

## THE INFLUENCE OF FOUR ROOTSTOCKS ON THE GROWTH, YIELD AND FRUIT QUALITY OF TWO PLUM CULTIVARS

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### ABSTRACT

The influence of three clonal rootstocks ('Pixy', 'Fereley' and 'St. Julien A') along with seedlings of Myrobalan (control) on growth, yield and fruit quality of plum cultivars 'Čačanska Najbolja' and 'Čačanska Lepotica' was studied in the Belgrade region (Serbia) for the six year-period (2013–2018). In comparison to control, clonal rootstocks have shown a significant effect on the decrease of trunk cross-sectional area. The lowest vigor was found in trees on the 'Pixy' rootstock, then on 'Fereley' and 'St. Julien A'. Yield per hectare on trees grafted on clonal rootstocks was higher for 62–82% in 'Čačanska Najbolja', and for 26–27% in 'Čačanska Lepotica' compared to Myrobalan. In cultivar 'Čačanska Najbolja' significantly higher fruit weight compared to control was obtained in the trees on the 'Fereley' and 'St. Julien A' rootstocks. The effects of rootstocks on the contents of soluble solids and total acids in the fruit were not significant. All three studied clonal rootstocks showed better results than standard Myrobalan, and can be recommended for establishing intensive plum plantations with higher planting density.

**Key words:** *Prunus domestica*, clonal rootstocks, vigor, fruit set, yield per tree, cumulative yield efficiency, fruit quality

### INTRODUCTION

European plum (*Prunus domestica* L.) is a stone fruit species, mostly grown in the temperature zone of the Northern hemisphere. In Serbia, it is the most important fruit species. The average production of 425,441 t in the period 2013–2017 ranks Serbia on the third place in world, behind China and Romania [FAOSTAT 2019]. Fruits of European plums are suitable for fresh consumption, drying and processing into different products (jam, juice, compote, brandy). In Serbia, most of produced plum fruits is processed into brandy (more than 70%), while much smaller amounts are eaten fresh, dried or processed into jam and other products.

The cultivar is the most important factor in fruit production [Ogašanović et al. 2005]. 'Čačanska Najbolja' and 'Čačanska Lepotica' are among most sig-

nificant plum cultivars in Serbian orchards. The choice of rootstock is also important for successful plum production, because they can affect not only the vegetative growth and yield [Blažek et al. 2004, Sitarek et al. 2007, Mészáros et al. 2015], but also the fruit quality [Rato et al. 2008].

Myrobalan (*Prunus cerasifera* Ehrh.) seedlings are the most popular and traditional rootstocks for European plum in Serbia [Milosevic et al. 2008]. However, the use of this rootstock is associated with some problems: non-uniformity of seedlings, too vigorous growth, delayed precocity, insufficient compatibility with some cultivars.

To overcome these problems, new dwarf or semi-dwarf clonal rootstocks (such as 'Pixy', 'St. Julien A',

‘Fereley’, ‘Ishtara’, and others) are increasingly being used in the intensive plum production. In the last 20 years, a large number of new clonal rootstocks providing considerable tree size reduction and higher yield per unit area have been examined [Botu et al. 2002, Kosina 2004, Sitarek et al. 2004, Blažek and Pištěková 2012, Mészáros et al. 2015]. New clonal rootstocks combined with the training system could serve as an appropriate basis for high-density orchards [Magyar and Hrotkó 2006]. According to Botu et al. [2007] new clonal rootstocks should reduce tree vigor, have good grafting compatibility with plum cultivars, good tolerance to major diseases and pests, and should be thornless. However, finding the ‘perfect rootstock’ is practically impossible.

The aim of this study was to examine the influence of three clonal rootstocks and one seedling rootstock on the tree vigor, productivity and fruit quality of two table plum cultivars (‘Čačanska Najbolja’ and ‘Čačanska Lepotica’).

