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Effect of tree conduce on the precocity, yield and fruit quality in apricot on acidic soil[1]

Efeito da condução de plantas na precocidade, rendimento e qualidade de frutos do damasco em solos ácidos

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Abstract - The experiment was carried out in the experimental orchard in Prislonica near Cacak (Western Serbia) on poor and acidic soil in 2008 and 2009 (second and third year after planting) to determine the effects of Mirobalan rootstock and Blackthorn interstocks with Open vase and Central leader tree conduce system on the length of shoot (LS), trunk cross-sectional area (TCSA), yield (Y), yield efficiency (YE), fruit weight (FW), soluble solids content (SS), titratable acidity (TA) and soluble solids/titratable acidity ratio or ripening index (SS/TA = RI). In the trial there were 5 trees from each apricot rootstock-cultivar and rootstock-interstock-cultivar combination in four replications. The analysis of variance was done in a completely randomized design. The treatment means were compared using LSD test at $p \leq 0.05$. Based on the results of this work, the Myrobalan rootstock with Open vase tree conduce induced a high vigorous of apricot trees and higher fruit weight. The Blackthorn interstock with Central leader tree conduce induced a less vigorous tree, higher yield and yield efficiency, and may be better suited for high-density plantings. Also, this interstock showed the higher SS/TA ratio when compared with Myrobalan rootstock. Other fruit quality traits, such as soluble solids content and titratable acidity were similar and respectable in both variant under poor and acidic soil conditions.

Key words - *Prunus armeniaca* L. Rootstock and interstock. Ripening index. Tree vigour. Yield efficiency.

Resumo - O experimento foi conduzido em um pomar experimental em Prislonica, próximo a cidade de Cacak (Oeste da Sérbia) em solos pobres e ácidos durante os anos de 2008 e 2009 (segundo e terceiro ano após o plantio). O objetivo do trabalho foi de determinar o efeito do porta-enxerto da Myrobalan de variedades criadas em forma de Vaso aberto e do interenxerto, Espinho prêto de variedades criadas em forma de Copa central liderada no comprimento da parte aérea (PA), da área do corte transversal do tronco (ACTT), da produção (P), coeficiente de rendimento (CR), massa do fruto (MF), conteúdo solúvel das matérias (CSM), da total quantidade de acidez (TQA) e a relação entre os conteúdos das matérias solúveis e da total quantidade de acidez, ou seja, o índice do maturidade (CSM/TQA = IA). Os testes incluiram 5 árvores de damasco de cada combinação porta-enxerto/ variedade e porta-enxerto/interenxerto/variedade em 4 repetições. Os valores médios dos tratamentos foram comparados pelo LSD teste para $p < 0,05$. Com base nos resultados deste estudo, o porta-enxerto Myrobalan com a criação da forma de Vaso aberto provocou o crescimento das árvores de damasco e maior peso dos frutos. O interenxerto Espinho prêto com criação da forma de Copa central liderada provocou a redução do crescimento da árvore, maior produção, coeficiente de rendimento e pode ser adequado para plantios de alta densidade. Além disso, este interenxerto causou maior relação entre CSM/TQA em comparação com o porta-enxerto Myrabalan. Outras características do fruto, tais como o conteúdo das matérias solúveis e da total quantidade de acidez, são semelhantes a este respeito em ambas as variantes em condições de solos pobres e ácidos.

Palavras-chave - *Prunus armeniaca* L. Porta-enxerto e interenxerto. Crescimento das árvores. Coeficiente de rendimento. Índice de maturidade.

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Introduction

Apricot (*Prunus armeniaca* L.) is mostly grown in Mediterranean countries, Russia, USA, Iran and Pakistan. Total world production of fresh fruit apricot is approximately 3.83 million tons (FAOSTAT, 2009). According to like source, 31,157 tons of apricots were produced in Serbia in 2009 (VELJKOVIĆ et al., 2009). The most important apricot-growing area in Serbia is the Region of Cacak located in Western Serbia. However, in this Region, the most limiting edaphic factors are excessively dry, shallow, sandy-loam and acidic soils (MILOSEVIC; MILOSEVIC, 2010). Low soil pH accounts for considerable yield losses of a wide variety of crops all over the world. This problem is more severe in mountain regions, including Western Serbia (MILOSEVIC; MILOSEVIC, 2010), where it is one of the major limiting factors to fruit crop productivity. This phenomenon can be prevented or mitigated by soil and water management, and crop productivity under acidic soils could be improved using tolerant genotypes (ASHRAF; AHMAD, 2000) and/or fruit cultivars grafted on tolerant rootstock (MONNEY et al., 2010). Acidic soils could inhibit plant growth and reduce plant productivity by water excess, ionic toxicity and nutritional imbalance (von UEXKÜLL; MUTERT, 1995). In these conditions, the most widely used rootstocks are Myrobalan seedlings (*P. cerasifera* Ehrh.) and/or other autochthonous plum cultivars originated from *P. domestica* L. and *P. insititia* L. such as 'Belošljiva', 'Petrovača' and 'Cerovački piskavac'. These rootstocks, especially 'Belošljiva', have good soil adaptation, good graft compatibility, but problems of excessive suckering and *Plum pox virus* infection are limiting its use (MILOSEVIC; MILOSEVIC, 2010).

