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Original Research Article

Correlation and Path Coefficient Analysis of Yield and Yield Components in Hexaploid Triticale (*X Triticosecale Wittmack*) Genotypes under Mediterranean Conditions

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ABSTRACT

During the 2004-05 and 2005-06 vegetation periods, a study was conducted to determine the suitable selection criteria in triticale breeding for higher yields in Bursa ecological conditions. To this end, path and correlation coefficient analyses were applied to 22 triticale genotypes. Field trials were performed in a randomized block design, with three replications. According to the results, the relationships between the grain yield and all of its components were significant and positive. The results of the path coefficient analysis indicated that the grain number spike^{-1}, thousand kernel weight and test weight had the highest direct effects on the grain yield, whereas the plant height and spikelet number spike^{-1} were positive but less direct effects. In addition, the spike length had negative and low direct effects, whereas the grain weight spike^{-1} had negative and high direct effects on the grain yield. The results suggest that the grain number spike^{-1}, thousand kernel weight and test weight are primary selection criteria for higher grain yields in triticale.

Keywords: Triticale, Grain yield, Thousand kernel weight, Plant height, Correlation and path analysis

INTRODUCTION

Hexaploid triticale (*x Triticosecale Wittmack*) is a not a naturally occurring species. Previous studies have indicated that the grain production of newer and improved triticale cultivars, both as monocrops and in small-grain mixtures, is acceptable in a wide range of environments (Pfeiffer, 1996, Juskiw *et al.*, 2000 a, b, Barnett et al., 2006). The forage production and silage yield and the quality of hexaploid triticale, both as monocrops and in small-grain mixtures, have been reported to be favorable in comparison with other small grains (Sun et al., 1996, Juskiw *et al.*, 2000 a, b, Rao *et al.*, 2000, Erekul and Kohn, 2006). The aim of cereal breeding programs is to improve genotype adaption to target environments; indeed, breeding programs seek to enhance grain yield, disease resistance and end-use quality. In particular, short mixing times usually have low mixing tolerance values, making them more sensitive to over-mixing in commercial bread production (Budak *et al.*, 2003). Correlation coefficients have been used for determining the relationship between the traits of crops (Turk and Celik, 2005). However, because correlation coefficients generally show relationships among independent variables and the degree of linear relationships among the variables, these values could not sufficiently describe the relationship when a clear cause-result relationship was found between the variables (Albayrak *et al.*, 2005). Clearly, the direct and indirect effects between yield and yield components should be known in breeding programs (Albayrak *et al.*, 2003, Turk and Celik, 2006), thus the path coefficient analysis is used to determine the amounts of direct and indirect effects of interrelated traits on a resulting trait, such as grain yield (Dewey and Lu, 1959, Yagbasanlar and Ozkan, 1995, Kang *et al.*, 2003, Albayrak *et al.*, 2004, Kara and Akman, 2007). Many studies were performed on wheat breeding in which both correlation and path analysis methods were simultaneously used; however, few studies were conducted using cereals. Some researchers reported a positive and significant correlation between plant height and yield (Sing *et al.*, 1999; Anwar *et al.*, 2009); however, a study in the literature reported a negative correlation between these variables (Bilinski *et al.*, 1997). In many studies, it has been reported that seed number spike^{-1} has a positive effect on yield (Yagbasanlar and Ozkan, 1995, Ulger et al., 1989, El-Hennawy, 1997, Naik *et al.*, 1998, Sing *et al.*, 1999, Okuyama *et al.*, 2004, Bisht and Gahalain, 2009, Dogan, 2009), and seed weightspike^{-1} has also been found to have a positive effect on yield (Yagbasanlar and Ozkan, 1995, Okuyama *et al.*, 2004, Yanbeyi *et al.*, 2006, Dogan, 2009). In correlation, in a path analyses performed by a large number of studies, it has been observed that the thousand kernel weight has a positive effect on the yield (Bilinski *et al.*, 1997, El-Hennawy, 1997, Irfan-ul haq *et al.*, 1997, Verma *et al.*,

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1998, Sing *et al.*, 1999, Furan *et al.*, 2005;Mohammed *et al.*, 2008). Alkus (1979) also reported positive and significant correlations between the grain yield and hectoliter weight, whereas another researcher reported that a negative correlation was found between the grain yield and hectoliter weight (Furan *et al.*, 2005).
The objective of the present study was to determine the correlation and path coefficients of the yield and yield contributing characters in bread wheat and to assess the suitability of using these analyses in breeding programs.

