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Separating correlation coefficients into direct and indirect effects of important morphological traits on grain yield in 28 bread wheat genotypes under terminal drought stress

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ABSTRACT: Analyzing the correlation of various traits and components of grain yield is a very important issue in selection and breeding programs for genotypes, thus an experiment was conducted using 28 bread wheat genotypes in the form of completely randomized blocks design with two replications in order to investigate the correlation of various traits with wheat grain yield under terminal drought stress and to determine the contribution of those traits with maximum effect on grain yield and also to explore the direct and indirect effects of grain yield on its components and vice versa. Results from variance analysis were indicative of a significant difference between study genotypes in terms of plant height, biological yield, grain number per spike, spike length, spike weight, days to anthesis, days to heading, days to maturity, grain filling period, ratio of Peduncle to height, spike number/m^2 and grain yield. In studying the simple correlation of traits of grain yield with traits of biological yield, traits such as spike weight and spike number/m^2 produced a positively significant correlation, in addition, apart from traits such as fertile tiller, days to anthesis and harvest index all other traits had a positively insignificant relation with grain yield. Results of step by step regression indicated that spike length, spike weight and spike number per m^2 with a description coefficient of as much as 0.73 accounted for the most part of grain yield changes. Path analysis of grain yield and its components indicated that 1000 grain yield had the highest direct effect (0.629) on grain yield, and after that spike number per m^2 had positively direct effect (0.573) on grain yield. Also, the direct effect of grain number per spike on yield was positive (0.457). The indirect effects through these traits don't play a major role on grain yield. Results from this study are indicative of the fact that traits such as 1000 grain weight and spike number per m^2 can be considered criteria for selecting productive bread wheat genotypes.

***Keywords*:** bread wheat, morphological traits, path analysis, simple correlation, step by step regression

INTRODUCTION

Wheat with the scientific name of *Triticum aestivum* is the most important crop in the world. As a result of its wide range and high adaptability and also the various usages of this crop in human feeding it is known as the most important crop in the world particularly in developing countries and it accounts for approximately 20% of world's

food sources (Mollasadeghi et al., 2011) and has always been of interest as the raw material for bread preparation, wheat and bread as the symbol of God's blessing have been highly respected and it has been considered a misdeed to squander it. Although, currently there are various types of crops being planted all over the world and people rely less upon wheat for their feeding, this strategic crop is being focused upon by world people and various investigations are being conducted to improve its quality and quantity (Poursaleh, 1994).

Hence, improving wheat grain yield through breeding and improving yield components are among the most efficient methods in breeding programs, thus studying the relations between yield components and yield plays an important role in this context. Analysis of path coefficients is a method for separation of correlation coefficients into their direct and indirect effects through other traits and can provide useful information about the relations between traits and how they are affected by each others. The contribution made by each component of yield to account for grain yield can also be affected indirectly by rest of the components (Heydari et al., 2008). (Khan et al., 1999) after investigating the correlation between the traits of bread wheat showed that there is a high correlation between grain yield and grain number per spike, 1000 grain weight and harvest index. In an investigation on vernal wheat (Goyuta and Chatruydi ,1995) showed that harvest index, plant height, date of maturity, biological yield and date of flowering had a direct effect on grain yield. (Moghaddam et al .,1997) showed in their study that grain number per spike and 1000 grain weight produced high correlation with grain yield and had a highly significant direct effect on this trait. (Mondal et al., 1997) concluded from the path coefficients in path analysis conducted on 99 bread wheat genotypes in India that grain number per spike, 100 grain weight and tiller number per plant had a direct effect on grain yield, whereas traits such as height and date of maturity had a negatively direct effect on grain yield. (Bakhit et al., 1989) by examining the correlation and path analysis in Durum wheat in Egypt showed that spike number per plant had the highest direct effect on grain yield. (Dakioku and Akaya, 1999) by conducting path analysis on wheat genotypes for yield and its components reported that spike number per m^2 and grain weight per spike had a positively direct effect on grain yield and grain number per spike had a positively indirect effect on yield through grain weight.(Hukasa and Suluvari, 1999) by studying the relation between production and some quantitative traits of hard wheat by path analysis showed that plant height, period of vegetative growth and mean spike weight had direct effect on yield, whereas traits such as leaf area, fertile tiller number, spike length, spikelet number, harvest index and leaf angle had indirect effect on yield.

