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Assessment of correlation and path analysis in wheat under drought stress

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Abstract

The study of relationships between plant traits particularly grain yield and its components has resulted in the selection of a components which contribute to an increase in grain yield. The objective of the present study was to investigate the relationship between grain yield and their components under drought stress conditions and identify the most effective grain yield components using 18 wheat genotypes. Correlation analysis of grain yield and its components showed that grain yield had a positive correlation with traits including agronomy score, 1000-grain weight, grain weight per spike, total spike weight and number of grains per spike. Stepwise multiple linear regression interpretation also indicated that 92% of variation in seed yield attributed to variation which arose from agronomy score, number of grains per spike, leaf chlorophyll content and 1000-grain weight. Result of path coefficient analysis showed that 1000- grain weight had the most direct effect on grain yield. Generally based on the results of correlation coefficients, stepwise multiple regression and path coefficient analysis, agricultural score, number of grains per spike, thousand grain weight and total spike weight are regarded as the most effective components on grain yield. So, it is recommended to pay more attention to these traits in the improvement programs of wheat in order to increase grain yield.

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Introduction

In recent years, population rise and occurrence of food crisis for most countries particularly developing countries and different advantages of wheat compared to other crops have turned this plant into an economical and political tool. Experts predict that the demand for wheat will increase by about 40% by 2020, so it must be produced rapidly (Rejesus *et al.*, 1996). Drought is among the most important factors restricting the production of crops such as wheat in Iran and the world (Ober and Luterbacher, 2002). This issue is more important in arid and semiarid regions in the world. The importance of the issue is clarified when it is mentioned that over one quarter of the earth belongs to arid and semiarid regions and it is estimated that about a third of plantable grounds in the world is affected with water stress conditions. Regions under drought stress are said to have less than 500 mm annual rainfall (Rajaram *et al.*, 1994). High rate of evaporation, soil unstable properties and farming characteristics along with water restriction result in decreased wheat yield in dry farming regions (Shimshi *et al.*, 1982). Grain yield in cereals is caused by cumulative effects of their components, namely, number of fertile tillers, number of grains per spike and grain weight per spike. Determination of correlation between different traits, especially grain yield and yield components and determination of their cause and effect relationships provide an opportunity to select the most appropriate components contributing to much more yield. In these types of studies selection based on simple correlation cannot lead to desired results, because correlation coefficients between the traits indicate their linear relationship between them and due to the influence of other traits they do not show the nature of relationships among them. It is possible to separate direct and indirect effects of the traits on the yield using path analysis (Bahmankar *et al.*, 2014). In a study on different varieties of wheat, the results of correlation, stepwise regression and path analysis showed that biological yield and harvest index, number of days to anthesis and peduncle length were entered into the regression model. The results also showed that biological yield and harvest index had positive direct effect on grain yield (Nur Khalaj *et al.*, 2010). Yuddin *et al.* (1997) in their study on wheat reported that number of grains per spike and 1000-grain weight was the most effective trait on grain yield (Uddin *et al.*, 1997). Result other study of different varieties of wheat indicated number of grains per surface unit was the most effective trait on grain yield (Arduni *et al.*, 2006). The purpose of the present research was to investigate relationships between grain yield and its components, determine traits affecting yield and study their direct and indirect effects on grain yield under drought stress conditions.

Materials and methods

Plant materials and growth condition

This experiment was conducted in agricultural Research Centre in Gachsaran (50° 50´ E and 30° 17´N, 710 m ASL), Iran. Gachsaran located in warm climate and possess warm to dry weather. The average annual rainfall is 480 mm (the average for thirty years). Eighteen genotypes were set to grow in a trail study of randomized completed blocks design with four replications. Each genotype was planted in a plot with 6 cultivation lines as long as 6 m and 17.50 cm line space. Recommended crop management practices such as weed killing were done with 2-4-D herbicide before stalk growth. Stress began from spike emergence and continued to the end of the season.

Studied characters and its measuring method

All genotypes were studies and measured in terms of days to flowering (DF), days to maturity (DM), agronomy score (AS), grain yield in square meter (GY), thousand grain weight (TGW), number of spikes in square meter (S/M^2), Grain weight per spike (GW/S), total spike weight (SW), number of grains per spike (G/S), chlorophyll content (CC) and grain length (GL).

