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Apricot rootstock breeding at the Faculty of Agriculture, Novi Sad

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Abstract. The aim of this study was the selection of genotypes as the potential rootstocks for apricot cultivars, within diploid species *Prunus cerasifera* Ehrh. (myrabolan) – 2*n* = 16, tetraploid *Prunus spinosa* L. (blackthorn) – 2*n* = 32, and hexaploid *Prunus domestica* L. (belošljiva) – 2*n* = 48. As a control, the rootstock/interstock combination *Prunus cerasifera* Ehrh/*Prunus domestica* L. ('Stanley') was used. Extraordinary robustness of blackthorn's root system could explain longevity of apricot trees in conditions of cultivation without irrigation. Belošljiva, compared to blackthorn, has a bit less developed root system, fewer number of skeletal root branches, smaller root diameter and depth, but has the same effect on longevity of apricot trees in environmental stress conditions. Selection of rootstocks within these two species can result in drought resistant genotypes. Proportional growth of rootstock stem, graft point and scion points to potentially good compatibility within all examined rootstock/scion interactions. Size of root system in all selections gave a supposition that support is not required cultivation process. Root suckers were found in myrabolan and blackthorn, while that negative characteristic was not found in belošljiva. The fruit quality of scion cultivar 'Big Red' was good in all examined species as rootstocks. The trees grafted on hexaploid plum, such as belošljiva, had 5 days earlier fruit ripening season compared to *P. cerasifera* and blacktorn as rootstock. Genotypes within *P. cerasifera, P. spinosa*, and *P. domestica* represent a potentially valuable germplasm for the selection of apricot rootstocks.

Keywords: apricot, genetic diversity, rootstock breeding

Introduction

The dynamic of apricot rootstock breeding is not intensive as breeding of apricot cultivars (Milatović, 2013). Rootstock, as an integral part of the fruit tree, has a very important place among the factors of successful fruit production. It influences numerous properties of fruit tree related to nutrition, vegetative growth, longevity, fertility, fruit quality, and resistance to biotic and abiotic factors (Đurić & Keserović, 2007). Due to very different and specific conditions for apricot growing, it is very difficult to choose universal rootstock for this fruit species (Gautier, 1980). The number of new rootstocks specifically selected for apricot is very small. Based on the data collected from 31 countries where apricots are grown, Oprita & Gavat (2018) state that apricot can be grafted on six rootstock species. The most commonly used are autochthonous cultivars of apricot (*P. armeniaca*) – in 31 countries, damson plum (*P. insititia*) in 14 countries, other species and cultivars of plum (*P. domestica*) in 13 countries, peach (*P. persica*) in 11 countries, myrabolan plum (*P. cerasifera*) in 10 countries, and almond (*P. amygdalus*) in 6 countries.

The selection of apricot (*P. armeniaca*) as a generative rootstock is being performed in several countries. The 'Haggith' rootstock was selected in Canada, and the rootstock 'Manicot GF 1236' in France. Seven generative rootstocks from the population of 'Tengeribarack' apricot cultivars – 'C.1300', 'C.1301', 'C.1650', 'C. 1652', 'C.145', 'C.1426' and 'C.2546' were selected at the Cegled Institute of Fruit Growing in Hungary (Szani et al., 2006). In Spain, nine clones of 'Canino' were selected, of which the 'Canino' 7 and 9 clones demonstrated the best performance as a generative rootstocks (Orero et al., 2004). In Romania, generative apricot rootstocks 'Constanta 14' and 'Constanta 16' were selected at the Constanta research station (Indreias et. al, 2004).

Selection of myrabolan plum as a generative rootstock is being performed in many countries. Four clones of myrabolan plum – 'C.162', 'C.174', 'C.359' and 'C.679' were selected in Hungary (Czinege et al., 2012). At the Pitesti Institute of Fruit Growing, Romania, two selections of myrobalan plum – vigorous 'Myrobalan C5', and low vigorous 'Myrobalan dwarf' were patented in 1999 (Dutu et al., 2011).

