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Correlation, path-coefficient and principal components analysis of yield and some characters related to the productivity of triticale genotypes

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Abstract

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During the period 2016–2020, a study was conducted to determine the suitable selection criteria in triticale breeding for higher yields in Sadovo ecological conditions. Correlation, path-coefficient and principal component analyses were applied to 7 triticale genotypes. Field trials were performed in a randomized block design, with four 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 plant height, grain number per spike, mass of thousand grains and spike length have the highest direct effect on yield. Principal components analysis shows that Olympus, Orbital and Falko have positive values for first PC. These cultivars were characterized by high yield, high plant height, high spike length, high grain number per a spike, high grain mass per a spike and high thousand grains mass.

Keywords: triticale; productivity; yield; correlation analysis; path-coefficient 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 (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 (Erekul & Kohn, 2006). The aim of cereal breeding programs is to improve genotype adaption to target environments; indeed, breeding programs seek to enhance grain yield and disease resistance. 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 & 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 (Turk & 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 (Kara & 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 (Anwar et al., 2009). In many studies, it has been reported that seed number per spike has a positive effect on yield (Bisht & Gahalain, 2009; Dogan, 2009), and seed weight of spike has also been found to have a positive effect on yield. 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 (Mohammad et al., 2002; Furan et al., 2005).

The objective of the present study was to determine the interrelationships between yield and its contributing traits in triticale genotypes using correlation, path-coefficients and principal components analysis for the needs of breeding programs.

Materials and Methods

The experimental work was conducted during the 2016-2020 growing seasons, in the experimental field of the Institute of plant genetic resources-Sadovo, South Central Bulgaria.

The total precipitation in the first year (327.8 mm) of the experiment during the growth season was lower than the multi-annual period (401.5 mm). The total precipitation in second year (661.8 mm) was higher than the multi-annual period and approximately the same as the normal value for the third and fourth year. The average temperature (9.7°C) in the first, (11.5°C) in the second, (10.9°C) for the third and fourth year were higher then the normal temperature (8.5°C).

The studied genotypes triticale are based on soil type Meadow Cinnamon Soil middle-ground (A + B = 60–80 cm). They are poorly stocked with nitrogen, on average well-stocked with phosphorus and rich in potassium. The soil response is close to neutral with pH = 6.5. Marginal humidity ranges from 24% to 26% .

The experiment was set up as a randomized block design in four repetitions of an area of 10 m^2, with sowing rate of 550 germinating seeds per m^2 .The genotypes were evaluated for seven traits – yield (kg/ha), plant height (cm), spike length (cm), grain number per spike, grain mass per spike (g), thousand grains mass (g) and hectoliter mass (kg). The plant material studied included 7 triticale genotypes from European-Siberian genetic center: 72–91 (Bulgaria), Olympus (France), Orbital (France), Vizerunok (Ukraine), Calao (France) Indiana (France) and Falko (France).

Phenotypic correlations, path-coefficient and principal components analysis were calculated on the basis of the average values of the traits for four years of study.

Results and Discussion

Table 1 presents biometric data and evidence of differences in yield and productivity elements for triticale genotypes. Calao has the most grain productivity value (7130 kg/ha) whereas Indiana has the least value (5420 kg/ha). Our results showed paralleling to the findings of Mut et al. (2006) and Atak & Ciftci (2006).

Plant height is a good indicator of vegetative growth and is a different significance for triticale. Triticale is not a cereal produced for only seed. At the same time, triticale is a cool climate cereal largely used as stalks, straw, arises in the form of feed and forage grass silage at animal feeding and marginal conditions. Therefore, the length of stem is important (Dogan & Vural, 2013). Indiana (93.3 cm) was smallest in terms of plant height while Calao has the most value (99.8 cm) in the same character. Atak & Ciftci (2006) and Mut et al. (2006) reported that plant height in triticale was shortened due to deficient precipitation.

Results of the present study revealed that spike length was the highest in Falko, but the lowest in genotype AD72-91. Our findings were similar to the results of (Atak & Ciftci, 2006; Alp, 2009). Grain numbers per spike levels of the genotypes ranged from 55.2 to 57.6. According to mean of four years, Calao gave the highest value with 57.6. In triticale, grains number per spike is an important yield component. Atak & Ciftci (2006) and Alp (2009) were reported similar results.

