Properties of some Late Season Plum Hybrids from Fruit Research Institute Čačak

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Summary

Since 1979 to 2012 fifteen plum cultivars were named and released in Fruit Research Institute, Čačak. Some of these cultivars, such as Čačanska Lepotica, Čačanska Rodna and Čačanska Najbolja are grown in most important plum growing countries in Europe. Also, these cultivars are used as parent cultivars in many plum breeding programs. In addition to the cultivars, large number of promising hybrids are created in Fruit Research Institute, Čačak and some of them, in this moment, are candidates for new cultivars. Therefore, in 2014 and 2015, we investigated the most important properties of four promising late season hybrids and standard cultivar 'Stanley'. All four hybrids were harvested since beginning of September (34/41/87) until the beginning of the third decade of September (10/23/87). The earliest flowering time was recorded in hybrid 34/41/87 and the latest in standard cultivar 'Stanley'. Hybrids 10/23/87 and 26/54/87 generally had the highest fruit weight and all three fruit dimensions. Also these hybrids had the highest content of total sugars and sucrose and highest pH value, but poorest total acids content. The highest content of invert sugars and total acids was recorded in hybrid 22/17/87. This hybrid also, had the highest yield per tree and per hectare while the hybrid 34/41/87 had the lowest these values. Standard cultivar 'Stanley' had the largest stone weight and the highest amount of soluble solids.

Key words

plum hybrids, late season, fruit quality, yield

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Introduction

European plum (*Prunus domestica* L.) is one of the most important fruit species in the Europe with the total production quantity of 2 808 152 t) (FAOSTAT, 2016), and the most important within the genus *Prunus*. In Serbia, plum is cultivated on about 425 585 ha, with an average production of 507 987 t (2010-2014), which is classified as the second largest world producer after China (FAOSTAT, 2016). The Serbian plum production is characterized by extensive growing technology, low unstable yields, low-quality fruit, PPV-induced problems and a multitude of cultivars (Nenadović-Mratinić et al. 2007; Milošević et al. 2012; Milošević et al. 2013). Nevertheless, the main problem for Serbian and European plum production was PPV infection which caused huge damages on fruits and in orchards (Jacob, 2007; Milošević et al. 2010). For this purposes, plum breeding programs have been defined and are more or less similar irrespective of the country where they are being conducted. Among stone fruit crops, the plum breeding is one of the most dynamic and the newest cultivars originated from *Prunus domestica* L. are released every year (Blažek et al., 2004). The plum breeding program at Fruit Research Institute, Čačak has had a long history of accomplishments since its initiation in 1947. The main breeding objectives include: large fruit size, high fruit quality and yield, very early and very late ripening time, resistance to diseases, particularly to Sharka (Plum Pox Virus). Since 1979 to 2012 fifteen plum cultivars were named and released at Fruit Research Institute, Čačak. Some of these cultivars, such as Čačanska Lepotica, Čačanska Rodna and Čačanska Najbolja are grown in most important plum growing countries in Europe. Also, these cultivars are used as parents in many plum breeding programs worldwide (Jacob, 2002; Hartmann and Neümuller, 2006; Milošević and Milošević, 2012). In addition to the cultivars, large number of promising hybrids is singled out and recognition of some of them is under way.

The aim of this study was to investigate pomological properties of four late season hybrids tolerant to Sharka virus, obtained in Fruit Research Institute Čačak, and to compare them with standard cultivar 'Stanley' grown under Western Serbia conditions.

Materials and methods

The trial was carried out in village Teočin, 35 km northwest from Čačak (Western Serbia). The plant material was four late season hybrids derived in Fruit Research Institute, Čačak: 22/17/87 ('Čačanska Najbolja' × 'Žolta Butilcovidna') (Figure 1), 34/41/87 ('Valjevka' × 'Čačanska Lepotica') (Figure 2), 26/54/87 ('Stanley' × 'Opal') (Figure 3) and 10/23/87 ('Stanley' × 'Čačanska Rana') (Figure 4) and standard cultivar 'Stanley' (Figure 5) grafted on Myrobalan seedling rootstock. The orchard was established in November 2011. Trees were planted at distance of 5 × 3 m and training system was pyramidal crown. The orchard was fertilized on the basic local empiric criterion with 400 kg of compound NPK (15:15:15) mineral fertilizer in fall and with 300 kg/ha of calcium ammonium nitrate (CAN) contained 27% of N to the onset of the growing cycle. Trees were grown under standard practices for plum, without any irrigation applied. Weather conditions of Čačak area are characterized by the average annual temperature of 11.3°C and total annual rainfall of 690.2 mm. The experiment was set up as a randomized block design in four replicates with 5 trees each (total 20 trees per

