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Original scientific paper

THE EFFECT OF YIELD COMPONENTS ON GRAIN YIELD IN DIFFERENT PROGENY TYPES OF AN F_3 MAIZE POPULATION

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This paper deals with the investigation of S_1 and HS progenies obtained from an F_3 maize population. Those two progeny groups were created in 2004, and field trials were carried out in the period 2005-2006 at three locations near Aleksinac, Leskovac, and Kruševac, in RCB design. After genotypic correlation coefficients were calculated, they were used to calculate path coefficients and multiple determination coefficients. Analysis of path coefficients showed significant direct effects of the all studied traits in both S_1 and HS progeny types. In S_1 progenies indirect effects were significant for the all paths, except for percent of stalk and root lodged plants through 1000 grain mass, 1000 grain mass through percent of stalk

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and root lodged plants, and for 1000 grain mass through number of grain rows. The strongest direct effect on grain yield in HS progenies was shown by percent of stalk and root lodged plants (0.68**), while number of grains per row gave the strongest negative direct effect on grain yield (-0.97**). Multiple determination coefficients were significant for the most of independent variables' combinations in both progeny types. Numerous combinations composed of just few traits showed joint effects almost equal to the one showed by all seven independent variables.

Key words: grain yield, maize, path coefficients, yield components

INTRODUCTION

Besides correlation, which express the level of interconnectedness between two traits, path analysis (WRIGHT, 1921; 1923) is also frequently used, and it enables better insight in relations that exist between the investigated traits. The existing interconnectedness among traits, expressed through correlation coefficients, can be divided by path analysis to direct and indirect effects. Path coefficient shows direct effect of a trait to the dependent variable, while indirect effect of an independent variable through another independent variable is measured by the product of simple correlation coefficient between those two variables and direct effect of the trait through which selection is done (IVANOVIĆ, 1984). Numerous reports point to the effect of grain mass on grain yield as the strongest one (OTTAVIANO and CAMUSSI, 1981*;* SINGH *et al.,* 1987*;* TRIFUNOVIĆ*,* 1994*)*. It is also possible to calculate joint effect of more than one yield component to grain yield, which is expressed by multiple determination coefficients (DELETIĆ*,* 2003*;* DELETIĆ *et al.,* 2005*)*. Therefore the aim of this paper is to give a detailed picture of grain yield dependence on yield components.

MATERIALS AND METHODS

The object of this study was F_3 maize population 2002-30, created in the Department of Maize, Institute of Field and Vegetable Crops, Novi Sad. During the first year of investigation (2004) about 150 plants of the population were selfed and simultaneously crossed with the tester 1491x1496, in order to get parallel S_1 and HS progenies. After the harvest, 41 progenies of each type (S_1 and HS) were selected for trials, by random sample method. During the second year (2005) a field trial was set in Aleksinac, and during the third year (2006) field trials were carried out in Leskovac and Kruševac (total three environments), in random complete block design with two replications, where the experimental plot area was 0.7x4.6 m. Number of plants per hectare amounted 62,112. After genotypic correlation coefficients were calculated, they were used to calculate path coefficients and multiple determination coefficients (DELETIĆ, 2003; STOJKOVIĆ, 2007), for the all combinations (from 2x2 to 7x7) of the independent variables.

RESULTS AND DISSCUSSION

In order to get a better view in correlative interconnectedness between traits multiple regression analysis was done and path coefficients were calculated for direct and indirect effects (tab. 1 and 2) of independent variables (yield components) to the dependent variable (grain yield). Path coefficients calculated by genotypic correlation coefficients were significant in S_1 progenies for the all direct effects, and for almost all indirect effects, except for percent of stalk and root lodged plants through 1000 grain mass, 1000 grain mass through percent of stalk and root lodged plants, and for 1000 grain mass through number of grain rows. The strongest direct effect was shown by plant height (1.85**), while ear height gave the strongest negative direct effect on grain yield (-0.74**).