Selection of generative rootstocks within other plum species is of the less importance. In Bulgaria, the generative rootstock 'Greengage CD-4' was obtained by selection of plum cultivar 'Greengage' (Dimitrova, 2000).

In the last few decades, a lot of effort is put worldwide on the clonal selection in order to obtain an uniform, less vigorous rootstock for apricot cultivars. At the Institute for Fruit Growing in Rome, rootstocks 'Penta' and 'Tetra' (Milatović, 2013) were selected from domestic plum 'Imperial Epineuse'. Among the newly developed rootstocks, the 'Myrabolan 29C' selected in USA, is the most used apricot rootstock in Italy. It is 10% less vigorous compared to myrabolan plum seedlings, tolerates dry and lime-rich soils, does not form suckers, and has a good affinity with leading cultivars, whereby the cultivars grafted on this rootstock have high fertility and fruit quality. The 'Wavit' rootstock, selected in Austria, is increasingly being applied in Central European countries in the last few years (Milatović et al., 2017).

The aim of this study was to select potential genotypes as a rootstock for apricot among the *Prunus cerasifera* Ehrh. (myrabolan), *Prunus spinosa* L. (blackthorn) and *Prunus domestica* L. (belošljiva) species.

Material and Methods

Generative rootstocks obtained by seed germination of one chosen genotype per species (myrabolan – *P. cerasifera*, blackthorn – *P. spinosa* and belošljiva – *P. domestica*) were used as the starting plant material. As a control, a widely used combination with the interstock was used – *P. cerasifera*/*P. domestica* ('Stanley'). The 'Big Red' cultivar, characterized by early ripening season, was used as a standard cultivar to study the influence of rootstock on scion. Young nursery trees were pulled out in autumn and evaluated by morphological measurements of root system, diameter of grafting point, 5 *cm* above the grafting point, 5 *cm* below the grafting point, as well as by morphological characteristics of the crown (height and diameter). The crown volume calculations for two years old trees were based on three variables: crown height (CH), crown diameter (CD), and crown shape index, as proposed by Lim (2007):

$CD^2 \times CH \times$ Crown shape index = Crown volume

The fruit measurements were performed on 30 replicates per yielding tree of 'Big Red' cultivar grafted on investigated rootstock. The fruit weight (*g*) was measured by technical weighing scale Kern 572–35 (Kern&Sohn, GmbH, Balingen, Germany). Fruit morphometric characteristics – length (*mm*), width (*mm*) and thickness (*mm*), were measured by digital caliper Mitutoyo. Fruit firmness was determined by a FT 627 manual penetrometer with a needle diameter of 5 *mm*, and expressed in $kg\ cm^{-1}$. The fruit shape index was calculated according to the formula: $length^2$ / width × thickness (Milatović, 2013). The mesocarp ratio was calculated as percentage of flesh weight in the total fruit weight.

Total titratable acidity was assessed using a digital bottle-top burette (BRAND® Titrette®, Germany), microtitrated with NaOH 0.1 N with phenolphthalein as an indicator and expressed in %. Total soluble solids were obtained via a digital refractometer PR-32 a (ATAGO, Cat. No. 3405, Japan), expressed in degrees Brix (°Brix).

Statistical data were processed using software Statistica 13 (StatSoft Inc., USA). Statistical significance of differences between means was tested by Duncan's Multiple Range Test ($p < 0.05$).

