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MORPHOMETRIC TRAITS OF NEWLY BRED ROOTSTOCKS SUCKERS IN DOMESTIC AND CHERRY PLUM

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Abstract. Breeding of stone rootstock is very important problem for orcharding. In many countries of the world have been obtained a lot of new breeding material for sweet and sour cherries and plums. An analysis was conducted in Cacak (Western Serbia) in the 2006–2007 period to examine major morphological traits of the aerial part and root of suckers derived from mother bushes of three newly vegetative rootstocks for stone fruit species, particularly plum, peach and apricot trees. The newly breed rootstocks have been developed from autochthonous genetic material, their specific designations being: FA 2/53 (*Prunus domestica* L.), FA 5/7 (*P. domestica* L.) and FA 6/209 (*P. cerasifera* Ehrh.). The analysis of suckers of the new rootstocks included the investigation of morphological traits through the determination of: a) length of the aerial part, b) number of feathers on aerial part, c) number of roots, d) length of roots, and e) volume, weight and category of the roots. They developed branch roots and exhibited good length of the aerial part, a substantial number of roots and root dry weight. The FA 2/53 rootstock can be classified into low-vigour rootstocks, FA 5/7 into low to moderately vigorous ones (slightly more vigorous than the FA 2/53 rootstock) and FA 6/209 into moderately vigorous rootstock for stone fruits.

Key words: aerial part, root, rooting, stone fruit, vegetative rootstock

INTRODUCTION

Stone fruit rootstock breeding programmes have been conducted in many world countries due to the exceptionally high genetic divergence of the genus *Prunus* [Zanetto et al. 2002]. As regards the rootstocks, particularly for plums, apricots and peaches, major focus has been placed on the development of rootstocks tolerant to Plum Pox Virus (PPV), which is a major issue [Rubio et al. 2005]. Specific attention has also been focused on the creation of lower vigour rootstocks of vegetative origin suitable for inten-

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sive and high density planting of stone fruits [Sosna 2004, Botu et al. 2004, Indreias et al. 2004, Hartmann et al. 2007, Indreias 2009,]. Researchers in Serbia and former Yugoslavia have been actively engaged in the development of both new rootstocks, particularly of plum, apricot and peach [Kapetanovic 1968, Kapetanovic et al. 1972, Kapetanovic and Prica 1976, Lucic et al. 1994]. In view of the huge wealth of biodiversity in Serbia that can be used as a source of germplasm, the above activity has resulted in the selection of three promising vegetative rootstocks, primarily for plum, but also for apricot and peach, with specific reference to positive morphological traits of the root and the aerial part [Paunovic 2000].

Vegetative propagation or cloning of trees has been a useful tool in traditional tree improvement [Henrique et al. 2006]. Conifers may be vegetatively multiplied in several different ways, for example via grafting, cuttings, adventitious shoots, suckers, somatic embryos or tissue culture methods. Propagating plants, including rootstocks, with particularly desirable characteristics is a very common practice in horticulture, used extensively with some fruit and forestry species [Hartman et al. 2002, Henrique et al. 2006]. Rahman et al. [2000] examined the morphometric traits of certain vegetative rootstocks for plum. Their examination involved vegetative rootstocks derived from cherry plum (*P. cerasifera* Ehrh.), Damas C and 'Desi', a local plum cultivar developed from *P. domestica* L. The morphometric traits of the root system of different rootstocks had been described previously [Atkinson 1983, Atger and Edelin 1994, Tadic 1999, Bieniek and Kawecki 2005].

The objective of the present study was to examine main morphometric traits of the root system and the aerial part of three promising vegetative rootstocks of the plum, apricot and peach trees belong to autochthonous domestic plum (*P. domestica* L.) and cherry plum (*P. cerasifera* Ehrh.).

