ACTA SCIENTIARUM POLONORUM *Acta Sci. Pol., Hortorum Cultus 10(2) 2011, 95-107*

QUANTITATIVE ANALYSIS OF THE MAIN BIOLOGICAL AND FRUIT QUALITY TRAITS OF F_1 PLUM GENOTYPES (*Prunus domestica* L.)

Tomo Milošević[1], Nebojša Milošević[2]
[1]Faculty of Agronomy in Čačak, Serbia
[2]Fruit Research Institute in Čačak, Serbia

Abstract. *Prunus domestica* L. is the most important fruit crop in the Europe and the most important within the genus Prunus. Serbia is the third world producer, after USA and China, of that friut. The seven F_1 plum genotypes (*Prunus domestica* L.) which originated from three cross-combinations ('Čačanska Lepotica' × 'Stanley', 'Čačanska Najbolja' × 'Stanley', 'Stanley' × 'Stanley') and these cultivars as controls were planted in the experimental orchard in Prislonica, near Cacak, in spring 2000. In 2005–2007 several biological (blooming period, harvest date and yield) and main fruit quality traits were evaluated. Considerable variation was observed among the F_1 genotypes, i.e. cross-combinations. All genotypes begun blooming later than their parents. The earliest harvest date was observed in 'P_4' and the latest in 'P_7'. The highest yield was observed in 'P_5'. The genotype 'P_4' had better values for some fruit quality traits (fruit weight, fruit rate, flash rate, fruit height, suture diameter, cheek diameter, soluble solids, fructose and total sugars content), when compared with other F_1 genotypes and control cultivars. The genotypes with better biological and fruit quality traits were included in the 'Čačanska Lepotica' × 'Stanley' cross-combinations.

Key words: biological and fruit quality traits, F_1 plum genotypes, multivariate analysis, yield

INTRODUCTION

European plum (*Prunus domestica* L.) is the most important fruit crop in the Europe (2 808 152 tons) [FAOSTAT 2010], and the most important within the genus Prunus. Serbia is the third world producer, after USA and China, with production of more than 600,000 tons [Milosevic et al. 2008; FAOSTAT 2010]. Among stone fruit crops, the plum breeding is one of the most dynamic and newest cultivars originated from *Prunus domestica* L. are released every year [Blažek et al. 2004].

Corresponding author – Adres do korespondencji: Tomo Milošević, Department of Fruit Growing and Viticulture, Faculty of Agronomy, University of Kragujevac, 32000 Čačak, Cara Dušana 34, Republic of Serbia, e-mail: tomom@tfc.kg.ac.rs

The creation of cultivars through controlled cross pollination is a common method used for producing new plum cultivars in many countries of Europe and the world. For this purpose, different cultivars are used as a donors of certain positive characteristics of trees and fruits [Paunovic and Misic 1975; Jakubowski and Lewandowska 2004; Hartmann and Neumüler 2006; Jacob 2007; Blazek and Vávra 2007].

In the research institutions in Serbia, the most frequently used cultivars for controlled cross pollination are 'Čačanska Lepotica', 'Čačanska Najbolja' and 'Stanley'. These cultivars were used as donors of positive biological and fruit traits. Namely, 'Čačanska Najbolja' is an excellent donor for tolerance of plum pox virus, robustness and vitality of trees and larger fruit size [Decroocq et al. 2004; Blazek and Vávra 2007; Jacob 2007]; 'Čačanska Lepotica' is a donor for the high content of SS, fruit taste and other fruit quality attributes, highest shares and tolerance of PPV [Hartmann and Neumüler 2006; Esmenjaud and Dirlewanger 2007]; Stanley is a good donor of high yield and biggest fruit size [Paunovic and Misic 1975; Jakubowski and Lewandowska 2004]. Also, 'Čačanska Lepotica' and 'Čačanska Najbolja' seemed to possess the best compromise between fruit size and other fruit quality parameters [Blazek and Vávra 2007].

At the Faculty of Agronomy, Cacak, planed hybridizations were carried out in the 1990's. As results of controlled cross pollination between 'Čačanska Lepotica', 'Čačanska Najbolja' and 'Stanley' in different combinations, the seven good F_1 plum genotypes were selected and segregated.

The aims of this work were to evaluate the existing biological and fruit quality traits among and within the F_1 genotypes and their parents (control cultivars) in high-density planting orchards. The materials evaluated are representative of the germplasm available for plum breeding in the Western Serbia area. The genotypes, with large genetic variability for many fruit quality traits, will improve the knowledge of the genetic studies on this species and will constitute a helpful tool to be applied in plum breeding programs.

MATERIAL AND METHODS

Plant material and experimental design. The hybridization material involved the cultivar 'Stanley' as the maternal parent and 'Čačanska Lepotica', 'Čačanska Najbolja' and 'Stanley' cultivars as the paternal parent (inbreeding) in 1991. A total of 13,123 flowers were pollinated, i.e. 3,763 in the 'Čačanska Lepotica' × 'Stanley' combination and 4,039 and 5,321 flowers in the 'Čačanska Najbolja' × 'Stanley' and 'Stanley' × 'Stanley' combinations, respectively. The flowers developed into 3,921 "hybrid" seeds. In the spring of 1992, stratified seeds were sown in the nursery at a spacing of 80 × 10 cm, yielding 3,013 hybrid seedlings or genotypes (F_1) at the end of the growing season. In autumn 1992, the hybrid seedlings were lifted from nursery beds and planted at a 3 m × 0.5 m spacing in the trial field immediately afterwards. Over the following years, routine care of the hybrid plants was performed accompanied by intensive visual monitoring and recording of all relevant developments. Over the 1995–1998 period, 1,657 or 55% of hybrid seedlings were eliminated out of the total of 3,013. The hybrid seedlings

gave their first yield in 1996. In this period, seven F_1 hybrid genotypes – 'P_1', 'P_4', 'P_5' and 'P_7' derived from 'Čačanska Lepotica' × 'Stanley, 'P_3' and 'P_6' derived from 'Stanley' × 'Stanley', and 'P_2' derived from 'Čačanska Najbolja' × 'Stanley' (fig. 1) good primarily in their sensorial and morphometrical properties were selected out of the remaining population of 1,356 hybrid seedlings.

