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GENETIC PARAMETERS OF YIELD AND MORPHOLOGICAL FRUIT AND STONE PROPERTIES IN APRICOT

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Yield, fruit and stone weight and dimensions were studied in 24 apricot cultivars over a four-year period, to determine components of variability, heritability and genetic and phenotypic correlations. The analysis of the components of total variance evidenced that genetic differences between cultivars determined to the highest percentage the variability of fruit height and stone weight and dimensions, whereas the variation of yield, and fruit weight, breadth and thickness was predominantly determined by ecological factors. The values of heritability coefficients, in a broader sense, were found to be relatively high for fruit and stone weight and dimensions (88-93%), and medium for yield (48%). It was established by correlation analysis that all genetic and phenotypic coefficients of correlation between fruit and stone weight and dimensions were positive and statistically very significant. Yield was in a very significant, positive genetic correlation with a majority of studied characters except for fruit breadth. However, the phenotypic coefficients of correlation between those properties were not statistically significant.

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INTRODUCTION

The morphological traits of apricot fruit and stone, such as weight and dimensions are used to describe and identify cultivars, select the most suitable genotypes for growing, define classes in quality standards and sort apricot fruits (VACHŮN, 2003). Fruit weight is one of the most important properties of apricot as it represents an important component of yield as well as of fruit quality.

The apricot yield, fruit and stone weight and dimension manifest continuous variability, which is characteristic of quantitative traits. The expression of most quantitative traits is complex and determined by a large number of segregated loci acting together with non-genetic factors. The degree of complexity depends on the manner of gene expression and on how much the non-genetic factors have an impact on the individual phenotypes. LAYNE *et al.* (1996) point out that there is very little knowledge about the inheritance of properties in apricots. One of the reasons for this is the fact that genetic studies in fruit species, including apricot, require a lot of space and a long time period.

The knowledge about heritability coefficients and correlation coefficients in apricot is limited. COURANJOU (1995) indicates that the values of the coefficients of heritability for the 11 studied apricot characters ranged from 0.294 for overcolor to 0.936 for flowering date. Heritability determined for fruit size amounted to 0.615 and for yield 0.784. BASSI *et al.* (1996) determined a relatively low heritability for total acids and mean heritability values (0.44 – 0.62) for sugar content, based on the results of regression analysis for 39 cultivars and four progenies obtained by controlled hybridization. On the basis of path analysis, OKUT and AKCA (1995) determined the highest correlation coefficient in apricot between fruit cheek and fruit weight (0.88) and the highest path coefficient between fruit weight and fruit suture (0.45).

The knowledge of the genetic mechanism that controls the inheritance of a character and the impact of genetic and environmental factors on their expression is essential for successful breeding programs. In addition to determining the components of variability and the coefficient of heritability, it is very important in apricot breeding to know the relationships existing between properties, because the selection of desirable genotypes is often carried out on the basis of several properties. Under the impact of selection a change in the correlated interdependence of traits occurs, therefore the testing of values of correlation coefficients must be done all the time. For this reason, the aim of the present work was to determine the components of variability and the coefficients of heritability for yield, fruit and stone weight and dimensions, and to observe the inter-relations of such traits in apricot, based on the values of genetic and phenotypic correlation coefficients.

MATERIAL AND METHODS

Research was done at the Experimental Station 'Radmilovac' of the Faculty of Agriculture in Belgrade. An apricot collection orchard was established in 1992 with five trees of each cultivar. The planting was done at a distance of 4.5 x 4.5 m. Rootstock is myrobalan seedling (*Prunus cerasifera* L.). Standard agrotechnical procedures were applied. The field experiment was performed during 1997, 1999, 2000 and 2001. The experiment was established as a completely randomized design. Three trees of uniform vigor were selected from every cultivar, which represented observation units i.e. replications.

On the basis of phenotypic differences, 24 cultivars were selected from the apricot collection orchard. Four cultivars ('Frühe Kittse', 'Ambrosia', 'Polonais', 'Bergeron') originate from West European countries, 13 cultivars ('Hungarian Best', 'Cegledi Orias', 'Cegledi Biborkajszi', 'Ligeti Orias', 'Szegedi Mammut', 'Kecskemeter Rose', 'Krasnyi Partizan', 'Kostjuzhenskyi', 'Sulmona', 'Marculesti 22/6', 'Selena', 'Roxana', 'Silistrenska Kompotna') from East European countries, five cultivars ('Stark Early Orange', 'NJA-1', 'Nugget', 'Stella', 'Harcot') from North America and two from Serbia ('Cacak's Gold', 'Cacak's Flat').

