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'DIVNA' AND 'PETRA' NEW LATE RIPENING PLUM CULTIVARS RELEASED AT FRUIT RESEARCH INSTITUTE, ČAČAK

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Abstract: In this study, the most important characteristics of tree vigour and productivity, as well as pomological traits (fruit morphometric and chemical characteristics) of new late ripening cultivars 'Divna' and 'Petra' released at Fruit Research Institute, Čačak were evaluated and compared to standard cultivar 'Stanley'. Both new cultivars had slightly larger tree and yield in comparison to 'Stanley', but smaller fruit in general. 'Petra' had the best chemical properties of fruit followed by 'Divna'. Both new cultivars could be very interesting for growing in new orchards due to very late ripening time, good fruit quality and high cropping potential and also could be used in further breeding activities.

Keywords: plum, new cultivars, ripening time, fruit properties, yield

Introduction

So far, over 6000 plum cultivars originated from 19 to 40 species and used for fresh market, processing, canning, drying and deep freezing is recognized all over the world (Milošević and Milošević, 2018). Regardless that, there is an intensive work in many breeding programmes worldwide on developing new cultivars which have been realising every year. In European plum (*Prunus domestica* L.), commonly grown in temperate climate zone in Europe including Serbia, the most important breeding objectives are similar in majority of programmes and include: large quality fruits of dark blue colour, yield performance and Sharka (*Plum pox virus*) tolerance/resistance (Milošević and Milošević, 2018; Milošević et al., 2021; Neumüller et al., 2021). Also, certain programmes have their own specific breeding goals.

One of the oldest and the most succesfull plum breeding programme in the Europe has been at the Fruit Research Institute, Čačak, which started in early 1950s of the 20th century, shortly after the founding of the Institute. This programme has been mainly in accordance with demands and needs of producers and includes, among common objectives, also specific such as very

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early and very late ripening time, self-fertility, medium tree size, tolerance to climate change and resistance to the most important funghal diseases (Glišić et al., 2018: Milošević et al., 2021). As a result of this long-term breeding work, so far 18 plum cultivars have been named and released. Some of these cultivars ('Čačanska Lepotica', 'Čačanska Rodna' and 'Čačanska Najbolja') have been well-known and used for production and further breeding worldwide (Jacob, 2002; Hartman and Neümuller, 2006; Milošević et al., 2021).

In 2018, two new late ripening cultivars 'Divna' ('Stanley' × 'Čačanska Rana') and 'Petra' ('Stanley' × 'Opal') were named and released. The main goal of this study was to evaluate and present the most important characteristics of tree vigour, yield, morphometric and chemical characteristics of fruits of these new cultivars in comparison to standard cultivar 'Stanley'.

Materials and methods

Plant material and experimental design. Characteristics of tree, yield and fruit of new plum cultivars 'Divna' and 'Petra' and standard cultivar 'Stanley' were evaluated. The trial was conducted at the Ljubić facility of the Fruit Research Institute, Čačak (43°53'N, 20°20'E, 250 m a.s.l.) at the plum orchard planted in March 2011 using standard one-year-old nursery trees grafted on Myrobalan (*Prunus cerasifera* Ehrh.) seedlings. Trees have been trained as pyramidal crown and grown under standard practices for plum, without irrigation applied. The experiment was designed as a randomized block system in three replicates with 5 trees each (total 15 trees of both new cultivars and standard cultivar).

Vigour and yield characteristics. Trunk circumferences (cm) were measured at 20 cm above the graft union using the digital caliper gauge (Kronen, Germany) and used to calculate the trunk cross-sectional area (TCSA) (cm^2). Yield per tree (Y) (kg) in 2020 and 2021 as well as cumulative yield (CY) in period (2016-2021) was determined using an ACS System Electronic Scale (Zhejiang, China). The yield efficiency (YE) was calculated by dividing values for Y and TCSA.

Morphometric properties of fruits. Twenty-five fruits from both new cultivars and standard of each of two replicates were collected and fruit (FW) and stone weight (SW) (g) were measured using an Ohaus Adventurer technical scale (Parsippany, NJ, USA). Flesh percentage (FP) (%) was calculated as the ratio of the weight of the edible part of the fruit to the total fruit weight. Fruit linear dimensions: hight (H), width (W) and thickness (T) (mm) were measured using a digital caliper Kronen (Kronen GmbH, Kehl am Rhein, Federal Republic of

Germany). Geometric mean diameter of fruit (Dg) was calculated according to formula: $D_g=(LWT)^{1/3}$. Thereafter, sphericity was obtained as the Dg/H ratio.

Chemical properties of fruits. Chemical properties of fruits were examined in the stage of commercial maturity. Soluble solids content (SSC) (%) was assessed by a binocular refractometer (Carl Zeiss, Germany) at 20°C. The total (TS) (%) and invert sugars (IS) (%) content were determined on triplicate samples by the Luff - Schoorl method previously described by Schneider (1979). The sucrose content (SU) was calculated according to the relationship: SU = (TS – IS) × 0.95. The results were expressed in % of fresh weight. The fruit juice pH was assessed by a CyberScan 510 pH-meter (Nijkerk, Netherlands). Total acids (TA) (%) were expressed as malic acids and determined by titration with 0.1 N NaOH up to pH 8.1, using phenolphthalein as an indicator. Once the SSC and TA contents were assessed, the ripening index (RI) was calculated as SSC/TA ratio.