## MATERIALS AND METHODS

**Plant material.** The study was conducted in the plum orchard at the Experimental Station “Radmilovac” of the Faculty of Agriculture in Belgrade (Serbia). During the six-year period (2013–2018) the influence of a seedling rootstock (Myrobalan as a control) and three clonal rootstocks (‘Pixy’, ‘Fereley’, and ‘St. Julien A’) were studied on two table plum cultivars (‘Čačanska Najbolja’ and ‘Čačanska Lepotica’).

The orchard was planted in spring of 2010. Planting distance is 4 m between rows and in the row different distances were applied depending on the rootstock vigor: 2.3 m for Myrobalan seedling, 2.0 m for ‘Fereley’ and ‘St. Julien A’ and 1.7 m for ‘Pixy’. Training system is the Spindle. Standard cultural practices were applied, including drip irrigation. Every variant (cultivar/rootstock) was represented by six trees (two replications with three trees).

**Methods.** As a vigor indicator, trunk cross-sectional area (TCSA) was used. TCSA was calculated on the basis of trunk circumference measured at 20 cm above the graft union. As for indicators of productivity fruit set, yield tree<sup>-1</sup> and cumulative yield efficiency (CYE) were examined. The fruit set was determined on the six selected branches (two replicates with three

branches) of each cultivar/rootstock combination. Every branch contained at least 100 flowers. The fruit set was determined two weeks before harvest and it was calculated as a ratio of the number of fruits and the number of flowers, expressed in %. CYE was calculated as a ratio of the cumulative yield per tree for six years (2013–2018) and the TCSA in the last year of investigation (2018), expressed in kg cm<sup>-2</sup>.

Characteristics of fruit (fruit and stone weight, fruit dimensions and pedicel length) were determined by measuring of individual fruits on a sample of 60 fruits of each variant (10 fruits per tree). Fruit shape index was calculated using the formula:

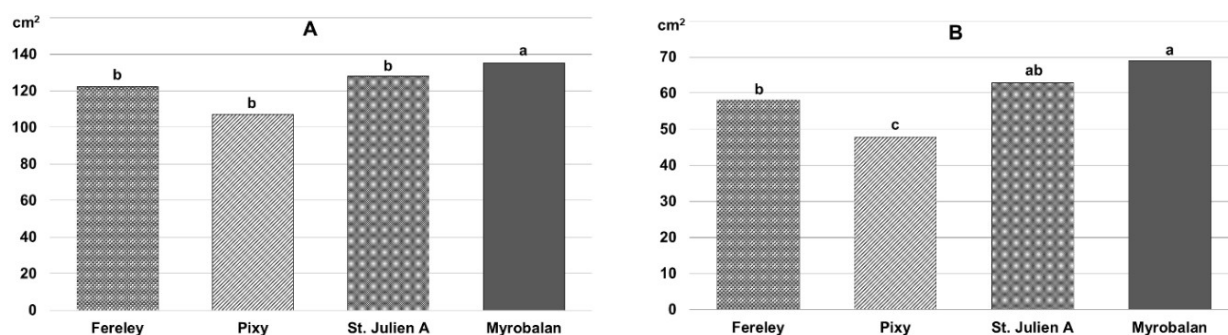
$$FSI = L^2 / (W \times T),$$

where: L – length; W – width; T – thickness. The soluble solids were determined using a refractometer (Pocket PAL-1, Atago, Japan). Total acids were determined by titration with NaOH and expressed as malic acid.

**Statistical analysis.** The results were processed statistically using the analysis of variance. The significance of differences between mean values was evaluated using Duncan’s multiple range test for significance level of 0.05. Data analysis was performed using the statistical software package IBM SPSS Statistics 20 (SPSS Inc., Chicago, IL, USA).

## RESULTS AND DISCUSSION

**Influence of rootstocks on tree vigor.** Trunk cross-sectional area (TCSA) is considered as the most important indicator of tree vigor. Cultivar ‘Čačanska Najbolja’ grafted on all three clonal rootstocks had statistically significantly lower TCSA values compared to control rootstock (Myrobalan) – Figure 1A. The highest TCSA in cultivar ‘Čačanska Najbolja’ was on Myrobalan seedling (122.3 cm<sup>2</sup>). Compared to control, reduction of TCSA was highest on ‘Pixy’ (21%), then on ‘Fereley’ (10%) and ‘St. Julien A’ (5%). Significant differences in TCSA between rootstocks were also found in cultivar ‘Čačanska Lepotica’ (Fig. 1B). The highest TCSA in the last year of the study was found on Myrobalan seedling rootstock (68.9 cm<sup>2</sup>). Reduction of TCSA compared to control was for 31% on ‘Pixy’, 16% on ‘Fereley’ and 9% on ‘St. Julien A’ rootstock.