The properties studied were as follows: yield (Y), fruit weight (FW), fruit height (FH), fruit breadth (FB), fruit thickness (FT), stone weight (SW), stone height (SH), stone breadth (SB) and stone thickness (ST). Yield was determined by measuring the weights of all fruits from the tree. A caliper was used to measure the dimensions of fruit and stone and scales to measure fruit and stone weight of a sample of 20 fruits per tree.

The mean values of the studied properties were determined. The obtained results were processed by ANOVA in the statistic program 'Statistica' (StatSoft, Inc.). Individual testing of the significance of differences between cultivars and years was carried out by LSD test.

Using the results of two-factorial variance analysis, according to JOVANOVIĆ *et al.* (1992), the following components of total variance were computed: variance of year (S^2_y), genetic variance (S^2_g), variance of year x genotype interaction (S^2_{yg}), variance of error (S^2_e), all expressed in per cent. Also, phenotypic variance (S^2_{ph}) was calculated.

Heritability coefficient (h^2), in a broader sense, was calculated as the relation of genetic and phenotypic variance and expressed in percent.

The coefficients of genetic (r_g) and phenotypic (r_{ph}) correlation were obtained by the following formula:

$$r_{g_{xy}(ph_{xy})} = COV_{g_{xy}(ph_{xy})} / \sqrt{S^2_{g_x(ph_x)} x S^2_{g_y(ph_y)}}$$

Genetic (COV_g) and phenotypic (COV_{ph}) covariance were obtained by the method of covariance analysis (ANCOVA) which is analogous to variance analysis, the difference being that the sums of products are used. The testing of the significance of correlation coefficients was done by t-test.

RESULTS AND DISCUSSION

Average yield in apricot cultivars for four study years (Table 1.) varied from 1.6 kg/tree ('Stella') to 39.0 kg/tree ('Sulmona'). 'Stella' had the lowest fruit weight (16.5 g), height (35.6 mm), breadth (30.8 mm) and thickness (28.1 mm), whereas 'Selena' had the highest fruit weight (68.3 mm), height (53.4 mm), breadth (50.6 mm), and thickness (46.0 mm). 'Frühe Kittse' had the lowest stone weight (1.8 g) and length (22.3 mm), 'Stella' had the lowest stone breadth (14.6 mm) and 'Cacak's Flat' had the lowest stone thickness (10.5 mm). Stone weight (4.2 g) and stone breadth (24.8 mm) were the highest in 'Silistrenska Kompotna', stone length (32.7 mm) in 'Marculesti 22/6' and stone thickness (14.6 mm) in 'NJA-1'. The lowest average value for yield was in 1997 and for fruit and stone weight and dimensions in 1999. The highest value for yield was in 1999, for fruit weight, length and thickness and stone weight and thickness in 1997, for fruit breadth in 2001, and for stone length and breadth in 2000. The analysis of variance indicated that the expressed differences for all nine properties were very significantly determined by genotype and year as well as by their interaction.

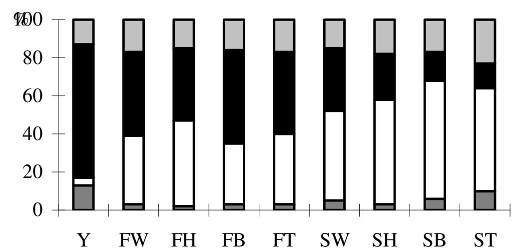

Figure 1. - Components of variability (S^2_{yg} – variance of year x genotype interaction; S^2_y – variance of year; S^2_g - genetic variance; S^2_e - variance of error and random factors in the experiment) for yield (Y) and eight morphological properties of apricot fruit and stone (FW - fruit weight; FH - fruit height; FB - fruit breadth; FT - fruit thickness; SW - stone weight; SH - stone height; SB - stone breadth; ST - stone thickness)

Random factors and error account for 2% to 13% in the total variability of studied properties (Figure 1). Genetic differences between apricot cultivars have determined stone breadth (S^2_g = 62%), stone height (S^2_g = 55%), stone thickness (S^2_g = 54%), stone weight (S^2_g = 47%) and fruit height (S^2_g = 45%) variability to the highest percentage, while the variability of yield (S^2_y = 70%), fruit thickness (S^2_y = 49%), fruit weight (S^2_y = 44%) and fruit breadth (S^2_y = 43%) were mainly determined by ecological factors (year). Variability caused by the cultivar x year interaction ranged in total variability from 13% for yield to 23% for stone thickness.