Table 1. Yield and structural elements of productivity in triticale genotypes average for the period (2016–2020)

Genotype	Yield kg/ha	Plant height, cm	Spike length, cm	Grain number per spike	Grain mass per spike, g	1000 grains mass, g	Hectoliter mass, kg
AD 72-91-St.	5650	95.4	9.3	55.9	1.44	49.3	64.6
Olympus	5880$^{n.s.}$	97.2$^{n.s}$	9.7$^{n.s}$	56.6$^{n.s}$	1.46$^{n.s}$	50.0$^{n.s}$	63.7$^{n.s}$
Orbital	5600$^{n.s}$	96.8$^{n.s}$	9.5$^{n.s}$	56.6$^{n.s}$	1.45$^{n.s}$	49.3$^{n.s}$	63.9$^{n.s}$
Vizerunok	5550$^{n.s}$	94.4$^{n.s}$	9.5$^{n.s}$	56.3$^{n.s}$	1.44$^{n.s}$	49.0$^{n.s}$	60.6$^{n.s}$
Calao	7130***	99.8*	9.7$^{n.s}$	57.6*	1.47$^{n.s}$	50.5$^{n.s}$	63.4*
Indiana	5420$^{n.s}$	93.3$^{n.s}$	9.5$^{n.s}$	55.2$^{n.s}$	1.42$^{n.s}$	49.4$^{n.s}$	63.9$^{n.s}$
Falko	5970$^{n.s}$	96.3$^{n.s}$	9.8*	57.0$^{n.s}$	1.46$^{n.s}$	50.2$^{n.s}$	63.1*
GD 5% (*)	620	3.0	0.4	1.5	0.90	1.10	1.00
GD 1% (**)	830	5.0	0.6	2.1	1.10	1.40	2.00
GD 0.1%(***)	1007	8.0	0.8	3.0	1.50	1.80	3.00

*, **, ***proven at GD 5.0%, GD 1.0% and GD 0.1%; n.s. – non significant

The grain mass per spike of genotypes ranged from 1.42 to 1.47 g. The grain mass per spike was maximum in Calao. Akgun et al. (1997) reported that grain number per spike and grain mass per spike are important factors for grain yield. Our results are in agreement to the findings of Akgun et al. (1997) and Furan et al. (2005).

As seen in Table 1, 1000 grains mass was ranged from 49.0 to 50.5 g according to the genotypes. It was obtained that Calao was high value (50.5 g), but Vizerunok has small value (49.0 g). Many previous researchers were reported similar results (Furan et al., 2005; Atak & Ciftci, 2006).

The hectolitre mass of genotypes ranged from 60.6 to 64.6 kg. AD 72-91 was the highest (64.6 kg) while Vizerunok has the least values. Our results were similar to the results of Akgun et al. (1997) and Mut et al. (2006).

Under field condition seven quantitative traits were observed for 7 varieties of triticale. Analysis of variance exposed considerable level of variability among accessions for majority of the traits observed. Basic descriptive statistics are presented for 7 characters in Table 2.

The highest variation was found for yield. Relatively, low variation was noticed for plant height, spike length, grain number per spike, grain mass per spike, thousand grains mass and hectolitre mass.

The results of the correlation coefficients between the yield and yield components of triticale presented in Table 3, which shows that the plant height was positively and significantly correlated with the grain yield (r = 0.880**). This conclusion is in agreement with the results of other researchers, who reported positive and significant correlations between the yield and plant height (Sultana et al., 2002; Aycicek & Yildirim, 2006; Aydin et al., 2010; Gulmezoglu et al., 2010). The simple correlation coefficient was highly positive and significant between the grain yield and grain number per spike (r = 0.817*). Similar results have been reported between the grain yield and grain number per spike (Aydin et al., 2010; Abinasa et al., 2011; Tas & Celik, 2011). The spike length was positively and significantly correlated with grain yield (r = 0.488*), respectively. The results of the present relationships are consistent with the findings of previous researcher (Abinasa et al., 2011).

The grain yield was positively and significantly correlated with the grain mass per spike (r = 0.799**). Aycicek & Yildirim (2006) and Tas & Celik (2011) reported similar results for the correlation between the grain yield and grain mass per spike. In this study, the mass of thousand grains showed significant and positive associations with the grain yield (r = 0.836*), which is in agreement with the results of Furan et al. (2005) and Aycicek & Yildirim (2006). Our results revealed that the grain yield was positively correlated with the hectoliter mass (r = 0.053). Previous authors reported positive relationships between the grain yield and hectoliter mass (Abinasa et al., 2011).