MATERIAL AND METHODS

The study area and plant material. The examinations were conducted over the 2006–2007 period at the mother bushes nursery of vegetative rootstocks located 10 km north-east of Cacak (43°53′N; 20°21′E), Western Serbia. Mother bushes were planted in nursery in the end of 2000, with planting space at 1.2 m × 0.5 m. Nursery management was consistent with standard practice for mother bushes, except irrigation. A completely random design with 20 mother bushes in three replications per each rootstock was used.

The analysis involved newly breed vegetative rootstocks originating from autochthonous genetic material, designated as FA 2/53 belong to autochthonous plum cultivar 'Belošljiva' (*P. domestica* L.), FA 5/7 belong to autochthonous plum cultivar 'Crvena Ranka' (*P. domestica* L.) and FA 6/209 belong to cherry plum (*P. cerasifera* Ehrh.). The 10 suckers sampled in November 2006 and 2007 from each mother bushes of the above three rootstocks were used.

Methods. The analysis of the suckers, i.e. rooted rootstock from the mounted crown in the stool bed of the mother bushes (fig. 1), involved examination of the morphological traits as manifested through: a) length of the aerial part (cm), b) number of feathers on the aerial part, c) number of roots, d) length of roots (cm), and e) volume (cm^3), weight (g) and category of the roots – skeleton and/or branch in %. All suckers were seven months old in both years.

The length of the aerial part and the length of roots were taken by a ± 0.01 cm precision ruler and digital caliper (Starrett, 727 Series, Athlon, New England, USA), and the number of feathers and number of roots were determined by counting. The volumetric method applied to suckers was used to determine the root volume by soaking the root into a 2000 ml graduated cylinder filled with water. The difference in the amount of water in the measuring cylinder prior to and following the root soaking was used to determine the root volume of particular selections. Furthermore, an analysis was made of the root categories, classifying the root into either the branch roots with a less diameter than 1 mm and/or the skeleton roots with a higher diameter than 1 mm [Tadic 1999].

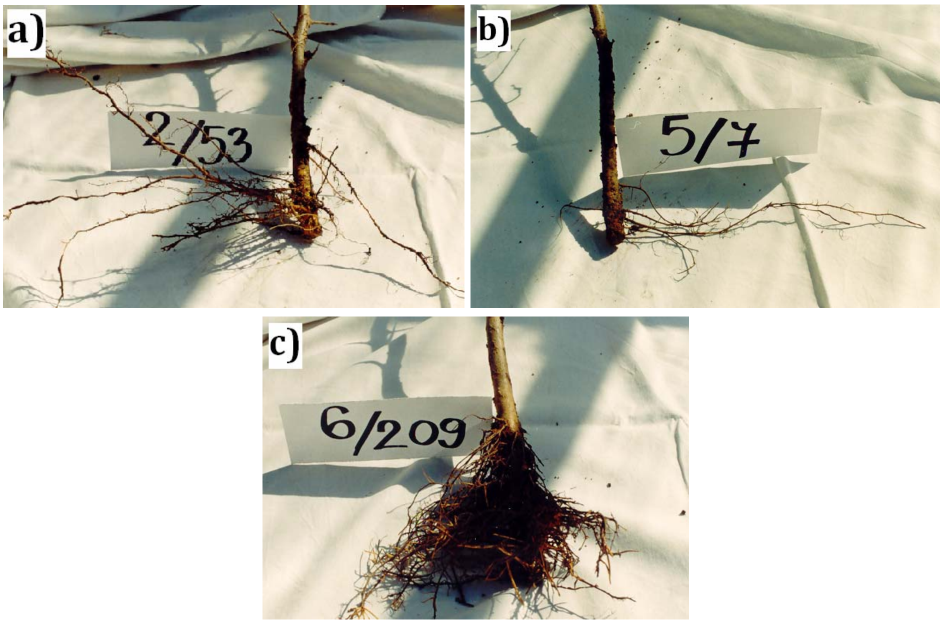

Fig. 1. Selected vegetative rootstocks FA 2/53 (a), FA 5/7 (b) and 6/209 (c) belong to autochthonous plum cultivar ‘Belosljiva’ (*P. domestica* L.), ‘Crvena Ranka’ (*P. domestica* L.) and cherry plums (*P. cerasifera* Ehrh.), respectively

Rys. 1. Wybrane podkładki wegetatywne FA 2/53 (a). FA 5/7 (b) i 6/209 (c) pochodzą od lokalnych odmian śliwy Belosljiva’ (*P. domestica* L.), ‘Crvena Ranka’ (*P. domestica* L.) oraz od śliwy wiśniowej (*P. cerasifera* Ehrh.).