Table 1. - Mean values of the yield and eight morphological fruit and stone properties in 24 apricot cultivars for four years of research

Cultivar		Yield (kg/tree)	Fruit weight (g)	Fruit height (mm)	Fruit breadth (mm)	Fruit thickness (mm)	Stone weight (g)	Stone height (mm)	Stone breadth (mm)	Stone thickness (mm)
'Ambrosia'		26.3	47.4	49.8	46.7	40.0	3.9	30.9	22.8	12.4
'Bergeron'		20.3	44.1	44.3	42.2	39.2	2.5	26.8	19.0	11.1
'Cacak's Gold'		24.4	45.0	43.9	43.8	40.5	3.4	27.4	21.4	12.8
'Cacak's Flat'		19.2	30.7	47.0	40.5	32.7	2.5	30.4	20.4	10.5
'Cegledi Biborkajszi'		24.2	55.7	50.8	47.9	43.5	3.8	30.9	24.4	12.4
'Cegledi Orias'		21.4	60.6	51.8	49.1	43.5	3.0	30.8	20.9	12.0
'Frühe Kittse'		29.0	27.1	35.7	36.9	34.1	1.8	22.3	17.0	10.6
'Harcot'		16.4	51.6	46.3	44.4	41.7	2.8	25.2	19.7	13.4
'Hungarian Best'		20.3	46.3	44.8	44.4	41.0	3.1	27.4	21.5	12.0
'Kecskemeter Rose'		15.7	35.4	42.1	40.9	35.8	2.9	27.3	21.3	11.6
'Kostjuzhenskyi'		22.8	64.5	52.7	50.2	44.7	3.2	30.6	21.5	12.2
'Krasnyi Partizan'		16.8	47.1	47.0	45.3	40.6	3.5	27.7	22.3	13.5
'Ligeti Orias'		22.6	66.2	52.8	50.3	45.6	3.1	30.5	21.6	12.2
'Marculesti 22/6'		33.0	48.8	51.1	45.5	38.4	3.5	32.7	22.4	11.5
'NJA-1'		12.8	62.8	47.8	48.1	45.8	3.2	25.3	20.5	14.6
'Nuggget'		9.4	34.1	39.3	39.1	36.5	2.6	22.8	18.0	12.5
'Polonais'		25.0	49.0	45.0	44.6	41.5	2.7	25.7	20.6	12.7
'Roxana'		22.4	53.2	50.1	46.2	41.4	3.7	30.8	24.2	12.5
'Selena'		17.1	68.3	53.4	50.6	46.0	3.3	29.4	22.1	12.5
'Silistr. Kompotna'		27.4	47.3	49.2	46.9	38.3	4.2	31.3	24.7	13.4
'Stark Early Orange'		20.1	37.7	41.3	40.9	37.6	2.6	24.8	19.2	12.6
'Stella'		1.6	16.5	35.6	30.8	28.1	1.8	24.9	14.6	10.8
'Sulmona'		39.0	52.7	49.7	45.5	40.7	3.8	30.7	22.8	12.2
'Szegedi Mammut'		28.4	61.7	52.2	49.4	44.2	3.0	31.0	21.0	12.5
Year	1997	1.8	60.7	50.7	48.3	43.8	3.4	29.2	21.6	12.6
	1999	50.6	30.2	40.4	37.1	34.1	2.3	25.8	19.4	11.7
	2000	6.3	44.8	47.0	43.7	38.9	3.4	30.2	21.8	12.2
	2001	27.3	56.5	49.2	49.2	43.3	3.3	27.8	21.2	12.6
LSD_G	0.05	7.83	3.04	0.89	0.99	0.93	0.16	0.51	0.57	0.35
	0.01	10.36	4.02	1.18	1.31	1.23	0.21	0.68	0.76	0.47
LSD_Y	0.05	3.20	1.24	0.36	0.40	0.38	0.06	0.21	0.23	0.14
	0.01	4.23	1.64	0.48	0.53	0.50	0.09	0.28	0.31	0.19

The values of heritability coefficients in a broader sense (Figure 2.), were relatively high for fruit and stone weight and dimensions, and ranged from 88% to 93%, while the heritability coefficient for yield was medium and amounted to 48%.