Table 1. Analysis of path coefficients for grain yield (dependent variable) and yield components (independent variables), calculated on the basis of phenotypic correlation coefficients, in HS progenies

Paths	path coefficient	Paths	path coefficient
% of lodged plants → grain yield		Grain row number → grain yield	
Direct effect p_{1y}	0.65**	Direct effect p_{5y}	-0.15**
Through ear height $r_{12}p_{y2}$	0.41**	Through % of lodged $r_{51}p_{y1}$	-0.32**
Through plant height $r_{13}p_{y3}$	-1.35**	Through ear height $r_{52}p_{y2}$	-0.30**
Through ear length $r_{14}p_{y4}$	-0.23**	Through plant height $r_{53}p_{y3}$	0.69**
Through row number $r_{15}p_{y5}$	0.07**	Through ear length $r_{54}p_{y4}$	0.07**
Through grains/row $r_{16}p_{y6}$	-0.12**	Through grains/row $r_{56}p_{y6}$	0.15**
Through 1000 g. mass $r_{17}p_{y7}$	0.01	Through 1000 g. mass $r_{57}p_{y7}$	-0.09**
Ear height → grain yield		Number of grains per row → grain yield	
Direct effect p_{2y}	-0.74**	Direct effect p_{6y}	0.25**
Through % of lodged $r_{21}p_{y1}$	-0.36**	Through % of lodged $r_{61}p_{y1}$	-0.30**
Through plant height $r_{23}p_{y3}$	1.58**	Through ear height $r_{62}p_{y2}$	-0.23**
Through ear length $r_{24}p_{4y}$	0.20**	Through plant height $r_{63}p_{y3}$	0.56**
Through row number $r_{25}p_{5y}$	-0.06**	Through ear length $r_{64}p_{y4}$	0.25**
Through grains/row $r_{26}p_{6y}$	0.08**	Through row number $r_{65}p_{y5}$	-0.04**
Through 1000 g. mass $r_{27}p_{7y}$	-0.08**	Through 1000 g. mass $r_{67}p_{y7}$	0.05**
Plant height → grain yield		1000 grain mass → grain yield	
Direct effect p_{3y}	1.85**	Direct effect p_{7y}	-0.26**
Through % of lodged $r_{31}p_{y1}$	-0.47**	Through % of lodged $r_{71}p_{y1}$	-0.02
Through ear height $r_{32}p_{y2}$	-0.63**	Through ear height $r_{72}p_{y2}$	-0.23**
Through ear length $r_{34}p_{y4}$	0.18**	Through plant height $r_{73}p_{y3}$	0.75**
Through row number $r_{35}p_{y5}$	-0.06**	Through ear length $r_{74}p_{y4}$	0.14**
Through grains/row $r_{36}p_{y6}$	0.08**	Through row number $r_{75}p_{y5}$	0.01
Through 1000 g. mass $r_{37}p_{y7}$	-0.10**	Through grains/row $r_{76}p_{y6}$	-0.05**

Table 1.continued Analysis of path coefficients for grain yield (dependent variable) and yield components (independent variables), calculated on the basis of phenotypic correlation coefficients, in HS progenies

path	Path coefficient		
Ear length → grain yield			
Direct effect p_{4y}	0.42**		
Through % of lodged $r_{41}p_{y1}$	-0.35**		
Through ear height $r_{42}p_{y2}$	-0.35**		
Through plant height $r_{43}p_{y3}$	0.80**		
Through row number $r_{45}p_{y5}$	-0.02*		
Through grains/row $r_{46}p_{y6}$	0.15**		
Through 1000 g. mass $r_{47}p_{y7}$	-0.09**	Multiple determination coefficient $R^2_{y1234567}$	0.999**

* $p<0.05$; ** $p<0.01$.

Path coefficients in HS progenies were significant for the all direct effects. Unlike S_1, in HS progenies path coefficients of indirect effect were not significant for plant height through ear height and 1000 grain mass; for ear height through 1000 grain mass; for ear length through the all traits except number of grains per row; for number of grain rows through the all traits except stalk and root lodged plants percent; while for 1000 grain mass path coefficients were significant only through grain row number, and highly significant through number of grains per row. The strongest direct effect on grain yield in HS progenies was shown by percent of stalk and root lodged plants (0.68**), while number of grains per row gave the strongest negative direct effect on grain yield (-0.97**).