Fig . 1. F_1 plum genotypes and their cross parents: a – 'P_1' ('Čačanska Lepotica' × Stanley); b – 'P_2' ('Čačanska Najbolja' × 'Stanley'); c – 'P_3' ('Stanley' × 'Stanley'); d – 'P_4' ('Čačanska Lepotica' × 'Stanley'); e – 'P_5' ('Čačanska Lepotica' × 'Stanley'); f – 'P_6' ('Stanley' × 'Stanley'); g – 'P_7' ('Čačanska Lepotica' × 'Stanley')

Rys. 1. Genotypy śliwy F_1 i ich rodzice krzyżowi: a – 'P_1' ('Čačanska Lepotica' × Stanley); b – 'P_2' ('Čačanska Najbolja' × 'Stanley'); c – 'P_3' ('Stanley' × 'Stanley'); d – 'P_4' ('Čačanska Lepotica' × 'Stanley'); e – 'P_5' ('Čačanska Lepotica' × 'Stanley'); f – 'P_6' ('Stanley' × 'Stanley'); g – 'P_7' ('Čačanska Lepotica' × 'Stanley')

The plant material used as progenitors for the controlled crosses included three commercial cultivars, i.e. genotype parents ('Čačanska Lepotica', 'Čačanska Najbolja' and 'Stanley'). Selected F_1 genotypes and control cultivars were budded onto Myrobalan rootstock on 25 cm above the ground in mid August 1999. The orchard trial of these plant material was established (five trees per each genotype and/or control cultivar in four replications) in 2000 in an experimental orchard at Prislonica near Cacak

(43°53'N latitude; 20°21'E longitude; 330 m altitude), Western Serbia. Trees were trained to the Central leader training system and planted at a spacing of 4 m × 2 m (1,250 trees · ha^{-1}). Orchard management was consistent with standard practice for plum, except irrigation. Summer pruning were used. Biological and fruit quality traits have been evaluated over three consecutive years (2005, 2006 and 2007, respectively). All biological and fruit quality traits were measured for each F_1 genotype and control cultivar and means of three years were calculated.

Biological and fruit quality traits measurement. For a period of three harvest seasons (2005–2007), biological and fruit quality traits was measured. Phenological characteristics were determined as below: the beginning of bloom (BB) was recorded when at least 5–10% of the flowers bloomed; full bloom (FB) was accepted when at least 80% of the flowers bloomed, the end of bloom (EB) was determined when 90% of the flowers bloomed and corollas began to fall off [Kobel 1954], and harvest date (HD) was established when the fruits were sufficiently coloured and soft to be eaten [Funt 1998]. The mean flowering and HD was also calculated for each F_1 genotype and control cultivar.

Fruit quality traits such as fruit weight (FW) and stone weight (SW), fruit dimensions – fruit height (H), suture diameter (SD), cheek diameter (CD), flesh rate (FRa), soluble solids content (SS), titratable acidity (TA) and juice pH were measured. Fruit weight (g) and SW (g) were taken using a Tehnica ET-1111 technical scale (Iskra, Slovenia). The FRa was calculated as the ratio of the weight of the edible portion of the fruit to the total fruit weight (%). Sphericity was calculated as H/SD ratio. Ten fruits in three replications from each genotype and control cultivar evaluated to determine each character. Average annual yield (Y) was determined for each genotype and control cultivar trees in all years. An ACS System Electronic Scale (Zhejiang, China) was used to measure fruit yield (kg $tree^{-1}$).

Five panelists evaluated plum genotypes sensory traits [fruit shape (FS), skin colour (SC) and flesh colour (FC) – ten fruits in four replications for each traits] on the basis IBPGR and UPOV methodologies [Cobianchi and Watkins 1984; Zanetto et al. 2002]. Fruit shape was evaluated on a six-step scale from rounded flat to oblong (1 = rounded flat, 2 = rounded, 3 = elliptic, 4 = ovate, 5 = heart shape, 6 = oblong), skin colour on a eight-step scale from pink to black (1 = pink, 2 = red, 3 = red-violet, 4 = violet, 5 = dark-violet, 6 = blue, 7 = dark-blue, 8 = black), and flesh colour on a nine-step scale from green to red (1 = green, 2 = light green, 3 = yellow-green, 4 = light yellow, 5 = yellow, 6 = amber, 7 = light-orange, 8 = orange, 9 = red).

Soluble solids content (ºBrix) was determined by an Milwaukee MR 200 (ATC, Belgium) hand refractometer, and juice pH by a Cyber Scan 510 pH meter (Nijkerk, Netherlands).

