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THE CORRELATION AND PATH COEFFICIENT ANALYSIS FOR YIELD AND SOME YIELD COMPONENTS OF DURUM WHEAT (*TRITICUM TURGIDUM* VAR. *DURUM* L.) IN WEST ANATOLIA CONDITIONS

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Abstract

A study was carried out in 1998-1999 and 1999-2000 growing seasons with 7 different "durum wheat" genotypes under West Anatolia conditions. The correlations among plant height, grain number per spike, grain weight per spike, 1000 grain weight, test weight and grain yield as well as direct and indirect effects of those traits on the grain yield were investigated using Path analysis. Grain number per spike, 1000-grain weight, plant height and test weight had significant direct effect on grain yield. It was concluded that these characteristics could be important selection criteria in durum wheat breeding studies.

Introduction

Grain yield in wheat (*Triticum* L.) is the results of a number of complex morphological and physiological processes affecting each other and occurring on different growing stage of vegetation period. Some yield components significantly affect grain yield through effects at different growing stages, from sowing to the harvest. Many of earlier studies indicated that plant height, the number of grains per spike, the grain weight per spike, 1000 grain weight and test weight were primary components of grain yield in durum wheat (*Triticum turg.* var. *durum* L.) [Hamid & Grafius (1978); Slafer & Andrade (1991); Simane *et al.,* (1993); Royo (1997); Royo & Tribo (1997); Kumar & Hunshal (1998); Denčić *et al*., (2000); García del Moral *et al*., (2003)]. In addition, Knapp & Knapp (1978); Shah *et al*., (1994) reported that of the three grain yield components- SPU, KPS and Grain weight (KW)- SPU and KPS generally are the most important determinants of grain yield. Therefore, one needs to know more about these traits and how they affect grain yield so one can breed new genotypes that have high yields (Ahmed *et al*., 2003).

In wheat, many breeders try to explain the relations between grain yield and agronomic and morphological traits by using simple correlation coefficients. Although correlation coefficient is very important to determine traits that directly affect grain yield, they are insufficient to determine indirect effect of these traits on grain yields (Bhatt, 1973; Mebrahtu *et al*., 1991). These situations are more common in cereals, because of yield traits that occur at a different growing stage and affect each other, especially where early occurring traits influence later traits (Doffing & Knight, 1992). There was a dynamic balance among yield traits, which prevent improvement of grain yield through selection for just one yield trait (Grafius, 1972).

It has been suggested that yield components have either a direct or indirect effect on grain yield or both. Therefore, it was essential to determine the effects of yield components on grain yield. Consequently, path coefficient analysis is the most common statistical method used for this purpose. Path coefficient analysis is a reliable statistical technique, which 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 pathways to produce an affect (Khaliq *et al*., 2004). Since path-coefficient analysis was applied by Dewey & Lu (1959) on crested wheat grass, this technique has been followed extensively to facilitate selection in various crop. Path coefficient analysis divides the correlation coefficients into direct and indirect effect. Thus, it is possible to calculate both direct and indirect effect of yield components on grain yield through the other components. In Path analysis can be used to calculate the quantitative impact on yield of direct or indirect effect caused by one or the other components. In addition, Dewey & Lu (1959) reported that the advantage of path analysis is that it permit the partitioning of the correlation coefficient into its components, one component being the path coefficient that measures the direct effect of predictor variable upon its response variable; the second component being the indirect of a predictor variable on the response variable through another predictor variable. Agronomist in wheat (Altinbas & Sepetoglu, 1993; Bhatt, 1973; Fonseca and Patterson, 1968; Weigand *et al.*, 1981; Gebeyhou *et al*., 1982a and b; Borojevic & Willams, 1982; Mou, 1990; Güler *et al*., 2001; Ahmed *et al*., 2003; Ulukan *et al*., 2003 and Khaliq *et al*., 2004) have commonly use path coefficient analysis to explain clearly the relations among yield components.

In agriculture, path-coefficient analysis has been used by plant breeders to assist in identifying traits that are useful as selection criteria to improve crop yield (Dewey & Lu, 1959; Milligan *et al.*, 1990; Ahmed *et al*., 2003; Garcia del Moral *et al*., 2003; Khaliq *et al*., 2004).