The controversies regarding rootstocks for the apricot speak of the very complex nature of this problem and of the need to study it with a view to establishing the most suitable rootstocks for each apricot cultivar. Apricot rootstocks influence the performance of the scion cultivar. They affect fruit size and fruit quality (MIGNANI et al., 1999; SON; KÜDEN, 2003), tree growth (HERNÁNDEZ et al., 2010), yield and yield efficiency (EGEA et al., 2004), nutritional status (VALE; PRADO, 2009) and orchard system (SOUTHWICK; YEAGER, 1999). Moreover, rootstock-scion interaction plays an important role in fruit and tree performance (WEBSTER, 1995). Just as important is the role of interstock (VACHUN, 1983). Myrobalan plum is dominant rootstock for apricot used in Serbia (PAUNOVIC, 1977). Apricot grafted on Myrobalan seedlings has a number of disadvantages, such as incompatibility, excessive vigour, early onset and late termination of the growing season, winter killing of blossom buds and a frequent occurrence of apoplexy (MILOSEVIC; MILOSEVIC, 2010). Trees are trained to a spare crown and spaced 6-7 m apart or at 204-278 trees ha^{-1}. However, one of the measures taken recently to intensify apricot production under environmental conditions of Cacak has been to "shift" to intensified crown forms (Open vase and Central leader) and increase the number of trees per unit area (> 1,000 trees ha^{-1}) through the use of interstocks that reduce the high vigour of Myrobalan seedlings. Blackthorn (*P. spinosa* L.) is an interstock grafted onto Myrobalan seedlings and used for grafting apricot cultivars (DJURIC; KESEROVIC, 1999).

The present study was carried out with 'Aleksandar', 'Biljana', 'Vera' and 'Roxana' apricot cultivars grafted on Myrobalan rootstock and on Blackthorn interstock. The objective was to assess if main agronomic and fruit quality traits is affected by tree training under dry, sandy-loam and acidic soil.

Material and methods

An orchard trial involving apricot rootstock and interstock was established at Prislonica near Cacak (43°53' N latitude; 20°21' E longitude; 340 m altitude), Western Serbia in 2007, using 'Aleksandar', 'Biljana', 'Vera' and 'Roksana' as the scion cultivars. The trial was conducted on dry, shallow and acidic soil, with 2.90% organic matter, 0.16% total nitrogen (N_{TOT}), 178 mg kg^{-1} available phosphorus (P_2O_5), 220 mg kg^{-1} potassium (K_2O), 0.39% calcium oxide (CaO), 6.2 mg kg^{-1} magnesium oxide (MgO), and a sandy-loam texture (USDA Soil Taxonomy, 1999). The soil pH in 0.01M KCl was in the range from 4.86 (0-30 cm) to 4.33 (31-60 cm soil depth). In general, soil conditions were poor (Protic et al., 2003). Local rainfall averages between 500 and 600 mm per year mostly concentrated in late spring (May and June) and autumn (October and November).

The evaluated cultivars were grafted onto Myrobalan rootstock and Blackthorn interstock (*P. spinosa* L.). The scion cultivars were grafted directly on Myrobalan rootstock at 60 cm above ground level. On the other hand, the interstocks were grafted onto Myrobalan seedling at 25 cm above ground level and the scion cultivars were grafted on interstocks at 60 cm above ground level. The training systems employed included Open vase planted at 5.5 m × 3.0 m (606 trees ha^{-1}), with Myrobalan seedlings used as the rootstock, and Central leader planted at 5.0 m × 2.0 m (1,000 trees ha^{-1}) with Blackthorn as the interstock. Summer pruning was used to control tree vigour and help induce early cropping during 2008-2009. Irrigation was not applied. The first harvest began in 2008.