An HPLC analysis of sugars was performed using a Thermo separation products (Waters Corporation, USA) HPLC refractive index detector. Separation of sugars was carried out using a Rezex RCM-monosaccharide column (300 × 7.8 mm) and the column temperature was maintained at 65ºC. Sugars were analyzed isocratically according to the method of Šturm et al. [2003] with a Rezex RCM column (300 × 7.8 mm, Phenomenex) at 80°C using an RI detector. Data are given as % of fresh weight for each

individual sugars [glucose (GL), fructose (FR), sucrose (SU)]. Total sugar (TS) content was calculated as sum of each individual sugar.

Titratable acidity (TA) was determined by titration to pH 8.1 with N/10 NaOH using 1 ml distilled water (Titrino 719 S, Metrohm). Data are given as % malic acid of fresh weight, since this is the dominant organic acid in plum. On the basis of the measured data, ripening index (RI) and index of sweetness (IS) was calculated as ratios of SS/TA and TS/TA, respectively.

Data analysis. All data in the present study were subjected by analysis of variance (ANOVA) using the MSTAT-C statistical package [M-STAT 1990] and mean were separated by LSD test at $p \leq 0.05$.

RESULTS AND DISCUSSION

Evaluation of blooming and harvesting date. All genotypes and control cultivars were blooming between 11 April ('Čačanska Lepotica') and 25 April ('P_2') (tab. 1). Higher differences were observed among genotypes for BB and EB, due to the existing differences on the length of the blooming period for different genotypes and control cultivars. In contrast, small differences were observed among genotypes studied for FB. In addition, all genotypes, except 'P_1', have later BB than control cultivars. Vitanova et al. [2004] reported similar results for blooming period in F_1 plum genotypes.

Table 1. Blooming and harvesting date for the plum genotypes and three control cultivars. Data are means of three consecutive years for each plum F_1 genotype and control cultivars

Tabela 1. Termin kwitnienia i zbioru dla genotypów śliwy i trzech odmian kontrolnych. Dane stanowią średnie z trzech kolejnych lat dla każdego genotypu śliwy F_1 i odmian kontrolnych

Genotypes and control cultivars (their parents) Genotypy i odmiany kontrolne (ich rodzice)	Blooming date – Termin kwitnienia			Harvesting date Termin zbioru
	beginning początek	full pełnia	end koniec	
P_1	13 Apr	18 Apr	24 Apr	07 Aug
P_2	16 Apr	19 Apr	25 Apr	15 Aug
P_3	15 Apr	18 Apr	23 Apr	20 Aug
P_4	15 Apr	18 Apr	23 Apr	10 Jul
P_5	15 Apr	19 Apr	24 Apr	05 Aug
P_6	17 Apr	18 Apr	22 Apr	15 Aug
P_7	15 Apr	18 Apr	21 Apr	25 Aug
Čačanska Lepotica®	11 Apr	16 Apr	22 Apr	30 Jul
Čačanska Najbolja®	12 Apr	17 Apr	22 Apr	19 Aug
Stanley	13 Apr	18 Apr	24 Apr	24 Aug

These traits could be important to avoid late spring frosts in some years. Blooming date is considered as a quantitative trait in Prunus species [Dirlewanger et al. 1999; Vargas and Romero 2001]. In addition, *Prunus domestica* L. were a useful gene source for late flowering [Ercisli 2004]. Thus, the differences for the blooming date observed

among the trees within any genotype from the seven F_1 genotypes evaluated and their parents were somehow expected.

Significant differences were observed among some genotypes for HD (tab. 1). All genotypes and control cultivars used were harvested between 10 July and late August; there were large variations in harvest season between the tested genotypes. The earliest genotypes were 'P_4', which were harvested in 10 July. Most genotypes were harvested in early and late August, respectively. One genotype ('P_4') harvested earlier than 'Čačanska Lepotica', four genotypes ('P_5', 'P_1', 'P_2' and 'P_6') earlier than 'Čačanska Najbolja'; one genotype ('P_7') harvested later than 'Stanley'. Genotype 'P_3' harvested between 'Čačanska Najbolja' and 'Stanley' harvest date. The harvesting time showed a normal distribution within each genotype for all crosses, reflecting a quantitative genetic control. This trait has been established as characteristic of each genotype, and quantitatively inherited [Dirlewanger et al. 1999]. Moreover, significant differences between years were found for the some evaluated genotypes (data not shown), which could be due to the influence of environmental conditions, especially temperature. Similar data for HD depend of plum genotypes and environmental conditions reported Nergiz and Yıldız [1997] and Blažek and Pištěková [2009]. In addition, harvesting time is a very important factor determining consumer acceptability and fruit quality [Crisosto et al. 2007]. In our study, 'P_4' genotype could be interesting for the producers and consumer because of the very early ripening, and 'P_7' for the late ripening.

Evaluation of main biological traits. Average annual yield showed a large range of variation among F_1 genotypes (16.40 ± 1.98 to 21.10 ± 2.77 kg · tree^{-1}). Both of them were significantly different among the seven studied genotypes and control cultivars (tab. 2). The 'P_1', 'P_4' and 'P_5' genotypes showed the significantly highest Y (19.90 ± 3.17, 20.60 ± 3.34 and 21.10 ± 2.77 kg · tree^{-1}, respectively) than other. On the other hand, their parents ('Čačanska Lepotica', 'Stanley' and 'Čačanska Najbolja', respectively) showed the significantly lowest Y (14.70 ± 1.96, 16.50 ± 3.29 and 16.70 ± 3.45 kg · tree^{-1}, respectively). The cross combination of 'Čačanska Lepotica' × 'Stanley', resulted in a higher productive genotypes, which was consistent with the previous study carried out in plum [Blažek and Vávra 2007]. The observed variability supports the quantitative genetic control of yield previously reported in plum [Decroocq et al. 2004].