**Fig. 1.** Trunk cross-sectional area of plum cultivars ‘Čačanska Najbolja’ (A) and ‘Čačanska Lepotica’ (B) on different rootstocks in 2018. Different letters above the bars indicate statistically significant differences according to Duncan’s multiple range test ( $P \leq 0.05$ )

**Table 1.** Fruit set of plum cultivars ‘Čačanska Najbolja’ and ‘Čačanska Lepotica’ on different rootstocks (%)

Rootstocks	Years						Average
	2013	2014	2015	2016	2017	2018	
‘Čačanska Najbolja’							
‘Fereley’	21.8	8.4	9.4	8.5	5.6	14.5	11.4 a
‘Pixy’	21.3	12.4	14.3	10.3	11.6	10.9	13.5 a
‘St. Julien A’	18.8	8.5	14.3	13.0	7.8	5.2	11.3 a
Myrobalan (control)	24.6	5.7	14.8	12.5	2.4	5.7	10.9 a
‘Čačanska Lepotica’							
‘Fereley’	33.4	31.4	33.3	23.5	26.1	49.4	32.9 a
‘Pixy’	28.2	15.6	37.8	15.0	35.8	21.5	25.7 b
‘St. Julien A’	25.3	16.1	33.4	17.8	24.3	23.4	23.4 b
Myrobalan (control)	17.5	22.6	34.7	25.9	25.3	37.9	27.3 b

Mean values followed by the same letter in a column for each cultivar are not significantly different according to Duncan’s multiple range test ( $P \leq 0.05$ )

Higher values of TCSA for all rootstocks were found in cultivar ‘Čačanska Najbolja’ compared to cultivar ‘Čačanska Lepotica’. Our results are in accordance with the previous findings [Sosna 2002, 2006, Blažek et al. 2004]. On the other hand, Blažek and Pištěková [2012] reported higher values of TCSA for the combination ‘Čačanska Lepotica’/Myrobalan compared with our results. Results of low vigor of the clonal rootstock ‘Pixy’ are in accordance with the previous findings [Sosna 2002, Kosina 2004, Sitarek et al. 2004]. This rootstock showed significantly lower values of the vigor compared to ‘St. Julien A’, which is in agreement with the results of Sosna [2006]. According to Botu et al. [2002] the value of TCSA for the rootstock ‘Pixy’ was 35% lower in comparison to seedling rootstock Myrobalan in environmental condi-

tional of Romania. The same authors reported that the clonal rootstock ‘St. Julien A’ influenced the decrease in value of TCSA by 29% on average. Comparing with these results, we obtained lower vigor reduction for both rootstocks, especially for ‘St. Julien A’. These differences in vigor decrease may be caused by environmental conditions, yield and cultural practices, such as fertilization and irrigation.

**Influence of rootstocks on fruit set.** Fruit set is one of the most significant indicators of fruit trees productivity [Glišić et al. 2012, Nikolić et al. 2012]. Results of fruit set of plum cultivars ‘Čačanska Najbolja’ and ‘Čačanska Lepotica’ grafted on four different rootstocks are presented in Table 1.