Organoleptic properties of fruits. Organoleptic properties of fruits of the studied cultivars were examined accordance to the guidelines for testing the values for cultivation and use of plum cultivars specified by the Regulations of the Ministry of Agriculture, Forestry and Water Management of the Republic of Serbia. Attractiveness (0–6), taste (0–8), aroma (0–4) and consistency (0–2) of fruits were obtained by positive scoring by five panellists. The overall organoleptic score (0–20) is the total of all individual points.

Data analysis. The obtained results were statistically analysed by analysis of variance (ANOVA) using the software package Microsoft Office Excel 2003. The means were separated by LSD test at $p \leq 0.05$.

Results and discussion

Plum tree vigour is dependant on genotype (Nenadović-Mratinić et al., 2007), rootstock, environmental conditions (Blažek and Pištěková, 2009), training system, orchard management and yield (Vitanova et al., 2007). In this work, tree vigiur was presented as TCSA and 'Divna' and 'Petra' had slightly larger tree compared with standard cultivar ('Stanley'). In our previous studies (Milošević et al., 2016; 2019), we found similar tendencies among these cultivars which confirm assumption that both new cultivars could be classified as a moderate vigorous, considering that 'Stanley' is moderate vigour cultivar (Milatović, 2019).

Y was the highest in 'Petra' while in 'Divna' and 'Stanley' was significantly lower (Table 1). On the other hand, CY (2016–2020) was significantly higher in 'Petra' and 'Divna' than in 'Stanley' (Table 1).

Table 1. Tree growth and productivity of new cultivars 'Divna' and 'Petra' and standard cultivar 'Stanley'

	Yield per tree (kg)	Cumulative Yield (kg)	TCSA (cm^2)	Yield efficiency
'Divna'	27.48±0.37 b	122.97±0.74 a	59.49±0.29 ab	0.46±0.00 a
'Petra'	29.66±0.28 a	129.54±0.78 a	63.03±1.47 a	0.47±0.01 a
'Stanley'	27.66±0.26 b	110.69±3.65 b	57.06±1.20 b	0.47±0.01 a

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

These results are higher then previous obtained by Glišić et al. (2018) and Milošević et al. (2016, 2019) for the same cultivars, probably because of more suitable weather conditions and precipitations over the examined years, as well as differences in orchard management and fertilization. YE was high in all cultivars thanks to large yield and moderate tree vigour, but differences were not significant (Table 1). However, our results were in harmony with perevious reports for different plum cultivars (Glišić et al., 2016; Milošević et al., 2018).

FW is one of the most important quantitative traits which affects yield, fruit quality characteristics and consumers' acceptability (Crisosto et al., 2004). This trait is mostly dependant on genotype, yield and cultural practices in the orchard (Grzyb and Sitarek, 2006). In this work, FW was significantly smaller in both new cultivars compared to 'Stanley' (Table 2).

Table 2. Fruit and stone weight and flesh percentage of new cultivars 'Divna' and 'Petra' and standard cultivar 'Stanley'

	Fruit Weight (g)	Stone Weight (g)	Flash Percentage (%)
'Divna'	27.54±0.14 c	1.28±0.00 c	95.34±0.02 a
'Petra'	29.90±0.15 b	1.36±0.01 b	95.44±0.02 a
'Stanley'	34.58±0.11 a	1.90±0.02 a	94.50±0.03 b

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

These results were higher than our previous for 'Divna' (Glišić et al., 2018) and 'Petra' (Milošević et al., 2019) and also for 'Stanley' reported by Molnár at al. (2016) and Dimkova et al. (2018). Similar situation was observed with SW, which was significantly smaller in 'Petra' and in particular in 'Divna' regarding to 'Stanley' (Table 2). Thanks to the small stone, FP in 'Divna' and 'Petra' was

similar and significantly larger in comparison to 'Stanley'. Generally, FP is preferable to be as large as possible and both new cultivars meet this criterion.

Fruit dimensions are directly related to the fruit size which is one of the main parameters for fresh market and consumer acceptance of plum (Singh and Singh, 2008). These characteristics are also important for postharvesting operations such transporting, sorting, grading, packaging and storage processes and also in processing operations (Jannatizadeh et al., 2008). In our work, significant differences among the fruit dimensions were found (Table 3). 'Petra' had the largest H, while 'Stanley' had the largest W and T. On the other hand, all these parametrs were the smallest in 'Divna'. Also, the largest Dg was found in 'Stanley' which was expected because two of three dimensions were the highest in this cultivar.