Analysis of fruit quality traits revealed significant variation among the seven genotypes and control cultivars, regardless of physical, sensorial (tab. 2 and 3) and chemical traits (tab. 4 and 5).

Fruit size is a major quantitative inherited factor determining yield, fruit quality and consumer acceptability [Crisosto et al. 2004]. The FW and SW varied greatly, ranging from 25.31 ± 1.27 to 57.62 ± 2.11 and from 1.20 ± 0.05 to 2.01 ± 0.02 g, respectively (tab. 2). Two genotypes ('P_1' and 'P_4') had higher FW than control cultivars. On the other hand, SW in all genotypes was significantly smaller than their parents. Its resulted in a higher FRa, which varied from 95.10 ± 1.71% ('Stanley') to 97.13 ± 1.55% ('P_1').

This agrees with previous reports where high variability in this parameter has been described among plum cultivars and/or F_1 genotypes [Paunovic and Misic 1975; Nergiz and Yıldız 1997; Sosna 2010]. 'Čačanska Lepotica' seemed to induce large fruits in its offspring, although the two other progenitors, involved in crosses with this cultivar, also showed big fruits in different cross combinations. Similar data reported Jakubowski and

Lewandowska [2004]. In contrast, 'Čačanska Najbolja' × 'Stanley' ('P_2') showed the lowest fruit weight among the some genotypes, which is oppositely to the results described by some authors. Namely, Blažek and Vávra [2007] found that 'Čačanska Najbolja' were excellent donors for large FW.

Table 2. Yield, fruit weight, stone weight and main sensorial traits of evaluated plum genotypes and control cultivars

Tabela 2. Plon, masa owocu, masa pestki i główne cechy sensoryczne ocenianych genotypów śliwy oraz odmian kontrolnych

F_1 genotypes and control cultivars Genotypy F_1 i odmiany kontrolne	Annual yield (kg · tree^{-1}) Plon roczny (kg · drzewo^{-1})	Fruit weight Masa owocu (g)	Stone weight Masa pestki (g)	Flesh rate Współczynnik miąższu (%)	Fruit shape* Kształt owocu*	Skin colour* Barwa skórki*	Flesh colour* Barwa miąższu
P_1	19.90 ± 3.17 a	47.59 ± 0.89 b	1.37 ± 0.05 gf	96.59 ± 1.23 c	6	7	3
P_2	18.70 ± 3.02 abc	31.44 ± 1.14 e	1.45 ± 0.07 e	95.76 ± 1.13 f	4	6	3
P_3	16.90 ± 2.33 bcd	44.89 ± 1.85 bc	1.65 ± 0.08 d	96.53 ± 1.22 d	3	7	3
P_4	20.60 ± 3.34 a	57.62 ± 2.11 a	1.45 ± 0.10 e	97.13 ± 1.55 a	2	7	3
P_5	21.10 ± 2.77 a	25.31 ± 1.27 g	1.33 ± 0.05 g	95.78 ± 1.20 e	2	7	6
P_6	16.40 ± 1.98 cd	45.18 ± 1.80 bc	1.33 ± 0.05 g	96.93 ± 1.31 b	3	6	3
P_7	19.30 ± 3.11 ab	29.11 ± 0.67 ef	1.20 ± 0.05 h	95.57 ± 1.32 h	2	6	6
Čačanska Lepotica®	14.70 ± 1.96 d	37.63 ± 1.36 d	1.69 ± 0.04 c	95.51 ± 1.45 i	2	7	3
Čačanska Najbolja®	16.70 ± 3.45 bcd	44.65 ± 1.38 c	1.93 ± 0.07 b	95.68 ± 1.19 g	3	7	3
Stanley	16.50 ± 3.29 bcd	41.07 ± 1.19 d	2.01 ± 0.02 a	95.10 ± 1.71 j	6	7	3

*IBPGR and UPOV Descriptor list for plum [Cobianchi and Watkins 1984; Zanetto et al. 2002]: Fruit shape: 2 – rounded, 3 – elliptic, 4 – ovate, 6 – oblong; skin colour: 6 – blue, 7 – dark blue; flesh colour: 3 – yellow green, 6 – amber – Kształt owocu: 2 – zaokrąglony, 3 – eliptyczny, 4 – owalny, 6 – podłużny; barwa skórki: 6 – niebieski, 7 – ciemnoniebieski; barwa miąższu: 3 – zielono-żółty, 6 – bursztynowy

Means followed by the same letter do not differ at $p \leq 0.05$ according to LSD test – Średnie oznaczone tą samą literą nie różnią się istotnie między sobą przy $p \leq 0,05$ (wg testu LSD)