Following fresh root drying in a dryer at 105°C to constant weight, the dry root weight, i. e. root dry matter was measured using the Technica ET-1111 analytical scale of ± 0.01 g precision (Iskra, Kranj, Slovenia).

Statistical analysis. Data obtained were statistically analyzed using analysis of variance (ANOVA) using *F* test. The treatment means were compared using LSD test at $p < 0.01$, using the MSTAT-C (1990) statistical computer package.

RESULTS

Length of the aerial part. The results given in table 1 suggested that the differences in aerial part length among rootstocks obtained in 2006 were not significant.

In contrast to 2006, the analysis of the length of the aerial parts in 2007 suggested that the rootstocks FA 2/53 and FA 5/7 derived from domestic plum exhibited highly significantly lower vigour when compared with FA 6/209 rootstock originating from cherry plum. The values for this trait in each of the above three rootstocks were quite uniform, as indicated by the low coefficients of variation. All three rootstocks showed similar and considerably wide ranges of variation via min-max values (tab. 1).

Table 1. The length of the aerial parts of the rootstocks evaluated
Tabela 1. Długość pędu badanych podkładek wegetatywnych

Rootstock Podkładka	Year of investigation – Rok badań							
	2006				2007			
	mean ± SE średnio ± SE cm	CV %	variation zróżnicowanie cm		mean ± SE średnio ± SE cm	CV %	variation zróżnicowanie cm	
			min	max			min	max
FA 2/53	75.47 ± 3.45 a	11.21	66.5	93.0	91.88 ± 4.99 b	15.02	79.5	120.6
FA 5/7	71.25 ± 3.72 a	7.35	66.0	76.5	99.42 ± 7.70 b	18.98	77.5	125.4
FA 6/209	96.38 ± 9.00 a	20.88	72.0	128.0	132.28 ± 7.72 a	19.37	83.7	176.8

The different letter in columns indicates significant differences between means at $p \leq 0.01$ by LSD test;
Inna litera wskazuje na istotne różnice między średnimi przy $\alpha < 0,01$ według testu NIR.

The number of feathers on aerial part. The analysis of 2006 and 2007 data suggested that number of feathers little varied among rootstocks (tab. 2). The ANOVA showed that differences in the number of feathers among rootstock were not significant.

Table 2. The number of feathers of the rootstocks evaluated
Tabela 2. Liczba pędów badanych podkładek

Rootstock Podkładka	Year of investigation – Rok badań							
	2006				2007			
	mean ± SE średnio ± SE cm	CV %	variation zróżnicowanie cm		mean ± SE średnio ± SE cm	CV %	variation zróżnicowanie cm	
			min	max			min	max
FA 2/53	7.75 ± 0.32 a	11.50	5.5	12.1	8.59 ± 0.37 a	12.26	7.2	10.5
FA 5/7	11.20 ± 1.12 a	24.57	10.1	12.3	12.01 ± 1.35 a	27.68	6.1	17.1
FA 6/209	9.20 ± 0.58 a	21.21	4.3	9.6	10.20 ± 0.81 a	26.32	6.9	16.3

The number of roots. There was no statistically significant variation in number of roots in 2006 (tab. 3). As opposed to 2006, the rootstocks highly significantly differed in the number of roots in 2007.