The aim of this study, carried out with 7 durum wheat genotypes was to use the path coefficient analysis to determine the direct and indirect effects of plant height, grain number per spike, grain weight per spike, 1000 grain weight and test weight on grain yield under West Anatolia conditions.

Materials and Methods

The research was carried out in the fields of Research and Application Centre of Faculty of Agriculture, Uludağ University during 1998-1999 and 1999-2000. The experimental area is located in the transitional zones of the country. Meteorological data for Bursa Province where the experiment was conducted for 1998-1999, 1999-2000 and long term are given in Table 1.

Average temperatures for the study period were 14.7^{o}C on an annual basis and average relative humidity was 68%. The long term annual precipitation was 699 mm, most of the precipitation occurred in winter and early spring. Late spring and summer rains are limited and erratic in this region. During growing season (November-June) in the years 1998-1999 and 1999-2000 growing season, total rainfall were 557.6 and 553.8 mm, respectively (Anon., 2001). The soil of the trial site is clay, pH is neutral (7.6), low organic matter (1.6%), high quantities of usable N and K.

Seven durum wheat breeding lines derived from 11 different cross populations and developed at the Department of Field Crops of Agriculture Faculty were evaluated in a randomized complete block experimental design with three replications at the Research and Application Centre. Gediz-75 cv. grown widely in the region was used as control. Grain was planted with plot drill @ 500 grains m^{-2} on 4-9 November each year. Each plot size was 1.2 x 5 m = 6 m^2, consisted 8 rows, spaced 17.5 cm apart. Nitrogen (in the ammonium nitrate) and phosphorus (in the form of triple super phosphate) were applied @ 150 and 50 kg ha^{-1}, respectively, in both years. The complete dose of phosphorus with 5 kg N^{-1} was applied as basal at planting and 5 kg N^{-1} at spike initiation. A herbicide was applied each year at the tillering stage for weed control.

Table 1. Value of temperature and precipitation belonging to wheat vegetation period of trial years 1999, 2000 and long-term average in Bursa.

Months	1999		2000		The mean of long-term	
	Temperature C°	Precipitation mm	Temperature C°	Precipitation Mm	Temperature C°	Precipitation mm
November	11.6	94.0	10.9	89.9	12.5	75.4
December	6.8	84.9	10.2	60.9	7.6	101.8
January	6.8	35.4	3.3	29.0	5.3	94.4
February	6.5	167.8	5.2	104.6	6.2	77.5
March	8.9	63.9	7.6	95.6	8.3	68.8
April	14.5	32.9	15.0	108.8	12.9	60.0
May	19.0	4.5	17.7	48.9	17.7	52.4
June	22.6	74.2	21.8	16.1	22.1	30.3
Mean	**12.1**		**11.5**		**11.6**	
Total		**557.6**		**553.8**		**560.6**

Table 2. Grain yields (kg ha^{-1}) of durum wheat lines and control variety.

Line No.	Lines	1998-1999 F8	1999- 2000 F9	Mean
30	Ambral x Çakmak-79	3840	6726 **a**	5283 **a**
26	Ambral x Çakmak-79	3850	4652 **e**	4251 **e**
36	Ambral x Çakmak-79	3340	5543 **c**	4442 **d**
28	Sham x Santa	4130	4794 **d**	4462 **d**
33	Gediz-75 x Çakmak-79	3667	5969 **b**	4818 **b**
44	Japiga x Gediz-75	3747	4807 **d**	4277 **e**
Control	Gediz-75	3803	5558 **c**	4681 **c**
	Mean	**3739**	**5148**	**4443**

Plant height, grains number per spike, grain weight per spike, 1000 grain weight and test weight were measured in 10 randomly selected plants per plot. The matured plants were harvested with HEGE-125 Combine on 11 July. The grain yield were calculated from each plot.

Analysis of variance was performed on morphological measurements and yield data using MINITAB (University Texas, Austin) and MSTAT-C (Version 2.1 Michigan State University, 1991) programs. The significance of main effects was determined by the F test. The path and correlation analyses were conducted following the methods of Dewey & Lu, (1959) and Snedecor & Cochran (1987), respectively.