Table 3. Size of fruit of evaluated plum genotypes and control cultivars

Tabela 3. Wielkość owoców ocenianych genotypów śliwy oraz odmian kontrolnych

F_1 genotypes and control cultivars Genotypy F_1 i odmiany kontrolne	Fuit height Wysokość owocu mm	Suture diameter Średnica szwu mm	Cheek diameter Średnica policzka mm	H/SD W/ŚSZ
P_1	49.47 ± 0.52 bc	36.00 ± 0.33 e	33.80 ± 0.40 ef	1.37 ± 0.03 b
P_2	45.67 ± 0.99 c	31.83 ± 0.37 fg	33.00 ± 0.33 f	1.43 ± 0.04 a
P_3	52.43 ± 0.95 ab	42.00 ± 0.55 cd	38.01 ± 0.03 d	1.25± 0.02 d
P_4	57.76 ± 0.98 a	53.02 ± 0.69 a	51.16 ± 0.82 a	1.09 ± 0.02 g
P_5	35.17 ± 0.56 e	33.12 ± 0.71 fg	30.91 ± 0.78 g	1.06 ± 0.02 i
P_6	45.35 ± 0.77 c	37.43 ± 0.53 e	40.00 ± 0.70 c	1.21 ± 0.04 e
P_7	37.33 ± 0.34 de	34.11 ± 0.40 f	32.50 ± 0.26 f	1.09 ± 0.03 g
Čačanska Lepotica®	45.11 ± 0.86 cd	42.21 ± 0.47 c	39.21 ± 0.39 cd	1.08 ± 0.02 h
Čačanska Najbolja®	50.34 ± 0.91 abc	45.11 ± 0.49 b	43.99 ± 0.73 b	1.11 ± 0.03 f
Stanley	48.09 ± 0.72 bc	36.33 ± 0.51 e	34.83 ± 0.65 e	1.32 ± 0.03 c

*see table 1 – patrz tabela 1

The FS, SC, FC, H, SD, CD and H/SD ratio had a significant impact on consumer acceptance and sales of plum [Crisosto et al. 2004]. Fruit shape varied from rounded to oblong, SC from blue to dark blue and FC from yellow green to amber (tab. 2). On the other hand, significant differences were also found for H, SD, CD and H/SD among the studied genotypes and their parents (tab. 3). The 'P_4' genotype ('Čačanska Lepotica' × 'Stanley') showed the largest fruits among the crosses with increased H, SD and CD, as it was confirmed by its highest mean fruit weight. After 'P_4' genotype, the highest fruits were found within 'Stanley' × 'Stanley' ('P_3'). Global shape of fruit (sphericity) was characterized by calculating H/SD and H/CD ratio [Wert et al. 2007]. All the genotypes and control cultivars showed ratios very close to 1, which means that some fruits were almost rounded to ovate. In plums, round shapes without protruding tips are preferred by consumers [Crisosto et al. 2004]. However, Cobianchi and Watkins [1984] reported that some sensorial traits are subjective factor, and varying between regions and between experts.

Evaluation of fruit quality traits. Significant differences were observed among genotypes and their parents for fruit quality attributes, except juice pH, GL and SU content (tab. 4 and 5).

The highest SS content obtained in 'P_4', 'P_2' and 'P_3' genotypes (19.20 ± 1.30, 18.75 ± 1.24 and 18.62 ± 1.32°Brix, respectively), and the lowest SS registered at 'P_6' and 'P_5' (16.85 ± 1.18 and 16.80 ± 1.18°Brix, respectively). The pedigree of these genotypes included 'Čačanska Lepotica' and 'Čačanska Najbolja', which is characterized by an excellent fruit quality [Blazek and Vávra 2007; Sosna 2010]. Also, the 'P_4', 'P_2' and 'P_3' genotypes showed higher SS than their parents i.e. control cultivars. On the other hand, 'P_5' and 'P_6' had significantly lower SS than 'Čačanska Lepotica' and 'Stanley' (tab. 4).

Table 4. Analysis of some chemical characters and ripening index of evaluated plum genotypes and control cultivars

Tabela 4. Analiza niektórych właściwości chemicznych oraz wskaźnik dojrzewania owoców ocenianych genotypów śliwy i odmian kontrolnych

F_1 genotypes and control cultivars Genotypy F_1 i odmiany kontrolne	Soluble solids Rozpuszczalne ciała stałe (°Brix)	Juice pH pH soku	Titratable acidity Kwasowość dająca się miareczkować (%)	Ripening index Wskaźnik dojrzewania
P_1	17.15 ± 1.19 de	3.36 ± 0.03 a	1.26 ± 0.02 d	13.61 ± 1.04 e
P_2	18.75 ± 1.24 a	3.51 ± 0.04 a	1.37 ± 0.03 a	13.69 ± 1.16 e
P_3	18.62 ± 1.32 ab	3.62 ± 0.07 a	1.31 ± 0.03 c	14.21 ± 1.18 de
P_4	19.20 ± 1.30 a	3.59 ± 0.05 a	1.25 ± 0.02 e	15.36 ± 1.19 c
P_5	16.80 ± 1.18 e	3.39 ± 0.04 a	1.22 ± 0.02 f	13.77 ± 1.09 e
P_6	16.85 ± 1.18 e	3.65 ± 0.06 a	1.16 ± 0.02 h	14.52 ± 1.31 cde
P_7	18.00 ± 1.27 bc	3.42 ± 0.05 a	1.04 ± 0.01 i	17.31 ± 1.24 b
Čačanska Lepotica®	17.75 ± 0.45 cd	3.35 ± 0.04 a	1.18 ± 0.02 g	15.04 ± 1.22 cd
Čačanska Najbolja®	17.00 ± 1.19 e	3.45 ± 0.06 a	0.88 ± 0.06 j	19.31 ± 1.33 a
Stanley	17.95 ± 1.34 c	3.66 ± 0.04 a	1.32 ± 0.03 b	13.60 ± 1.01 e

*see table 1 – patrz tabela 1

Daza et al. [2008] and Sosna [2010] found that genotypes have a significant influence on SS content, which were confirmed results in our study. In addition, many authors performed a detailed monitoring of fruits related to nutritional composition and consumer acceptability. Most studies focus on a more limited number of parameters, and it would be of importance to identify those of major importance for quality. In addition, generic single quality index have been developed, based on SS content [Robertson et al. 1992; Scott et al. 1993; Crisosto et al. 2004]. In our study, the SS contents of the genotypes and control cultivars examined were significantly lower than the SS contents obtained by Scott et al. [1993]. Their values were 208–241 g kg^{-1}. Robertson et al. [1992] reported that the threshold values of SS for acceptable quality was 125 g kg^{-1} for plums. Also, plums with SS content ≥ 12.0% had ~75% consumer acceptance, regardless of TA [Crisosto et al. 2004]. In addition, Blazek and Vávra [2007] concluded that content of SS was highest in cv. 'Čačanska Lepotica', 'Zimmers Frühzwetsche' and 'Common Prune'.

