).

According to Agrama (1996) step-wise regression can reduce the effect of non-important traits in regression model; in this way, traits accounting for considerable variations of dependent variables could be determined. The results of stepwise regression in normal condition showed that the most effective traits on grain yield was number of fertile spike (R-Squared= 74%). Other effective traits were harvest index, biomass and straw yield respectively. Cumulative effect of these four traits on grain yield was 98%. The same result was obtained in drought stress but in this case, harvest index was not in model (Table 3 and 4).

Table 1. Name and pedigree of genotypes used for drought assessment.

No. Genotype	Genotype	Row type	Pedigree	Origin
G1	Zar jo	6 Rows	1-28-9936	Hamedan- Iran
G2	Kavir	6 Rows	Arivat	USDA
G3	Gohar jo	6 Rows	1-30-14267	Choobak, Hamedan, Irna
G4	Reihan	6 Rows	Rihane	ICARDA
G5	Torkaman	6 Rows	Rihane04	ICARDA
G6	Karoon	6 Rows	Strain-205	USDA
G7	Valfajr	6 Rows	CI-108985	International Collection of Barley
G8	Dasht	2 Rows	Probest dwarf	France
G9	Nosrat	6 Rows	Karoon/Kavir	Iran
G10	Yoosef	6 Rows	Lingee527/Chn-01//Gustoe/4/Rhn-08/3/Deir Alla106//D171/Strain	Iran and ICARDA

Table 2. Mean of rain fall and mean temperature in 2010-2011 at Karaj during growth season.

Climatic parameters	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
Mean Temp (C°)	12.9	9.8	1.9	2.4	6.7	17.7	18.6	24.9
Rain fall	31.5	4.1	41.5	28.9	67.7	79.1	34.9	1.6

Table 3. Estimated equations for grain yield based on stepwise regression in normal condition.

Step	Regression model	R-squared
1	$Y = 2533.73 + 1.55 X_1$	$R^2 = 0.74$
2	$Y = 159.99 + 1.31 X_1 + 94.04 X_2$	$R^2 = 0.88$
3	$Y = -3255.61 + 0.35 X_1 + 126.01 X_2 + 0.24 X_3$	$R^2 = 0.98$
4	$Y = -2642.8 + 0.27 X_1 + 95.21 X_2 + 0.4 X_3 - 0.22 X_4$	$R^2 = 0.98$

X_1= Fertile Tillers Number, X_2= Harvest Index, X_3= Biomass and X_4= Straw yield.

Table 4. Estimated equations for grain yield based on stepwise regression in terminal drought stress condition.

Step	Regression model	R-squared
1	$Y= 1824.69 + 2.7 X_1$	$R^2 = 0.47$
2	$Y = 232.73 + 2.13 X_1 - 58.05 X_2$	$R^2 = 0.62$
3	$Y = -3423.46 + 0.18 X_1 + 146.69X_2 + 0.22X_3$	$R^2 = 0.97$

X_1= Fertile Tillers Number, X_2= Harvest Index and X_3= Biomass.

Understanding relationship between effective traits on grain yield is one of the most important bases in breeding programs. In this way, in addition to study on correlation between traits, recognition of direct and indirect effect of each trait is very important. Therefore conclusion of path analysis is essential.

According to this result, the greatest direct effect on the grain yield in normal condition was related to the Biomass which justifies a total of 0.79 of grain yield variations, 0.67 of which is the direct effect of this trait (Table 5). After this trait, harvest index with the direct effect of 0.50 had positive effect.

Table 5. Direct and indirect effects of some yield components on grain yield based on path analysis in normal condition.

	FTN	SY	B	HI	Total	Direct effect
Fertile Tillers Number (FTN)	-	-0.062	0.564	0.16	0.86	0.196
Straw yield (SY)	0.125	-	0.625	-0.146	0.51	-0.096
Biomass (B)	0.162	0.088	-	0.035	0.79	**0.679
Harvest index (HI)	0.062	0.027	0.047	-	0.639	**0.501
Residual						0.147

In terminal drought stress conditions, Biomass had the greatest direct effect on grain yield (0.77) (according to the findings of Singh *et al.,* 2010) and then harvest index was ordered in second ranks (0.74). Also Molasadeghi *et al,* (2011) reported that in terminal drought stress condition, biomass has a greatest direct effect on grain yield.

Table 6. Direct and indirect effects of some yield components on grain yield based on path analysis in terminal drought stress condition.