Fruit set in the cultivar ‘Čačanska Najbolja’ ranged from 2.4% in 2017 on Myrobalan seedling rootstock

**Table 2.** Yield of plum cultivars ‘Čačanska Najbolja’ and ‘Čačanska Lepotica’ on different rootstocks (t ha<sup>-1</sup>)

Rootstocks	2013	2014	2015	2016	2017	2018	Average	Index (Myrab. = 100)
‘Čačanska Najbolja’								
‘Fereley’	53.5	14.1	13.1	12.7	20.3	22.3	22.7 a	176
‘Pixy’	50.8	14.7	19.0	15.3	20.5	20.5	23.5 a	182
‘St. Julien A’	40.2	19.6	16.7	23.7	9.9	15.1	20.9 a	162
Myrobalan (control)	29.7	10.4	11.2	9.7	5.9	10.8	12.9 b	100
‘Čačanska Lepotica’								
‘Fereley’	33.7	26.4	17.0	46.0	27.0	24.6	29.1 a	127
‘Pixy’	25.3	36.1	14.6	60.1	19.8	17.6	28.9 a	126
‘St. Julien A’	28.0	37.0	17.7	53.1	19.6	18.1	28.9 a	126
Myrobalan (control)	21.7	32.3	15.5	40.5	15.2	12.9	23.0 b	100

Mean values followed by the same letter in a column for each cultivar are not significantly different according to Duncan’s multiple range test ( $P \leq 0.05$ )

to 24.6% in 2013 on the same rootstock. Differences in average fruit set among rootstocks were not significant. On the other hand, in the cultivar ‘Čačanska Lepotica’ the lowest fruit set was in 2016 on rootstock ‘Pixy’ (15.0%), while the largest value was in 2018 on rootstock ‘Fereley’ (49.4%). Fruit set was significantly higher on ‘Fereley’ rootstock compared to Myrobalan seedling rootstock. In cultivar ‘Čačanska Lepotica’ higher fruit set (27.3% on average) was obtained than in cultivar ‘Čačanska Najbolja’ (11.8% on average).

The percentage of fruit set depends mostly on the self-compatibility of cultivars. ‘Čačanska Lepotica’ was classified as a self-compatible cultivar, while ‘Čačanska Najbolja’ was classified as self-incompatible cultivar [Nikolić and Milatović 2010]. This is one of the reasons for the higher fruit set in the cultivar ‘Čačanska Lepotica’. Cultivar ‘Čačanska Najbolja’ in some years had good and in some years moderate fruit set. This mostly depends on weather conditions during the flowering.

Based on fruit set of European plum cultivars, Neumüller [2011] gives the following classification: low (under 10%), middle (10–20%), high (20–40%) and very high (above 40%). According to this classification, the cultivar ‘Čačanska Najbolja’ can be classified in the group of middle fruit set, while the cultivar ‘Čačanska Lepotica’ belongs the group of high fruit set. Our results of fruit set are consistent with the values reported by other authors. Namely, Surányi [2006] found the average fruit set in the interval of 10.9% to 44.4% in 21 cultivars of plum. Fruit set of six plum hybrids in the study of Glišić et al. [2012] ranged from 7.6% to 30.6%.

**Influence of rootstocks on yield.** The average yield per hectare in the cultivar ‘Čačanska Najbolja’ was the highest on the rootstock ‘Pixy’ (23.5 t), then on the clonal rootstocks ‘Fereley’ (22.7 t) and ‘St. Julien A’ (20.9 t), while it was the lowest on Myrobalan seedling rootstock (12.9 t) – Table 2. Among years, maximum yield was obtained on the rootstock ‘Fereley’ in 2013 (53.5 t ha<sup>-1</sup>), and the minimum yield was found on Myrobalan rootstock in 2017 (5.9 t ha<sup>-1</sup>). The average yield on all three clonal rootstocks was significantly higher compared to the Myrobalan seedling rootstock (control). The average yield per hectare in the cultivar ‘Čačanska Najbolja’ grafted on clonal rootstocks was higher for 82% on ‘Pixy’, 76% on ‘Fereley’ and 62% on ‘St. Julien A’ compared to control.

