

Dynamic of Fruit Growth and Internal Fruit Quality of Apricot Trees Grafted on Rootstock or with Interstem

T. Milošević^{1*}, N. Milošević², and I. Glišić¹

ABSTRACT

This study was carried out to investigate impacts of Myrobalan rootstock and Blackthorn interstem on fruit growth, physico-chemical features and bioactive compounds of two apricot cultivars ('Harcot' and 'Roksana') in 2010 and 2011. Fruits of both cultivars on Myrobalan and/or Blackthorn grew with a classic double sigmoid curve from full bloom time to harvest. During growth and development periods, average fruit weight of both cultivars significantly increased, but differences between rootstock and interstem were not found. Myrobalan induced higher values of most fruit physical features (fruit thickness, sphericity, aspect ratio, surface area, fruit volume, flesh firmness) and some chemical attributes (soluble solids content and titratable acidity), whereas Blackthorn induced only higher ripening index values. Regarding cultivars, 'Roksana' possessed better physical features, except flesh firmness, and higher soluble solids content, ripening index value, total flavonoids content and total antioxidant capacity. Present results confirm the better adaptation of Myrobalan rootstock with 'Roksana' and 'Harcot' scion cultivar to sandy loam and acidic soil than Blackthorn interstem.

Keywords: Bioactive compounds, Cultivars, Growth stages, *P. armeniaca* L., Soluble solids.

INTRODUCTION

Apricot (*Prunus armeniaca* L.) is one of the most important stone fruits grown in the world, basically due to its good taste and multi uses. The fruits are climacteric and characterized by a very rapid ripening (Chahine *et al.*, 1999). This is manifested by the quick degradation of the fruits and their low storability (2-4 weeks) and shelf life (3-5 days) (Egea *et al.*, 2007).

The fruit of *Prunus* spp. is a drupe, the term "stone fruit" expresses the fact the seed is surrounded by a hard shell or stone, the endocarp. Over the past few decades, models of stone fruit growth, especially peach, nectarine and apricot, and plant development have identified useful

principles for assisting growers in making horticultural management decisions (Jackson and Coombe, 1966; DeJong, 2005). Fruit growth, from full bloom to harvest, represents a quantitative process, which leads to increase of fruit weight and volume (James *et al.*, 1989). Also, fruit growth has been shown to involve coordinated metabolic events such as changes in anatomy, physiology, biochemistry, and gene expression (Giovannoni, 2004). Fruit of apricot and other *Prunus* fruit crops exhibit a cyclic growth pattern and has been described as a double sigmoid with three developmental stages I, II, and III (Jackson and Coombe, 1966). The first is a rapid growth period that lasts about 30-42 days. Pit hardening marks the beginning of the

¹ Department of Fruit Growing and Viticulture, Faculty of Agronomy, University of Kragujevac, Cara Dusana 34, 32000 Cacak, Republic of Serbia.

* Corresponding author; e-mail: tomomilosevic@kg.ac.rs

² Department of Pomology and Fruit Breeding, Fruit Research Institute, Kralja Petra I/9, 32000 Cacak, Republic of Serbia.



second stage, during which fruit size increases more slowly. The second stage lasts several weeks in early maturing varieties and longer in late-maturing varieties. The final stage is the period of rapid fruit growth that usually begins 4 to 6 weeks before harvest (James *et al.*, 1989). Generally, fruit growth and plant development have identified useful principles for assisting growers in making horticultural management decisions such as fruit thinning, irrigation, fertilization and disease protection (Pérez-Pastor *et al.*, 2004; DeJong, 2005). The apricot fruit development period is highly dependent on cultivar (Jackson and Coombe, 1966), however, previous research has shown an influence of spring temperatures on the harvest date of apricot cultivars (Drogoudi *et al.*, 2008). Analogous situations were found in the peach and nectarine: the fruit development rate and final fruit weight were governed by exposure to heat in the first 30 days after bloom (DeJong, 2005).

The most important factors influencing the final physical and chemical features of fully ripe apricot fruits are: cultivar, maturity, weather conditions of the harvesting season, agricultural conditions, crop load, development of infection, fruit position within the canopy, and geographic location (Drogoudi *et al.*, 2008; Ruiz and Egea, 2008; Durmaz *et al.*, 2010). The effect of rootstock, especially interstem, is less discussed (Hernández *et al.*, 2010). In Serbia, the most widely used rootstock for apricots are Myrobalan seedlings (*P. cerasifera* Ehrh.), although there are a number of disadvantages, such as incompatibility, excessive vigour, early onset and late termination of the growing season, winter killing of blossom buds, instable yield, and a frequent occurrence of apoplexy (Milošević *et al.*, 2012). Growers are attempting to mitigate the numerous defects of Myrobalan through the use of other rootstocks and/or interstems in some Serbian apricot orchards (Milošević and Milošević, 2011). For example, Blackthorn (*P. spinosa* L.) as interstem reduces tree

vigour, and induced precocity, yield efficiency, good fruit size and fruit colour (Milošević *et al.*, 2012).

