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**BIOLOGICAL AND POMOLOGICAL PROPERTIES OF PROMISING PLUM
HYBRIDS CREATED AT THE FRUIT RESEARCH INSTITUTE–ČAČAK, SERBIA**

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Abstract

This paper presents the results of a three-year study of ripening time and major physical and chemical properties of fruits of six promising plum (*Prunus domestica* L.) hybrids created at the Fruit Research Institute, Čačak. One of these hybrids was released as a new cultivar and was named ‘Nada’. The cultivar ‘Čačanska Lepotica’ served as the standard. The genotypes under study ripened between 29 July (hybrid 38/62/70) and 2 September (hybrid 22/17/87). An elongated fruit shape, a yellowish-green flesh colour and a firm fruit prevailed, whereas violet blue and dark blue skin colours were equally present. Fruit weight ranged from 26.96±0.68 g (22/17/87) to 56.92±2.87 g (38/62/70), with higher values obtained in 38/62/70 and the new cv. ‘Nada’, compared to the standard. The highest flesh/stone ratio was found in hybrid 38/62/70 (96.91±0.19%), which was the only significantly higher result compared to the control cultivar. The highest soluble solids content was measured in hybrid 22/17/87 (17.01±0.96%), and the lowest in hybrid 38/62/70 (11.39±0.44%). Compared to the standard, higher values of soluble solids were exhibited by ‘Nada’ and hybrids 32/21/87, 34/41/87 and 22/17/87. Total acid levels were highest in hybrid 32/21/87 (1.42±0.05%), and lowest in ‘Nada’ (0.35±0.02%). Compared to the standard, higher levels were found in fruits of hybrids 38/62/70, IV/63/81 and 32/21/87. The ratio of soluble solids to total acids was highest in ‘Nada’ (43.72±1.47) and lowest in hybrid 32/21/87 (10.25±0.58). Compared to the control cultivar, higher values of this parameter were observed in ‘Nada’, and hybrids 34/41/87 and 22/17/87. The results of this research suggest that ‘Nada’ can be singled out among the tested genotypes as having the best combination of positive traits.

Key words: plum, hybrid, cultivar, fruit properties

Introduction

Breeding of continental fruit species has been developed in continuity at the Fruit Research Institute in Čačak, since its establishment in 1946, to date (Ogašanić *et al.*, 1996). The most prominent achievements and the best results belong to the domestic plum (*Prunus domestica* L.). During the period spanning over six decades, 15 plum cultivars have been created (Paunović *et al.*, 2011). The initial breeding objectives were governed by the imperative to create table cultivars and cultivars with combined properties (Ogašanić *et al.*, 2006). Further expansion of breeding objectives went in the direction of developing resistance to the Plum Pox virus (Ranković *et al.*, 1994), enhancing the level of adaptability to the conditions of temperate climate, regular and high cropping, harmonic taste, good transportability of the fruits and their multi-purpose utilisation value (Milenković *et al.*, 2006). The initial selection of promising hybrids from the population of hybrid seedlings was performed based on analysis of their most significant biological and pomological properties after the start bearing, for three consecutive years. Further selections were performed among promising hybrids, based on results of many-year comparative studies involving best standard cultivars, aiming to select the genotypes with the best combinations of positive properties.

The aim of this study pertains to analysis of the most important biological and pomological properties of six promising plum genotypes that were created within different breeding programmes, through comparative studies involving cultivar ‘Čačanska Lepotica’.

Material and methods

The experimental research was conducted at the plantation of plum of the Fruit Research Institute in Čačak, located at approximately 4 km to the north of Čačak, at the altitude of around 250 m above the sea level. The plantation was set up in spring 2002, using standard one-year-old seedlings grafted on a Myrobalan rootstock and planted at the 6 x 5 m distance (333 trees per ha⁻¹). The planting was performed using the random block system, with each genotype participating with 15 trees in three replications. The open vase crown was chosen as the training system, and the plantation was treated using standard cultivation measures. The research was conducted during three years (2009–2011). The testing material comprised six promising plum genotypes created at the Fruit Research Institute in Čačak: hybrid 38/62/70 (‘Hall’ × ‘California Blue’); hybrid IV/63/81 (‘Large Sugar Prune’ × ‘Scoldus’); hybrid 32/21/87 (‘Stanley’ × ‘Scoldus’); hybrid 29/29/87 (‘Stanley’ × ‘Scoldus’); hybrid 34/41/87 (‘Valjevka’ × ‘Čačanska Lepotica’) and hybrid 22/17/87 (‘Čačanska najbolja’ × ‘Zelta Boutilcovidna’). Hybrid 29/29/87 was approved as a cultivar in March 2012 and was named ‘Nada’ (Ogašanić *et al.*, 2012).