Results and Discussion

Vegetative characteristics of apricot nursery trees – cultivar 'Big Red', grafted on different rootstocks are presented in Table 1. The average number of skeletal roots ranged from 2 to 5. Blackthorn (*P. spinosa*) and *P. cerasifera*/*P. domestica* combination had 5 skeletal roots on average, while belošljiva (*P. domestica*) had 4. The minimum number of skeletal roots (2 skeletal roots on average) had myrabolan (*P. cerasifera*). Rootstocks belošljiva and blackthorn had the same average value of the root system width, 62 *cm*, *P. domestica*/*P. cerasifera* had 45 *cm*, and the lowest value of the root system width had myrabolan (41 *cm*). The greatest depth of the root system had blackthorn (38 *cm*), followed by belošljiva with 31 *cm*, myrabolan with 23 *cm* and *P. domestica*/*P. cerasifera* with a depth of 19 *cm*. The maximum value of the rootstock diameter 5 *cm* below the grafting point was determined in the blackthorn (25 *mm*), while the minimum value was in the myrabolan (18 *mm*). *P. domestica*/*P. cerasifera* combination had the value 20 *mm*, while value for belošljiva was 24 *mm*, nearly similar to blackthorn. The value of grafting point on trees was uniform and ranged from 27–28 *mm*. The maximum value of scion diameter 5 *cm* above the grafting point was measured at the blackthorn (27 *mm*), while at the myrabolan had the minimum value (17 *mm*). Diameter 5 *cm* above the grafting point for belošljiva was 22 *mm*, while for *P. domestica*/*P. cerasifera* combination was 19 *mm*. The diameter and height of the crown, as a reflection of the nursery trees branching intensity, was in agreement with the height of the young nursery trees, ie. with the vigor. The maximum average height of the nursery trees was at the blackthorn rootstock (276 *cm*), and then at the belošljiva (243 *cm*). *Prunus cerasifera* with and without interstock influenced the much lower height of nursery trees (about 170 *cm*).

Diameter 5 *cm* below the grafting point of two-year-old apricots trees of the 'Big Red' cultivar was in the range of 32–40 *mm* (Tab. 2). The maximum value of the grafting point diameter was measured in the combination *P. domestica*/*P. cerasifera* (51 *mm*), followed by belošljiva (48 *mm*), while myrabolan and blackthorn as rootstocks influenced the same value (39 *mm*). Trunk diameter 5 *cm* above the grafting point was 27 *mm* in trees grafted on myrabolan, 40 *mm* at the combination *P. domestica*/*P. cerasifera*, while for the blackthorn and belošljiva as rootstocks this value was the same (37 *mm*). The maximum average tree height was determined at trees grafted on blackthorn

Tab. 1. Vegetative characteristics of apricot nursery trees of 'Big Red' cultivar grafted on different rootstocks
Vegetativne karakteristike sadnica kajsije sorte Big Red, kalemljene na različitim podlogama

Characteristic *Osobina*	Rootstock/*Podloga* Myrabolan/*Džanarika* *P. cerasifera*	Blackthorn/*Crni trn* *P. spinosa*	Belošljiva *P. domestica*	*P. cerasifera*/ *P. domestica*
Diameter 5 *cm* below the grafting point *Prečnik na 5 cm ispod spojnog mesta (mm)*	18 a[1]	25 a	24 a	20 a
Grafting point diameter *Prečnik spojnog mesta (mm)*	27 a	28 a	27 a	27 a
Diameter 5 *cm* above the grafting point *Prečnik na 5 cm iznad spojnog mesta (mm)*	17 a	27 b	22 ab	19 a
Height of the trunk to the first branch *Visina sadnice do prvog razgranjenja (cm)*	86 b	70 a	66 a	63 a
Tree height/*Visina sadnice (cm)*	170 a	276 c	243 b	173 a
Crown diameter/*Dijametar krune (cm)*	40 a	76 b	68 b	30 a
Crown height/V*isina krune (cm)*	19	76	56	/
Crown shape index/*Indeks oblika krune*	S5	S5	S5	S5
Number of skeletal roots/*Broj skeletnih korenova*	2 a	5 a	4 a	5 a
Width of the root system/*Širina korenovog sistema (cm*)	41 a	62 b	62 b	45 a
Depth of the root system/*Dubina korenovog sistema (cm*)	23 a	38 b	31 b	19 a

[1]Mean values followed by different letters within a column represent significant differences at P = 0.05 according to Duncan's Multiple Range Test/*Srednje vrednosti u kolonama praćene različitim malim slovima su statistički značajno različite prema Dankanovom testu višestrukih intervala za P = 0,05*

(213 *cm*), then on belošljiva (212 *cm*) and *P. domestica*/*P. cerasifera* (198 *cm*), while the smallest height was determined on trees grafted on myrabolan (169 *cm*). The crown shape index was S5 (Lim, 2007), indicating wide oval crown. Root suckers occur in all rootstocks, except in belošljiva.