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

Table 2. Descriptive statistics of grain yield and related characters in triticale genotypes

Characters	Range	Minimum	Maximum	Mean	Std. Error	Std. Deviation	Variance	CV, %
Yield kg/ha	171	5420	7130	589	21.94241	58.05416	3370.286	9.86
Plant height, cm	6,5	93.3	99.8	96	0.79604	2.10611	4.436	2.19
Spike length, cm	0.58	9.26	9.84	10	0.07002	0.18527	0.034	1.93
Grain number per spike	2.36	55.24	57.6	56	0.28864	0.76366	0.583	1.35
Grain mass per spike, g	0.05	1.42	1.47	1	0.0065	0.0172	0	1.19
1000 grains mass, g	1.5	49	50.5	50	0.21338	0.56456	0.319	1.14
Hectoliter mass, kg	3.97	60.63	64.6	63	0.48198	1.2752	1.626	2.01

Table 3. Correlation coefficients among grain yield and related characters in triticale genotypes

№	Characters	1	2	3	4	5	6	7
1	Yield	1	0.880**	0.488*	0.817*	0.799*	0.836*	0.053
2	Plant height		1	0.482*	0.904**	0.934**	0.776*	0.199
3	Spike length			1	0.680*	0.649*	0.748*	-0.238
4	Grain number per spike				1	0.966**	0.744*	-0.138
5	Grain mass per spike					1	0.798*	0.005
6	Mass of 1000 grains						1	0.226
7	Hectoliter mass							1

* sufficient evidence for reliability $\alpha = 0.05$; ** sufficient evidence for reliability $\alpha = 0.01$

(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 4.

The highest positive direct effect on the grain yield was the plant height (0.690), followed by the mass of thousand grains (0.330). In most of the previous studies, the plant height demonstrated positive direct effects on the grain yield (Gupta et al., 2004; Aydin et al., 2010).

The spike length had positive direct effect on the grain yield (0.285). Other authors also indicated a positive direct effect of the spike length on the grain yield (Khaliq et al., 2004; Khan et al., 2005; Tas & Celik, 2011). The indirect effects of the spike length via the grain number per spike and mass of thousand grains were small but great via the plant height.

The grain mass per spike had a positive direct effect on the grain yield (0.164), also previously reported (Ismail, 2001; Okuyama et al., 2004; Tripathi et al., 2011). Generally, the indirect effects of the grain mass per spike via all of the components were positive and great via plant height.

The direct effect of the mass of thousand grains on the grain yield was positive and high (0.330), as previously reported (Mohammed et al., 2002; Khan et al., 2005; Akram et al., 2008; Dogan, 2009). The indirect effects of the mass of thousand grains via the spike length, grain number per spike, grain mass per spike and hectoliter mass were positive and negative, whereas the indirect effects via the plant height was also positive but great.

The direct effect of the hectolitre mass on the grain yield was positive and weak (0.014). Similar results were found previously (Kara & Akman, 2007; Dogan, 2009; Aydin et al., 2011; Tripathi et al., 2011). The indirect effects of the hectolitre mass via plant height, spike length, grain number per spike, grain mass per spike and mass of thousands grains were positive or negative but small.

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 plant height, grain number per spike and mass of thousand grains are the primary selection criteria for higher grain yields in triticale.

The variation studied through Principal Component Analysis revealed that two principal components having greater than 1 eigenvalues contributed 86.77% of the total variation (Table 5). It was found that Principal Component 1 (PC1) contributed 69.51% and PC2 contributed 17.26%, respectively, of the total variation. All traits contributed positively to PC1. Maximum genetic variance to PC1 was contributed by grain mass per spike (0.435), grain number per spike (0.431) and plant height (0.423). Hectoliter mass contributed positively to PC2 (0.881).