Regarding juice pH, significantly differences among genotypes and their parents were not observed (tab. 4). Its values ranged from 3.35 ± 0.04 ('Čačanska Lepotica') to 3.66 ± 0.04 ('Stanley'), which is in agreement with previous works in plum [Nergiz and Yıldız 1997; Tomás-Barberán et al. 2001]. In contrast, significantly differences registered between genotypes and control cultivars for TA (tab. 4). All genotypes and their parents, except 'Čačanska Najbolja' (0.88%) had the TA higher than 1.00%. Titratable acidity of stone fruits generally was expressed as malic acid, and played a significant role in consumer acceptance. Plums within this SS content range combined with low TA (≤ 0.60%) were disliked by 18% of consumers, while plums with TA ≥ 1.00% were disliked by 60% of consumers [Crisosto et al. 2004]. Our range of values is in agreement with previous work in plum [Scott et al. 1993; Nergiz and Yıldız 1997; Daza et al. 2008]. The fruit maturity stage at the harvest date is the principal factor affecting fruit acidity and also the SS content.

The relationship between SS and TA has an important role in consumer acceptance of some apricot, peach, nectarine and plum cultivars [Ruiz and Egea 2008]. The sugar-acid ratio is commonly used as a quality index [Robertson et al. 1992]. Crisosto et al. [2004] stated that in the case of plum cultivars with TA > 0.90% and SSC < 12.0%, consumer acceptance was controlled by the interaction between TA and SS content rather than SS content alone. Therefore, a single generic RSSC quality index would not be reliable with regard to assuring consumer satisfaction across all cultivars [Crisosto and Crisosto 2005]. In our study, there were significant differences among genotypes and control cultivars concerning the RI (SS/TA ratio), except 'Stanley', 'P_1', 'P_2' and 'P_5'. The RI in European plums (P. domestica L.) should be between 12 and 24 [Robertson et al. 1992]. Our values ranged between 13.60 ± 1.01 and 19.31 ± 1.33 (tab. 4). The results obtained in this study are in accordance with the values above.

Glucose, FR, SU, TS contents and IS of the genotypes and their parents are shown in tab. 5. No significant differences among genotypes and control cultivars for GL and SU content.

Table 5. The sugars content and fruit sweetness index s of evaluated plum genotypes and control cultivars

Tabela 5. Zawartośc cukrów oraz wskaźnik słodkości owoców ocenianych genotypów śliwy oraz odmian kontrolnych

F1 genotypes and control cultivars Genotypy F1 i odmiany kontrolne	Glucose Glukoza %	Fructose Fruktoza %	Sucrose Sacharoza %	Total sugars Cukry ogółem %	Index of sweetness Wskaźnik słodkości
P_1	3.99 ± 0.12 a	2.72 ± 0.13 ef	3.81 ± 0.07 a	10.52 ± 0.23 d	8.35 ± 0.66 i
P_2	4.36 ± 0.23 a	2.98 ± 0.16 b	4.17 ± 0.05 a	11.51 ± 0.41 ab	8.40 ± 0.57 h
P_3	4.33 ± 0.21 a	2.95 ± 0.15 c	4.13 ± 0.04 a	11.41 ± 0.38 b	8.71 ± 0.89 f
P_4	4.46 ± 0.34 a	3.05 ± 0.19 a	4.27 ± 0.05 a	11.78 ± 0.34 a	9.42 ± 1.01 c
P_5	3.91 ± 0.19 a	2.67 ± 0.12 g	3.73 ± 0.06 a	10.31 ± 0.19 d	8.45 ± 0.43 g
P_6	3.92 ± 0.41 a	2.67 ± 0.14 g	3.74 ± 0.04 a	10.33 ± 0.18 d	8.90 ± 0.54 e
P_7	4.19 ± 0.39 a	2.85 ± 0.13 d	4.00 ± 0.07 a	11.04 ± 0.25 c	10.61 ± 0.73 b
Čačanska Lepotica®	4.34 ± 0.20 a	2.73 ± 0.08 e	3.89 ± 0.08 a	10.96 ± 0.30 c	9.29 ± 0.21 d
Čačanska Najbolja®	3.94 ± 0.08 a	2.71 ± 0.11 f	3.72 ± 0.04 a	10.38 ± 0.12 d	11.79 ± 0.70 a
Stanley	4.17 ± 0.61 a	2.85 ± 0.10 d	3.99 ± 0.05 a	11.01 ± 0.28 c	8.34 ± 0.49 j

*see table 1 – patrz tabela 1

In contrast, Meredith et al. [1992] reported that significant differences were found between plum genotypes for SU content. This may be due to the differences in genotypes and geographical factors [Nergiz and Yıldız 1997]. On the other hand, 'P_4' genotype had the highest FR and TS content (3.05 ± 0.19% and 11.78 ± 0.34, respectively). Significant differences were registered among genotypes for IS (TS/TA ratio). The IS of the control cultivars ranged between 8.34 ± 0.49 and 11.79 ± 0.70. Forni et al. [1992] reported that the TS/TA ratio (IS), for good quality plums, should be between 12 and 24. In our study the highest ratio obtained was 11.79 ± 0.70 for 'Čačanska Najbolja'and 10.61 ± 0.73 for 'P_7' genotype ('Čačanska Lepotica' × 'Stanley'), and the others had ratios lower than 10. This may be due to the differences in genotypes, their maturity stage, pedo-climatic factors and orchard management [Kumar et al. 2001]. Also, some authors reported that various organic acids and their relative concentrations differ in the level they affect of sugars [Colarič et al. 2005].

