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CORRELATION AND PATH ANALYSIS OF GRAIN YIELD AND COMPONENTS OF GRAIN YIELD OF MAIZE (*Zea mays* L.)

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Summary: Maize is one of the most important cereal crops. Besides its use as food and feed, maize is also an energy crop. In order to ensure sufficient quantities of maize, the main goal of every breeding program is to develop new, better hybrids. Correlation and path coefficient analysis can be used for indirect selection of high-yielding hybrids. In light of that, one of the objectives of this paper was to determine relationship between grain yield and morphological traits, for 8 inbred lines and their hybrids. Strong genetic and phenotypic correlations were found between grain yield and other studied traits, except between grain yield, on one side, and kernel row number, where we found medium phenotypic correlations. Between morphological traits of plant and ear the highest values of genotypic and phenotypic coefficient of correlations were found between ear length and kernel number per row. Also, the objective of this research was to find the direct and indirect effects of morphological traits on grain yield. Desirable, high significant influence on grain yield in path coefficient analysis, was found for almost all studied traits. Ear height was the only trait that had negative direct genetic and phenotypic influence.

Key words: maize, morphological traits, grain yield, correlations, path analysis

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INTRODUCTION

Maize is one of the most used cereal crops globally (**Taube et al., 2020**). The superior position of maize is due to its very wide and variety utilization. Besides its use as food and feed, maize is also, one of the most commonly used cereals for bioethanol production (**Aghaei et al, 2022**). The use of maize as an energy crop has plenty of benefits. It can increase the development of the rural area, ensure energy security, and has a positively impact on the environment (**Skoufogianni et al, 2020**).

Due to maize usage diversity, the main goal of all maize breeding programs is to develop variates that will be better than existing hybrids in a number of traits. Particular attention is paid to grain yield. Grain yield is a quantitative trait with a complex mode of inheritance and within great influence of environmental conditions. It depends on different processes during the life cycle, and it is in relationship with dissimilar components. Therefore, knowing the relationships between grain yield and its components can significantly increase the success of the breeding program (**Aman et al, 2020**). Due to the sequential development of yield through different growth stages, the importance of some yield components cannot be assessed using the correlation coefficient. Path coefficient analysis is more suitable because offers more information among variables than correlation coefficients, since this analysis provides the direct effects of specific yield components on yield, and indirect effects via other yield components (**Garcia del Moral et al., 2003**).

Thus, the objective of this paper was to determine the genetic and phenotypic interrelationship between grain yield and components of grain yield, in 15 hybrids and their parental inbred lines. Furthermore, the goal of this study was to find the direct and indirect effects of morphological traits on grain yield.

MATERIAL AND METHODS

The test-cross population studied in this research was developed by crossing 5 inbred lines (NSL 4026, NSL 4099, NSL 4065, B73 Ht, and A632) and three testers (NSL 115-2, NSL 130-5, and NSL 221/I). One year experiment was set up in an experimental field in a single location (Rimski Šančevi) using a complete block design with three replications. Each plot consisted of one, 5 m long row. The spacing between plots was 0,7 m and 0.25 m between plants. The standard growing technique was used and harvesting was done by hand.

The data for plant (PH) and ear height (EH), ear length (EL), kernel number per row (KNR), kernel row number (KRN), 100-kernel weight (KW), and grain yield per plant (GY) were recorded on 10 randomly taken competitive plants and ears per replication.

The coefficients of correlations (genetic and phenotypic) were calculated as a ratio of joint variation and a summary of individual variation of two traits (**Hallauer and Miranda, 1988**). The significance of the correlation coefficient was determined using t-test. The method of the inverse symmetric correlation matrix (**Edwards, 1979**) was used for path coefficients and levels of their significance determinations.

RESULTS AND DISCUSSION

In order to obtain the level of relationship between studied traits, we calculated the genetic and phenotypic coefficient of correlation.

Grain yield had the strongest, highly significant, genetic correlation with kernel number per row (r_g = 0.969**, Tab. 1). High significant, strong relationship also was found between grain yield, on one side, and plant height (r_g = 0.962**), ear height (r_g = 0.855**), ear length (r_g = 0.962**) and 100-kernel weight (r_g = 0.856**), on the other side.