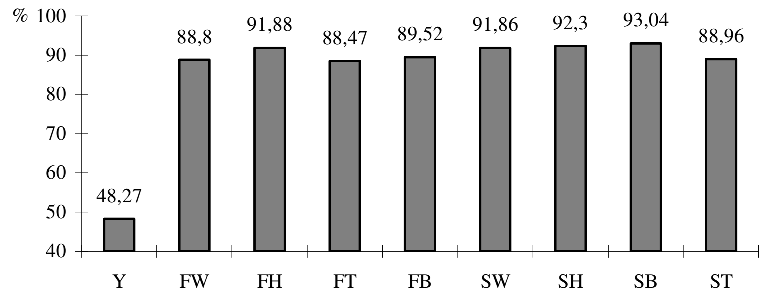

Figure 2. - Coefficients of heritability in a broader sense for yield (Y) and eight morphological properties of apricot fruit and stone (FW - fruit weight; FH - fruit height; FB - fruit breadth; FT - fruit thickness; SW - stone weight; SH - stone height; SB - stone breadth; ST - stone thickness)

Our results of the correlation analysis are presented in Table 2 and show that value of most genetic correlation coefficients was higher than that of adequate phenotypic correlation coefficients.

Table 2. - Coefficients of genetic (above the diagonal) and phenotypic (below the diagonal) correlation between yield and eight morphological fruit and stone properties in apricot

Properties	Yield	Fruit weight	Fruit height	Fruit breadth	Fruit thickness	Stone weight	Stone height	Stone breadth	Stone thickness
Yield	-	0.63**	0.76**	0.76**	0.53**	0.77**	0.88**	0.89**	-0.04
Fruit weight	0.34	-	0.88**	0.98**	0.99**	0.60**	0.54**	0.62**	0.55**
Fruit height	0.45	0.88**	-	0.94**	0.77**	0.73**	0.86**	0.78**	0.32
Fruit breadth	0.44	0.96**	0.93**	-	0.94**	0.73**	0.67**	0.78**	0.54**
Fruit thickness	0.30	0.99**	0.78**	0.93**	-	0.65**	0.38	0.58**	0.62**
Stone weight	0.48	0.60**	0.72**	0.71**	0.55**	-	0.72**	0.95**	0.55**
Stone height	0.54**	0.55**	0.85**	0.66**	0.40	0.71**	-	0.78**	-0.04
Stone breadth	0.56**	0.62**	0.77**	0.76**	0.58**	0.93**	0.77**	-	0.40*
Stone thickness	-0.04	0.54**	0.33	0.53**	0.61**	0.55**	-0.01	0.42*	-

**, * Indicates significance at the P<0.01and P<0.05, respectively.

The strongest genetic and phenotypic correlation, on the basis of correlation coefficients, was observed between fruit weight and thickness

(r_g=0,99**, r_{ph}=0.99**). Also, most other values of genetic and phenotypic coefficients of correlation between fruit and stone weight and dimensions were statistically either very significant or significant. No significant correlations were found only between stone height and fruit thickness, stone thickness and fruit height, and stone thickness and stone breadth.

Yield was in a very significant genetic correlation with fruit weight (r_g=0.63**), fruit height (r_g=0.76**), fruit breadth (r_g=0.76**), fruit thickness (r_g=0.53**), stone weight (r_g=0.77**), stone height (r_g=0.88**) and stone breadth (r_g=0.89**). The genetic correlation between yield and a majority of fruit and stone properties was not expressed in phenotype, because the phenotypic correlation coefficients between these characteristics were not statistically significant for the most part.

DISCUSSION

Mean four-year values of yield, fruit and stone weight and dimensions indicate that a relatively high variability of these properties has been expressed in studied apricot cultivars. It was found by the analysis of variance, based on F-test results, that expressed differences for all nine properties were very significantly determined by genotype. Apart from genetic factors, a very significant impact on the variability of characters also came from the year. A considerable influence of the cultivar x year interaction indicates that there is a specific aspect in the reaction of a cultivar to different environmental conditions which manifested themselves in the course of a four-year study.

The analysis of variance components indicates that random factors and error in the experiment account for the lowest percentage (2-10%) in the total variability of all morphological fruit and stone properties. It was only the percentage of this factor that was somewhat higher (13%) in total yield variability. This can be partly explained by the fact that the set up of experiment did not make it possible to calculate the variance percentage caused by rootstock, which MIŠIĆ (1987) indicates as a significant component of variability, especially when generative rootstock is used. In that case rootstock represents a random factor and is included in the error variance. Differences in study years produced the greatest impact on the total yield variability (70%). The variability of this character is determined to a much lower percentage by the cultivar x year interaction (13%), whereas genetic differences between apricot cultivars determined only 4% of total variability. The variability of fruit properties is caused to a similar percentage by genetic factors (32 – 45%) and year (38 – 49%), however, genetic differences in stone character between apricot cultivars (47 – 62%) present a dominant component in relation to year (13 – 33%).