Table 3. The number of roots per suckers of the rootstocks evaluated
Tabela 3. Liczba korzeni na odrostach ocenianych podkładek

Rootstock Podkładka	Year of investigation – Rok badań							
	2006				2007			
	mean ± SE średnio ± SE	CV (%)	variation zróżnicowanie		mean ± SE średnio ± SE	CV (%)	variation zróżnicowanie	
			min	max			min	max
FA 2/53	6.69 ± 0.81 a	29.82	3.0	8.7	8.62 ± 0.37 b	12.21	7.0	10.5
FA 5/7	6.25 ± 0.18 a	4.15	6.0	7.0	8.73 ± 0.76 b	21.30	5.9	11.5
FA 6/209	10.75 ± 1.96 a	40.84	3.2	11.8	10.93 ± 0.38 a	11.46	9.0	13.6

* see table 1 – patrz tabela 1.

Namely, the FA 6/209 rootstock developed more roots per suckers, as compared with other two rootstocks (tab. 3). The low coefficients of variation in each individual rootstock indicated high uniformity of the vegetative progeny as regards the above trait, i.e. the number of roots per suckers (tab. 3). The number of roots via min-max values was lower in FA 2/53 than in FA 5/7 and FA 6/209, respectively (tab. 3).

The length of roots. Little genotypic variability was found for length of roots in 2006 (tab. 4). In addition, no statistically significant differences were observed between them. In contrast, the length of roots of FA 2/53 in 2007 highly significantly differed from that of FA 6/209 and FA 5/7. Namely, the length of roots was the lowest in FA 5/7 and the highest in FA 2/53. The highest uniformity of root length was determined in FA 2/53, as indicated by the low coefficient of variation. Low variations were also registered in FA 6/209, FA 5/7 exhibiting somewhat higher variation in root length. The interval of variation for the length of roots during 2007 was the lowest in FA 2/53, the values being very similar in FA 5/7 and FA 6/209, respectively (tab. 4).

Table 4. The length of roots of the rootstocks evaluated
Tabela 4. Długość korzeni na ocenianych podkładkach

Rootstock Podkładka	Year of investigation – Rok badań							
	2006				2007			
	mean ± SE średnio ± SE cm	CV (%)	variation zróżnicowanie cm		mean ± SE średnio ± SE	CV %	variation zróżnicowanie cm	
			min	max			min	max
FA 2/53	10.71 ± 0.98 a	18.22	4.1	15.3	13.75 ± 0.53 a	10.93	11.3	15.2
FA 5/7	9.33 ± 0.95 a	14.46	7.9	10.8	9.86 ± 0.98 b	24.44	6.2	13.4
FA 6/209	10.23 ± 0.82 a	17.89	8.1	12.5	10.77 ± 0.52 b	15.92	6.4	13.6

* see table 1 – patrz tabela 1.

Root volume, root category and root dry weight. The average data for the volume, dry weight and category of root of the rootstocks in period of 2006–2007 are given in table 5. The ANOVA of root volume shows that all rootstocks show high significant variation for one another. Namely, the lowest and highest root volumes were found in FA 5/7 and FA 6/209 rootstocks, respectively.

Table 5. Root volume, root category and root dry weight of the rootstocks evaluated (mean for two years)
Tabela 5. Objętość, rodzaj oraz sucha masa korzeni z badanych podkładek (średnio z dwóch lat)

Rootstock Podkładka	Root volume Objętość korzeni cm^3	Root category Rodzaj korzeni	Root dry weight Sucha masa korzeni g	
FA 2/53	5.6 b	Skeleton root = 20%	0.286	0.904 c
		Branch roots = 80%	0.618	
FA 5/7	2.5 c	Branch roots = 100%		1.196 b
FA 6/209	9.4 a	Branch roots = 100%		1.706 a

* see table 1 – patrz tabela 1.

As regards root category, the branch root highly predominated in all rootstocks examined. It was only FA 2/53 that had about 20% of skeleton root.

A highly significant difference was observed among rootstocks for root dry weight (tab. 5). Similarly with the root volume data, the highest root dry weight was obtained in FA 6/209 and the lowest in FA 2/53. As these are vegetative rootstock, there is a noticeable predominance of branch roots, suggested that the above rootstocks are low in vigour, as evidenced by the objective of both the present study and development of vegetative rootstocks for stone fruits.