The rootstock did not exhibit major influence on the fruit weight, height, width, thickness, and shape index (Tab. 3). The percentage of flesh weight in the total fruit weight was high and ranged from 93.95 to 95.19%. Fruit firmness ranged from 3.32 to 7.17 *kg* cm^{-2}. The highest fruit firmness was on trees grafted on blackthorn, while the lowest was on the trees with belošljiva (*P. domestica*) as a rootstock. Such large differences in fruit firmness comes as a difference in the ripening period caused by the rootstock. Fruits maturated first at trees grafted on belošljiva, and last at trees grafted on blackthorn.

Tab. 2. Vegetative characteristics of two-year-old apricot nursery trees of the 'Big Red' cultivar grafted on different rootstocks
Tab. 2. Vegetativne karakteristike dvogodišnjih sadnica kajsije sorte Big Red, kalemljene na različitim podlogama

Characteristic *Osobina*	Rootstock/*Podloga* Myrabolan/*Džanarika* *P. cerasifera*	Blackthorn/*Crni trn* *P. spinosa*	Belošljiva *P. domestica*	*P. cerasifera*/ *P. domestica*
Diameter 5 *cm* below the grafting point *Prečnik na 5 cm ispod spojnog mesta (mm)*	32 a[1]	36 a	37 a	40 a
Grafting point diameter/*Prečnik spojnog mesta (mm)*	39 a	39 a	48 b	51 b
Diameter 5 *cm* above the grafting point *Prečnik na 5 cm iznad spojnog mesta (mm)*	27 a	37 b	37 b	40 b
Height of the trunk to the first branches *Visina sadnice do prvog razgranjenja (cm)*	71 a	72 a	70 a	70 a
Tree height/*Visina sadnice (cm)*	169 a	213 c	212 c	198 b
Crown diameter/*Dijametar krune (cm)*	93 a	132 b	152 c	148 c
Crown height/*Visina krune (cm)*	85 a	116 b	135 c	142 c
Crown volume/*Zapremina krune* (dm^3)	203 a	636 b	763 c	792 c
Crown shape index/*Indeks oblika krune*	S5	S5	S5	S5
Root suckers/*Korenovi izdanci*	3*	3*	1*	3*

* Root sucker occurrence: (1) absent, (3) medium intensity, (5) high intensity/*Pojava korenovih izdanaka (1) odsutni, (3) srednji intenzitet, (5) visoki intenzitet*

[1]Mean values followed by different letters within a column represent significant differences at P = 0.05 according to Duncan's Multiple Range Test/*Srednje vrednosti u kolonama praćene različitim malim slovima su statistički značajno različite prema Dankanovom testu višestrukih intervala za P = 0,05*

Tab. 3. Pomological characteristics of 'Big Red' apricot cultivar, grafted on different rootstocks
Tab. 3. Pomološke osobine sorte kajsije Big Red kalemljene na različite podloge