Multiple regression analysis enables establishing of joint effect on the dependent variable shown by many independent variables, by calculating multiple determination coefficients. It represents sum of products between path coefficients of independent variables and their correlations with the dependent variable. As the aim of the study was to establish joint effect of every possible combination of independent variables, it was necessary to analyze 120 matrices of correlation coefficients (one of 7x7, seven of 6x6, 21 of 5x5, 35 of 4x4, 35 of 3x3, and 21 of 2x2) for both S_1 and HS progenies. This procedure enabled to establish and test joint effects shown by every combination of independent variables to grain yield, on the basis of correlation coefficients (tab. 3 and 4).

Table 2. Analysis of path coefficients for grain yield (dependent variable) and yield components (independent variables), calculated on the basis of phenotypic correlation coefficients, in HS progenies.

Paths	path coefficient	Paths	path coefficient
% of lodged plants → grain yield		Grain row number → grain yield	
Direct effect p_{1y}	0.68**	Direct effect p_{5y}	0.64**
Through ear height $r_{12}p_{y2}$	-0.09**	Through % of lodged $r_{51}p_{y1}$	-0.04
Through plant height $r_{13}p_{y3}$	0.26**	Through ear height $r_{52}p_{y2}$	-0.03
Through ear length $r_{14}p_{y4}$	0.06*	Through plant height $r_{53}p_{y3}$	0.12
Through row number $r_{15}p_{y5}$	-0.04	Through ear length $r_{54}p_{y4}$	0.01
Through grains/row $r_{16}p_{y6}$	-0.79**	Through grains/row $r_{56}p_{y6}$	-0.36**
Through 1000 g. mass $r_{17}p_{y7}$	0.01	Through 1000 g. mass $r_{57}p_{y7}$	-0.07
Ear height → grain yield		Number of grains per row → grain yield	
Direct effect p_{2y}	0.19**	Direct effect p_{6y}	-0.97**
Through % of lodged $r_{21}p_{y1}$	-0.33**	Through % of lodged $r_{61}p_{y1}$	0.56**
Through plant height $r_{23}p_{y3}$	0.22**	Through ear height $r_{62}p_{y2}$	0.03
Through ear length $r_{24}p_{4y}$	0.15**	Through plant height $r_{63}p_{y3}$	0.25
Through row number $r_{25}p_{5y}$	-0.10**	Through ear length $r_{64}p_{y4}$	0.20
Through grains/row $r_{26}p_{6y}$	-0.17**	Through row number $r_{65}p_{y5}$	0.13
Through 1000 g. mass $r_{27}p_{7y}$	0.05	Through 1000 g. mass $r_{67}p_{y7}$	0.13
Plant height → grain yield		1000 grain mass → grain yield	
Direct effect p_{3y}	0.37**	Direct effect p_{7y}	-0.30*
Through % of lodged $r_{31}p_{y1}$	0.48**	Through % of lodged $r_{71}p_{y1}$	-0.01
Through ear height $r_{32}p_{y2}$	0.11	Through ear height $r_{72}p_{y2}$	-0.03
Through ear length $r_{34}p_{y4}$	0.37**	Through plant height $r_{73}p_{y3}$	-0.02
Through row number $r_{35}p_{y5}$	0.20**	Through ear length $r_{74}p_{y4}$	0.12
Through grains/row $r_{36}p_{y6}$	-0.64**	Through row number $r_{75}p_{y5}$	-0.31*
Through 1000 g. mass $r_{37}p_{y7}$	0.02	Through grains/row $r_{76}p_{y6}$	0.41**
Ear length → grain yield			
Direct effect p_{4y}	0.54**		
Through % of lodged $r_{41}p_{y1}$	0.08		
Through ear height $r_{42}p_{y2}$	0.05		
Through plant height $r_{43}p_{y3}$	0.26		
Through row number $r_{45}p_{y5}$	0.01		
Through grains/row $r_{46}p_{y6}$	-0.36**	Multiple determination	
Through 1000 g. mass $r_{47}p_{y7}$	-0.07	coefficient $R^2_{y1234567}$	0.824**

* p<0.05; ** p<0.01.