Table 3. Morphometric properties of new cultivars 'Divna' and 'Petra' and standard cultivar 'Stanley'

	Fruit Height (mm)	Fruit Width (mm)	Fruit Thickness (mm)	Geometric Mean Diameter	Sphericity
'Divna'	44.99±0.13 c	32.37±0.08 c	31.05±0.12 c	35.63±0.02 c	0.79±0.00 b
'Petra'	48.30±0.20 a	33.29±0.18 b	32.63±0.03 b	37.43±0.10 b	0.77±0.00 c
'Stanley'	47.12±0.14 b	38.93±0.03 a	33.01±0.07 a	39.29±0.07 a	0.83±0.00 a

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

Results for fruit dimensions in our work was similar to our previous results (Milošević et al., 2016, 2019) and results of Glišić et al. (2018), whilst our results were higher in comparison to results reported by Molnar et al. (2016) and Dimkova et al. (2018). These discrepancies may be associated with different climatic and soil conditions, as well as different orchard management. Overall, according to classification reported by Milatović (2019) both 'Divna' and 'Petra' can be classified as medium sized cultivars. The consumers of plum fruits in the Republic of Serbia and also in most of Europe, prefers elongated fruits compared to spherical (Milošević and Milošević, 2018). There were significant differences among all cultivars concerning this trait and obtained values showed that all of them had elongated fruits which is particularly relevant to 'Petra'.

Concerning chemical properties in this study, significant differences were observed among cultivars 'Divna', 'Petra' and 'Stanley' (Table 4). The highest SSC, TS and SU content was found in 'Petra' and the smallest in 'Divna'.

Amount of IS was similar in 'Divna' and 'Stanley' and significantly higher in comparison to 'Petra'.

Table 4. Chemical properties of new cultivars 'Divna' and 'Petra' and standard cultivar 'Stanley'

	Soluble Solids Content (%)	Total Sugars (%)	Invert Sugars (%)	Sucrose (%)
'Divna'	19.95±0.03 b	12.55±0.02 c	7.12±0.02 a	5.16±0.00 b
'Petra'	21.72±0.08 a	12.92±0.03 a	6.64±0.06 b	5.97±0.09 a
'Stanley'	19.10±0.06 c	12.80±0.02 b	7.24±0.03 a	5.28±0.03 b

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

'Divna' had the highest amount of TA, and smallest pH value, which means that this cultivar had the most acidic fruit (Table 5). This high content of TA caused the smallest ripening index in 'Divna'. In contrary, the highest SSC and the smallest amount of TA affected the highest RI in 'Petra'.

Table 5. Other chemical properties of new cultivars 'Divna' and 'Petra' and standard cultivar 'Stanley'

	Total Acids (%)	pH	Ripening Index
'Divna'	1.01±0.03 a	3.80±0.02 b	19.81±0.61 c
'Petra'	0.82±0.01 b	3.91±0.01 a	26.58±0.16 a
'Stanley'	0.85±0.01 b	3.90±0.01 a	22.41±0.21 b

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

In this study, 'Petra' and 'Divna' showed similar tendencies in terms of SSC, TS, IS and SU, as well as TA to our previous results (Milošević et al., 2019) and results of Glišić et al. (2018) in similar conditions which confirms theory that genotype had very high impact on these properties (Usenik et al., 2014). On the other hand, in this work, the content of TS and IS was lower, while the content of TA was higher compared to results obtained in our previous work regarding the same cultivars but grown in different conditions (Milošević et al., 2016), which showed that climate, soil and orchard management also influenced these characteristics. Overall, plums SSC ≥ 12.0% had ~75% consumer acceptance, regardless of TA (Crisosto et al., 2004). Therewith, various organic acids and their relative contents differ in the level they have an

effect on sugars (Colarič et al., 2005). In this regard, the assumption is that 'Divna' and 'Petra' could satisfy main consumer requirements.

Table 6. Chemical properties of new cultivars 'Divna' and 'Petra' and standard cultivar 'Stanley'

	Attractiveness (0–6)	Flavour (0–8)	Aroma (0–4)	Consistency (0–2)	Total (0–20)
'Divna'	5.00	6.00	1.00	3.00	15.00
'Petra'	5.00	7.00	2.00	3.00	17.00
'Stanley'	5.00	6.00	1.00	3.00	15.00

The subjective perception of the fruit quality by the consumers is very important in the final estimation and acceptance of new cultivar (Crisosto et al., 2007). New plum cultivars 'Divna' and 'Petra' examined in this work showed similarities among each other and standard cultivar 'Stanley' with small differences in 'Petra' (Table 6). Only distinctions were observed in flavour and teste where 'Petra' was slightly better assessed than other two cultivars. On some way, it was expected, because 'Stanley' is one of perents of both other cultivars. In total, both new cultivars were highly rated for all organoleptic traits which indicates that they could be well accepted from consumers.

Conclusion

Evaluation of the most important tree growth and yield characteristics, morphometric, chemical and organoleptic properties of new cultivars 'Divna' and 'Petra' released at Fruit Research Institute, Čačak and standard cultivar 'Stanley' indicated that both cultivars were characterized by very good productive and fruit quality traits and could be very interesting for growing in new orchards in the Republic of Serbia. Very significant preference of these cultivars is their very late ripening time, especially if it is known that there is a small number of cultivars that ripens at a similar or the same time. These both cultivars could be interesting as a perents in further breeding programme at the Fruit Research Institute, Čačak or other plum breeding programmes.

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