	FTN	B	HI	Total	Direct effect
Fertile Tillers Number (FTN)	-	0.395	0.251	0.68	0.033
Biomass (B)	0.016	-	-0.133	0.66	**0.755
Harvest index (HI)	0.11	-0.14	-	0.61	**0.738
Residual		0.12			

Table 7. correlation coefficients between characteristics in barley genotypes in normal condition.

Variable	GY	Gn.Sp-1	MSW	WG/S	FTN	TKW	SY	B	PH	PL	HI	LAI	DHE
Gn.Sp-1	0.006	-											
MSW	-0.02	**0.83	-										
WG/S	-0.08	**0.81	**0.95	-									
FTN	**0.86	-0.06	-0.1	-0.13	-								
TKW	0.02	0.06	-0.03	-0.05	-0.02	-							
SY	**0.51	-0.09	-0.15	-0.13	**0.46	0.006	-						
B	**0.79	-0.09	-0.13	-0.15	**0.38	0.02	**0.92	-					
PH	-0.06	-0.07	0.02	0.05	-0.13	-0.18	-0.1	-0.09	-				
PL	0.26	0.05	-0.03	-0.07	0.2	0.08	*-0.33	-0.11	*0.33	-			
HI	**0.64	0.04	0.06	-0.03	*0.33	0.02	-0.29	0.07	0.03	**0.55	-		
LAI	0.06	*-0.34	**-0.41	*-0.38	0.27	0.3	0.27	0.19	-0.19	-0.12	-0.12	-	
DHE	**-0.44	-0.09	-0.18	-0.09	*-0.39	-0.15	0.13	-0.11	0.07	**-0.56	**-0.53	0.09	-
DMA	-0.1	-0.09	-0.19	-0.17	-0.14	-0.23	-0.02	-0.05	*0.43	-0.03	-0.06	0.1	0.13

DMA: Days to Maturity, DHE: Days to Heading, PH: Plant Height, PL: Peduncel Length, Gn.Sp-1: Grain per Spike, MSW: Main Spike Weight, TKW: Thousand Grain Weight, WG/S: Weight of Grain/Spike, FTN: Fertile Tillers Number, HI: Harvest Index, B: Biomass, SY: Straw Yield, GY: Grain Yield, LAI: Leaf Area Index.

Table 8. correlation coefficients between characteristics in barley genotypes in terminal drought stress condition.

Variable	GY	Gn.Sp-1	MSW	WG/S	FTN	TKW	SY	B	PH	PL	HI	LAI	DHE
Gn.Sp-1	0.23	-											
MSW	-0.28	**0.83	-										
WG/S	-0.28	**0.84	**0.98	-									
FTN	**0.68	**-0.63	**-0.62	**-0.61	-								
TKW	0.24	**-0.64	-0.3	*0.33-	*0.36	-							
SY	**0.41	-0.25	-0.14	-0.15	**0.4	0.22	-						
B	**0.66	-0.22	-0.14	-0.16	**0.51	0.23	**0.93	-					
PH	0.21	0.2	0.1	0.07	-0.07	-0.2	*0.31	*0.35	-				
PL	**0.54	0.07	-0.007	-0.03	0.31	0.001	0.21	*0.37	**0.6	-			
HI	**0.61	-0.06	-0.19	-0.18	*0.34	0.12	**-0.42	-0.17	-0.01	*0.37	-		
LAI	-0.3	0.11	0.08	0.06	-0.07	-0.15	-0.15	-0.25	-0.09	0.15	-0.13	-	
DHE	**-0.45	-0.12	-0.11	-0.06	0.17-	-0.07	0.11	-0.1	-0.05	**0.59	**-0.56	0.06	-
DMA	0.03	-0.25	**-0.4	*-0.36	0.22	-0.03	0.13	0.08	*0.34	0.09	-0.04	0.17	0.19

DMA: Days to Maturity, DHE: Days to Heading, PH: Plant Height, PL: Peduncel Length, Gn.Sp-1: Grain per Spike, MSW: Main Spike Weight, TKW: Thousand Grain Weight, WG/S: Weight of Grain/Spike, FTN: Fertile Tillers Number, HI: Harvest Index, B: Biomass, SY: Straw Yield, GY: Grain Yield, LAI: Leaf Area Index.

Conclusion

Considering the results in most of studied genotypes relative resistance to stress conditions were shown the potential of these genotypes in stress condition. Totally from these result, we can conclude that in normal conditions, biomass and harvest index and in terminal drought stress, biomass had the highest direct effect on grain yield.

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