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Variability and Path Coefficient Analysis of Yield Components in 'Oblačinska' Sour Cherry Sub-Clones

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Abstract

The present paper examines variability of initial fruit set, final fruit set, number of flower buds/cm^2 limb cross-sectional area, number of flowers/cm^2 limb cross-sectional area, number of flowers per bud, fruit weight and yield in 10 selected sub-clones of 'Oblačinska' sour cherry (*Prunus cerasus* L.). Correlation and path coefficient analysis indicated both direct and indirect effects of yield components on yield. Sub-clones of 'Oblačinska' sour cherry differed significantly in all characteristics studied. Genetic variance was found to be a dominant component of yield variability, whereas year had the greatest effect on variability of the majority of yield components, except for number of flower buds/cm^2 limb cross-sectional area. Correlation analysis showed that only fruit weight was correlated significantly with yield. However, apart from fruit weight, initial fruit set and the number of flowers per bud were isolated by path analysis as other important yield components.

'Oblačinska' sour cherry (*Prunus cerasus* L.) is an autochthonous self-compatible cultivar representing the majority of sour cherry fruit trees in Serbian commercial orchards. Mišić (11) reported that the existing population of 'Oblačinska' sour cherry trees has mainly developed by vegetative propagation of shoots, although sexual propagation cannot be excluded during the spread of this cultivar. This history contributed to the fact that 'Oblačinska' sour cherry is today a heterogeneous cultivar population, i.e. a mixture of a large number of genotypes and/or sub-clones.

Since there is a lack of uniformity in vigor, flowering and maturing time, productivity, size and quality of fruits in many 'Oblačinska' sour cherry orchards, it is necessary to study variability of characteristics and isolate clonal material for future propagation and breeding work. We started our work on clonal selection of 'Oblačinska' sour cherry at the Faculty of Agriculture (Belgrade) by studying this cultivar's variability in commercial orchards and by isolating phenotypically different clones (10, 12). The results of long-term research have shown that the studied clones had identical shape, skin color, flesh color, juice color and fruit taste, but differed significantly in yield, fruit weight, stone weight, percentage of flesh in total fruit weight, fruit stalk length, and total acids content (13, 14).

Yield increase is a top-priority task in many breeding programs. However, yield is a complex characteristic influenced by genetic, environmental and cultural factors. Therefore, to achieve the goal as quickly as possible, it is recommended to select for individual yield components, particularly because the heritability of yield components is known, as a rule, to be higher than heritability of yield itself. Yield component analysis has provided information on the partitioning of resources within the plant and is useful in evaluating breeding material and selecting parents (3). In their examinations of individual yield components in sour cherry, Chang et al. (1) found that fruit number, fruit weight, number of reproductive buds and fruit set are the most significant yield components in 'Montmorency' and 'Meteor' sour cherry cultivars.

The objectives of this study were to determine in 'Oblačinska' sour cherry sub-clones: a) the variability of total yield and yield components including fruit set, abundance of flowering and fruit weight, and b) the interdependence between yield and other studied characteristics using coefficients of phenotypic correlation and path coefficient analysis.

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Materials and Methods

Ten selected sub-clones of 'Oblačinska' sour cherry were studied. The sub-clones were isolated from commercial orchards in southern Serbia, according to maturity time, yield and fruit quality. Thereafter, they were vegetatively propagated by grafting on Mahaleb seedling rootstocks. The sub-clone collection was planted in 1994 in the "Radmilovac" experimental field (Faculty of Agriculture, Belgrade) with plants being spaced at 4 x 3 m. The experimental design was a two-factorial, randomized complete block system with three replicates. Single trees were the unit of replication for all analyses.

During 2003 and 2004, the characteristics studied were: initial fruit set, final fruit set, number of flower buds, number of flowers, number of flowers per bud, fruit weight and yield.

To analyze level of fruit set and abundance of flowering, 3 four-year-old limbs were marked on each tree of all studied sub-clones. The level of fruit set was expressed as initial fruit set and final fruit set after open pollination. Initial fruit set was the ratio of the number of fruits three weeks after flowering to the number of flowers, while final fruit set was the ratio of the number of fruits prior to harvesting to the number of flowers (9). Abundance of flowering was expressed as the number of flower buds, number of flowers and number of flowers per bud. To make comparisons between sub-clones and for further statistical analysis, these two characteristics were expressed per cm^2 of limb cross-sectional area (LCSA). The number of flowers per bud was the ratio of the number of flowers to the number of fruit buds. Fruit weight was measured on a sample of 30 fruits per tree, and yield was defined as the total weight of fruit harvested from each tree.

