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Full Length Research Paper

Path analyses of yield and some agronomic and quality traits of bread wheat (*Triticum aestivum* L.) under different environments

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This research was conducted to determine characters effecting grain yield in fifty bread wheat (*Triticum aestivum* L.) cultivars and advanced lines by using simple correlation coefficient and path analysis under 2 locations (high rainfall and low rainfall; 745 and 506 mm, respectively). A total of 50 genotypes, 25 for each independent experiment, were tested for grain yield, test weight, 1000-kernel weight, Zeleny sedimentation, protein content and plant height. Grain yield was significantly correlated with plant height in high rainfall condition. It was significantly correlated with all components except Zeleny sedimentation and protein content in low rainfall condition. Results suggest that plant height and test weight are primary selection criteria for improving grain yield in bread wheat in high and low rainfall conditions.

Key words: Bread wheat, grain yield and components, correlation coefficient, path analyses.

INTRODUCTION

Bread wheat (*Triticum aestivum* L.) is one of the most important cereal crops in the world. The aim of wheat breeding programs is to improve the genotypes adaption to target environments. The breeding programs seek to enhance grain yield, disease resistance and end-use quality; especially, short mixing times usually have low mixing tolerance values, which make them more sensitive to over-mixing in commercial bread production (Budak et al., 2003). The correlation coefficient has been used for determining the relationship between the traits of crops (Türk and Çelik, 2005). Since the correlation coefficients generally show relationships among independent variables and the degree of linear relations among the variables, they could not sufficiently describe the relationship when a clear cause-result relationship was found between the variables (Albayrak et al., 2005). Therefore, the direct and indirect effects between yield and yield components should be known in breeding programs (Albayrak et al., 2003; Türk and Çelik, 2006). For this aim, the path coefficient analysis is used to determine the amounts of direct and indirect effects of the interrelated traits on a resulting trait such as grain yield (Albayrak et al., 2004; Kara and Akman, 2007; Kang et al., 2003; Dewey and Lu, 1959).

Albayrak et al. (2003) illustrated the following concluding remarks: a) If the correlation coefficient between a causal factor and the effect is almost equal to its direct effect, then the correlation explains the true relationship and a direct selection through this trait will be effective; b) if the correlation coefficient is positive, but the direct effect is negative or negligible, the indirect effects seem to be reason of correlation. In such situations, the indirect causal factors must be considered simultaneously, and c) Correlation coefficient can be negative, but the direct effect may be positive and high. Under these circumstances, a restricted simultaneous selection model is to be followed, that is, restrictions are to be imposed to nullify the undesirable indirect effects, to make use of the direct effect.

The aim of this study was to determine characters affecting grain yield in bread wheat genotypes grown in

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Table 1. Monthly precipitation and mean temperature at Samsun and Amasya locations in Turkey.

2004 - 2005 Months	Precipitation (mm)		Temperature (°C)	
	Samsun	Amasya	Samsun	Amasya
October	59.5	7.1	16.9	15.4
November	174.2	105.4	12.2	8.6
December	84.4	29.0	8.9	3.5
January	62.8	22.3	9.0	5.2
February	43.1	32.2	7.5	5.5
March	141.6	112.6	7.2	7.4
April	87.8	89.7	11.4	13.9
May	34.7	41.9	15.8	17.8
June	51.1	46.4	20.2	20.9
July	5.9	19.5	24.2	25.5
Total	745	506	-	-
Mean	-	-	13.3	12.4

Samsun and Amasya using simple correlation and path analyses in high and low rainfall conditions.

MATERIALS AND METHODS

Twenty-five bread wheat (*T. aestivum* L.) cultivars/advanced lines per trial were used in this study. Two independent experiments were conducted during 2004 and 2005 growing season in two different locations, Samsun and Amasya, in Turkey. A total of 50 genotypes were tested for grain yield, test weight, 1000-kernel weight, Zeleny sedimentation rate, protein content and plant height. The locations were Samsun (41° 21´ N Lat., 36° 15´ E Long., 4 m above sea level) and Amasya (40° 35´ N Lat., 35° 39´ E Long., 450 m above sea level). Genotypes were sown in a randomized complete block design with four replications. Seeding rates was adjusted for density of 500 seeds m^{-1}. Plot size was 6 m^2 (6 rows, 20 cm apart). Mineral fertilizers were applied at the rate of 120 kg N and 60 kg P_2O_5 ha^{-1} for all the locations. The soil was silty-loam in Samsun, and silty clay loam in Amasya. Average temperature, rainfall and relative humidity of the rowing seasons are shown in Table 1.

Simple correlation and stepwise multiple regression analysis were carried out using the Statistical Analysis System (SAS) program. The relative importance of direct and indirect effects on grain yield was determined by path analysis for the different environment of data. PROC CORR procedures in SAS were used to quantify the relationship between the variables (SAS Institute, 1998). In path analysis, grain yield was the dependent variable and the five characteristics were considered as independent variables. Data from two independent experiments were analyzed to test the relationship between grain yield and the traits studied for each location.