The average yield per hectare in the cultivar ‘Čačanska Lepotica’ was the lowest on Myrobalan seedling rootstock (23.0 t), while it was the highest on the rootstock ‘Fereley’ (29.1 t). Among years, maximum yield was obtained on the rootstock ‘Pixy’ in 2016 (60.1 t ha<sup>-1</sup>), and minimum yield was found on Myrobalan in 2018 (12.9 t ha<sup>-1</sup>). Differences in average yield between control rootstock (Myrobalan) and all three clonal rootstocks were statistically significant. Compared to the control, the yield per hectare was higher for 26% on the rootstocks ‘Pixy’ and ‘St. Julien A’, and for 27% on the rootstock ‘Fereley’. Higher values of the yield were recorded in the cultivar ‘Čačanska Lepotica’ (27.5 t ha<sup>-1</sup> for on average for all rootstocks) than in the cultivar ‘Čačanska Najbolja’ (20.0 t ha<sup>-1</sup> on average).

Higher yield on clonal rootstocks can be partly explained by their influence on lower vigor of grafted

cultivars. Because of that, more nutrients are available for flower bud development. The other possible reason is higher fruit set in some cultivar/rootstock combinations. According to Radović et al. [2016], clonal rootstocks influenced the increase in the number of flower buds on the fruiting branches, especially on the 'Fereley' rootstock. Grzyb and Sitarek [2006] and Ogašanović et al. [2011] stated the positive influence of the rootstock 'Fereley' on increasing the yield of grafted cultivars. Our results of yield on the clonal rootstock 'Pixy' are in accordance with previous reports [Kosina et al. 2000, Sosna 2002]. However, under our environmental conditions, the yield of the cultivar 'Čačanska Najbolja' was lower than under the conditions in Czech Republic [Blažek et al. 2004].

Cumulative yield efficiency (CYE) was lowest on combination 'Čačanska Najbolja'/Myrobalan ( $0.53 \text{ kg cm}^{-2}$ ) – Figure 2. Highest value was obtained in combination 'Čačanska Lepotica'/'Pixy' ( $2.47 \text{ kg cm}^{-2}$ ) and it was almost five times higher. In both studied cultivars CYE was significantly higher on all three clonal rootstocks compared with Myrobalan seedling rootstock.

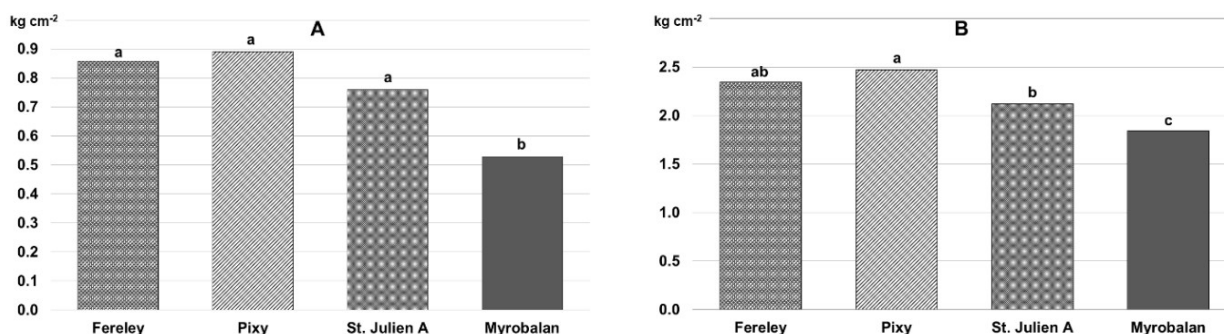
Cumulative yield efficiency was higher in the cultivar 'Čačanska Lepotica' ( $2.20 \text{ kg cm}^{-2}$  on average for all rootstocks) compared with the cultivar 'Čačanska Najbolja' ( $0.76 \text{ kg cm}^{-2}$  on average). The reasons for higher values for 'Čačanska Lepotica' cultivar are lower vigor on one side, and higher yield on the other side. The results obtained for CYE in our research are within the previously reported ranges Sosna 2002, Magyar and Hrotkó 2006, Świerczyński and Stachowiak 2009].