Many authors found a strong correlation between grain yield and morphological traits of plants and ear. **Vara Prasad and Shivani (2017)** studied 18 maize genotypes in order to estimate the relationship between grain yield and yield-contributing traits. They detected strong and highly significant correlations between grain yield, on one side, and plant height, ear length, kernel row number and number of kernels per row, on the other side. Grain yield was insignificant, but medium strong relationship with ear height. Our results were similar to the results found by **Aman et al (2020)**. These authors studied the genetic potential of 45 quality protein maize (QPM) and found highly significant strong correlations between grain yield and plant and ear height. Between grain yield and kernel row number they also found highly significant strong correlations, but that relationship was negative, which is dissimilar to our results. Also, they found a weak genetic relationship, between the number of kernels per row and kernel yield which is in disagreement with the results obtained herein. Genetic correlations estimated in our research also were similar to the results of **Kanna et al. (2021)**. These authors studied the genetic variability of eight maize hybrids and found strong genetic correlations between ear height and length and kernel row number and grain yield per plant. Hundred kernel weight also was in strong genetic correlations with grain yield, but that relationship was negative.

On the contrary, **Ahmed et al. (2020)** determined low, negative genetic correlations between grain yield and plant and ear height. Ear length and the number of kernels row was in positive, but medium strong relationship with grain yield, and 1000 kernel weight was in positive, but weak correlation with yield.

Between other studied traits, the strongest genetic relationship was found between ear length and kernel number per row (r_g =0,955**). A highly significant and strong genetic relationship between these two traits also was obtained by **Kann et al (2021)**. **Vara Prasad and Shivan (2017)** found medium strong, and **Ahmed et al (2020)** weak genetic correlations between ear height and length. Results in this study are opposite to the results obtained by previous authors.

Table 1. Genetic (above diagonal) and phenotypic (below diagonal) correlation coefficient between morphological traits of plant and ear

	PH (cm)	EH (cm)	EL (cm)	KNR	KRN	KW (g)	GY (g)
PH (cm)		0.861**	0.934**	0.920**	0.640	0.813**	0.962**
EH (cm)	0.858**		0.830**	0.818**	0.686	0.644	0.855**
EL (cm)	0.927**	0.827**		0.955**	0.481*	0.851**	0.962**
KNR	0.915**	0.817**	0.951**		0.462	0.810**	0.969**
KRN	0.630	0.679	0.478	0.458		0.326	0.606
KW (g)	0.788**	0.629	0.830**	0.789**	0.306		0.856**
GY (g)	0.956**	0.853**	0.957**	0.966**	0.599	0.839**	

* $p < 0.05$

** $p < 0.01$

Mutual effects of genetic factors and environment on relationship of traits are determined by the phenotypic correlation coefficient.

The greatest value of the phenotypic coefficient of correlation was obtained between grain yield and kernel number per row (r_p = 0.951**, Tab. 1). Highly significant, positive values of phenotypic coefficient also were determined between grain yield, on the one side, and plant (r_p = 0.956**) and ear height (r_p = 0.853**), ear length (r_p = 0.957**), kernel number per row (r_p = 0.966**) and 100-kernel weight (r_p = 0.839**), on the other side. With kernel row number, grain yield was in a medium relationship (r_p = 0.599). The results, we obtained in our research, are in agreement with the results of **Yahaya et al. (2021)**. They studied growth and yield reaction on irrigation and different levels of fertilizers in two locations, and in both locations found highly significant and strong phenotypic correlations between grain yield and plant height, ear length, and kernel weight.

Table 2. Path coefficient analysis for grain yield based on genetic (a) and phenotypic (b) correlations

Pathway	*Population*	
	a	*b*
Plant height vs. Grain yield		
Direct effect (p_i)	**0.0714****	**0.0987****
Indirect effect via Ear height	-0.024	-0.017
Ear length	0.121	0.104
Kernel number per row	0.512	0.504
Kernel row number	0.126	0.118
100-kernel weight	0.154	0.149
Ear height vs. Grain yield		
Direct effect (p_i)	**-0.0274**	**-0.0203**
Indirect effect via Plant height	0.061	0.085
Ear length	0.108	0.093
Kernel number per row	0.455	0.450
Kernel row number	0.136	0.127
100-kernel weight	0.122	0.119
Ear length vs. Grain yield		
Direct effect (p_i)	**0.1300****	**0.1124****
Indirect effect via Plant height	0.067	0.091
Ear height	-0.023	-0.017
Kernel number per row	0.532	0.524
Kernel row number	0.095	0.089
100-kernel weight	0.161	0.157
Kernel number per row vs. Grain yield		
Direct effect (p_i)	**0.5567****	**0.5506****
Indirect effect via Plant height	0.066	0.090
Ear height	-0.022	-0.017
Ear length	0.124	0.107
Kernel row number	0.091	0.086
100-kernel weight	0.154	0.149