The phenotypic variation found in our genotypes indicates that there was a genetic potential to develop plum with optimum sugar and acid contents. Due to their sensorial relevance, these traits were considered in every pre-selected F_1 genotypes.

CONCLUSIONS

1. Significant differences among F_1 genotypes were observed for all biological and fruit quality traits, which indicates that there is a genetic potential to develop plum with high quality.

2. All genotypes were later beginning of flowering than their parents; the earliest harvest date was observed in 'P_4' ('Čačanska Lepotica' × 'Stanley'), and the latest in 'P_7' ('Čačanska Lepotica' × 'Stanley'); the highest yield was observed in 'P_5' ('Čačanska Lepotica' × 'Stanley').

3. The 'P_4' genotype had the best values for fruit weight, fruit rate, flash rate, fruit height, suture diameter, cheek diameter, soluble solids, fructose and total sugars content.

4. The 'P_5' resulted in less interesting genotypes regarding some evaluated traits, especially fruit size, in spite of having higher yields and late ripening.

REFERENCES

Blažek J., Vávra R., Pištěkova I., 2004. Orchard performance of new plum cultivars on two rootstocks in a trial at Holovousy in 1998–2003. Hortic. Sci. 31, 37–43.

Blazek J., Vávra R., 2007. Fruit quality in some genotypes of plum varieties with tolerance to PPV. Acta Hortic. 734, 173–182.

Blažek J., Pištěková I., 2009. Preliminary evaluation results of new plum cultivars in a dense planting. Hortic. Sci. 36, 45–54.

Cobianchi D., Watkins R., 1984. Descriptor list for plum and allied species. Comission of the European Communities, Directorate General Information Market & Innovation, Luxembourg and for the IBPGR, Rome.

Colarič M., Veberič R., Štampar F., Hudina M., 2005. Evaluation of peach and nectarine fruit quality and correlations between sensory and chemical attributes. J. Sci. Food Agric. 85, 2611––2616.

Crisosto C.H., Garner D., Crisosto G.M., Bowerman E., 2004. Increasing 'Blackamber' plum (*Prunus salicina* Lindley) consumer acceptance. Postharvest Biol. Technol. 34, 237–244.

Crisosto C.H., Crisosto G.M., 2005. Relationship between ripe soluble solids concentration (RSSC) and consumer acceptance of high and low acid melting flesh peach and nectarine [Prunus persica (L.) Batsch] cultivars. Postharvest Biol. Technol. 38, 239–246.

Crisosto C.H., Crisosto G.M., Echeverria G., Puy J., 2007. Segregation of plum and pluot cultivars according to their organoleptic characteristics. Postharvest Biol. Technol. 44, 271–276.

Daza A., Garcia-Galavis P.A., Grande M.J., Santamaria C., 2008. Fruit quality parameters of 'Pioneer' Japanese plums produced on eight different rootstocks. Sci. Hortic. 118, 206–211.

Decroocq V., Hagen S.L., Favé G.M., Eyquard P.J., Pierronnet A., 2004. Microsatellite markers in the hexaploid Prunus domestica species and parentage lineage of three European plum cultivars using nuclear and chloroplast simple-sequence repeats. Mol. Breed. 13, 135–142.

Dirlewanger E., Moing A., Rothan C., Svanella L., Pronier V., Guye A., Plomion C., Monet R., 1999. Mapping QTLs controlling fruit quality in peach [P. persica (L.) Batsch]. Theor. Appl. Genet. 98, 18–31.

Ercisli S., 2004. A short review of the fruit germplasm resources of Turkey. Genet. Resour. Crop Ev. 51, 419–435.

Esmenjaud D., Dirlewanger, E., 2007. Plum. In: Genome Mapping and Molecular Breeding in Plants, Vol. 4, Fruits and Nuts. Cole C. (ed), Springer-Verlag-Berlin-Heidelberg, 119–135.

FAOSTAT, 2010. Available: http://www.faostat.fao.org

Forni E., Erba M.L., Maestrelli A., Polesello A., 1992. Sorbitol and free sugar contents in plums. Food Chem. 44, 269–275.

Funt R.C., 1998. Plums: A guide to selection and use. Fact Sheet, Ohio State University Extension, 1–2.