(Mohammadi Gonbad et al. ,2010) by exploring the relations between yield and its components in bread wheat genotypes under condition of heat stress showed that in a favorable conditions spike number per m^2 had the highest positively direct effect on grain yield, whereas in an unfavorable condition biomass had the highest positively direct effect on grain yield among the study traits.

(Zakizadeh et al., 2010) showed in their study that the greatest direct effects on grain yield belonged to traits such as spike number per m^2, grain weight per spike and biological yield.(Ahmadizadeh, 2010) by path analysis and examining the correlation during an investigation conducted on genetic variation of local masses of durum wheat in terms of antioxidant activities and some of physiological traits under drought condition showed that under these conditions plants being selected based on traits such as grain number per spike, plumule length (in mean stress), 1000 grain weight, total tiller number and stem length (in intensive stress) and damage on membrane (20% polyethylene glycol stress) produce a high amount of yield.

(Mollasadeghi ,2010) by studying the correlation and path analysis of bread wheat showed that the highest direct effect belonged to grain number per main spike, whereas the lowest one belonged to grain number per secondary spikes. The highest positively indirect effect belonged to grain number per main spike that was controlled through grain number per secondary spikes, whereas the highest negatively indirect effect belonged to grain number per main spike that was controlled through 1000 grain weight per main spike.

(Mollasadeghi et al., 2011) after an investigation conducted on correlation and path analysis of morphological traits for 9 bread wheat genotypes under the condition of terminal drought stress reported that grain yield had a positively direct effect on harvest index, whereas straw yield had a negatively direct effect on harvest index. In addition, among traits effective on grain yield, four traits namely grain number per spike, grain weight, 1000 grain weight and biological yield had the highest positively direct effect on grain yield, whereas three traits namely spike length, spike weight and biological yield had the highest direct effect on straw yield.

(Mollasadeghi and Shahryari ,2011) in an investigation on relations of some of the most important morphological indicators with grain yield demonstrated that the highest direct effect on grain yield belongs to biological yield (2.143) followed by weight of main spike (0.129), they claimed that biological yield and weight of main spike can be used as criteria for selection aimed at improving the yield of wheat grain.

This research was aimed to find direct and indirect effect of some morphological traits on wheat yield in facing to end seasonal drought of Ardabil region.

MATERIALS AND METHODS

This investigation was conducted on 28 bread wheat genotypes under the condition of terminal drought stress as a completely randomized blocks design with two replications in the Research Farm of Agriculture, Islamic Azad University, Ardabil Branch, Iran in 2006-2007 farming year. 28 study genotypes (Table 1) were prepared from Agronomical Research Center of Ardabil. Operations to prepare the land included plowing after the harvest of preceding crop, one time disking, two times perpendicular leveling, application of fertilizer and furrowing. Each genotype was sown in a plot measuring 0.6 × 1.2 m^2, which by deleting 0.5m from each ends the harvest area was 6m^2. Quantity of seed usage was determined based on 450 seeds/m^2 for each variety. The irrigation was done in flooding manner. To apply drought after flowering two times of irrigations were deleted.