The respective dates of full technological ripeness were monitored and recorded, in order to establish the fruit ripening time. The fruit weight (g) and stone weight (g) were determined by measuring 25 randomly selected fruits and their stones in three replications, using the technical scales (Adventurer Pro AV812M, Ohaus Corporation, Switzerland). The flesh percentage (%) was determined by calculation. Soluble solids content (%) was established using the manual refractometer (Carl Zeiss, Jena, Germany) at room temperature (20°C). Total acids content (%) manifested in malic acid was determined by neutralising the fruit juice using 0.1 N NaOH, with the addition of phenolphthaleine as the indicator of pH value up to 8.1. Based on the obtained data, the ratio between the soluble solids content and total acids was calculated. The fruit shape, skin colour, as well as the colour of the flesh and its firmness was described in accordance with the methodology recommended by UPOV-a (2002). The standard cultivar was ‘Čačanska Lepotica’.

Data analysis was performed using the SPSS statistical software package, Version 8.0 for Windows (SPSS, Inc., Chicago, IL). The variance analysis (ANOVA) was used for establishing the impact of genotype on the fruit weight and stone weight, the flesh percentage, soluble solids content and content of total acids, as well as the ratio between the total soluble solids content and total acids. In the cases when the *F* test was significant, testing of arithmetic means was performed using the test of Least Significant Differences (LSD test) for significance threshold of $P \leq 0.05$.

Results and discussion

The analysed plum genotypes ripened in the period from 29th July (hybrid 38/62/70) and 2nd September (hybrid 22/17/87). An earlier ripening time when compared to cv. Čačanska lepotica was established in hybrid 38/62/70 (Table 1). The average values of fruit and stone weight and the flesh percentage differed significantly depending on the examined plum genotype (Table 1). The average fruit mass of the analysed plum genotypes varied within the range from 25.10±0.89 g (hybrid 34/41/87) to 56.92±2.87 g (hybrid 38/62/70). A larger fruit compared to the standard was determined in hybrid 38/62/70 and the ‘Nada’ cultivar. The largest average stone weight was determined in hybrid 38/62/70 (1.76±0.03 g), which was in accordance with the largest fruit weight, whereas the smallest stone weight was recorded in the standard ‘Čačanska Lepotica’ cultivar (1.34±0.04 g). The only insignificant differences in relation to the standard were established in hybrid IV/63/81. The highest value of flesh percentage was

determined in hybrid 38/62/70 ($96.91 \pm 0.19\%$), which was the only significantly higher result in comparison to the control cultivar. The fruit flesh ratio in the ‘Nada’ cultivar was at the level of the standard cultivar, whereas it was significantly lower in all the other genotypes.

Table 1. Harvest time, fruit and stone weight and flesh percentage of plum hybrids.

Genotyp	Harvest time	Fruit weight (g)	Stone weight (g)	Flesh percentage (%)
Hybrid 38/62/70	29 Jul	56.92±2.87 a	1.76±0.03 a	96.91±0.19 a
Hybrid IV/63/81	08 Aug	31.98±0.65 e	1.36±0.05 e	95.75±0.07 c
Hybrid 32/21/87	15 Aug	35.11±1.71 d	1.62±0.01 c	95.38±0.23 d
Nada	19 Aug	45.54±0.29 b	1.68±0.03 b	96.57±0.04 b
Hybrid 34/41/87	29. Aug	25.10±0.89 g	1.43±0.03 d	94.30±0.42 e
Hybrid 22/17/87	02 Sep	26.96±0.68 f	1.46±0.02 d	94.58±0.18 e
Čačanska leptotica	31 Jul	42.24±0.69 c	1.34±0.04 e	96.75±0.06 b

The different lower-case letters assigned to columns show significant differences for $P \leq 0.05$ after applying *LSD* test.