The values of heritability coefficients for studied fruit and stone properties were relatively high (88 - 93%). Much lower values for peach fruit weight and dimensions were obtained by HANSCHE *et al.* (1972), HANSCHE and BERES (1980), MONET and BASTARD (1982), HANSCHE (1986) and de SOUZA *et al*. (1998). These differences are not unexpected if we know that heritability coefficient value is a function of variability of a specific character in the studied population as well as a function of ecological conditions that the trees are grown in (COCKERHAM, 1963, FALCONER 1989). The heritability coefficient value depends also on the experiment design as well as on the applied statistical procedure for its estimation (COCKERHAM, 1963; SEARLE, 1971; FALCONER, 1989; NYQUIST 1991). In addition, most of the mentioned authors use heritability coefficients in a narrow sense, which represent the relation between additive and phenotypic variance. However, in the present work heritability coefficients have been used in a broader sense and they represent the relation between total genetic and phenotypic variance. In that case, the genetic variance, apart from variation caused by additive gene effects, also contains variation caused by allelic interaction (intra- and intergene). A different definition for calculating these two types of heritability coefficients may result in significant differences in some characters, even in the case when they are determined on the basis of the results of a single experiment, and particularly if they are calculated on the basis of the results from different experiments.

A correlation between two quantitative properties is caused by genetic and ecological factors and it can also be a consequence of their interaction directed to the same or opposite trends. Therefore, it is necessary to determine not only the phenotypic correlation coefficient but also the values of genetic correlation coefficients.

In the present work it has been established that there are very significant both genetic and phenotypic correlations between most fruit and stone properties, which suggests that pleiotropic or closely linked genes control these traits.

The coefficients of genetic correlation between yield and most fruit and stone properties were very significant, while the coefficients of phenotypic correlation among these properties were mainly statistically non-significant. Differences in the statistical significance of coefficients of genetic and phenotypic correlation were determined by HANSCHE *et al*. (1967) in sweet cherry as well as by RAKONJAC (2005) in peach. TOPP and SHERMAN (1989) have also observed that interrelation between some traits can be caused by ecological factors too. One of the reasons for expressed differences in the significance of the coefficients of genetic and phenotypic correlation between the indicated characters may be the consequence of the effects of ecological factors tending to opposite directions in the two observed characters (SEARLE, 1961). In our experiment low temperatures during the flowering season may have produced such effects. They caused the decline in the number of fruits and at the same time increase in dimensions and weight of fruit and stone. The increase was in accordance with cultivars' genetic potential and could not make up fully for decrease in the number of fruits, which had impact on yield level in the long run.

A wide range of variability and relatively high heritability coefficients values of apricot properties studied in this work indicate that the selection of parents for combining breeding can be based on their phenotype. Since the heritability coefficient for yield was lowest in the case when this character is the basic aim of breeding, indirect selection is recommendable via some of the morphological properties of fruit or stone, considering they possessed high heritability level and at the same time correlated strongly with yield.

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GENETIČKI PARAMETRI PRINOSA I MORFOLOŠKIH OSOBINA PLODA I KOŠTICE KOD KAJSIJE

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I z v o d

Tokom četiri godine, kod 24 sorte kajsije, utvrđeni su prinos, masa i dimenzije (visina, širina i debljina) ploda i koštice. Rezultati analize varijanse su pokazali da je varijabilnost svih proučavanih osobina bila veoma značajno uslovljena i genetičkim i ekološkim faktorima, kao i njihovom interakcijom. Analizom komponenti ukupne varijabilnosti ustanovljeno je da su genetičke razlike među sortama u najvećem procentu uslovile varijabilnost mase koštice (S^2_g=47%), visine ploda (S^2_g=45%), visine koštice (S^2_g=55%), širine koštice (S^2_g=62%) i debljine koštice (S^2_g=54%), dok je variranje prinosa (S^2_y=70%), mase ploda (S^2_y=44%), širine ploda (S^2_y=43%) i debljine ploda (S^2_y=49%) bilo u najvećem procentu uslovljeno ekološkim faktorima. Vrednosti koeficijenata heritabilnosti u širem smislu bile su relativno visoke za masu i dimenzije ploda i koštice (h^2=88,5-93,0%), a srednja za prinos (h^2=48,3%). Korelacionom analizom ustanovljeno je da su svi koeficijenti genetičke i fenotipske korelacije, između mase i dimenzija ploda i koštice, bili pozitivni i statistički veoma značajni. Prinos je bio u veoma značajnoj, pozitivnoj, genetičkoj korelaciji sa većinom proučavanih osobina, osim sa širinom koštice. Međutim fenotipski koeficijenti korelacije između ovih osobina nisu bili statistički značajni.

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