Results and Discussion

Grain yield, plant height, grains number per spike, grain weight per spike, test weight and 1000 grain weight value of the lines and control variety (Gediz-75) are given Table 2 and 3. According to means of two years, statistically significant differences among genotypes were observed for height plant, grains number per spike, grain weight per spike, 1000 grain weight and grain yield (Tables 2 and 3). Grain yield of durum wheat lines ranged between 4251 to 5283 kg ha^{-1}. The line 30 produced the highest grain yield (5283 kg ha^{-1}) and was followed by line 33 with grain yield of 4818 kg ha^{-1}.

The control variety Gediz-75 was the tallest with 83.6 cm plant height and was followed by line 26 and 33 (80.9 and 80.3 cm, respectively). The plant height is very important in term of resistance to lodging and harvest index. Many local researchers reported that ideal plant height changed from 90 to 100 cm (Tosun, 1987; Yürür, 1998).

Table 3. Variation of grain yield components in seven durum wheat lines (average of 2 years).

Line No.	Lines	Plant height	grains/ spike	grain weight/ spike	test weight	1000-grain Weight
30	Ambral Çakmak-79	76.8 **d**	38.8 **c**	1.74 **a**	82.2	44.4 **b**
26	Ambral Çakmak-79	80.9 **b**	46.2 **a**	1.67 **b**	80.2	42.7 **c**
36	Ambral Çakmak-79	78.9 **c**	44.4 **a**	1.76 **a**	80.7	43.7 **bc**
28	Sham Santa	77.4 **d**	38.3 **c**	1.57 **c**	82.6	47.9 **a**
33	Gediz-75 Çakmak-79	80.3 **b**	31.6 **d**	1.63 **bc**	81.2	44.1 **bc**
44	Japiga Gediz-75	80.0 **bc**	41.6 **b**	1.74 **a**	80.9	43.4 **bc**
Control	Gediz-75	83.6 **a**	37.6 **c**	1.74 **a**	81.5	42.7 **c**

[1]Means of the same column followed by the same letter was not significantly different at 0.05 level using LSD test, 0.05 level using LSD test

Table 4. Correlation coefficients among six characters determined for seven durum wheat lines developed in Agriculture Faculty of Bursa

Characters	Grains number/ spike	Grain weight/ spike	1000 Grain weight	Test weight	Grain yield
Plant height	0.046	-0.208	-0.261	0.085	-0.545*
	-0.291	-0.241	-0.239	-0.537*	-0.628**
	-0.566**	**0.066**	**-0.428**	**-0.227**	**-0.620****
Grains number/spike		-0.344	0.202	0.298	0.048
		0.318	0.178	0.328	0.157
		0.169	**0.524***	**0.161**	**0.675****
Grain weight/spike			-0.113	-0.187	0.120
			-0.091	0.206	0.129
			0.158	**0.116**	**0.168**
1000Grain weight				0.258	0.726**
				0.664	0.634**
				-0.180	**0.516***
Test weight					0.147
					0.760**
					0.389

*,** = Significant at p=0.05 and 0.01, respectively.
* = Correlations coefficient are value in 1999, 2000 and mean of 2 years, down ward, respectively.

Line 26 has maximum grains number per spike (46.2 grain per spike) but grain yield, grain weight per spike and 1000 grain weight produced less compared to line 30 (4251 kg ha^{-1}, 1.67 g and 42.7 g, respectively). The differences between the lines in grain weight per spike were significant. The grain weight per spike of lines ranged between 1.57 and 1.76 g. The line 36 produced the highest grain weight per spike (1.76 g), while line 28 was the lowest (1.57 g). The line 30 produced both the highest test weight and grain yield (82.2 kg, 5283 kg ha^{-1}, respectively).

Two line out yielded from the variety (control) Gediz-75 in trial year. As the overall mean of two years with grain yields of 5283 and 4818 kg ha^{-1}, line 30 and 33 exhibited superiority to the control variety Gediz-75. As a result, line 30 combinations appeared to be consistent when grain yield is considered.

The simple correlation coefficients determined at the end of the research between the characteristics investigated are presented in Table 4 for individual years and as mean values of the two years. A negative but significant correlation exists between grain yield ha^{-1} and plant height in both individual year and combined years (r = -0.545**, r = -0.628** and r = -0.620**, respectively). Similarly, positive and significant correlations were determined between 1000 grain weight- an important trait- and yield in both year and as the mean of both years (r = +0.726, r = +0.634 and r = +0.516, respectively). The correlation between yield and grains number per spike was positive but non significant in individual year, in contrast, it was found significant considering the mean values of both years (r = +0.675). On the other hand, significant positive correlation was determined between plant height and grains number per spike in the first year and, negative but significant in the second year, however, the correlation was found negative and significant (r = -0.566) regarding the mean values of both years. Similarly, the correlation between grains number per spike and 1000 grain weight was found non significant in both experimental year, but positive and significant (r = +0.524) with regard to the mean of both years.