RESULTS

The correlation coefficients between grain yield and yield components of bread wheat showed variations in the different rainfall conditions. In high rainfall conditions, positive and significant relationships existed between grain yield and plant height (r = 0.417**), while negative correlation coefficients were found for protein content, Zeleny sedimentation value, 1000-kernel weight and test weight (r = -0.445**, r = -0.406**, r = -0.038 and r = -0.015, respectively) (Table 2).

In low rainfall conditions, grain yield was positively and highly correlated with test weight, plant height and 1000-kernel weight (r = 0.372**, r = 0.196** and r = 0.151*, respectively), but it correlated negatively with protein content and Zeleny sedimentation value (r = -0.422** and r = -0.110, respectively). Plant height gave positive correlation with all other components (Table 2).

Path coefficients divided the correlation coefficient into a series of direct and indirect effect of yield components on the grain yield of bread wheat (Table 3). In high rainfall conditions, path coefficient analysis (Table 3) identified plant height as having the greatest direct effect on grain yield, with test weight having a large secondary effect. Other components had negative direct effects on grain yield except thousand seed weight. Protein content showed a large positive indirect effect via plant height, whereas Zeleny sedimentation value had a large negative indirect effect via protein content on grain yield. Although 1000-kernel weight and test weight had negative correlation value (r = -0.038 and r = -0.015, respectively), their direct effect on grain yield was positive (Table 3). In low rainfall conditions, path coefficient analysis showed that test weight and plant height had positive directs effects on the grain yield, while other components had strongly negative or negligible direct effects. Thousand kernel weights showed a large positive indirect effect via test weight, whereas test weight had a large negative indirect effect via thousand kernel weight on grain yield. Although thousand kernel weight had high correlation value (r = 0.151), its direct effect on grain yield was negative (-0.188) (Table 3).

DISCUSSION

In this study, grain yield correlated significantly and positively with plant height but correlated significantly and

Table 2. Simple correlation coefficients of grain yield components in bread wheat under different rainfall conditions.

Traits	GY	TW	TKW	ZS	PC	PH
High rainfall conditions in Samsun localtion						
GY	-	-0.015	-0.038	-0.406**	-0.445**	0.417**
TW		-	0.367**	0.155*	0.378**	0.130
TKW			-	0.064	0.284**	0.053
ZS				-	0.438**	-0.448**
PC					-	-0.316**
Low rainfall conditions in Amasya location						
GY	-	0.372**	0.151*	-0.110	-0.422**	0.196**
TW		-	0.742**	0.183**	-0.189**	0.510**
TKW			-	0.184**	-0.021	0.408**
ZS				-	0.257**	0.283**
PC					-	0.060

GY: Grain yield; TW: test weight; TKW: 1000-kernel weight; ZS: Zeleny sedimentation; PC: protein content; PH: plant height; *P < 0.05, ** P < 0.01.

Table 3. Path coefficients for grain yield components of bread wheat.

Traits	Direct effects	Indirect effects				
		PH	PC	ZS	TKW	TW
Samsun						
PH	0.212	-	0.11	0.07	0.001	0.01
PC	-0.347	-0.06	-	-0.07	0.006	0.04
ZS	-0.176	-0.09	-0.15	-	0.001	0.02
TKW	0.021	0.01	-0.09	-0.01	-	0.04
TW	0.108	0.03	-0.13	-0.03	0.01	-
Amasya						
PH	0.109	-	-0.02	-0.02	-0.07	0.21
PC	-0.330	0.007	-	-0.02	0.004	-0.07
ZS	-0.097	0.03	-0.08	-	-0.03	0.07
TKW	-0.188	0.04	0.006	-0.01	-	0.31
TW	0.411	0.06	0.06	-0.01	-0.13	-

PH: Plant height; PC: protein content; ZS: Zeleny sedimentation; TKW: 1000-kernel weight; TW: test weight.

negatively with protein content under all rainfall conditions. In former studies with bread wheat, it was emphasized that plant height is one of the most important traits determining yield (Belay et al., 1993; Dokuyucu et al., 2002; Kashif and Khaliq, 2004). Our results are consistent with the findings of these researchers. Important agronomical traits are generally inversely correlated with quality characteristics (Yagdi and Sozen, 2009). Barnard et al. (2002) reported that the negative correlation which often exists between quality and yield is a further constraint in breeding. Furthermore, Chung et al. (2003) found a negative correlation between protein content and grain yield.

In our study, both in high and low rainfall conditions, grain yield was negatively correlated with some quality traits. Correlation coefficient can be negative but the direct effect may be positive and high. Under these circumstances, a restricted simultaneous selection model is to be followed, that is, restrictions are to be imposed to nullify the undesirable indirect effects, to make use of the direct effect (Albayrak et al., 2003). In addition, if the correlation coefficient is positive, but the direct effect is negative or negligible, the indirect effects seem to be the reason for correlation. In such situations, the indirect causal factors must be considered simultaneously (Albayrak et al., 2004).

Conclusion

The data obtained from this study could be useful for wheat breeders and grain producers in order to increase grain yield in different rainfall conditions. The correlation coefficients between grain yield and yield components showed variation in different rainfall conditions. Results suggest that plant height and test weight are primary selection criteria for improving grain yield in wheat in high and low rainfall conditions.

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