Table 5. Principal Component Analysis of triticale genotypes

	PC1	PC2
Eigenvalue	4.86606	1.20815
Percent of variance	69.515	17.259
Cumulative percentage	69.515	86.774
Characters	Component Weights	
Yield kg/ha	0.408238	0.096047
Plant height	0.423409	0.194504
Spike length	0.331686	-0.366673
Grain number per spike	0.430849	-0.147638
Grain mass per spike	0.434919	-0.0210184
Mass of 1000 grains	0.411097	0.14224
Hectoliter mass	0.0162693	0.880922

Figure 1 represents a biplot in the dimension of the first and second PCs. Olympus, Orbital and Falko have positive values for first PC. These cultivars were characterized by high yield, high plant height, high spike length, high grain number per a spike, high grain mass per a spike and high thousand grains mass.

The dendrogram of the evaluated triticale genotypes was presented in Figure 2. Cultivars were grouped into two clusters. Cluster II (in green) have genotypes with maximum in yield, plant height, length spike, grain number per a spike, grain mass per a spike, 1000 grains mass and high hectolitre mass. Cluster I is constituted of 4 cultivars (in red).

Table 4. Direct and indirect effects on grain yield via various characters in triticale genotypes

№	Characters	Direct effect	Indirect effect						Total indirect coefficient	Correlation coefficient (r)
			1	2	3	4	5	6		
1	Plant height	0.690	–	0.054	0.020	0.015	0.085	0.016	0.190	0.880
2	Spike length	0.285	0.120	–	0.065	-0.021	0.062	-0.023	0.203	0.488
3	Grain number per spike	0.303	0.178	0.185	–	0.010	0.131	0.010	0.514	0.817
4	Grain mass per spike	0.164	0.298	0.128	0.102	–	0.056	0.051	0.635	0.799
5	Mass of 1000 grains	0.330	0.311	0.112	0.086	-0.006	–	0.003	506	0.836
6	Hectoliter mass	0.014	0.020	0.010	0.016	-0.005	0.008	–	0.049	0.053

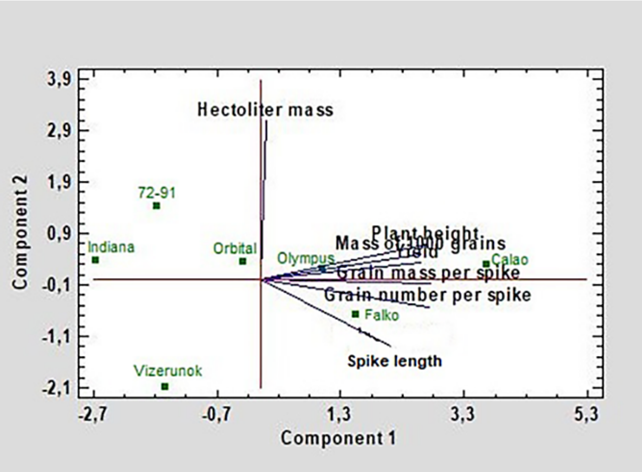

Fig. 1. Biplot of the principal components analysis of studied characters of triticale genotypes

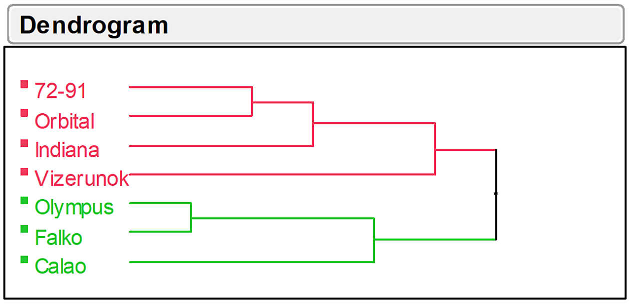

Fig. 2. Dendrogram base on studied characters of 7 triticale genotypes

Conclusions

Calao is characterized by the highest yield 7130 kg/ha, highest plant height 99.8 cm and grain number per spike 57.6 exceeding the standard AD 72-91 with good evidence.

In all tested triticale accessions was found statistically proven strong correlation between yield and plant height, grain number per spike, mass of thousand grain and grain mass per spike. Path-coefficient analysis shows that the traits plant height, grain number per spike, mass of thousand grains and spike length have the highest direct effect on yield.

These relationships should be taken into account when determining the criteria for increasing triticale productivity.

Olympus, Orbital and Falko have positive values for first PC. These cultivars were characterized by high yield, high plant height, high spike length, high grain number per a spike, high grain mass per a spike and high thousand grains mass.

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