For these reasons, the aim of this study was to evaluate the impact of Myrobalan rootstock and Blackthorn interstem on the fruit growth, physico-chemical features, and bioactive compounds content of fully ripe fruits of two apricot cultivars grown on typical sandy loam and acidic soil in the Cacak region, Western Serbia.

MATERIAL AND METHODS

Field Trial and Plant Material

The trial was conducted in an experimental orchard in Prislonica, in the region of Cacak, Western Serbia (latitude 43°53' N, longitude 20°21' E). Weather conditions of Cacak are characterized by the average annual temperature of 11.3°C and total annual rainfall of 690.2 mm. The experimental field was situated at 340 m altitude. Soil conditions were poor due to its marked sandy loam texture with water deficiency problems. Soil was highly acidic (pH= 4.86 in 0-30 cm soil depth), moderate in organic matter (1.68%), low in N_{TOT} (0.16%), Ca (0.39%), Mg (6.2 mg kg⁻¹), Mn (7.8 mg kg⁻¹), Cu (1.6 mg kg⁻¹), Zn (0.52 mg kg⁻¹) and B (2.3 mg kg⁻¹) contents, whereas P (77.68 mg kg⁻¹), K (182.63 mg kg⁻¹) and Fe (78.0 mg kg⁻¹) amounts were higher than optimum, as previously obtained by Milošević and Milošević (2011). Trees were trained to the open vase system and planted at a spacing of 5.5×3.0 m. Standard cultural practices (pruning, fertilization, and pest and disease protection) were performed. The trial was not irrigated. Orchard was planted in 2007; the study was carried out over three and four years after planting.

The two apricot cultivars ('Harcot' and 'Roksana') were evaluated. Both of them were grafted directly on Myrobalan seedlings rootstock, and through Blackthorn interstem on Myrobalan as a stock, at 60 cm

above ground level, respectively. The experiment was established in a randomized block design with five trees in four replicates for each rootstock/cultivar and/or rootstock/interstem/cultivar combination. Data are expressed as a means $\pm$ standard error (SE) over two consecutive years (2010 and 2011).

Experimental Procedure

Fruit growth was evaluated between full bloom and harvest. The date of full bloom was considered to be when 80% of the flowers of the tree were open, according to guidelines of Wertheim (1996), and was observed on 28 March for 'Harcot' and on 2 April for 'Roksana', in average for 2010 and 2011. Fruits samples of each rootstock-cultivar and rootstock-interstem-cultivar combination were taken repeatedly during their growth, in interval of 15 days after full bloom (DAFB) for determining the dynamics and length of growth period. First fruit collection was performed on 15 April in average i.e. 20 DAFB, when measurable fruit formation occurred (~3 g of fruit). The generalized function of a double sigmoid growth curve for apricots is represented by the equation $Y = a \pm bx \pm cx^2 \pm dx^3$. For each measurement during fruit growth, 25 fruits per each rootstock/cultivar and/or rootstock/interstem/cultivar combination were used from all parts of crown for evaluation of changes of fruit weight (FW, g). The date of ripening was considered to be the time of the commercial harvest (fully-coloured) of the fruits by visual observation (Ruiz and Egea, 2008), being on 1 July for 'Harcot' and on 10 July for 'Roksana' in both season in average.

For final physical and chemical features evaluation of fully ripe fruits, samples of total 100 fruits (25 $\times$ 4 replicates) per each of the above combinations were hand harvested randomly for experimentation. After harvest, the fruits were immediately taken to the laboratory in the same day for sample preparation and analysis.

The FW and stone weight (SW, g) of apricots were determined with a digital balance Tehnica ET-1111 (Iskra, Horjul, Slovenia, ± 0.01 g accuracy). On the basis of the measured data, flesh percentage (FP, %) was recorded as the ratio of the weight of the edible portion of the fruit to the total fruit weight. An electronic caliper gauge Starrett 727 Series (Athol, NE, USA, ± 0.01 mm accuracy) was used to measure three fruit linear dimensions, length (L), width (W), and thickness (T). Data are expressed as mm. Flesh firmness (FF, kg cm⁻²) was determined with a Bertuzzi FT-327 penetrometer (Facchini, Alfonsine, Italy) with an 8 mm-diameter plunger, on both cheeks of the fruit after skin removal. The arithmetic mean diameter (D_a , mm), geometric mean diameter (D_g , mm), sphericity (ϕ), surface area (S , mm²) and fruit volume (V_m , cm³) were calculated by using the relationships previously described by Mohsenin (1986), whereas aspect ratio (R_a) was determined by the relationship previously described by Maduako and Faborode (1990).