In the trial there were 5 trees from each apricot rootstock-cultivar and rootstock-interstock-cultivar

combination in four replications. A total of 10 fruits and one-year-old shoots were sampled per tree for analysis, also in four replications. Samples of fruits per above combinations were hand harvested randomly for experimentation at the commercial maturity stage, on the basis of their skin ground colour (fully-coloured) (RUIZ; EGEA, 2008).

For each apricot cultivar, the length of one-year-old shoot (LS) (cm) was determined at the end of the growing season, and trunk circumference was measured at 10 cm above the graft union and expressed as a trunk cross-sectional area (TCSA). The measurements were made by a ruler and a digital caliper (Starrett, 727 Series, Athlon, New England, USA). The obtained values were used to determine the TCSA (cm^2) and yield efficiency (YE) (kg cm^{-2}) of the evaluated cultivars. The YE was computed from the relationship between fruit yield per tree (kg) and final TCSA (cm^2). Measurements were made of yield per tree (Y) (kg $tree^{-1}$) and cumulative yield (CY) (kg $tree^{-1}$). An ACS System Electronic Scale was used to measure fruit yield. The fruit weight (FW) (g) was determined using a Tehnica ET-1111 technical scale (Iskra, Kranj, Slovenia). Fruit chemical traits such as soluble solids content (SS), titratable acidity (TA) and soluble solids/titratable acidity ratio or ripening index (SS/TA = RI) were measured immediately after picking (commercial maturity stage). The SS (ºBrix) was determined at 20°C with a Milwaukee MR 200 (ATC, Belgium) hand refractometer. TA was measured by neutralization to pH 7.0 with 0.1N NaOH, and data are given as percentage of malic acid. On the basis of the measured data, SS/TA ratio was calculated.

Data obtained were statistically analyzed using analysis of variance (ANOVA) using the F test. The treatment means were compared using LSD test at $p \leq 0.05$, using the MSTAT-C statistical computer package (Michigan State University, East Lansing, MI, USA).

Results and discussion

The data from 2008-2009 indicated that average LS was significantly higher in Open vase on Myrobalan than the Central leader on Blackthorn at $p \leq 0.05$ (TAB. 1). The differences in LS among cultivars were also significant at $p \leq 0.05$. In the case of Open vase on Myrobalan, LS was highest in Aleksandar, 'Biljana' and Vera, and lowest in 'Roksana'. The Central leader on Blackthorn induced the highest LS in 'Vera' and 'Aleksandar', and the lowest in 'Biljana' and 'Roksana' (TAB. 1). Also this research implies that trees with the highest vegetative growth generally produce the lowest yield per tree, confirming previous study (STRIKIC et al., 2007).

Tree growth, as measured by TCSA, was significantly affected by tree training starting from the third year after planting: all cultivars showed the higher values in Open vase on Myrobalan, and lower values in Central leader on Blackthorn (TAB. 1 and FIG. 1). The TCSA showed by Myrobalan was related to the expected vigour of the trees (PAUNOVIC, 1977). In contrast, Blackthorn, being a less vigour interstock with a good capacity to control vigour (DJURIC; KESEROVIC, 1999). In Open vase, the highest TCSA observed in 'Roxana',

Table 1 - Influence of Open vase on Myrobalan rootstock and Central leader on Blackthorn interstock on the tree growth, cumulative yield and yield efficiency of 'Aleksandar', 'Biljana', 'Vera' and 'Roxana' apricot cultivars, in the third (2009) year after planting[1]

Tree conduce	Cultivar	LS (cm)	TCSA (cm^2)	Y (kg tree-1) Year - 2009	CY (kg $tree^{-1}$) 2008-2009	YE (kg $tree^{-1}$)
Open vase	Aleksandar	66.77a	3.87d	1.05bc	1.19b	0.27a
	Biljana	67.83a	6.42b	1.12b	1.28b	0.17c
	Vera	66.33a	5.72c	0.97c	1.15c	0.16c
	Roxana	60.20b	7.94a	1.55a	1.71a	0.19b
Average		65.28A	5.99A	1.17B	1.33B	0.20B
Central leader	Aleksandar	66.67a	4.15c	3.49a	3.82a	0.84a
	Biljana	59.83b	3.80d	3.01a	3.44a	0.79b
	Vera	67.00a	5.55a	3.11a	3.59a	0.56c
	Roxana	58.31b	5.14b	1.88b	2.33b	0.36d
Average		62.95B	4.66B	2.87A	3.29A	0.64A