After measuring and taking notes about vegetative traits and calculating the traits associated with yield, variance analysis was conducted and coefficients of simple correlation between all the traits were estimated and those traits with the highest effect on grain yield were indentified using step by step regression. Finally, under the basis of path coefficients based on simple correlation it was determined how the traits and yield components of grain affect each other and the cause and effect reasons were presented. Study traits in this investigation included plant height, fertile tiller number, infertile tiller number, biological yield, 1000 grain weight, grain number per spike, node number, spike length, days number to anthesis, days number to heading, days number to maturity, grain filling period, ratio of peduncle to height, spike number per m^2, harvest index and grain yield. MSTAT-C, SPSS-15 and Minitab-15 software were used to analyze the data and LSD test was used to compare the means of each trait at 5% probability level. In addition, the related diagrams, graphs and shapes were drawn using Excel and Snagit-8 software.

Table 1 . genotypes sown in 2006-07 farming year

Number	Genotype	Number	Genotype
1	Appolo/90 zhong 87	15	SABALAN/4/VRZ/3/
2	Mv 17/Zrn	16	ATAY/GALVEZ87
3	NVd/Gaspard	17	LFN/STDY//LOV24(ES8424)/5/
4	Shahriar	18	PYN/BAU/3/AGR1/BJY//VEF
5	Viking/5/Gds/4/Anza/3/Pi/Nar//Hys/6/Spn/Mcd//	19	Toos
6	Viking/5/Gds/4/Anza/3/Pi/Nar//Hys/6/Spn/Mcd//	20	Cross Shahi
7	Aghbugda/90Zhong87/4/Spn/Mcd//Cama/3/Nzr	21	Fenkan
8	Bkt/90-Zhong 87	22	Gasgogne
9	Bkt/90-Zhong	23	Bezostaya
10	Alvd/90-Zhong 87	24	Sardari
11	Apollo/Alvd/4/Spn/Mcd//Cama/3/Nzr	25	Sabalan
12	Mv 17/Bcn88	26	Azar2
13	SARDARI-HD39/6/SN64//SKE/2*ANE/3/SX/4/BEZ/5/SERI	27	Agosta
14	SARDARI-HD39/6/SN64//SKE/2*ANE/3/SX/4/BEZ/5/SERI	28	Gaspard

RESULTS AND DISCUSSION

Results from simple variance analysis for 17 traits of bread wheat showed (Table 1) that there is a significant difference between genotypes in terms of traits such as plant height, biological yield, grain number per spike, spike length, spike weight, days to anthesis, days to heading, days to maturity, grain filling period, ratio of peduncle to height, spike number per m^2 and grain yield, at 5% and 1% probability levels. Most of the traits had a high range of changes which was indicative of high genetic variation among these genotypes. During the investigation on simple correlation between traits of grain yield with traits of biological yield, spike weight and spike number per m^2 produced a positively significant correlation, in addition, apart from traits such as fertile tiller, days to anthesis and harvest index all the other traits had a positively insignificant relation with grain yield.

Variable with significant effect which remained in the equation, included: spike length, spike weight and spike number per m^2 (Table 2). Corrected description coefficient in standardized model was as high as 0.73 which represents that 73 per cent of the changes in yield took place by abovementioned variables. The highest regression coefficient belonged to 1000 grain weight while the regression coefficient for spike number per m^2 and grain number per spike were also positive. These three traits can be designated as traits effective on grain yield.

(Vaezi ,1994) claimed that the traits such as biological yield, harvest index, 1000 grain weight, straw yield and plant height are effective on grain yield through step by step regression. In the investigation conducted by Naghavi et al. (2002) grain number per spike had the highest regression coefficient and individually accounted for 82% of yield changes. After that, 1000 grain weight followed by spikelet number per spike, were introduced into the model and finally these three variables accounted 94% of yield changes. (Moghaddam et al., 1997 and 1998) by conducting two separate investigations studied wheat native to the Southeast and Southwest of Iran and after doing analysis, they found a significant regression for traits such as days number to flowering, plant height, spike number per plant, grain number per spike and 1000 grain weight. (Mass et al., 1996) after doing a phased regression analysis for wheat demonstrated that grain yield is dependent upon the number of fertile tiller produced by each plant. (Golparvar et al., 2002) after a study on 567 bread wheat genotypes concluded that traits such as grain number per plant and grain yield per spike had the highest positively direct effect on grain yield of plant, whereas the trait of grain number per spike had the highest negatively direct effect on it. (Afyoni and Mahluji ,2005) after conducting phased regression analysis on 42 lines and varieties of bread wheat demonstrated that traits such as grain filling period, grain number per spike, spike number per m^2 and plant height were introduced into the model earlier than other traits and were the most effective traits on grain yield. (Zakizadeh et al., 2010) in an investigation titled as examining the genetic variation and relation between various traits and grain yield in bread wheat genotypes based on phased regression, realized that biological yield, grain weight per spike, spike number per m^2 were among the most important components of yield and made more effective contribution to grain yield.