Soluble solids contents (SSC, °Brix) were assessed in triplicate with a digital refractometer Milwaukee MR 200 (ATC, Rocky Mount, NC, USA) at 20°C. Titratable acidity (TA, % of malic acid) was also determined in triplicate using an automatic titration device Titrino 719 S (Metrohm, Herisau, Switzerland) with 0.1N NaOH up to pH 8.2. Once the SSC and TA contents were assessed, the ripening index (RI) was determined as their ratio.

Total phenolic content [TPH, mg GAE g⁻¹ dry extract (de)], total flavonoid content (TFC, mg RU g⁻¹ de) and total antioxidant capacity (TAC, mg AA g⁻¹ de) were determined spectrophotometrically using UV-VIS spectrophotometer MA9523-SPEKOL 211 (Iskra, Horjul, Slovenia). The TPH was estimated according to the Folin-Ciocalteu method (Gutfinger, 1981), whereas TFC was determined according to the method described by Brighente *et al.* (2007). The TAC of the methanol extracts were evaluated by the phosphor-



molybdenum method (Prieto *et al.*, 1999). All three values are presented as means of triplicate analyses for each rootstock/cultivar and/or rootstock/interstem/cultivar combination per year.

Statistical Analysis

Data for each parameter measured were subjected to an analysis of variance (ANOVA) using the MSTAT-C statistical package (Michigan State University, East Lansing, MI, USA). Differences between treatments were assessed using the F-test, and the least significant difference (LSD) was calculated at 0.05 probability level ($P \leq 0.05$). The figures are performed by the Microsoft Excel software (Microsoft Corporation, Roselle, IL, USA).

RESULTS AND DISCUSSION

Evaluation of Fruit Growth

Changes of fruit size from full bloom to harvest are illustrated in Figures 1 and 2. According to the reported data, we observed classical double sigmoid growth curve with three traditional stages (I, II, III) on

Myrobalan rootstock and Blackthorn interstem, as previously reported by Jackson and Coombe (1966), James *et al.* (1989), and Durmaz *et al.* (2010). In 'Harcot' grafted on rootstock or interstem, FW between subsequent measurements significantly differed, although differences at the same DAFB were not significant, including final values (Figure 1). Similar tendency was observed for 'Roksana' (Figure 2). However, differences were observed for length of fruit growth period, being 95 days in 'Harcot' and 99 days in 'Roksana'. In our earlier study, we also observed differences among apricots regarding fruit growth period (Milošević *et al.*, 2010), which could be due to the impact of genotype characteristics (Giovannoni, 2004). The FW of both cultivars grafted on Myrobalan or Blackthorn increased approximately 20 and/or 29 fold throughout the fruit development period, respectively. Previously, it was found that small fruit was usually produced by early season cultivars in apricot trees due to their shorter maturation time (Pérez-Pastor *et al.*, 2004). Recently, DeJong (2005) found that in peach trees the fruit development rate and final FW were governed by exposure to heat in the first 30 DAFB, which may also be the case in apricots affecting differently the FW in

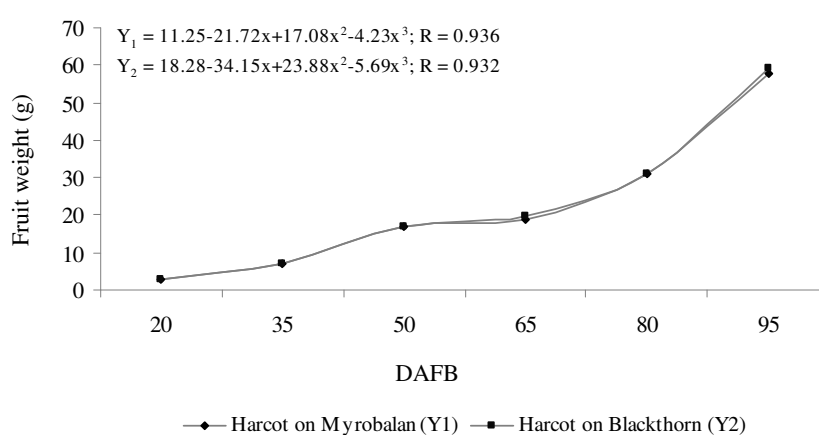


Figure 1. Fruit growth tendency of 'Harcot' cultivar grafted on Myrobalan rootstock and Blackthorn interstem between full bloom and start of fruit ripening. Values in panel indicate function of a double sigmoid fruit growth curve (Y) and significant correlation coefficient (R) between fruit growth and days after full bloom (DAFB) at 0.05 probably level.