[1]The same small letters in columns shows insignificant differences ($p \leq 0.05$) by LSD test among cultivars; the same capital letters in columns shows insignificant differences ($p \leq 0.05$) by LSD test between Myrobalan rootstock and Blackthorn interstock; LS: length of shoot; TCSA: trunk cross-sectional area; Y: yield; CY: cumulative yield; YE: yield efficiency

and lowest in 'Aleksandar'. In the case of Central leader, the highest values of TCSA observed in 'Vera', and the lowest in 'Biljana'.

The first production was obtained one year after planting (2008), but this was relatively poor (approximately ~0.3 kg tree^{-1}) and there were no differences between treatments at $p \leq 0.05$ (data not shown). However, in the next cropping year (2009), differences in precocity among treatments became evident; Central leader on Blackthorn being the most efficient variant (FIG. 1a and 1b).

As opposed to these results, Kapel (2003) found that no differences in trunk cross-sectional area between two rootstocks and two pruning systems (Central leader and Spanish bush) used for apricot. The differences between the results of the present study and those of the above author were likely due to different environmental conditions, cultivars and rootstocks studied. Moreover, Myrobalan rootstocks used in our study induced vigorous tree growth in all evaluated cultivars. These data showed that Blackthorn interstock grows more slowly than Myrobalan rootstocks under sandy-loam and acidic soil conditions, which is in agreement with previous study in apricot (MONNEY et al., 2010). Given the above, apricot trees grafted onto Blackthorn interstock can be planted at shorter distances apart, resulting in reduced tree vigour of apricot (DJURIC; KESEROVIC, 1999). However, as the Cacak region has insufficient irrigation water, Myrobalan rootstock should continue to be used in this area, which is in agreement with the previous studies on apricot (DIMITROVNA, 1982; SON; KÜDEN, 2003). Egea et al. (2004) reported that interaction between cultivar and rootstock is presented as an interesting strategy for cultivar adaptation to different climatic areas. Similar data for interstock usage were reported by Vachun (1983), Plazinic et al. (1995) and Scarpare Filho et al. (2000). Those results again are in line with our observations. Oposite to herewith results, Djuric and Keserovic (1999) reported that Blackthorn interstock induced uniform development and less to moderate tree growth in apricot trees under non-irrigated conditions, due to the root originating from Myrobalan seedlings. Southwick and Yeager (1999) also observed rootstock-dependent yield variations, and showed that summer pruning and regulated deficit irrigation were used to control tree vigour and help induce earlier production.

Yield per tree, CY and YE were statistically significantly higher in Central leader on Blackthorn than Open vase on Myrobalan (TAB. 1), because higher density systems were as or more productive than the more conventional system (SOUTHWICK; YEAGER, 1999). In addition, although it is assumed that trees on dwarf rootstocks and/or interstock have limited vegetative growth resulting to higher yield (WEBSTER, 1995) but may be differences among cultivars in this study has been resulted from different morphological traits, confirming study by Strikic et al. (2007).

As for rootstock or interstock, the values showed statistically significant differences among the cultivars. In the case of Open vase, the highest Y and CY were observed in 'Roxana', and the lowest in 'Vera'. These values in 'Aleksandar' and 'Biljana' were intermediate. In contrast, Central leader tree training on Blackthorn induced the highest Y and CY in 'Aleksandar', 'Biljana' and 'Vera', and the lowest in 'Roxana'. Also, the YE significantly differ between tree training treatments. The highest and the lowest YE were found in 'Aleksandar' and 'Vera' in both treatments, respectively. In the case of 'Vera' this is probably due to its high TCSA (HERNÁNDEZ et al., 2010). In general, the most TCSA and the lowest yield resulted to the