Ripening time and the duration of the fruit development are a specific property of each genotype (García-Mariño *et al.*, 2008). Considering the fact that genotypes with either earlier or later fruit-ripening time are generally given preference (Neumüller, 2010; Пауновић *et al.*, 2011) it is probably worth noting the potential of the early-ripening hybrid 38/62/70, as well as the late-ripening ‘Nada’ cultivar and hybrids 34/41/87 and 22/17/87. According to the classification of plum cultivars in relation to the fruit weight as stated by Mišić (1996), hybrids IV/63/81, 32/21/87, 34/41/87 and 22/17/87 represent genotypes with medium-large fruits, whereas hybrid 38/62/70 and cv. ‘Nada’ belong to genotypes with large fruits. The large fruit of hybrid 38/62/70 is a confirmation that cv. ‘California Blue’ appeared as a donor of this property (Mišić, 2002). Hybrid 34/41/87 was characterised by the smallest fruit mass, which contradicted the results previously published by Jakubowski and Lewandowska (2004), where it was reported that cultivar ‘Čačanska Lepotica’ produces progeny with large fruits. The positive impact made by ‘Stanley’ as the mother plant on the fruits weight in the hybrid progeny, as reported by Mišić (2002) and Jakubowski & Lewandowska (2004) is observed in ‘Nada’ cultivar, but not in hybrid 32/21/87. Contrary to results of Blazek and Vávra (2007), and in agreement with the findings of Milošević and Milošević (2011), the positive impact of cultivar ‘Čačanska Najbolja’ on the fruit weight in the hybrid progeny was not confirmed in our studies. The results of our research related to the stone weight have confirmed the previous reports that the mass of stone is considered as a stable cultivar-specific property (Огашановић *et al.*, 1996; Depypere *et al.*, 2007). The previous research in this field have established a high degree of positive correlation between the stone mass and the mass of fruit (Okut and Akca, 1995), which was partly confirmed by our research. The flesh percentage is considered as an important property of plum (Miletić and Petrović, 1996; Nenadović-Mratinić *et al.*, 2007). The same authors have reported the cultivar variability of this property, which is in accordance with the results obtained in our research.

The results of the study related to the fruit shape, skin colour, colour of the flesh and fruit firmness are shown in Table 2. Oval fruit shape was typical for hybrids 38/62/70 and 32/21/87, whereas all the other studied genotypes had an elongated fruit shape, including ‘Čačanska Lepotica’ as the standard cultivar. In addition to the standard cultivar, dark blue colour of the fruit skin was established in hybrids 32/21/87, 34/41/87 and the ‘Nada’ cultivar, whereas hybrids 32/21/87, IV/63/81 and 22/17/87 had a violet- blue colour of the skin. The yellow colour of the flesh was found in hybrid 32/21/87 and the ‘Nada’ cultivar, whereas the remaining genotypes under consideration had a yellowish-green colour of the flesh, which was also present in the standard cultivar as well. Hybrid 32/21/87 had the lowest firmness of

the fruit, as opposed to hybrids IV/63/81 and 22/17/87 which had medium fruit firmness; at the same time, hybrids 38/62/70, IV/63/81 and 34/41/87, together with cultivar ‘Nada’ and standard ‘Čačanska Lepotica’ recorded the highest degree of this parameter.

Table 2. Fruit shape, skin colour, flesh colour and fruit firmness of plum hybrids.

Genotype	Fruit shape	Skin colour	Flesh colour	Fruit firmness
Hybrid 38/62/70	circular	violet blue	yellowish green	firm
Hybrid IV/63/81	elliptical	violet blue	yellowish green	medium
Hybrid 32/21/87	circular	dark blue	yellow	soft
‘Nada’	elliptical	dark blue	yellow	firm
Hybrid 34/41/87	elliptical	dark blue	yellowish green	firm
Hybrid 22/17/87	elliptical	violet blue	yellowish green	medium
‘Čačanska Lepotica’	elliptical	dark blue	yellowish green	firm

In the assessment of the fruit attractiveness, the primary importance is assigned to the fruit size, followed by its colour and shape. In certain Central European countries, preference is given to cultivars with an elongated fruit and blue colour of the skin, with intense bloom (Neumüller, 2010). The same author reports that firmness of the fruit and flesh colour represent highly important properties of table plum cultivars, where advantage is given to genotypes with firm fruits and orange of yellow flesh colour. In this regard, ‘Nada’ stands out owing to its elongated fruits with dark-blue skin and firm yellow flesh.

The soluble solids content and the content of total acids in the fruit, as well as the ratio between them were cultivar-specific for each of the examined plum genotype (Table 3).