MATERIALS AND METHODS

Twenty-two hexaploid triticale (*x Triticosecale Wittmack*) genotypes were used as the plant material in this study. Variety 'Pehlivan' was used as the standard wheat cultivar (Table 1). The study was conducted in the experimental areas of the Field Crops Department, Agriculture Faculty, University of Uludag, located at 40° W and 28° 30´N, during the 2004-05 and 2005-06 growing seasons. A total of 22 genotypes were evaluated for plant height, spike length, spikelet number spike^{-1}, the grain number and weight spike^{-1}, thousand kernel weight, test weight and grain yield. The experimental design was a randomized complete block design, with three replications. The plots were eight rows, 10 m in length, with 15 cm in between rows; the harvest area was 12 m^2. The total precipitation (as a long-term average), mean temperature and relative humidity were 556.4 mm year^{-1}, 14.8 ^{o}C and 68.9 %, respectively, in Bursa. The total rainfall during the growing period for 2004-05 and 2005-06 was 615.1 mm and 564.5 mm, respectively (Anonymous, 2008).

The genotypes were sown at a seed rate of 500 seed m^{-2} in November and harvested in the second half of July. Mineral fertilizer was applied at the rate of 160 kg N and 60 kg P_2O_5 per hectare.

In the present study, the direct and indirect effects of the traits were evaluated using correlation and path coefficient analyses, which were calculated using TARPOPGEN Statistical Software.

RESULTS AND DISCUSSION

Correlation coefficient analysis

The results of the correlation coefficients between the yield and yield components of triticale are presented in Table 1. show that the plant height was positively and significantly correlated with the grain yield (r = 0.300**). Our findings are in agreement with the results of other researchers who reported positive and significant correlations between the yield and plant height (Subhani and Khaliq, 1994, Chaturvedi and Gupta, 1995, Khan et al., 1999, Sultana *et al.*, 2002, Aycicek ve Yildirim, 2006, Aydin *et al.*, 2010 Gulmezoglu *et al.*, 2010). In contrast, some researchers reported negative and significant correlations between GY and plant height (Ashraf et al., 2002, Aashfaq et al., 2003, Nayeem and Baig 2003, Tila *et al.*, 2005). In previous studies on bread wheat, it was emphasized that the plant height is one of the most important traits determining yield (Belay et al., 1993, Dokuyucu *et al.*, 2002, Kashif and Khaliq, 2004). The simple correlation coefficient was highly positive and significant between the grain yield and grain number spike^{-1} (r = 0.661**). In most of the previous studies, similar results have been reported between the grain yield and grain number per spike^{-1} (Okuyama *et al.*, 2004, Furan et al. 2005, Aycicek and Yildirim 2006, Yanbeyi and Sezer, 2006, Aydin *et al.*, 2010, Abinasa *et al.*, 2011, Tas and Celik, 2011). The spike length and number of spikelet spike^{-1} were positively and significantly correlated with GY (r = 0.0624**, 0.526**), respectively. The results of the present relationships are consistent with the findings of previous researchers (Akram et al.,2008, Abinasa *et al.*, 2011).