For all characteristics studied, mean values per sub-clone are presented in the paper. Coefficients of variation were determined as indicators of each characteristic's variability. The significance of the effects of year and genotype and their interaction on the variability of studied characteristics was assessed by F-test (17). Differences among clones were determined by Fisher's LSD test.

Using the results of two-factorial variance analysis according to Jovanović et al. (8), the components of variance were computed as follows: variance of year (S^2_y), genetic variance (S^2_g), variance of year x sub-clone interaction (S^2_{yg}), and error variance (S^2_e), all expressed as percentages of the total variance. Coefficients of correlation (r_{yi}) were computed between yield components and yield, and by applying the methods of symmetric correlation matrices (7, 18). The coefficient of multiple determination ($R^2_{y.123456}$) and individual values of path coefficients (p_{yi}) were computed (7, 18). For significance of r, R^2 and p coefficients, the t-test was used at the 1% and 5% levels, respectively.

Results

The examined sub-clones of 'Oblačinska' sour cherry differed significantly in all the characteristics studied (Table 1). Concerning initial fruit set and final fruit set, two groups of clones are prominent according to significance of differences. The first group comprises sub-clones D5, D6, D7, D8, D9 and D10 that had significantly higher fruit set than sub-clones from the second group (D1, D2, D3 and D4). Sub-clones D1 and D3, with no significant difference between them, possessed significantly more flower buds/cm^2 LCSA than sub-clones D7 and D10, and did not differ significantly from the other sub-clones. Regarding the number of flowers/cm^2 LCSA, sub-clones D1, D2, D3, D6 and D8 had significantly more flowers/cm^2 LCSA than sub-clone D10. Sub-clone D6, which had the highest number of flowers per bud, did not significantly differ from sub-clones D7 and D10, but had more flowers per bud than the other sub-clones. Differences in fruit weight among sub-clones D3, D4, D8 and D9 were not significant; however, those sub-clones had significantly larger fruit than sub-clones D1 and D2. Sub-clones D3 and D4 had significantly higher yield than the majority of sub-clones (except for sub-clone D8),

Table 1. Mean values (2003 – 2004) and coefficients of variation (C.V.) of yield components and yield for 10 'Oblačinska' sour cherry sub-clones.

Clone	Initial fruit set (%)	Final fruit set (%)	No. flower buds/cm² LCSA[z]	No. flowers/cm² LCSA[z]	No. flowers per bud	Fruit weight (g)	Yield (kg per tree)
D1	31.7 by	20.7 b	189.8 a	381.5 a	1.9 de	2.8 c	6.0 d
D2	26.1 b	19.5 b	178.5 ab	358.5 a	2.0cde	2.9 bc	13.8 c
D3	26.0 b	19.3 b	185.0 a	401.5 a	2.0 cde	3.4 a	25.8 a
D4	31.0 b	24.6 b	156.7 abc	342.5 ab	2.1 cde	3.5 a	25.6 a
D5	44.0 a	36.1 a	157.5 abc	339.5 ab	2.2 bc	3.3 ab	18.7 bc
D6	44.5 a	36.1 a	179.8 ab	389.4 a	2.6 a	3.1 abc	17.1 bc
D7	46.4 a	39.8 a	143.8 bc	343.7 ab	2.5 ab	3.1 abc	14.6 c
D8	40.4 a	34.1 a	177.7 ab	419.8 a	2.1 cd	3.5 a	22.3 ab
D9	46.9 a	39.0 a	162.6 ab	346.2 ab	1.8 e	3.4 a	16.1 bc
D10	47.5 a	40.0 a	118.8 c	260.8 b	2.5 ab	3.3 ab	17.5 bc
C.V.	22.9	28.5	13.2	12.3	12.0	7.3	33.3

[z] LCSA, limb cross-sectional area

[y] Mean separation within columns by LSD at the 1% level

while sub-clone D1 had significantly lower yield than any of the others.

Most of the variation in yield among sub-clones (Fig. 1) was attributable to genetic differences (S^2_g=58%), while variability in initial fruit set (S^2_y=45%), final fruit set (S^2_y=68%), number of flowers/cm² LCSA (S^2_y=65%), number of flowers per bud (S^2_y=79%) and fruit weight (S^2_y=86%) was caused mainly by year to year differences. Variability attributable to experimental error was greatest for number of flower buds/cm² LCSA (S^2_e=52%).

Coefficients of correlation (Fig. 2) showed that yield was positively correlated with fruit weight (r=0.886**); the correlations between yield and the other studied characteristics ranged from r= -0.005 to r= -0.158 and were not significant.