Rootstock *Podloga*	Fruit characteristics/*Karakteristike ploda* Weight *Masa* (*g*)	Height *Visina* (*mm*)	Width *Širina* (*mm*)	Thickness *Debljina* (*mm*)	Firmness *Čvrstina* (kg cm^{-1})	Fruit shape index *Indeks oblika ploda*	Mesocarp ratio *Randman mezokarpa*	Ripening date *Datum zrenja*
Myrabolan/*Džanarika* *P. cerasifera*	44.7 a[1]	43.2 a	44.3 a	39.4 a	7.2 ab	1.1 a	94.3 b	08. 06
Blackthorn/*Crni trn* *P. spinosa*	44.0 a	42.8 a	43.4 a	39.1 a	7.4 a	1.1 a	94.0 b	09. 06
Belošljiva *P. domestica*	44.7 a	42.6 a	43.3 a	40.0 a	3.3 c	1.1 a	95.2 a	03. 06.
P. cerasifera/ *P. domestica*	42.4 a	43.4 a	43.5 a	39.4 a	6.0 b	1.1 a	94.8 a	08. 06

[1]Mean values followed by different letters within a column represent significant differences at P = 0.05 according to Duncan's Multiple Range Test/*Srednje vrednosti u kolonama praćene različitim malim slovima su statistički značajno različite prema Dankanovom testu višestrukih intervala za P = 0,05*

Tab. 4. Chemical composition of fruits of 'Big Red' apricot cultivar, grafted on different rootstocks
Tab. 4. Hemijske osobine ploda sorte kajsije Big Red, kalemljene na različitim podlogama

Rootstock *Podloga*	Total acids content *Sadržaj ukupnih kiselina (%)*	Soluble solids content *Sadržaj rastvorljivih suvih materija (Brix)*
Myrabolan/*Džanarika (P. cerasifera)*	1.18 a[1]	16.58 ab
Blackthorn/*Crni trn (P. spinosa)*	1.25 a	17.19 a
Belošljiva/*P. domestica*	1.06 a	16.85 ab
P. cerasifera/*P. domestica*	1.08 a	15.63 b

[1]Mean values followed by different letters within a column represent significant differences at P = 0.05 according to Duncan's Multiple Range Test/*Srednje vrednosti u kolonama praćene različitim malim slovima su statistički značajno različite prema Dankanovom testu višestrukih intervala za P = 0,05*

The chemical composition of fruits depends on a number of factors: cultivar, environmental conditions, fruit maturity stage, applied agro-technical measures and soil characteristics (Niketić-Aleksić, 1988). The content of the soluble solids was the highest in the tree with a blackthorn rootstock (17.19 Brix), and the lowest with the combination of the *P. cerasifera*/*P.domestica* (15.63 Brix). Total titratable acidity in all fruits was above 1%, and the differences were not significant (Table. 4).

In general, rootstock breeding goals are common to most fruit species: propagability, graft compatibility, yield and longevity (Moore & Janick, 1983). Although several good rootstocks have been introduced so far, none of them is widely distributed, scion compatibility and soil adaptation being the major restrains (Bassi, 1999). In our research, vigor of the one- and two-year old apricot trees of 'Big Red' cultivar grafted on blackthorn, is the result of the extraordinary robustness of its root system, and slightly smaller parameters in the number of skeletal branches, width and depth of the root system in belošljiva. The proportional growth of the root stem, grafting point and scion indicate potentially good compatibility between rootstock and stem in all investigated genotypes within the three investigated species. This could explain longevity of the apricot trees on the belošljiva rootstock, and indicates that in the cultivation of apricot without irrigation, the blackthorn can give even better results.

Thanks to the unique biodiversity, the Balkan Peninsula can be considered as a secondary center of diversity for a high number of species that are of special interest in the selection of apricot rootstocks, such as *P. cerasifera, P. persica, P. armeniaca, P. domestica, P. insititia* and *P. amygdalus*. Autochthonous plum germplasm (*P. domestica*), beside belošljiva, includes a large number of indigenous cultivars (Mišić, 2002). The old indigenous cultivars and the richness of natural populations of plum species on the Balkan Peninsula have never been the subject of comprehensive research work on collecting and studying in order to develop new rootstocks for apricot. In apricot, there are many challenges in the areas of adaptation to biotic and abiotic stresses, graft compatibility, and rootstock influence on scion performance and fruit quality (Beckman & Lang, 2003). Also, the issue of preserving genetic resources is especially actual, since many local populations have disappeared or are reduced to a small number of biotypes during the development of fruit production and agricultural modernization. The examined germplasm follows the evolutionary flow of plum from the diploid *P. cerasifera* (myrabolan) – $2n = 16$, tetraploid *P. spinosa* (blackthorn) – $2n = 32$, to hexaploid *P. domestica* (belošljiva) – $2n = 48$. In order to above mentioned germplasm give its full contribution to the improvement of the apricot rootstocks, it is necessary to conduct a positive clonal selection, release plants from the viruses, develop methods of vegetative propagation and examine the yielding potential of the leading scion cultivars on selected clones.