Table 3. Analysis of multiple determination coefficients, calculated on the basis of phenotypic correlation coefficients, in S_1 progenies.

Ind. variables[#]	R^2_{yi}	Ind. variables[#]	R^2_{yi}	Inde. variables[#]	R^2_{yi}
1,2,3,4,5,6,7	0.999**	1,3,4,6	0.869**	2,3,5	0.814**
1,2,3,4,5,6	0.997**	1,3,4,7	0.818**	2,3,6	0.866**
1,2,3,4,5,7	0.992**	1,3,5,6	0.923**	2,3,7	0.759**
1,2,3,4,6,7	0.999**	1,3,5,7	0.795**	2,4,5	0.504*
1,2,3,5,6,7,	0.977**	1,3,6,7	0.863**	2,4,6	0.538*
1,2,4,5,6,7	0.727**	1,4,5,6	0.487*	2,4,7	0.481*
1,3,4,5,6,7	0.926**	1,4,5,7	0.487*	2,5,6	0.589*
2,3,4,5,6,7	0.946**	1,4,6,7	0.613**	2,5,7	0.443
1,2,3,4,5	0.907**	1,5,6,7	0.637**	2,6,7	0.619**
1,2,3,4,6	0.979**	2,3,4,5	0.873**	3,4,5	0.831**
1,2,3,4,7	0.983**	2,3,4,6	0.874**	3,4,6	0.815**
1,2,3,5,6	0.977**	2,3,4,7	0.827**	3,4,7	0.762**
1,2,3,5,7	0.823**	2,3,5,6	0.942**	3,5,6	0.909**
1,2,3,6,7	0.944**	2,3,5,7	0.818**	3,5,7	0.795**
1,2,4,5,6	0.638**	2,3,6,7	0.881**	3,6,7	0.830**
1,2,4,5,7	0.583*	2,4,5,6	0.593*	4,5,6	0.380
1,2,4,6,7	0.655**	2,4,5,7	0.508*	4,5,7	0.332
1,2,5,6,7	0.703**	2,4,6,7	0.622**	4,6,7	0.520*
1,3,4,5,6	0.926**	2,5,6,7	0.653**	5,6,7	0.522*
1,3,4,5,7	0.869**	3,4,5,6	0.909**	1,2	0.453
1,3,4,6,7	0.869**	3,4,5,7	0.843**	1,3	0.728**
1,3,5,6,7	0.924**	3,4,6,7	0.831**	1,4	0.392
1,4,5,6,7	0.657**	3,5,6,7	0.912**	1,5	0.365
2,3,4,5,6	0.946**	4,5,6,7	0.522*	1,6	0.417
2,3,4,5,7	0.889**	1,2,3	0.775**	1,7	0.426
2,3,4,6,7	0.882**	1,2,4	0.493*	2,3	0.759**
2,3,5,6,7	0.945**	1,2,5	0.548*	2,4	0.470*
2,4,5,6,7	0.656**	1,2,6	0.543*	2,5	0.428
3,4,5,6,7	0.912**	1,2,7	0.501*	2,6	0.528*
1,2,3,4	0.896**	1,3,4	0.793**	2,7	0.417
1,2,3,5	0.815**	1,3,5	0.790**	3,4	0.761**
1,2,3,6	0.944**	1,3,6	0.860**	3,5	0.790**
1,2,3,7	0.779**	1,3,7	0.729**	3,6	0.813**
1,2,4,5	0.567*	1,4,5	0.430	3,7	0.720**
1,2,4,6	0.549*	1,4,6	0.441	4,5	0.300
1,2,4,7	0.519*	1,4,7	0.455	4,6	0.376
1,2,5,6	0.638**	1,5,6	0.474*	4,7	0.332
1,2,5,7	0.574*	1,5,7	0.466	5,6	0.304
1,2,6,7	0.642**	1,6,7	0.601*	5,7	0.138
1,3,4,5	0.838**	2,3,4	0.823**	6,7	0.520*