Table 2 . standardized regression coefficients and description coefficients of traits associated with grain yield in 28 bread wheat genotypes

Traits	Standardized Coefficients	t	sig	VIF
	Beta			
spike number per m2	0.576	2.790	0.01	1.712
1000 grain yield	0.641	3.082	0.005	1.739
Seed number per spike	0.458	2.864	0.009	1.029

Grain yield is a very complex feature resulting from the process of plant growth. Grain yield resembles a primary function where yield components to some extent are related to each other in its improvement (Pandy and Torrie, 1973). Adams ,1967) based on studies which he conducted on balancing the yield components in so many crops concluded that grain yield is a result of interaction between numerous genes and environment and for this reason direct selection has not proven so successful for that and does lead to remarkable increase in yield and so that the selection for yield components has been suggested as a solution for evermore progress in yield increase. Unfortunately, negative correlations between yield components lead to trade off between them on selection. Although it is important to estimate the correlation between traits and yield, the simple correlation coefficients by itself doesn't completely specify the nature of relation between traits. Thus, path analysis was used to identify direct and indirect effects of traits effective on grain yield.

Yield improvement of wheat grain through breeding and improvement of yield components are among the most efficient methodologies in breeding programs (Sidwell et al., 1976). Thus, investigating the relations between yield components and yield plays an important part in this context. Path analysis is a way to separate correlation coefficients into direct and indirect effects of traits and can provide useful information about the relations between traits and how they interact with one another (Dofing and Knight, 1992). Results from path analysis conducted to understand the cause and effect relations between dependent variables (grain yield) and other remaining traits in regression model as dependent variables have been given Table 3 and Fig. 1. Path analysis introduced in 1956 by Lee, has been widely used to dissolve the correlation between yield components in barley, wheat, rice, tobacco, millet, peanut and corn (Golparvar et al., 2002).

Based on this analysis, 1000 grain weight had the highest direct effect (0.629) on grain yield, followed by spike number per m^2 which had the highest positively direct effect (0.573) on grain yield. In addition, the direct effect of grain number per spike on yield was as much as 0.457. Indirect effects through these traits are not of so

importance in grain yield.(Aly and El-Bana ,1994) also indicated through path analysis on yield components of bread wheat and in various levels of Nitrogen fertilizer that spike number per m^2, grain number per spike and 1000 grain weight accounted for 98.9 of yield changes and claimed the highest value of direct effect belongs to spike number per m^2.

S. O. V	df	Mean of Squares								
		Plant height	fertile tiller number	infertile tiller number	Biological yield	1000 grain yield	Seed number per spike	node number	Spike length	spike weight
Replication	1	6.311*	0.018	0.161	4.6*	60.071	265.79*	3.018**	2.953*	0.915*
Genotype	27	355.701**	0.965*	0.706	1.474*	126.149	133.304*	0.409	1.507**	0.729**
Error	27	1.696	0.536	0.494	0.667	81.343	63.008	0.277	0.511	0.25
C. V (%)		1.73	25.66	21.04	18.12	16.38	22.56	15.43	8.9	18.35