#### Influence of rootstocks on fruit characteristics.

One of the most important pomological properties of cultivar is fruit weight. Fruit weight of cultivar 'Čačanska Najbolja' ranged from 52.5 g on control rootstock to 56.8 g on the medium vigorous clonal rootstock 'Fereley' (Tab. 3). Significantly higher fruit weight was obtained on rootstocks 'Fereley' and 'St. Julien A' compared with control (Myrobalan). Also, stone weight was significantly higher in clonal rootstocks compared to control. Fruit shape index was largest on rootstock 'Fereley' indicating its influence on more elongated fruit shape. Our results for fruit size of 'Čačanska Najbolja' cultivar were similar to those obtained by Sosna [2006], and higher compared to results of Blažek et al. [2004] and Kosina [2004].

Cultivar 'Čačanska Lepotica' had the lowest fruit weight on clonal rootstock 'Pixy', while the highest value was on medium vigorous rootstock 'St. Julien A'. However, differences among rootstocks were not significant. This is in line with results of Sitarek et al. [2007] and Meland [2010]. Our values for fruit size of 'Čačanska Lepotica' cultivar were similar or slightly lower than the results of other authors [Blažek et al. 2004, Blažek and Pištěková 2012, Mészáros et al. 2015].

There were no significant differences among rootstocks on contents of soluble solids and total acids in fruits of both studied cultivars. It is in agreement with previous research of plum [Sitarek et al. 2007, Meland 2010, Milošević and Milošević 2012, Reig et al. 2018].



**Fig. 2.** Cumulative yield efficiency of plum cultivars 'Čačanska Najbolja' (A) and 'Čačanska Lepotica' (B) on different rootstocks. Different letters above the bars indicate statistically significant differences according to Duncan's multiple range test ( $P \leq 0.05$ )

**Table 3.** Fruit characteristics of plum cultivar ‘Čačanska Najbolja’ and ‘Čačanska Lepotica’ on different rootstocks (average values for the 2013–2018 period)

Rootstocks	Fruit weight (g)	Stone weight (g)	Flesh ratio (%)	Fruit shape index	Pedicle length (cm)	Soluble solids (%)	Total acids (%)
‘Čačanska Najbolja’							
‘Fereley’	56.8 a	2.41 a	95.8 a	1.56 b	1.52 a	13.9 a	0.73 a
‘Pixy’	55.6 ab	2.41 a	95.7 a	1.52 ab	1.55 a	14.1 a	0.73 a
‘St. Julien A’	56.7 a	2.40 a	95.8 a	1.50 ab	1.61 a	14.0 a	0.71 a
Myrobalan (control)	52.5 b	2.27 b	95.7 a	1.48 a	1.48 a	14.6 a	0.72 a
‘Čačanska Lepotica’							
‘Fereley’	34.5 a	1.66 a	95.2 a	1.35 a	1.19 a	13.0 a	1.06 a
‘Pixy’	33.7 a	1.65 a	95.1 a	1.38 a	1.18 a	13.5 a	1.05 a
‘St. Julien A’	35.2 a	1.67 a	95.3 a	1.36 a	1.25 a	13.3 a	1.06 a
Myrobalan (control)	35.0 a	1.59 a	95.5 a	1.30 a	1.25 a	13.8 a	0.98 a

Mean values followed by the same letter within a column for each cultivar are not significantly different according to Duncan’s multiple range test ( $P \leq 0.05$ )

## CONCLUSION

All studied clonal rootstocks (‘Fereley’, ‘Pixy’ and ‘St. Julien A’) had a positive effect on reducing the vigor and increasing the yield of plum cultivars ‘Čačanska Najbolja’ and ‘Čačanska Lepotica’. The lowest vigor was found in trees grafted on ‘Pixy’ rootstock, followed by ‘Fereley’ and ‘St. Julien A’. The yield per hectare was significantly higher on trees grafted on clonal rootstocks compared to Myrobalan seedling rootstock. The highest yield in the cultivar ‘Čačanska Najbolja’ was obtained on the rootstock ‘Pixy’, and in the cultivar ‘Čačanska Lepotica’ on the rootstock ‘Fereley’. Based on the results obtained, it can be concluded that all three clonal rootstocks showed better results than Myrobalan, and can be recommended for establishing intensive plum plantations with higher planting density. Among the rootstocks tested, the best results in terms of productivity and fruit quality were obtained on the ‘Fereley’ rootstock.

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