Table 3. Soluble solids content, total acids content and soluble solids content and total acids ratio of plum hybrids.

Genotyp	Soluble solids content (%)	Total acids content (%)	Soluble solids content/ Total acids content
Hybrid 38/62/70	11.39±0.44 g	1.03±0.04 b	11.11±0.16 ef
Hybrid IV/63/81	12.62±0.65 f	1.06±0.02 b	11.98±0.80 e
Hybrid 32/21/87	14.27±0.52 d	1.42±0.05 a	10.25±0.58 f
‘Nada’	14.73±0.28 c	0.35±0.02 e	43.72±1.47 a
Hybrid 34/41/87	16.49±3.21 b	0.77±0.05 d	21.37±3.94 b
Hybrid 22/17/87	17.01±0.96 a	0.97±0.04 c	17.77±1.02 c
‘Čačanska Lepotica’	13.97±0.70 e	0.97±0.03 c	14.63±0.99 d

The different lower-case letters assigned to columns show significant differences for $P \leq 0.05$ after applying *LSD* test.

The highest average value of the soluble solids content was established in the fruits of hybrid 22/17/87 (17.01±0.96%), as the latest-ripening one, whereas the lowest value of this parameter was found in the fruits of hybrid 38/62/70 (11.39±0.44%) as the earliest-ripening one. Compared to ‘Čačanska Lepotica’ the highest content of soluble solids in the fruit was recorded in ‘Nada’ cultivar and hybrids 32/21/87, 34/41/87 and 22/17/87. The highest content of total acids in the fruit was found in hybrid 32/21/87 (1.42±0.05%), whereas the lowest value of this parameter was recorded in ‘Nada’ cultivar (0.35±0.02%). Compared to the standard, higher values of the total acids content were typical of the fruits of hybrids 38/62/70, IV/63/81 and 32/21/87. The highest ratio between the soluble solids content and the total acids content was established in ‘Nada’ cultivar (43.72±1.47), whereas the lowest value of this ratio was found in hybrid 32/21/87 (10.25±0.58). Compared to the control cultivar, the highest values of this parameter were typical of cultivar ‘Nada’ and hybrids 34/41/87 and 22/17/87 (Table 3).

The results obtained based on the analysis of the soluble solids contents in the fruits of the cultivars examined in this study confirm the existence of a positive correlation between the soluble solids content and the ripening time of the fruit (Neumüller, 2010). Considering the fact that the soluble solids content of $\geq 12,0\%$ is generally taken as the limiting value for better acceptability of a plum cultivar by consumers (Crisosto *et al.*, 2004), it can be concluded that these criteria are not met only by the earliest hybrid 38/62/70. Given the assumptions that later-ripening cultivars ought to have a soluble solids content in excess of 17% (Neumüller, 2010), hybrid 22/17/87 has made a distinction in this regard. With the exception of the values obtained for cultivar ‘Nada’, the total acids contents obtained in this paper were within the ranges reported in the studies conducted by Miletic and Petrovic (1996). On the other side, Družic *et al.* (2007) have reported total acids content in certain German plum cultivars which corresponded to values obtained for cultivar ‘Nada’ in our research. It is a well-known fact that the ratio between the soluble solids content and total acids, rather than the very content of dry soluble solids, represents a reliable indicator of a cultivar’s suitability for acceptance by consumers (Crisosto *et al.*, 2004). It is also known that European plum cultivars are generally regarded as cultivars with a good fruit quality, provided that the ratio between the soluble solids content and the total acids falls within the range between 12 and 24 (Robertson *et al.*, 1992). In this regard, hybrids 34/41/87 and 22/17/87 can be viewed as promising. Owing to its low content of total acids in the fruit, cultivar ‘Nada’ recorded considerably higher values of this parameter compared to the upper border value reported by the cited author. Similar information is reported by Družic *et al.* (2007) for ‘Elena’ cultivar.

Conclusion

The late ripening time and the large size of the fruit, its firmness, elongated shape, dark blue colour of the skin, the yellow flesh and good chemical composition – these are all properties that support the assertion that the new cultivar ‘Nada’ represents a genotype with the best combination of positive characteristics. Considering its early ripening time, as well as the large size and firmness of its fruits, hybrid 38/62/70 can also be interesting, and so can be hybrid 22/17/87, from the point of view of its late ripening time and the good chemical composition of the fruit. Apart from their obvious potential in production, the examined cultivars can be used in future plum breeding programmes.

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