Kernel row number vs. Grain yield			
Direct effect (p_i)		**0.1976****	**0.1868****
Indirect effect via Plant height		0.046	0.062
	Ear height	-0.019	-0.014
	Ear length	0.063	0.0534
	Kernel number per row	0.257	0.252
	100-kernel weight	0.062	0.058
100-kernel weight vs. Grain yield			
Direct effect (p_i)		**0.1896****	**0.1891****
Indirect effect via Plant height		0.058	0.078
	Ear height	-0.018	-0.013
	Ear length	0.111	0.093
	Kernel number per row	0.451	0.434
	Kernel row number	0.064	0.057
Coefficient of determination	$R^2_{y1234567}$	*0.9918***	*0.9871***

Also, our results are similar to the results of **Aman et al (2020)** who founds strong correlations between grain yield and plant height, kernel weight and number of kernels per row, and a medium strong correlation between grain yield and kernel row number, like we are, but they also found medium strong relationship between grain yield and ear height, with which our results are not in agreement. **Muliadi et al (2021)** did the genetic analysis of 10 waterlogging hybrids of maize and found a highly significant, the strong phenotypic relationship between grain yield on one side and 100 kernel weight and ear length, on the other side, like we are, but contra to our results they estimated low correlations between plant and ear height, and number of kernels per row with grain yield per plant, and medium strong phenotypic relationship between kernel row number and grain yield.

The genetic direct effects, obtained in path coefficient analysis, indicated that grain yield per plant at most depended upon the number of kernels per row (p_5 = 0.5567**). **Vara Prasad and Shivani (2017)** also found the greatest direct effect of the number of kernels per row on grain yield. The indirect influence of kernel row number didn't show significance.

Highly significant, positive influence also was found for kernel row number (p_5 = 0.1976**), 100-kerel weight (p_6 = 0.1896**), ear length (p_3 = 0.1300**), and plant height (p_1 = 0.0714**). These results are in agreement with the results of **Muliadi et al (2021)**. **Kann et al (2021)** and **Aman et al (2020)** also found the positive direct influence of kernel row number, kernel weight, and ear length, but these authors estimated a negative genetic direct influence of plant height on grain yield. Our results are not in agreement with the results of **Ahmed et al**. (**2020**). These authors found the highest direct influence of ear height on grain yield, but the influence was negative. Also, in their research only ear length has a positive direct effect on grain yield.

Path coefficient analysis showed an undesirable, direct effect of ear height on grain yield (p_2 = -0.0274). High values of the genetic coefficient of correlations of ear height with grain yield are in disagreement with values of path coefficients. That could be explained that ear height was influencing the grain yield through other studied morphological traits of plant and ear. Negative values of the path coefficient for ear height were obtained and by **Alvi et al.** (**2003**) and **Sofi and Rather** (**2007**).

A positive direct phenotypic effect was found for almost all studied traits (Tab. 3). Ear height only had a negative, but not significant, direct phenotypic effect on grain yield. The highest value of the phenotypic path coefficient was estimated for a number of kernels per row, and it was highly significant. The highly significant direct phenotypic effect also determines for plant height, ear length, kernel row number and 100-kernel weight.

CONCLUSION

Based on the results obtained herein it could be concluded:

Grain yield had strong, genetic and phenotypic correlations, with all traits, except with kernel row number. The highest correlation was calculated between grain yield and kernel number per row. Between other studied traits, the highest value of correlation coefficient was found between ear length and kernel number per row.

Path coefficient analysis indicates that the greatest influence on grain yield has the number of kernels per row. High significant, genetic direct influence also was found for plant height, ear length, kernel row number and 100-kernel weight. Ear height has an undesirable influence on grain yield.

Path coefficient analysis based on phenotypic coefficient indicates positive and highly significant direct influence of plant height, ear length, kernel row number, number of kernels per row and 100-kernel weight. Ear height have negative, but not significant phenotypic direct effects.

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