DISCUSSION

Evaluation of morphological traits of the above ground part. The vegetative rootstocks FA 2/53 and FA 5/7 belong to domestic plum have lower vigour when compared with FA 6/209 belong to cherry plum (tab. 1). For this reason, we can be said that FA 2/53 and FA 5/7 being a dwarfing rootstocks with a good capacity to control vigour. The variation in aerial part length in our study may be due to the genotype traits and soil conditions, which is in agreement with previous works in plum and apricot rootstocks [Kapetanovic 1968, Kapetanovic and Prica 1972, Tadic 1999, Rahman et al. 2000]. With this in mind and in terms of breeding vegetative rootstocks of lower vigour, selection should be made of mother bushes with lower length of the aerial part.

The number of feathers of the generative progeny of the genotypes 2, genotype 5 and genotype 6 used in the creation of the examined vegetative rootstocks FA 2/53, FA 5/7 and FA 6/209. According to Paunovic [2000], in genotype 2, the number of feathers was 1.21 per 10 cm length of the aerial part of the seedling, as was in genotype 5, whereas the genotype 6 produced 1.63 of feathers. A comparison between the values for the generative progeny and those for the vegetative one suggests that the vegetative progeny, i.e. the FA 2/53 and FA 6/209 rootstocks, exhibited a smaller number of feathers, and FA 5/7 a slightly higher values (tab. 2). In general, the number of feathers on the aerial part in our study was similar in both years, which is in agreement with previous studies in rootstocks [Thorp and Sedgley 1993].

Evaluation of morphological traits of the root system. The process of root formation at the base of suckers may be divided into three stages: initiation, elongation of root initials, and root growth and development [Hartmann et al. 2002, Henrique et al. 2006].

Some authors reported that suckers originated from domestic and cherry plum have good rooting capacity [Kapetanovic et al. 1972, Morini and Perrone 2006]. However, differences among fruit species were evident [Bieniek and Kawecki 2005]. In this way, Tadic [1999] reported that BB_1 rootstock (*P. domestica* L.) has a smaller number of roots than cherry plum. In our study, the FA 6/209 rootstock belong to cherry plum exhibited a considerably higher number of roots when compared with rootstock derived from cherry plum studied by Lucic et al. [1994], which was due to the high variability of population belong to *P. cerasifera* Ehrh. (tab. 3). In contrast, Rahman et al. [2000] reported that Myrobalan produced smaller root number than 'Desi' plum and Damas C (*P. domestica* L.). The differences between our results and those of Rahman et al. [2000] and Bieniek and Kawecki [2005] may be due to differences in soil conditions and plant material used. In general, our range of values for number of roots per suckers is in a good agreement with previous study in plum rootstocks [Kapetanovic et al. 1972, Tadic 1999, Morini and Perrone 2006].

In the case of root length, the FA 2/53 had better capacity for this trait when compared with rest rootstocks, especially in second season (tab. 4), which is in accordance with previous work carried out in vegetative plum rootstocks [Rahman et al. 2000]. Above authors stated that 'Desi' plum and Damas C produced higher root length than Myrobalan. Similar data reported Paulic [1983] for different plum rootstocks. Moreover, *in vitro* propagated vegetative rootstock Mr.S. 2/5 (*P. cerasifera* Ehrh.) produced an average length of roots of 6.0–6.4 cm [Morini and Perrone 2006], being lower than the results obtained in our study. In addition, Damas 1869 vegetative rootstock, derived from *P. domestica* L. reached root length of 20 cm in one year [Vercambre et al. 2003], being higher than the results of the present study. In study of Bieniek and Kawecki [2005], total roots length and skeleton roots length of black cherry seedlings varied from 22.00 to 28.85 cm and 9.96 to 16.22 cm, respectively. The inconsistencies of the results obtained in the our study with those of the Morini and Perrone [2006], Vercambre et al. [2003] and Bieniek and Kawecki [2005] are due to genotypic variance of the used material as well as to the research conditions (*in vivo* or *in vitro*).