The characteristics related to grain yield indicated that grains number per spike, grain weight per spike, 1000 grain weight and test weight were positively correlated with grain yield except plant height. However, this positive correlation between grain weight per spike, test weight and grain yield was not significant. It was also reported in earlier studies that grains number per spike were positively correlated with grain yield (De Pauw & Shabeski, 1973; Moreira & Osaria, 1978; Mohy-ud-Din, 1995; Kumar, *et al*., 1998; Tammam, *et al*., 2000; Okuyema *et al*., 2004; and Furkan *et al.,* 2005). Plant height had negative but significantly correlation with grains number per spike and grain yield. These results are partially in accordance with findings of Yürür, 1998; Ashraf *et al.,* (2002); Aashfaq *et al.,* (2003) and Nayeem and Baig (2003). The negative correlation of some important character as plant height vs grain yield may lead to some undesirable selection depend on whether negative association is due to linkage or pleiotropic effect. The negative associations of these character pairs were to impose problem in combining important yield components in one genotypes. To improve yield components with negative association with other, suitable recombinations may be obtained through biparental mating, mutation breeding or diallel selective mating by breaking undesirable linkages.

Although the positive correlation between grain yield and test weight generally considered as a quality criterion was obtained negative and non significant relation in some studies (Furkan *et al*. 2005), the increase in test weight leaded to an indirect increase in grain yield in our study. It was also determined in our study that 1000 grain weight is positively correlated with grain yield and similar results were obtained in many studies (Bohac & Cermin 1969; Knott and Talukdar 1971; Akhtar, 1991; Uddin *et al*., 1997; Narwal *et al*., 1999; Chowdhry, 2000; Tammam, *et al*., 2000 and Furkan *et al*., 2005).

Yield is a very complex character. It is formed by the effect of numerous simple characters that are easily observed and that don't change or change a little from one environment to another. If there is no significant correlation between the sample characters, then their effects on yield are direct and determined by applying path analysis method and the coefficients obtained are called path coefficients. Significance test of path coefficients are not done, they are compared with their absolute values. High absolute value indicates greater effect. The signs of path coefficients show the direction of direct or indirect effect on yield (Dewey & Lu 1959; Turan 1989).

The path coefficient analysis appeared to provide a clue to the contribution of various components of yield to over all grain yield in the genotypes under study. It provides an affective way of finding out direct and indirect sources of correlation. Direct and indirect effects of these components determined on grain yield and their contribution ratios are summarized in Table 5.

Table 5. The path coefficients* - Direct effects (in diagonal line) and indirect effects.

Characters	Plant height		Grains number/ spike		Grain weight/ spike		1000 Grain weight		Test weight	
	P	%	P	%	P	%	P	%	P	%
	-0.3558	64.4	-0.0018	0.3	-0.0235	4.3	-0.1676	30.3	0.0004	0.7
Plant height	-0.3780	52.9	0.0430	6.0	-0.0080	1.1	-0.0750	10.5	-0.2097	29.4
	-0.2355	**37.7**	**-0.1840**	**29.5**	**0.0029**	**0.5**	**-0.1273**	**20.4**	**-0.0754**	**12.1**
Grains number/ spike	-0.0164	6.9	-0.0395	16.6	-0.0389	16.4	0.1295	54.5	0.0131	5.5
	0.1102	24.4	-0.1475	32.6	0.0105	2.3	0.0560	12.4	0.1282	28.3
	0.1333	**19.7**	**0.3254**	**48.2**	**0.0073**	**1.1**	**0.1559**	**23.1**	**0.0535**	**7.9**
Grain weight/spike	0.0740	26.3	0.0136	4.8	0.0031	40.2	-0.0727	25.8	-0.0082	2.9
	0.0910	32.5	-0.0469	16.7	0.0332	11.8	-0.0287	10.2	0.0804	28.7
	-0.0156	**7.8**	**0.0550**	**27.6**	**0.0432**	**21.7**	**0.0469**	**23.6**	**0.0384**	**19.3**
1000 Grain weight	0.0928	12.1	-0.080	1.3	-0.0128	1.7	0.6423	83.7	0.0114	1.5
	0.0904	13.1	-0.0263	3.8	-0.0030	0.4	0.3139	45.3	0.2593	37.4
	0.1009	**15.9**	**0.1707**	**26.9**	**0.0068**	**1.1**	**0.2973**	**46.8**	**0.0598**	**9.4**
	-0.0301	11.1	-0.0118	4.3	-0.0211	7.7	0.1657	60.7	0.0441	16.2
Test weight	0.2029	23.7	-0.484	5.7	0.0068	0.8	0.2083	24.3	0.3907	45.6
	0.0536	**10.8**	**0.0525**	**10.6**	**0.0050**	**1.0**	**-0.0536**	**10.8**	**0.3314**	**66.8**