The grain yield was positively and significantly correlated with the grain weight spike^{-1} (r = 0.488**). Aruna and Raghavaiah (1997), Moghaddam et al. (1998), Dokuyucu and Akkaya (1999), Ismail (2001), Sultana *et al.* (2002), Aycicek and Yildirim (2006) and Tas and Celik (2011) reported similar results for the correlation between the grain yield and grain weight spike^{-1}. In this study, the thousand kernel weight showed significant and positive associations with the grain yield (r = 0.634**), a result that is in agreement with the results of Sarkar et al. (1988), Hadjichristodoulou (1989), Subhani and Khaliq (1994), Mondal et al. (1997), Dokuyucu andAkkaya (1999), Mondal and Khajuria (2001) and Sarkar et al. (2002), Furan *et al.*, (2005) and Aycicek and Yildirim (2006). In contrast, some other authors reported negative and insignificant correlations between the grain yield and thousand kernel weight (Yanbeyi and Sezer, 2006, Aydin *et al.*, 2010, Abinasa *et al.*, 2011). Our results revealed that the grain yield was positively and highly correlated with the test weight, spike length and spikelet number spike^{-1} (r = 0.257**, r = 0.421** and r = 0.229*, respectively). Previous authors reported positive and significant relationships between the grain yield and test weight (Abinasa *et al.*, 2011), whereas others found negative and nonsignificant correlations between the same traits (Sultana *et al.*, 2002, Furan et al, 2005 Kara and Akman, 2007, Dogan *et al.*, 2009, Aydin *et al.*, 2010, Tripathi *et al.*, 2011).

Table 1. Correlation coefficients between yield and yield components of triticale.

Characters	GY	PH	SL	SPS^{-1}	GNS^{-1}	GWS^{-1}	TKW	TW
GY	**1000**							
PH	0.300**	**1000**						
SL	0.257**	0.427**	**1000**					
SPS^{-1}	0.421**	0.420**	0.624**	**1000**				
GNS^{-1}	0.661**	0.334**	0.425**	0.526**	**1000**			
GWS^{-1}	0.596**	0.437**	0.531**	0.577**	0.820**	**1000**		
TKW	0.634**	0.227**	0.111	0.241**	0.275**	0.445**	**1000**	
TW	0.229**	-0.032	-0.176	-0.125	-0.100	-0.016	0.415**	**1000**

GY, Grain Yield (kg ha^{-1}); PH, Plant Height (cm); SL, Spike Length (cm); SPS, Number of Spikelet Spike^{-1}; GNS^{-1}, Number of Grains Spike^{-1}; GWS^{-1}, Weight of Grain Spike^{-1} (g); TKW, Thousand Kernel Weight (g); TW, Test Weight (kg 100 L^{-1}).
**, *significant at 1 and 5 % probability level, respectively

Path coefficient analysis

The path coefficient analysis appeared to provide a clue to the contribution of the various components of the yield to the grain yields of the genotypes used in the study. This analysis is used to partition the relative contribution of yield components via standardized partial regression coefficients (Li, 1975, Williams et al., 1990), providing an effective way in which to distinguish direct and indirect sources of correlation. The direct and indirect effects of all of the components observed on grain yield are presented in Table 2.

In this study, the grain yield (GY), as a response variable, and seven determinative variables, plant height (PH), spike length (SL), number of spikelet spike^{-1} (SPS^{-1}), number of grain spike^{-1} (GNS^{-1}), weight of grain spike^{-1} (GWS^{-1}), thousand kernel weight (TKW) and test weight (TW), were used for the path coefficient analysis (Table 2).

The highest positive direct effect on the grain yield was the grain number spike^{-1} (0.6722), followed by the thousand kernel weight (0.4779). The indirect effects of the GN via the PH, SPS^{-1} and GWS^{-1} were high (0.2224, 0.3534 and 0.5514, respectively), was moderate via the TKW (0.1849) and was both too small and negative via the TW (-0.0674). In most of the previous studies, the GNS^{-1} demonstrated positive direct effects on the GY (Sharma and Rao, 1989, Garcia et al., 1991, Chaturvedi and Gupta, 1995, Dokuyucu and Akkaya, 1999, Verma *et al.*, 1998, Mohammed et al., 002, Okuyama *et al.*, 2004). In contrast, other authors determined that the GNS^{-1} had a negative direct effect on the GY (Aydin *et al.*, 2010; Tas and Celik, 2011).
The plant height (PH) had a small positive direct effect on the GY (0.0382).