* and ** Significantly at p < 0.05 and < 0.01, respectively

S. O. V	df	Mean of Squares							
		days number to anthesis	days number to heading	days number to maturity	grain filling period	ratio of peduncle to height	spike number per m2	Harvest index	Grain yield
Replication	1	7.875*	14**	5.786	1.786	0.006	3536.16**	1.143	29865764.6**
Genotype	27	7.161**	8.360**	18.458**	8.489	0.1*	1361.39**	63.143	4490554.3**
Error	27	1.319	1.63	4.638	6.934	0.005	170.42	63.069	1551428.68
C. V (%)		0.53	0.59	0.84	6.09	18.92	2.69	18.75	23.13

* and ** Significantly at p < 0.05 and < 0.01, respectively

Traits	Direct effect	Indirect effect through			Total correlation
		Seed number per spike	spike number per m2	1000 grain yield	
Seed number per spike	0.457	-	-0.005	-0.079	0.374*
spike number per m2	0.573	-0.004	-	-0.409	0.162
1000 grain yield	0.639	-0.057	-0.367	-	0.216

Residual effect = 0.27

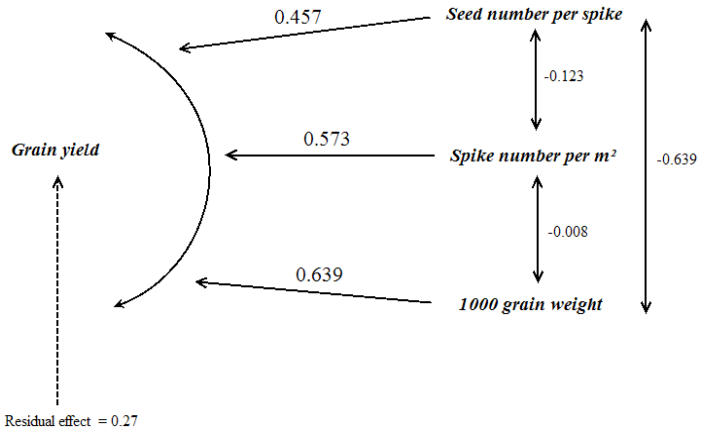

Figure 1 . Diagram of path coefficients for describing relations between yield and various traits of bread wheat, one direction arrows indicate the direct effects whereas bidirectional arrows indicate phonotypical correlation coefficients between dependent traits

(Naghavi et al., 2002) claimed after their investigations that among the studied traits grain number per spike have the highest direct effect on yield, followed by 1000 grain weight which have the highest positively direct effect

on spike yield, whereas the spikelet number only has the high positively indirect effect on yield through grain number per spike. (Heydari et al., 2007) demonstrated that grain number per spike had the highest positively direct effect on grain yield over the two years of evaluation. (Mobser et al., 2000) by examining the path analysis for grain yield of barley expressed that grain number per spike with a direct effect of 1.36 is considered the most important component effective on grain yield. In addition, the direct effect of spike number per unit area and grain weight was also positive. (Mohammadi ,2000) after studying the relation of yield with its own components in 600 native bread wheat genotypes of Iran demonstrated that the highest direct effect on grain yield belongs to 100 grain weight trait. (Tarinejad ,1998) reported that the direct effect of plant height on grain yield was negative and negligible (-0.051), and argued that due to the positively direct effect of traits such as grain number per main spike, 1000 grain weight per main spike on grain yield, selection for each of either of these traits will lead to increased yield. Moghaddam et al. (quoted by Tarinejad, 1998) reported that the direct effect of three main yield components on grain yield was positive in native masses of Southeastern Iran. (Basirat, 1991) declared that the highest direct effect on grain yield belongs to grain number per spike. (Ahmadizadeh ,1998) reported that the direct effect of 1000 grain weight and spike length on yield was positive.

Results from this experiment suggest that traits such as 1000 grain yield and spike number per m^2 can be criteria to select productive bread wheat genotypes. Nonetheless, in selection programs also we can use traits such as yield production speed, grain number per spike, biological yield and harvest index to improve grain yield of wheat.

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