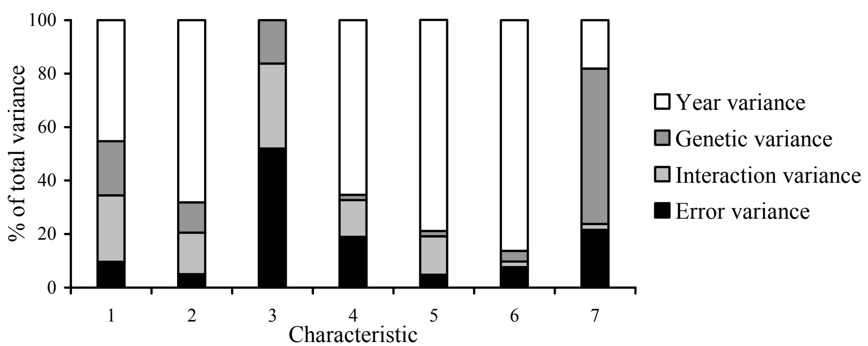

Figure 1. Components of variability for six yield components in 10 sub-clones of ' Oblačinska' sour cherry (1 - initial fruit set; 2 - final fruit set; 3 - no. flower buds/cm² limb cross-sectional area; 4 - no. flowers/cm² limb cross-sectional area; 5 - no. flowers per bud; 6 - fruit weight; 7 – yield).

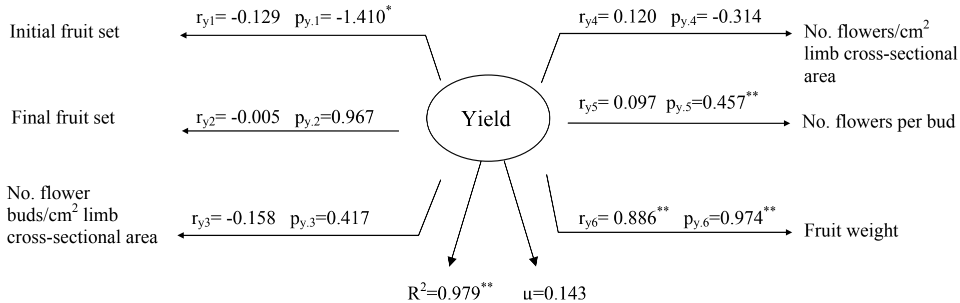

Figure 2. Path diagram the correlation relationships among yield components and yield for ' Oblačinska' sour cherry sub-clones. Significant relationship between characteristics is indicated at the 1% (**) and 5% (*) levels.

The coefficient of multiple determination (R^2=0.979**) indicated that characteristics studied in the present work, taken observed together, significantly influenced yield. Individual values of path coefficients (Fig. 2; Table 2) indicate that yield was positively related to the number of flowers per bud ($p_{y.5}$=0.457**) and fruit weight ($p_{y.6}$=0.974**), and negatively related to initial fruit set ($p_{y.1}$= -1.410*). The indirect effect (Table 2) of number of flower buds/cm² LCSA (via initial fruit set ($r_{13}p_{y.1}$=0.860) and final fruit set ($r_{23}p_{y.2}$= -0.633)) on yield was considerably higher than the direct effect ($p_{y.3}$=0.417). Similarly, the indirect effect of the number of flowers/cm² LCSA via initial fruit set ($r_{14}p_{y.1}$=0.591) and final fruit set ($r_{24}p_{y.2}$= -0.409) was considerably higher than the direct effect ($p_{y.4}$= -0.314). The indirect effect of the number of flowers per bud via initial fruit set ($r_{15}p_{y.2}$= -0.839) and final fruit set ($r_{25}p_{y.2}$=0.600) on yield was greater than the significant direct effect ($p_{y.5}$=0.457**).

Discussion

Although differences among sub-clones proved to be a significant source of variability (Table 1) for all characteristics studied here, the analysis of variance components (Fig. 1) indicated that the genetic effect accounted for a small percentage of the total variance for yield (2 to 20%). This phenomenon was especially pronounced for the number of flowers/cm² LCSA, number of flowers per bud and fruit weight, where the variability attributable to genetics was less than 5% of the total. Only for yield was the genetic component responsible for the majority of the variance (58%). In contrast to our results, which showed that variability of fruit weight was most conditioned by year, Iezzoni (5) found that genetic variance in 17 sour cherry cultivars was the dominant component in variability of fruit size. Hansche and Brooks (4) reported similar results in sweet cherry. Using the analysis of variance components in sweet cherry, Rakonjac et al. (15) found that variability conditioned by genetic factors caused most of the total variation in fruit weight. Differences between our results and those of others might be the outcome of different ecological factors at the time of experiments, or of the fact that those authors were testing various cultivars, while the subject matter of our studies was sub-clones of the same cultivar.