Figure 2. Hybrid 34/41/87

Figure 1. Hybrid 22/17/87

Figure 3. Hybrid 26/54/87

Figure 4. Hybrid 10/23/87

Figure 5. Standard cultivar 'Stanley'

hybrid/cultivar). Phenological characteristics were assessed as following: the beginning of bloom was determined when at least 5–10% of the flowers bloomed; full bloom was recorded when at least 80% of the flowers bloomed, the end of bloom was determined when 90% of the flowers bloomed and corollas began to fall off (Kobel 1954), and harvest date was established when the fruits were sufficiently colored and soft to be eaten fresh (Funt 1998). The mean flowering and harvest date for two consecutive years was also calculated for each hybrid and control cultivar 'Stanley'. The fruit samples were hand harvested fully mature, at commercial maturity stage in 2014 and 2015. For a period of two harvest seasons, 25 fruits from each hybrid/cultivar of each of four replicates were collected and fruit and stone weight (g) were measured using an Ohaus Adventurer technical scale (Parsippany, NJ, USA). Yield per tree (kg) and hectare (kg ha^{-1}) were measured in 2015 using an ACS System Electronic Scale (Zhejiang, China). For determining flesh/stone ratio fruits were cut in half horizontally with a stainless-steel knife and the stones were removed and weighed. The flesh percentage (%) was calculated by subtracting the stone weight from the whole plum fruit weight. For each plum fruit, three linear dimensions, length, width and thickness were measured by using a digital caliper Starrett, 727 Series (Athol, NE, USA) with a sensitivity of 0.01 cm. Soluble solids content was determined by Milwaukee MR 200 hand refractometer (ATC, Rocky Mount, NC, USA) at 20°C (°Brix). Titratable acidity, as malic acid (%), were determined by titration with 0.1 N solution of NaOH. The juice pH was assessed by a Cyber Scan 510 pH meter (Nijkerk, The Netherlands). The total sugars and invert sugars content were determined on triplicate samples by the Luff-Schoorl method previously described by Schneider (1979). The sucrose content was calculated according to the relationship: SU = (TS – RS) × 0.95. The results were expressed in % of fresh weight.

Data in the present study were subjected by analysis of variance (ANOVA) using the MSTAT-C statistical package [Michigan State University, East Lansing, MI, USA] and means were separated by LSD test at $p \leq 0.05$.

Results and discussion

All hybrids and standard cultivar were blooming between 15 April (34/41/87) and 26 April ('Stanley') (Table 1). Blooming period was similar in all genotypes except for the control cultivar 'Stanley' which had the latest blooming compared to the hybrids. The similar results for blooming period in plum genotypes were obtained by Vitanova et al. (2004) and Milošević and Milošević (2011). These properties are considered as a quantitative in *Prunus* species (Dirlewanger et al. 1999), while Pudas et al. (2008) stated that air temperature and day length had large impact on blooming time. Latter blooming period could be important to avoid late spring frosts in some years.

All hybrids and standard cultivar 'Stanley' were harvested very late during the first and the second decade of September (Table 1). Standard cultivar 'Stanley' had the earliest harvest

Table 1. Blooming and harvesting date of the plum hybrids and standard cultivar 'Stanley'. Data are means of two consecutive years for each plum hybrid and standard cultivar 'Stanley'

Hybrids and standard cultivar	Blooming date			Harvesting date
	Beginning	Full	End	
10/23/87	16 April	18 April	24 April	21 September
26/54/87	16 April	19 April	24 April	18 September
34/41/87	15 April	18 April	23 April	2 September
22/17/87	16 April	19 April	24 April	5 September
'Stanley'	19 April	22 April	26 April	1 September