Some authors also indicated that the plant height had a positive direct effect on GY(Chaturvedi and Gupta, 1995, Khan et al., 1999, Moghaddam et al., 1998, Gupta ., 2004, Aydin *et al.*, 2010). In contrast, other authors reported that the PH had a negative direct effect on the GY (Subhani and Khaliq, 1994, Mondal et al., 1997, Mohammed et al., 2002, Ahmad, 2003; Bhutta *et al.*, 2005, Khan *et al.*, 2005, Gupta., 2007, Khokhar *et al.*, 2010, Tas and Celik, 2011). The indirect effects of the PH via the SL, SPS^{-1}, GWS^{-1} and TW were small but great via the GNS^{-1} and TKW.

The spike length (SL) had a small negative direct effect on the grain yield (GY) (-0.0152). Other authors also indicated a positive direct effect of the SL on the GY (Khan *et al.*, 2005, Tas and Celik., 2011), whereas some authors reported that the SL had a positive direct effect on the GY (Chowdhry *et al.*, 2000; Khaliq *et al.*, 2004). The indirect effects of the SL via the PH, SPS^{-1}, GWS^{-1}, TKW and TW were small but great via the GNS^{-1}

Table 2. Path coefficients and indirect effects of PH, SL, SPS^{-1}, GNS^{-1}, GWS^{-1}, TKW and TW on grain yield.

Character	PH		SL	2	SPS^{-1}	3	GNS^{-1}	4	GWS^{-1}		TKW	5	TW	6
	P	%	P	%	P	%	P	%	P	%	P	%	P	%
	-0.0935	**25.7**	0.0019	0.5	0,0308	8,5	0,0962	26,4	0,1081	29,6	0,0017	0,5	0,0324	8,9
PH	**0.3192**	**48.2**	-0.0651	9.8	-0,0141	2,1	0,0099	1,5	0,0957	14,4	0,1178	17,8	0,0412	6,2
	0.0382	**7.4**	-0.0065	1.3	0,0376	7,3	0,2224	43,4	-0,0939	19,1	0,1086	21,0	-0,0033	0,6
	-0.0214	6.4	**0.0083**	**2.5**	0,0819	24,4	0,0904	26,9	0,0889	26,5	-0,0004	0,1	0,0446	13,3
SL	0.1781	33.6	**-0.1166**	**22.0**	-0,0142	2,7	0,0149	2,8	0,1418	26,7	0,0521	9,8	-0,0132	2,5
	0.0163	2.9	**-0.0152**	**2.7**	0,0559	9,9	0,2857	50,6	-0,1201	21,3	0,0531	9,4	-0,0183	3,2
	-0.0265	6.6	0.0062	1.6	**0,1091**	**27,1**	0,1131	28,1	0,1059	26,4	-0,0002	0,6	0,0407	10,1
SPS^{-1}	0.1597	34,3	-0,0591	12,7	**-0,0281**	**6,0**	0,0136	2,9	0,1207	25,9	0,0794	17,1	-0,0051	1,1
	0.0161	2,2	-0,0095	1,3	**0,0895**	**12,3**	0,3534	48,6	-0,1305	18,0	0,1152	15,9	-0,013	1,8
	-0,0307	5,1	0,0026	0,4	0,0423	7,0	**0,2931**	**48,7**	0,1839	30,6	-0,0032	0,5	0,0466	7,7
GNS^{-1}	0,1168	25,5	-0,0642	14,0	-0,0141	3,1	**0,0271**	**5,9**	0,1636	35,7	0,0673	14,7	0,0051	1,1
	0,0128	1,2	-0,0064	0,6	0,0471	4,4	**0,6722**	**63,1**	-0,1856	17,4	0,1315	12,3	-0,0104	1,0
	-0,0418	7,2	0,0033	0,5	0,0477	8,2	0,2419	41,5	**0,2229**	**38,3**	0,0041	0,7	0,0214	3,7
GWS^{-1}	0,1434	26,3	-0,0776	14,3	-0,0159	2,9	0,0208	3,8	**0,2131**	**39,2**	0,0638	11,7	0,0097	1,8
	0,0167	1,6	-0,0081	0,8	0,0517	4,9	0,5514	51,6	**-0,2262**	**21,2**	0,2125	19,9	-0,0017	0,2
	-0,0129	5,8	-0,0003	0,1	-0,0018	0,8	-0,0776	35,0	0,0807	36,4	**0,0121**	**5,5**	-0,0365	16,4
TKW	0,0939	12,0	-0,0152	1,9	-0,0056	0,7	0,0046	0,6	0,0339	4,33	**0,4004**	**51,1**	0,2298	29,3
	0,0087	1,1	-0,0017	0,2	0,0216	2,9	0,1849	22,1	-0,1006	12,0	**0,4779**	**57,0**	0,0431	5,2
	0,0247	7,2	-0,0032	0,9	0,0361	10,5	-0,1111	32,3	-0,0422	12,3	0,0036	1,1	**-0,1229**	**35,8**
TW	0,0369	5,6	0,0043	0,7	0,0004	0,1	0,0004	0,1	0,0058	0,9	0,2581	39,0	**0,3565**	**53,8**
	-0,0012	0,31	0,0027	0,7	-0,0112	2,9	-0,0674	17,4	0,0036	0,9	0,1918	51,0	**0,1041**	**26,8**