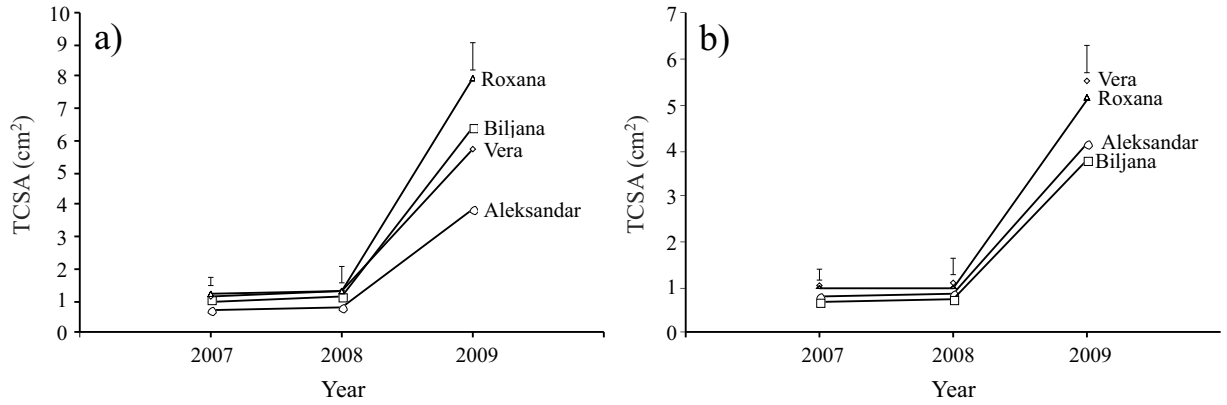

Figure 1 - Open vase on Myrobalan rootstock (a) and Central leader on Blackthorn interstock (b) influence on trunk cross-sectional area (TCSA) of four apricot cultivars from the second (2008) to third (2009) year after planting. Vertical lines indicate LSD at $p \leq 0.05$

lowest yield efficiency in our study, which is in agreement with previous work in apricot (STRIKIC et al., 2007). The most productive cultivars were 'Roxana' on Myrobalan and 'Aleksandar', 'Biljana' and 'Vera' on Blakthorn. It may be concluded that apricot trees grafted on Blackthorn interstock gave the highest yield. This finding confirms the results obtained by Loreti et al. (1999), who observed that 'San Castrese' apricot cultivar on less vigour seedling rootstocks (Rubira and Julior) gave better results in terms of yield than Myrobalan B and Myrobalan 29C. Similar results were obtained by Plazinic et al. (1995), Scarpare Filho et al. (2000) and Son and Küden (2003). However, Djuric and Kesrovic (1999) reported that the highest yield was produced by 'Roksana' at different planting distances in high density. The differences in data may be due to tree age, climatic and soil differences between the Western Serbian and Northern Serbian conditions. In the present study, 'Aleksandar' was followed by 'Vera' and 'Biljana' in terms of high yield (TAB. 1). This may be due to the fact that the three Serbian apricot cultivars have adapted well to the acidic soil conditions (ASHRAF; AHMAD, 2000). The previous study by Djuric and Keserovic (1999) indicate that the Afghan cultivar 'Roksana' of the Irano-Caucasian eco-geographical group has also adapted well to the acidic soil conditions in Western Serbia. On the other hand, another research showed that there are significant differences in growth and productivity between local and foreign cultivars in apricot trained to high density system (STRIKIC et al., 2007). From this point, Son and Küden (2003) and Egea et al. (2004) reported that interaction between cultivar and rootstock or interstock as an interesting strategy for cultivar adaptation to different climatic areas. However, some researches show that yield linearly is related to light interception (VACHUN, 1983; PLAZINIC et al., 1995) but the best time for calculating the light interception is in the 4th or more year (HERNÁNDEZ et al., 2010).

In our study, Open vase on Myrobalan induced the highest FW than Central leader tree training on Blackthorn interstock (TAB. 2).

'Roxana' had higher values for FW then other cultivars in both treatments. The lowest values of FW were observed in 'Vera' on Myrobalan, and in 'Aleksandar', 'Biljana' and 'Vera' on Blackthorn, although differences among them were not found. Kapel (2003) reported that the lower yields and smaller fruits of trees suggest that it should not be recommended as an apricot rootstock and/or interstock. On the other hand, the early ripening cultivars ('Aleksandar', 'Biljana' and 'Vera') produced smaller fruits than late ripening 'Roksana' which is in accordance with results obtained by Djuric and Keserovic (1999). This seems to represent a major advantage for the growers. Southwick and Yeager (1999) found that fruit size was similar between the Citation and Marianna 2624 apricot rootstocks in different training system. These different findings can be attributed to the characteristics of different kinds of rootstocks and/or interstock (DJURIC; KESEROVIC, 1999). However, the fact to bear in mind is that the rootstock and the rootstock-interstock effects have cumulative character in the natural environment, i.e. orchards (WEBSTER, 1995). Previous work on apricot also reported a high variability among cultivars regarding this parameter (HERNÁNDEZ et al., 2010; KAPEL, 2003; MIGNANI et al., 1999; RUIZ; EGEA, 2008; SON; KÜDEN, 2003).