Table 2. Yield per tree and per hectare of the plum hybrids and standard cultivar 'Stanley' in the fifth year after planting

Hybrids and standard cultivar	Yield (kg)	Yield per hectare (kg ha^{-1})
10/23/87	13,05±0,11 c	16.312,50±0,11 c
26/54/87	13,49±0,17 b	16.862,50±0,17 b
34/41/87	12,91±0,24 c	16.137,50±0,24 c
22/17/87	14,96±0,12 a	18.700,00±0,12 a
'Stanley'	13,09±0,11 c	16.362,50±0,11 c

The different letters in columns showed significant differences among means by LSD test at P ≤ 0.05

date (1 September), while hybrids 26/54/87 (18 September) and 10/23/87 (21 September) had the latest. These two hybrids can be very interesting to producers and consumers due very late harvest date. Similar data for harvest date depended of plum genotypes reported Blažek and Pištková (2009). This trait has been established as characteristic of each genotype, and quantitatively inherited (Dirlewanger et al. 1999).

In the second and third year after planting, 2012 and 2013, yields were low, in fourth year, 2014 slightly higher and there were no significant differences among hybrids and 'Stanley' (data not shown). In the fifth year (2015), differences among hybrids were obvious and significantly different. The highest yield per tree and per hectare was established in hybrid 22/11/87 and the lowest in 34/41/87 (Table 2). Yield per tree and per hectare in the fourth year after planting, in our study, were higher than yield of three plum cultivars in the fourth year obtained by Meland (2005). In similar conditions as in our study, Milošević et al. (2012) were found similar yields of three German plum cultivars. In addition, yields of all hybrids and 'Stanley' in our study can be considered as a very good, compared to the yields of 8.6 kg tree^{-1} that were obtained in the typical Serbian plum orchards (Nenadović-Mratinić et al., 2007).

Fruit size is a major quantitative inherited factor determining yield, fruit quality and consumer acceptability (Crisosto et al. 2004). Data in Table 3. showed that the highest fruit weight was found in hybrid 10/23/87 and the lowest in 'Stanley', with the significant differences compared to the other two hybrids. Hybrids 10/23/87 and 26/54/87 had fruits larger than 30 g, so these hybrids could be classified as plums with medium-size fruits, while another two hybrids and 'Stanley' could be classified as plums with small-size fruits according to similar data obtained by Blažek and Pištěková (2009) for some cultivars. In the present study, fruit weight of 'Stanley' was smaller than those measured in studies of Nenadović-Mratinić et al. (2007) and Milošević and Milošević (2011) in similar conditions, which could be explained with high yields per tree in the third and fourth leaf. Previous works on plum reported a high variability among cultivars regarding this parameter (Meland, 2005; Peppelman et al., 2007). Values for stone weight were reversed from values for fruit weight. Nemely, 'Stanley' had the largest stone while hybrid 10/23/87 had the smallest. This is in accordance with data obtained by Nenadović-Mratinić et al. (2007) and Milošević and Milošević (2011). The differences in flesh/stone ratio among all hybrids were significant. The largest flesh percentage was observed in hybrid 10/23/87, and the smallest in hybrids 22/17/87 and 34/41/87. Plums with higher flesh percentage are better accepted by customers (Milošević et al. 2012). The fruit dimensions are important in determining aperture size of machines, particularly in separation of materials, and these dimensions may be useful in estimating size of machine components, especially for mechanical harvesting (Jannatizadeh et al. 2008). In our work, fruit dimensions (fruit lenght, width and thickness) were significantly different (Table 3). The highest values for all fruit dimensions were found in hybrid 26/54/87. On the other

Table 3. Fruit and stone weight, flesh percentage and fruit linear dimensions of the plum hybrids and standard cultivar 'Stanley'