Year was a dominant component of the variability in initial fruit set, final fruit set, number of flowers/cm² LCSA, number of flowers per bud and fruit weight. However, year did not influence the variability in the number of flower buds/cm² LCSA (S^2_y=0%). This finding does not mean that there was no variability in this characteristic between the study years, but rather was the result of the computation method used, which interprets the expression of negative values as zero (2).

Variability conditioned by the interaction of sub-clone and year was lowest for fruit weight

Table 2. Path coefficients for direct and indirect effects of six yield components on yield of 'Oblačinska' sour cherry sub-clones.[z]

Type of effect	Initial fruit set	Final fruit set	No. flower buds/cm² LCSA[y]	No. flowers LCSA[y]	No. flowers per bud	Fruit weight
Direct effect	-1.410*	0.967	0.417	-0.314	0.457**	0.974**
Indirect effect via:						
Initial fruit set	-	-1.392	0.860	0.591	-0.839	-0.258
Final fruit set	0.954	-	-0.633	-0.409	0.600	0.275
No. flower buds/cm² limb cross-sectional area	-0.254	-0.273	-0.374	-0.213	-0.102	
No. flowers/cm² limb cross-sectional area	0.132	0.133	-0.282	-0.091	-0.003	
No. flowers per bud	0.272	0.284	-0.233	-0.133	-0.000	
Fruit weight	0.178	0.277	-0.238	0.010	0.000	-

[z] **, * indicates significance at the 1% and 5% levels, respectively.

[y] LCSA, limb cross-sectional area

and yield (2%) but was higher for the other characteristics (14 to 32%). This indicates that with respect to the level of fruit set and abundance of flowering, a specific aspect of the sub-clones reacts differentially to the environmental conditions which manifested themselves in the course of the two-year study.

Despite the fact that significant differences with regard to yield and fruit weight between sub-clones and investigational years were registered, the reaction of most clones was identical under changed environmental conditions. For this reason the interaction variance was small.

Correlation analysis showed that of the six yield components studied, yield was correlated significantly only with fruit weight (Fig. 2), and not with fruit set or abundance of flowering. In a study of yield components in sour cherry cultivars 'Montmorency' and 'Meteor', Chang et al. (1) found that the number of fruits, fruit weight, the number of buds and fruit set were the characteristics that most influenced yield in both cultivars. Iezzoni et al. (6) also reported that the number of fruits and fruit weight were major yield components in sweet cherry. Similarly, the results of correlation and path analysis in our work affirmed that fruit weight is statistically a significant yield component. However, apart from fruit weight, the application of path analysis isolated initial fruit set and number of flowers per bud as significant yield components. The number of flowers per bud and fruit weight produced positive direct effects on yield, while initial fruit set had a negative direct effect on yield. Although number of flower buds/cm² LCSA and number of flowers/cm² LCSA had no significant direct effect on yield, they influenced yield indirectly via the level of fruit set (Table 2), confirming the results of Stančević (16), who pointed out that in some sour cherry cultivars both abundance of fruit set and yield depend on abundance of flowering and its intensity.

In selecting for high yield in 'Oblačinska' sour cherry sub-clones, fruit weight in combination with the number of flowers per bud may be the best criteria to use because of their significant and positive path coefficients with yield.

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Reduced Irrigation May Improve Fruit Keeping Quality in Apricot

Spanish scientists have studied the effect of different irrigation strategies on the fruit quality at harvest and during storage at 1ºC of 'Billida' apricots (*Prunus armeniaca* L.). Irrigation treatments consisted of a control irrigated at 100% of crop evapotranspiration (ETc) throughout the season, and two deficit irrigation treatments consisting of continuous irrigation at 50% of control, and regulated deficit irrigation (RDI) at 100% of ETc during the critical periods (second rapid fruit growth and early post-harvest) and at 25% during the rest of the season. Fruits at harvest from both deficit irrigation treatments showed higher values of total soluble solids (TSS), titratable acidity and hue angle than control fruits, whereas their diameter, fresh weight, firmness and maturity index values were similar to those in the control. Weight loss and fungal attacks during a post-storage retail sale period of 4 days at 13ºC were the lowest in RDI. Deficit irrigation was demonstrated to be commercially advantageous for maintaining fruit quality, and saved considerable amounts of water. See Perez-Pastor, A. et al. 2007. Effect of deficit irrigation on apricot fruit quality at harvest and during storage. J. Sci. Food Agric. 87(13):2409-2415.