Statistical analysis

Correlation coefficients were conducted using pearson correlation coefficient. Stepwise regression was used to determine cumulative effect of traits on grain yield. Then path analysis was used to investigate cause relationships and direct and indirect effects of traits on grain yield. Data analysis was conducted using SAS software 9.1.

Results and discussion

Correlation coefficients between traits

The study of simple correlation coefficients between grain yield and yield components showed a positive significant correlation between grain yield and thousand grain weight (TGW), grain weight per spike (GW/S), total spike weight (SW), agronomy score (AS) and number of grains per spike (G/S) (Table 1). The study also showed that there was highest correlation between grain weight per spike (GW/S) and grain yield. Correlation coefficient between total spike weight (SW) and grain yield was ranked secondly. Regarding the significant correlation between the mentioned traits and grain yield, it can be stated that in wheat more yield can be produced via the selection of genotypes with grain weight per spike and higher total spike weight. In another study, it was reported that grain yield had a positive significant correlation with thousand grain weight and number of grains per spike (Dokuych and Akaya, 1999). In this study, there was a positive but not significant relationship between number of spikes in square meter (S/M^2) and grain yield (Table 1). The results suggested positive significant correlation between number of grains per spike (G/S) with thousand grain weight (TGW), total spike weight (SW) and grain weight per spike (GW/S) (Table 1). These relationships represented the balance role of grain yield components. Lee la *et al.* (2005) in their study on wheat represented that there was a positive significant correlation between grain yield and thousand grain weight, number of grains per spike and total spike weight (Lee la *et al.*, 2005). Generally, grain weight per spike (GW/S) and total spike weight were of more importance in determining wheat grain yield, respectively, so it is recommended to pay more attention to these traits in order to increase grain yield.

Table 1. Study of correlation coefficient among ten characters of eighteen wheat genotypes.

Character	DF	DM	AS	GY	TGW	S/M2	GW/S	SW	G/S	CC	GL
DF	1										
DM	0/52**	1									
AS	-0/11	-0/01	1								
GY	0/02	0/2*	0/65**	1							
TGW	0/22*	0/25*	0/38**	0/66**	1						
S/M^2	0/17	0/01	-0/17	-0/07	-0/21*	1					
GW/S	0/17	0/33**	0/44**	0/75**	0/81**	0/21*	1				
SW	0/13	0/45**	0/42**	0/72**	0/71**	-0/24*	0/17	1			
G/S	0/03	0/49**	0/32**	0/56**	0/48**	-0/22*	0/71**	0/71**	1		
CC	-0/04	-0/14	0/21*	0/40**	0/07	-0/12	0/22*	0/23*	0/24*	1	
GL	-0/16	-0/15	-0/06	0/25*	0/26*	-0/02	0/07	0/1	-0/1	0/21*	1

*and ** significant at $p<0.05$ and $p<0.01$ respectively.

DF: Days to flowering; DM: days to maturity; AS: agronomy score; GY: grain yield in square meter; TGW: thousand grain weight; S/M^2: number of spikes in square meter; GW/S: Grain weight per spike; SW: total spike weight; G/S: number of grains per spike; CC: chlorophyll content; GL: grain length.