Hybrids and standard cultivar	Fruit weight (g)	Fruit length (mm)	Fruit width (mm)	Fruit thickness (mm)	Stone weight (g)	Flesh Percentage (%)
10/23/87	32,39±1,34 a	42,91±1,49 b	33,47±0,85 a	34,56±1,04 a	1,11±0,01 c	96,46±0,22 a
26/54/87	30,36±1,49 b	47,43±0,41 a	33,48±0,65 a	34,39±0,80 a	1,47±0,02 b	95,48±0,12 b
34/41/87	25,19±0,79 d	40,36±0,64 c	33,72±0,21 a	30,14±0,67 b	1,43±0,02 b	94,48±0,34 c
22/17/87	27,01±0,72 c	42,78±0,18 b	32,26±0,57 b	31,34±0,22 b	1,46±0,01 b	94,55±0,13 c
'Stanley'	22,22±0,99 e	46,01±0,75 a	27,97±0,60 c	28,32±0,39 c	1,77±0,02 a	94,89±0,11 bc

The different letters in columns showed significant differences among means by LSD test at P ≤ 0.05

Table 4. Chemical properties of the plum hybrids and standard cultivar 'Stanley'

Hybrids and standard cultivar	Soluble solids (%)	Total sugars (%)	Invert sugars (%)	Sucrose (%)	Titratable acidity (%)	pH
10/23/87	20,42±0,20 b	14,65±0,13 a	8,93±0,04 a	5,18±0,03 a	0,78±0,01 c	3,72±0,01 a
26/54/87	20,97±0,21 b	14,80±0,06 a	8,82±0,08 a	5,59±0,03 a	0,70±0,01 d	3,89±0,01 a
34/41/87	16,50±1,33 c	10,41±0,44 c	7,55±0,25 b	3,10±0,17 b	0,78±0,02 c	3,06±0,04 b
22/17/87	17,01±0,64 c	12,31±0,35 b	8,96±0,29 a	3,18±0,26 b	0,94±0,03 a	3,18±0,04 b
'Stanley'	25,57±0,33 a	12,23±0,14 b	7,88±0,28 b	3,14±0,03 b	0,83±0,02 b	3,23±0,12 b

The different letters in columns showed significant differences among means by LSD test at P ≤ 0.05

hand, hybrid 34/41/87 had the smallest fruit length, while the smallest fruit width and thickness were determined in 'Stanley'.

Results presented in Table 4. showed the existence of significant variations among chemical properties in examined hybrids and standard cultivar 'Stanley'. The highest soluble solids content was recorded in 'Stanley'; total sugars, sucrose and pH value in hybrid 26/54/87 and invert sugars and total acids in hybrid 22/17/87. Hybrid 34/41/87 had the smallest values of all examined chemical properties except of titratable acidity Generally, hybrids 10/23/87 and 26/54/87 had the best values of evaluated fruit traits. Sosna (2012), stated that plum genotypes significantly influence soluble solids content, which confirmed data obtained in this work. The relationship between soluble solids content and total acids has an important role in consumer acceptance of apricot, peach, nectarine and plum cultivars. Plums with soluble solids content ≥ 12.0% had ~75% consumer acceptance, regardless of total acids (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). Our results regarding to total and invert sugars and sucrose are higher than results of Nenadović-Mratinić et al. (2007); Družić et al. (2007) and Blažek and Pištěková (2009) for some late plum cultivars, which can be explained by different climatic conditions, cultural practices, maturity stage at harvest date and rootstocks used, as previously obtained by Crisosto et al. (2004). The juice pH was significantly different among hybrids and standard cultivar 'Stanley', and this interval range agreed with those reported from other cultivars grown in similar conditions (Milošević and Milošević, 2011; Milošević et al. 2012).

Conclusion

The highest fruit weight and flesh percentage was determined in hybrid 10/23/87, while hybrid 26/54/87 had the largest fruit dimensions (height, width and thickness). Standard cultivar 'Stanley' had the poorest values of fruit weight, width and thickness and largest stone weight.

Hybrids 10/23/87 and 26/54/87 had very similar values for total and invert sugars, sucrose, and juice pH, which were higher than in other hybrids and 'Stanley'. The highest soluble solids content and total acids were found in 'Stanley' and hybrid 22/17/87, respectively.

The largest yield per tree and per hectare was determined in hybrid 22/17/87 and the poorest in hybrid 34/41/87.

All hybrids ripened in September. The latest ripening time was observed in hybrid 10/23/87, while the earliest ripening time had standard cultivar 'Stanley'.

Generally, hybrids 10/23/87 and 26/54/87 had very good properties and could be very interesting for further evaluation and suggested as candidates for new plum cultivars.

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