Hartmann W., Neumüller M., 2006. Breeding for resistance: breeding for Plum pox virus resistant plums (Prunus domestica L.) in Germany. EPPO Bullet. 36, 332–336.
Jacob H.B., 2007. Ripening time, quality and resistance donors of genotypes of Prunus domestica and their inheritance pattern in practical plum breeding. Acta Hortic. 734, 77–82.
Jakubowski T., Lewandowska G., 2004. Evaluation of fruit size and quality of plum seedlings (*Prunus domestica* L.). Acta Hortic. 663, 309–312
Kobel F., 1954. Lehrbuch des obstbaus auf physiologischer grundlage. Göreberg-Heidelberg, Berlin.
Kumar J., Rana S.S., Verma H.S., Parmar D.K., 2001. Long-term effects of intercrops on growth, yield and fruit quality of plum (Prunus salicina). Indian J. Agric. Sci. 71, 687–690.
Meredith I.F., Senter D.S., Forbus R.W.Jr., Robertson A.J., Okie R.W., 1992. Postharvest quality and sensory attributes of 'Byrongold' and 'Rubysweet' plums. J. Food Qual. 15, 199–209.
Milosevic T., Zornic B., Glisic I., 2008. A comparison of low-density and high-density plum plantings for differences in establishment and management costs, and in returns over the first three growing seasons. J. Hortic. Sci. Biotechn. 83, 539–542.
M-STAT, 1990. A microcomputer program for the design, management and analysis of biological research experiments. Michigan State University, EL.
Nergiz C., Yıldız H., 1997. Research on chemical composition of some varieties of European plums (Prunus domestica) adapted to the Aegean district of Turkey. J. Agric. Food Chem. 45, 2820–2823.
Paunovic A.S., Misic D.P., 1975. The study of inheritance in the plum genotypes. Acta Hortic. 48, 67–78
Robertson J.A., Meredith F.I., Senter S.S., Okie W.R., Norton J.D., 1992. Physical, chemical and sensory characteristics of Japanese-type plums growing in Georgia and Alabama. J. Sci. Food Agric. 60, 339–347.
Ruiz D., Egea J., 2008. Phenotypic diversity and relationships of fruit quality traits in apricot (*Prunus armeniaca* L.) germplasm. Euphytica 163, 143–158.
Scott K.J., Yuen C.M.C., Kim G.H., 1993. Sensory quality of Australian D'Agen prunes in relation to fruit maturity and chemical composition. J. Sci. Food Agric. 62, 95–97.
Sosna I., 2010. Effect of pruning time on yielding and fruit quality of several early ripening plum cultivars. Acta Sci. Pol., Hortorum Cultus 9(1), 37–44.
Šturm K., Koron D., Štampar F., 2003. The composition of fruit of different strawberry varieties depending on maturity stage. Food Chem. 83, 417–422.
Tomás-Barberán F.A., Gil M.I., Cremin P., Waterhouse A.L., Hess-Pierce B., Kader A.A., 2001. HPLC-DAD-ESIMS analysis of phenolic compounds in nectarines, peaches and plums. J. Aric. Food Chem. 49, 4748–4760.
Vargas F.J., Romero M.A., 2001. Blooming time in almond genotypes. Options Méditerran. 56, 29–34.
Vitanova I., Dimkova S., Ivanova D., 2004. Biological characterization of the plum cultivars 'Gabrovska' and 'Goulyaeva'. J. Fruit Ornamen. Plant Res. 12, 269–274.
Wert T.W., Williamson J.G., Chaparro J.X., Miller E.P., Rouse R.E., 2007. The influence of climate on fruit shape of four low-chill peach cultivars. HortScience 42, 1589–1591.
Zanetto A., Maggoni L., Tobutt R.K., Dosba F., 2002. Prunus genetic resources in Europe: Achievement and perspectives of a networking activity. Genet. Resour. Crop Ev. 49, 331–337.

ANALIZA ILOŚCIOWA GŁÓWNYCH CECH WARTOŚCI BIOLOGICZNEJ ORAZ JAKOŚCI OWOCÓW GENOTYPÓW F_1 ŚLIWY DOMOWEJ (*Prunus domestica* L.)

Streszczenie. *Prunus domestica* L. jest najważniejszym gatunkiem drzew owocowych w Europie, a także najważniejszym w obrębie rodzaju Prunus. Serbia jest trzecim po USA i Chinach światowym producentem owoców tego gatunku. Siedem genotypów śliwy (*Prunus domestica* L.) F_1, pochodzących z trzech połączeń krzyżowych ('Čačanska Lepotica' × 'Stanley', 'Čačanska Najbolja' × 'Stanley', 'Stanley' × 'Stanley') i te same odmiany jako rośliny kontrolne posadzono w sadzie doświadczalnym w Prislonicy, koło Cacaku, wiosną 2000 r. W latach 2005–2007 oceniono kilka cech wartości biologicznej (okres kwitnienia, termin zbioru oraz plon), a także główne cechy jakościowe owoców. Znaczną różnorodność zaobserwowano wśród genotypów F_1, tj. połączeń krzyżowych Wszystkie genotypy zaczynały kwitnąć później niż ich rodzice. Najwcześniejszy termin zbioru zaobserwowano u 'P_4', a najpóźniejszy u 'P_7'. Najwyższy plon stwierdzono u 'P_5'. Genotyp 'P_4' miał wyższe wartości niektórych cech jakościowych owoców (masa owocu, współczynnik owocu, współczynnik miąższu, wysokość owocu, średnica szwu, średnica policzka, rozpuszczalne ciała stałe, fruktoza i całkowita zawartość cukrów), w porównaniu z innymi genotypami F_1 oraz odmianami kontrolnymi. Genotypy z lepszymi cechami biologicznymi i cechami jakościowymi owoców zaliczono do połączeń krzyżowych 'Čačanska Lepotica' × 'Stanley' .

Słowa kluczowe: cechy wartości biologicznej i jakości owoców, genotypy śliwy F_1, analiza wielu zmiennych, plon

Accepted for print – Zaakceptowano do druku: 22.02.2011