Conclusions

Breeding the rootstocks within blackthorn (*P. spinosa*) and belošljiva (*P. domestica*) germplasm could result in selections resistant to drought. In all examined rootstock/scion combinations, good compatibility was de-

termined. Rooting in all species as rootstocks was good, making it possible for them to be cultivated without support. The occurrence of root suckers was present in myrabolan and blackthorn, while in the belošljiva, this negative property did not occur. The fruit quality was uniform, regardless of the rootstock. The ripening time of fruits from the trees grafted on the belošljiva was five days earlier than from the trees on blackthorn and myrabolan as rootstocks (ripening was later and nearly at the same time). Variability within the diploid species *P. cerasifera* (myrabolan) – $2n = 16$, tetraploid *P. spinosa* (blackthorn) – $2n = 32$, and hexaploid *P. domestica* (belošljiva) – $2n = 48$, represents a potentially valuable germplasm for the selection apricot rootstocks, which should be the next step in selection work.

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OPLEMENJIVANJE PODLOGA ZA KAJSIJU NA POLJOPRIVREDNOM FAKULTETU U NOVOM SADU

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Rezime

Cilj ovoga rada je selekcija potencijalnih genotipova kao podloga za kajsiju u okviru diploidne vrste *Prunus cerasifera* Ehrh. (džanarika) – $2n = 16$, tetraploidne *Prunus spinosa* L. (crni trn) – $2n = 32$, i heksaploidne *Prunus domestica* L. (belošljiva) – $2n = 48$. Kao kontrola korišćena je kombinacija sa posrednikom – *Prunus cerasifera* Ehrh./*Prunus domestica* L. (džanarika/sorta Stanley). Rezultati jasno ukazuju na potencijal u okviru izučavane germplazme vrsta roda *Prunus* kao novih podloga za kajsiju. Izuzetna robusnost korenovog sistema crnog trna i nešto manjih parametara broja skeletnih grana korena, širine i dubine korenovog sistema kod belošljive, objašnjavaju dugovečnost stabala kajsije u uslovima gajenja bez navodnjavanja. Selekcijom podloga u okviru ove dve vrste mogu se izdvojiti genotipovi otporni na sušu. Debljanje korenovog vrata, spojnog mesta i plemke bilo je proporcionalno, što ukazuje na potencijalno dobru kompatibilnost kod svih ispitivanih genotipova u okviru tri vrste. Ukorenjavanje je kod svih selekcija bilo dobro, što čini pretpostavku za gajenje bez potpore. Pojava izdanaka je bila prisutna kod džanarike i crnog trna, dok se kod belošljive ovo negativno svojstvo nije ispoljavalo. Kvalitet ploda je bio ujednačen, bez razlika nastalih pod uticajem podloge koja je bila predmet istraživanja. Stabla kalemljena na heksaploidnoj šljivi (belošljiva) utiču na ranije vreme zrenja (oko 5 dana). Varijabilnost unutar diploidne vrste *P. cerasifera*, tetraploidne *P. spinosa*, i heksaploide *P. domestica* predstavlja potencijalno vrednu germplazmu za selekciju podloga za kajsiju.

Ključne reči: kajsija, genetički diverzitet, oplemenjivanje podloga