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

*Path coefficients are the values in 2004-05, 2005-06 and mean of the two years, in descending order, respectively.

Bold numbers show the direct effects on the grain yield

The spikelet number at spike^{-1} (SPS^{-1}) had a small positive direct effect on the GY (0.0895), which has been previously reported (Khan *et al.*, 2005, Tas and Celik, 2011, Bhutta *et al.*, 2005, Gupta *et al.*, 2007, Tripathi *et al.*, 2011). The indirect effects of the SPS^{-1} via the PH, SL, GWS^{-1}, and TW were small but great via the GNS^{-1} and TKW.

The grain weight spike spike^{-1} (GWS^{-1}) had a negative direct effect on the GY (-0.2262), also previously reported (Naik *et al.*, 1998, Verma *et al.*, 1998, Fathi and Rezaeimogdam, 2000, Kara and Akman, 2007, Aydin *et al.*, 2010, Tas and Celik, 2011). Conversely, other authors found that the GWS^{-1} had a positive direct effect on the GY (Aruna and Raghavaiah, 1997, Moghaddam et al., 1998, Verma *et al.*, 1998, Dokuyucu and Akkaya, 1999, Ismail, 2001, Okuyama *et al.*, 2004, Tripathi *et al.*, 2011). Generally, the indirect effects of the GWS^{-1} via all of the components were negative but small.

The direct effect of the TKW on the GY was positive and high (0.4779), as previously reported (Sharma and Rao, 1989, El-Marakby et al., 1994, Verma *et al.*, 1998, Mohammed et al., 2002, Khan *et al.*, 2005, Akram *et al.*, 2008, Dogan, 2009). The indirect effects of the TKW via the PH, SL, SPS^{-1}, GWS^{-1} and TW were positive and negative but small, whereas the indirect effects via the GNS^{-1} was also positive but great.

The direct effect of the test weight (TW) on the GY was positive and moderate (0.1041); similar results were found previously (Kara and Akman, 2007, Dogan, 2009, Aydin *et al.*, 2011, Tripathi *et al.*, 2011). The indirect effects of the TW via the PH, SL, SPS^{-1}, GNS^{-1} and GWS^{-1} were either positive or negative but small, whereas the indirect effects via the TKW were also positive but great.

The data obtained in this study could be useful for triticale breeders and grain producers in efforts to increase grain yield. The correlation coefficients between the grain yield and yield components showed variation, and the results suggest that the grain number per spike, thousand kernel weight and test weight are the primary selection criteria for higher grain yields in triticale.

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