The FA 6/209 rootstock revealed 3.76 and 1.68 times higher root volume as compared to FA 5/7 and FA 2/53, respectively (tab. 5), which is in accordance with previous work carried out in rootstocks [Tadic 1999]. This trait indicated greater ability to permeate a larger volume of soil or to have thicker roots [Nour et al. 1978]. It also gave the greatest root dry weight. For this reason, FA 6/209 can be recommended for cultivation on dry and poor soils.

Branch root is a dominant root category of rootstocks in our study, and FA 2/53 being the only one made up of skeleton root, about 20% [Atkinson 1983, Atger and Edelin 1994, Botu et al. 2004]. The above results confirm the potential of the rootstocks for the higher vigour of the aerial part and the root as compared with FA 2/53 and FA 5/7. Pagès et al. [1993] and Pagès and Serra [1994] reported that root volume and root dry weight, as well as their other morphometrical traits, are mostly dependent on root origin. On the other hand, in the study of Kulkarni et al. [2008] highly significant genotypic variance for root weight was found. Similar data reported Bieniek and Kawecki [2005]. The results in our study showed that root volume and root dry weight differed among rootstocks; moreover, as they are of different origin, it can be inferred that our results are consistent with previous works [Pagès et al. 1993, Pagès and Serra 1994].

CONCLUSION

1. The obtained results on the morphometrical traits of newly vegetative rootstocks suggested that the FA 2/53 rootstock belong to *P. domestica* L. can be successfully propagated by suckers used mounding of "base" crown in mother bushes nursery.

2. Root dry weight was identified as the major criterion for selection of rootstocks under similar conditions.

3. The FA 2/53 exhibits lower vigour when compared with FA 6/209. It can be classified into low-vigour rootstocks producing a satisfactory number of both branch and skeleton root, whereas the FA 6/209 rootstock had the best rooting capacity.

4. Based on the results from this study, the rootstock FA 2/53, FA 5/7 and FA 6/209 stand out as the most promising for commercial cultivation.

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BIOMETRIA ODROSTÓW NOWO WYHODOWANYCH KLONÓW ŚLIWY WĘGIERKI I ŚLIWY WIŚNIOWEJ W MATECZNIKU PODKŁADEK

Streszczenie. Hodowla podkładek dla drzew pestkowych jest bardzo ważna dla sadownictwa. W wielu krajach uzyskano liczny materiał hodowlany dla czereśni, wiśni i śliwy. Analizę przeprowadzono w Cacak (Serbia zachodnia) w latach 2006–2007, w celu zbadania głównych cech morfologicznych części nadziemnej i systemu korzeniowego odrostów, pochodzących z krzewów matecznych trzech nowo wyhodowanych podkładek wegetatywnych dla drzew pestkowych, zwłaszcza śliwy, brzoskwini i moreli. Podkładki wegetatywne rozwinęły się z wyhodowanego materiału genetycznego i oznaczono je w sposób następujący: FA 2/53 (*Prunus domestica* L.), FA 5/7 (*P. domestica* L.) oraz FA 6/209 (*P. cerasifera* Ehrh.). Analiza odrostów podkładek wegetatywnych polegała na badaniu następujących cech morfologicznych: a) długości części nadziemnej, b) liczby pędów na części nadziemnej, c) liczby korzeni, d) długości korzeni oraz e) objętości, masy i rodzaju korzeni. Podkładki wytworzyły dobrze rozwinięty system korzeniowy oraz dobrze wyrośniętą część nadziemną. Podkładka wegetatywna FA 2/53 może być klasyfikowana jako podkładka słaborosnąca, FA 5/7 jako półkarłowa (nieco silniej rosnąca niż podkładka wegetatywna FA 2/53), zaś FA 6/209 jako półkarłowa podkładka wegetatywna dla drzew pestkowych.

Słowa kluczowe: część nadziemna, korzeń, ukorzenianie, drzewa pestkowe, podkładka wegetatywna

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