* $p<0.05$; ** $p<0.01$

Independent variables: 1 - % of lodged plants; 2 – ear height; 3 – plant height; 4 - ear length; 5 – grain row number; 6 – number of grains per row; 7 - 1000 grain mass.

Table 4. Analysis of multiple determination coefficients, calculated on the basis of phenotypic correlation coefficients, in HS progenies.

Independent variables#	R^2_{yi}	Independent variables#	R^2_{yi}	Independent variables#	R^2_{yi}
1,2,3,4,5,6,7	0.824**	1,3,4,6	3.421*	2,3,5	1.287**
1,2,3,4,5,6	0.796**	1,3,4,7	2.760**	2,3,6	1.716**
1,2,3,4,5,7	0.632**	1,3,5,6	1.453**	2,3,7	1.328**
1,2,3,4,6,7	0.513*	1,3,5,7	1.432**	2,4,5	0.664**
1,2,3,5,6,7,	0.645**	1,3,6,7	1.456**	2,4,6	0.300
1,2,4,5,6,7	0.665**	1,4,5,6	0.682**	2,4,7	0.373
1,3,4,5,6,7	0.661**	1,4,5,7	0.674**	2,5,6	0.458
2,3,4,5,6,7	-3.734	1,4,6,7	0.350	2,5,7	0.480
1,2,3,4,5	0.578*	1,5,6,7	0.598*	2,6,7	0.105
1,2,3,4,6	-0.002	2,3,4,5	1.394**	3,4,5	0.978**
1,2,3,4,7	-0.322	2,3,4,6	1.985**	3,4,6	1.023**
1,2,3,5,6	0.642**	2,3,4,7	1.403**	3,4,7	0.861**
1,2,3,5,7	0.529*	2,3,5,6	1.719**	3,5,6	1.114**
1,2,3,6,7	-0.095	2,3,5,7	1.334**	3,5,7	0.985**
1,2,4,5,6	0.654**	2,3,6,7	2.378**	3,6,7	1.091**
1,2,4,5,7	0.677**	2,4,5,6	0.665**	4,5,6	0.664**
1,2,4,6,7	0.347	2,4,5,7	0.667**	4,5,7	0.667**
1,2,5,6,7	0.549*	2,4,6,7	0.373	4,6,7	0.330
1,3,4,5,6	0.036	2,5,6,7	0.552*	5,6,7	0.533*
1,3,4,5,7	7.230*	3,4,5,6	1.127**	1,2	0.012
1,3,4,6,7	0.223	3,4,5,7	0.992**	1,3	1.424**
1,3,5,6,7	1.456**	3,4,6,7	1.105**	1,4	0.260
1,4,5,6,7	0.692**	3,5,6,7	1.137**	1,5	0.431
2,3,4,5,6	2.145**	4,5,6,7	0.670**	1,6	0.188
2,3,4,5,7	1.436**	1,2,3	-0.955	1,7	0.030
2,3,4,6,7	2.501**	1,2,4	0.279	2,3	1.279**
2,3,5,6,7	-11.771	1,2,5	0.474*	2,4	0.277
2,4,5,6,7	0.670**	1,2,6	-0.482	2,5	0.427
3,4,5,6,7	1.145**	1,2,7	0.031	2,6	0.105
1,2,3,4	-0.369	1,3,4	2.465**	2,7	0.022
1,2,3,5	0.332	1,3,5	1.429**	3,4	0.859**
1,2,3,6	-0.359	1,3,6	1.453**	3,5	0.975**
1,2,3,7	-0.948	1,3,7	1.431**	3,6	0.973**
1,2,4,5	0.669**	1,4,5	0.669**	3,7	0.842**
1,2,4,6	-0.114	1,4,6	0.303	4,5	0.664**
1,2,4,7	0.386	1,4,7	0.331	4,6	0.279
1,2,5,6	0.457	1,5,6	0.457	4,7	0.330
1,2,5,7	0.557*	1,5,7	0.469*	5,6	0.453
1,2,6,7	-0.141	1,6,7	0.231	5,7	0.449
1,3,4,5	7.162*	2,3,4	1.389**	6,7	0.103

* $p<0.05$; ** $p<0.01$.