Stepwise regression and path analysis

The results of stepwise regression for grain yield as a dependent variable and other traits as independent variables showed that agronomy score by itself can justify 44% of total variation in grain yield (Table 2). Then this trait along with number of grains per spike justified 69% of total variation for grain yield. Grain length, leaf chlorophyll content, thousand grain weight were entered into the model, respectively which along with the two previous traits justified 92% of total variation (Table 2). The results showed that after adding these traits to the model, only 8% of changes had not been justified that this amount of change may be hidden in other traits. The results showed that less effective or ineffective traits were eliminated from the model using stepwise regression model. Positive regression coefficients of these traits were entered into the model suggest that these traits were effective and logical criteria for selection, which can be used in wheat breeding programs regarding heritability and their correlation coefficients with grain yield (Bahmankar *et al.*, 2014). Nurkhalaj *et al.* (2010), considering grain yield as a dependent reported that 95% out of total grain yield variation were justified by the traits entered into the regression model (Nurkhalaj *et al.*, 2010). Amini *et al.* (2008) concluded that the two traits namely biological yield and harvest index are traits which were entered into the model and justified high percentage of grain yield (Amini *et al.*, 2008). It can be said that as agronomy score in this study has been estimated based on desirable morphological and biological traits, thus the effect of biological yield was hidden in it and its entrance into regression model involves yield biological effect. Because simple correlation between the traits cannot capture the cause and effect relations, so this ambiguity was resolved using path analysis. Considering the results of stepwise regression, direct and indirect effects of the traits entered into the model on grain yield were studied using path analysis. The results showed that thousand grain weight had the most direct effect on grain yield (Table 3). Assuming other variables as constant, thousand grain weight will result in an increase in grain yield, therefore, this trait could be used to select for the sake of increasing grain yield. Indirect effect of thousand grain yield through agronomy score, chlorophyll content, and grain length was positive, but through grain weight it was negative (Table 3). Regarding correlation between thousand grain weight (r= 0.66) with grain yield, it can be concluded that this trait correlates with grain yield mainly through its direct effect. Result demonstrated that agronomy score, number of grains per spike, grain length and chlorophyll content exerted the most direct effect on grain yield respectively (Table 3). Golabadi *et al.* (2011) reported that thousand grain weight exerted the most direct effect on grain yield. Similar results were also reported in Densik *et al.* (2000), Dalival and Suchin (2003) and Okuyama *et al.* (2004), which all verified great importance of grain weight in grain yield. Studies showed that indirect effect of grain length on grain yield had been more than its direct effect (Table 3), so regarding this issue, this trait can be selected through its indirect effect. The results of path analysis also suggested that leaf chlorophyll content had the least direct effect on grain yield. As the indirect effect of leaf chlorophyll content through thousand grain weight on grain yield was more than its indirect effect through other traits, it can be said that the more the chlorophyll content, the more the ability to produce and assigning more photosynthetic substances will be and this process lead to increasing weight and grain yield.

Table 2. Equations of stepwise multiple regression of grain yield and ten morpho-phenological characters in eighteen wheat genotypes.

Regression equations	Coefficient of partial determination	Cumulative coefficient determination
GY= -4.25+0/663AS	0/44	0/44
GY=-12.2+0/467AS+ 0/016G/S	0/25	0/69
GY=-14.2+0/32AS+0/15G/S+0/28GL	0/12	0/81
GY= -15.6+ 0/25AS+ 0/12G/S+0/15GL+0/08CC	0/06	0/87
GY= -18.6+ 0/22AS+ 0/11G/S+0/12GL+0/06CC+0/20TGW	0/05	0/92

GY: grain yield in square meter; AS: agronomy score; G/S: number of grains per spike; GL: grain length; CC: chlorophyll content; TGW: thousand grain weight.

Table 3. Direct and indirect effects of remained characters in the regression model on grain yield in wheat genotypes using path coefficients analysis.

Characters	Correlation	Direct effects	Indirect effects via				
			AS	G/S	TKW	CC	GL
AS	0/65	0/522	-	0/06	0/013	0/022	0/033
G/S	0/56	0/50	-0/015	-	0/14	-0/1	-0/064
TGW	0/66	0/61	0/025	-0/06	-	0/03	0/055
CC	0/40	0/30	0/01	0/045	0/08	-	0/055
GL	0/44	0/21	0/04	-0/05	0/22	0/01	-

AS: agronomy score; G/S: number of grains per spike; TGW: thousand grain weight; CC: chlorophyll content; GL: grain length.

Conclusion

Determining correlation between grain yield and grain yield components resulted in the determination of the most important components leading to increased grain yield. As correlation coefficients between the traits represented only linear relationship between them and did not show the nature of relationships between them due to the influence of other traits, so ambiguity was resolved through path analysis. Generally, based on the results of correlation coefficients, stepwise regression and path analysis, agronomy score, number of grains per spike, thousand grain weight, and total spike weight are regarded as the most important effective components on grain yield. Also the main cause of differences in genotypes yield can be attributed to differences in these traits. Thus, it is recommended to pay more attention to these traits so as to increase grain yield in wheat breeding programs.

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