P; Path coefficient, %; Percentage direct and indirect effects

***Path coefficients are value in 1999 and 2000 mean of 2 years, down ward, respectively

The yield components such as plant height, grains number per spike, grain weight, 1000 grain weight and test weight were considered as independent variables and path analysis was applied in order to determine the effect and contribution ratios of these components on grain yield which is dependent variable.

The results of Path coefficient analysis (Table 5), revealed that test weight exerted the highest direct positive effect (+ 0.3314) on grain yield followed by grains number per spike (+0.3254) and 1000 grain weight (+0.2973). Plant height exhibited negative direct effect (- 0.2355) while grain weight per spike had low positive effect (+ 0.0432) on grain yield. Direct effect of test weight had a proportion of 66.8% in positive but insignificant correlation (r = +0.389) between test weight and grain yield while grains number per spike directly affected 48.2% of positive and significant correlation between grains number per spike and grain yield. Our results are in agreement with those reported by Khaliq *et al.,* (2004) and Okuyama *et al.,* (2004) who found that grains number per spike exerted direct positive effect on grain yield. Akhtar (1999) and Chowdhry *et al.,* (2000) reported that yield components like grains number per spike and 1000 grain weight were main contributors to grain yield in wheat. Similar results were also found by Sidwel *et al*., (1976). Grains number per spike had indirect significant effect over 1000 grain weight and plant height in positive direction, nearby its high direct effect on grain yield. The contribution ratio of these indirect effects were 23.1 and 19.7%, respectively. Also, 1000 grain weight exhibited high indirect effects in positive direction over grains number per spike and plant height, besides its direct effect at high level in positive direction. Percentages of these indirect effects were 26.9 and 15.9%, respectively.

The greatest part of significant correlation coefficient in negative direction (r = -0.620) calculated between plant height and grain yield was formed by the negative direct effect (-0.2355) of plant height on grain yield. Contribution of the direct effect in question was determined as 37.7 %. Furthermore, plant height had negative indirect effects over grains number per spike and 1000 grain weight in negative direction on grain yield as 29.5% and 20.4%, respectively. Ahmed *et al.,* (2003) also reported similar type of results. On the other hand, our findings are partially in concordance with the results of Khan *et al*., (1999), Ashaf *et al.,* (2002) and Khan *et al.,* (2003) who found that direct effect of plant height on grain yield per plant was positive.

Grain weight per spike, another yield component showed a positive but non significant correlation with grain yield, nevertheless, direct effect of grain weight per spike on the grain yield in this correlation was in positive direction at medium level (+0.0432), and its contribution ratio was found as 21.7%. Grain weight per spike exhibited indirect effect in terms of grains number per spike and 1000 grain weight as 27.6%, respectively. Owing to the pleiotropic effects of Path coefficients which explain these relatively high-level indirect effects, the correlation coefficients between grain weight per spike and grain yield were found lower than expected. Similar situations are also in question for the correlation coefficient between test weight and grain yield which was determined to be non significant. According to the results of path analysis, it was determined that grains number per spike and 1000 grain weight which are significantly correlated with grain yield had the highest direct effect in positive direction on the mentioned parameter; also test weight had the highest positive direct effect on grain yield, although they were non significantly correlated with each other. Another important component plant height exhibited direct effect at the highest level in negative direction on grain yield. It was concluded that grains number per spike, 1000 grain weight, plant height and test weight which were determined to have significant direct effects on grain yield could be major selection criteria for breeding studies.

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