Independent variables: 1 - % of lodged plants; 2 – ear height; 3 – plant height; 4 - ear length; 5 – grain row number; 6 – number of grains per row; 7 - 1000 grain mass.

In S_1 progenies, genotypic coefficients of multiple determination were highly significant for the most of investigated combinations of independent variables, but the highest one was multiple determination coefficient for the all seven independent variables (0.999**), and the same value was shown by combination of the all traits except grain row number. There also were lower grade combinations showing almost equal effect on grain yield as combination of the all investigated traits. Significant negative values of joint effect of yield components to grain yield were not found.

As in S_1 progenies, in HS progenies genotypic coefficients of multiple determinations were highly significant for the most of investigated combinations of independent variables. These coefficients showed a greater variability in HS progenies than in S_1 ones. Many lower grade joint effects gave high values. Significant negative values of yield components joint effect to grain yield were not found.

However, it should be mentioned that such large number of significant joint effects of yield components to grain yield indicate a complex genetic determination of grain yield, which represents a "super trait", so it was expected that investigated traits, showing an obvious influence on grain yield, would also show a significant joint effect, even in the cases where direct effects were not significant. That fact points to possibility of indirect selection for grain yield through yield components, although is usually more convenient to do direct selection for grain yield because it is much easier to be measured in field trials.

CONCLUSION

On the basis of the presented facts it can be concluded the following:

- Analysis of path coefficients showed significant direct effects of the all studied traits in both S_1 and HS progeny types. Indirect effects were significant for the most of the paths in S_1 progenies and for many paths in HS progenies.
- Multiple determination coefficients were significant for the most of independent variables' combinations in both progeny types. Numerous combinations composed of just few traits showed joint effects almost equal to the one showed by all seven independent variables.
- A large number of significant joint effects of yield components to grain yield indicate a complex genetic determination of this trait.

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UTICAJ KOMPONENTI PRINOSA NA PRINOS ZRNA KOD RAZLIČITIH POTOMSTAVA JEDNE F_3 POPULACIJE KUKURUZA

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I z v o d

U radu su ispitivana S_1 i HS potomstva dobijena od jedne F_3 populacije kukuruza. Nakon stvaranja navedenih potomstava tokom 2004 godine, ogledi su obavljeni u periodu 2005-2006 u okolini Aleksinca, Leskovca i Kruševca, po RCBD metodi. Nakon izračunavanja koeficijenata genotipskih korelacija, na osnovu njih su izračunati koeficijenti putanje i koeficijenti višestruke determinacije. Analiza "*path*" koeficijenata je pokazala značajan direktan uticaj za sva svojstva i kod S_1 i HS potomstava. Kod S_1 potomstava indirektni uticaji bili su značajni za sve osim za procenat poleglih i slomljenih biljaka preko mase 1000 zrna, mase 1000 zrna preko procenta poleglih i slomljenih biljaka i mase 1000 zrna preko broja redova zrna. Najjači direktan uticaj na prinos zrna kod HS potomstava je pokazao procenat poleglih i slomljenih biljaka (0,68**), dok je broj zrna u redu ostvario najjači negativni direktan uticaj na prinos zrna (-0,97**). Koeficijenti višestruke determinacije su bili značajni za većinu kombinacija nezavisno promenljivih kod obe grupe potomstava. Veliki broj kobinacija od svega par svojstava je pokazao združeni uticaj skoro jednak uticaju svih sedam ispitivanih svojstava.

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