Table 2 - Influence of Myrobalan rootstock and Blackthorn interstock on fruit quality traits of 'Aleksandar', 'Biljana', 'Vera', 'Harcot' and 'Roxana' apricot cultivars in the fourth (2010) year after planting[1]

Tree conduce	Cultivar	FW (g)	SS (°Brix)	TA (%)	SS/TA ratio
Open vase	Aleksandar	62.40b	17.49a	0.64c	27.33a
	Biljana	58.10bc	16.15a	0.73b	22.12b
	Vera	56.30c	16.16a	0.58d	27.86a
	Roxana	80.00a	12.97b	1.12a	11.58c
Average		64.20A	15.84A	0.80A	21.31B
Central leader	Aleksandar	47.40b	17.40a	0.61d	28.52a
	Biljana	46.60b	16.00b	0.69b	23.19a
	Vera	43.90b	16.00b	0.64c	25.00a
	Roxana	71.80a	13.35c	0.99a	13.48b
Average		52.42B	15.83A	0.74A	22.19A

[1]The same small letters in columns shows insignificant differences ($P \leq 0.05$) by LSD test among cultivars; the same capital letters in columns shows insignificant differences ($P \leq 0.05$) by LSD test between Myrobalan rootstock and Blackthorn interstock; FW: fruit weight; SS: soluble solids content; TA: titratable acidity; SS/TA: ripening index

Values of SS and TS were similar in Open vase on Myrobalan and in Central leader on Blackthorn (TAB. 2). Nevertheless, all cultivars in both treatments showed SS values higher than 12 °Brix. Some authors reported that apricot genotypes which have a SS content >12 ºBrix, characterized by an excellent gustative quality (EGEA et al., 1994). Also, Ruiz and Egea (2008) stated that soluble solids content is a very important quality attribute, influencing notably the fruit taste. Moreover, Daza et al. (2008) reported that genotype has important effect on SS content, which was confirmed by results in our study.

In our study, Open vase on Myrobalan and Central leader tree training system on Blackthorn produced similar fruit TA content (TAB. 2). Hernández et al. (2010) also reported that TA in fruit was not significantly affected by the rootstock. Some authors stated that fruit maturity stage at the harvest date is the principal factor affecting fruit acidity and also the SS content (RUIZ; EGEA, 2008). The range of TA values obtained in this study is in agreement with previous work in apricot (HERNÁNDEZ et al., 2010).

The relationship between SS and TA (RI) has an important role in consumer acceptance of some apricot, peach, nectarine and plum cultivars, as it has been previously mentioned (RUIZ; EGEA, 2008). Crisosto et al. (2004) reported that in the case of cultivars with TA > 0.90% and SS < 12.0%, consumer acceptance was controlled by the interaction between TA and SS rather than SS alone. In our study, Blackthorn induced higher SS/TA ratio than Myrobalan at $p \leq 0.05$ (TAB. 2). This result concurs with the findings of Sadhu (1989). The highest and the lowest SS/TA ratio were registered in 'Aleksanadar' and 'Roxana', respectively.

Conclusions

1. In Region of Cacak (Western Serbia), one of the most limiting factor for successful apricot growing are excessively dry, shallow, sandy-loam and acidic soils with low content of organic and inorganic matter;
2. The four apricot cultivars grafted on Myrobalan rootstock with Open vase tree conduce system appears to induce higher tree growth and fruit weight when compared with the Central leader on Blackthorn interstock;
3. The Central leader on Blackthorn interstock showed a tendency to reduce a high vigour of apricot trees grafted on Myrobalan, and to increase yield and yield efficiency. Also, this interstock showed the higher SS/TA ratio when compared with Myrobalan rootstock. Other fruit quality traits, such as soluble solids and titratable acidity were similar;
4. The application of Blackthorn as an interstock, i.e. Central leader conduce system can be useful to establish a high-density planting and may be used as a satisfactory system for apricots under Serbian conditions;
5. The Open vase on Myrobalan rootstock at > 600 trees per hectare coupled with summer pruning can be a better option than the conventional system of apricot growing;
6. The Myrobalan seedlings are recommended for dry, sandy-loam and acidic soil, but the incompatibility problem between Blackthorn and Myrobalan should be kept in mind.

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