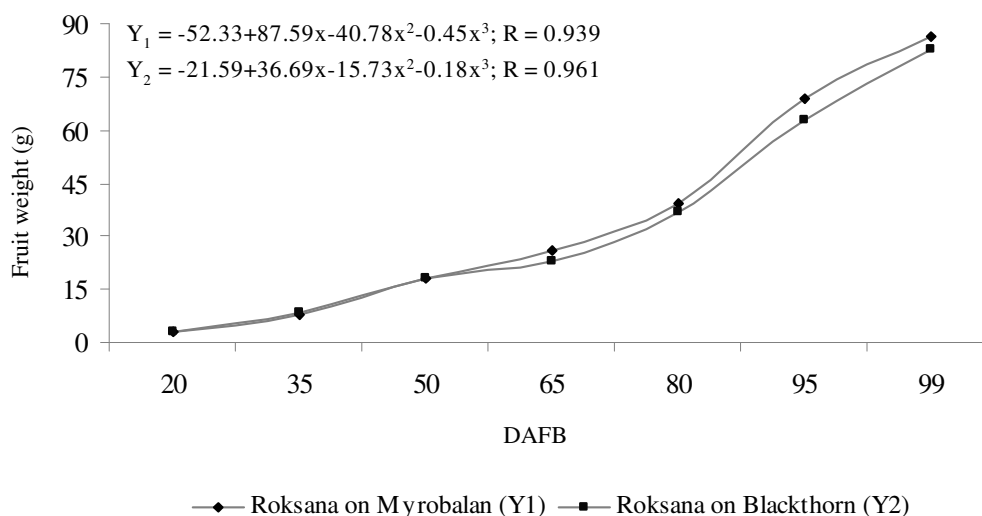


Figure 2. Fruit growth tendency of ‘Roksana’ cultivar grafted on Myrobalan rootstock and Blackthorn interstem between full bloom and start of fruit ripening. Values in panel indicate function of a double sigmoid fruit growth curve (Y) and significant correlation coefficient (R) between fruit growth and days after full bloom (DAFB) at 0.05 probably level.

cultivars depending on their blooming date and exposure to heat. However, high air temperatures in the first 30 DAFB were not usual occurrences under western Serbian conditions. In the present study, changes of FW between subsequent measurements represent changes of FW during their growth period. These were much higher than the findings of Durmaz *et al.* (2010) for group of Turkish cultivars, due to the different eco-geographical groups of apricot cultivars studied.

Fruit Physical Features

Table 1 shows apricot physical features. The FW, SW, FP, L and W were similar in both combinations, while T was significantly higher in cultivars grafted on Myrobalan than on Blackthorn. Similar tendencies for FW and fruit dimensions were previously reported by Hernandez *et al.* (2010) for some rootstock/cultivar combinations. In contrast, Egea *et al.* (2004) reported that FW was significantly affected by the yields and rootstock, being higher in cultivar on rootstock which induced lower

yield. Frequently, there was a correspondence between low yield and large fruit weight.

Regarding the cultivars, ‘Roksana’ had higher fruit and stone weight and fruit three linear dimensions than ‘Harcot’ on both stocks, whereas FP was similar (Table 1). Serafimov and Borisov (1980) were the first to describe Afghan apricot cultivar ‘Roxana’ in European conditions and reported that it was characterized by large fruit with average weight of 72 g, generally confirming our results. Previous works by several authors on apricot have also reported a high variability among cultivars regarding FW (Ruiz and Egea, 2008; Milošević *et al.*, 2010; Hernandez *et al.*, 2010). Generally, FW is a major criterion of apricot fruit quality, yield, and consumer acceptance (Durmaz *et al.*, 2010).

In relation to SW, values were much lower in ‘Harcot’ than in ‘Roksana’. Serafimov and Borisov (1980) reported that stone of ‘Roksana’ was medium sized (about 5% of FW). Similar differences among apricots for SW were previously reported by Milošević *et al.* (2010). Differences for SW between Myrobalan and Blackthorn were not

Table 1. Fruit and stone weight, flesh percentage and linear fruit dimensions of Harcot and Roksana apricots grafted on Myrobalan rootstocks and Blackthorn interstem. Data are mean $\pm$ SE for two successive years.

Stock	Cultivar	FW ^a (g)	SW (g)	FP (%)	L (mm)	W (mm)	T (mm)
Myrobalan	Harcot	57.71 $\pm$ 2.22 b	2.93 $\pm$ 0.16 b	95.21 $\pm$ 0.33 a	51.07 $\pm$ 0.62 b	47.21 $\pm$ 0.76 b	44.08 $\pm$ 0.53 b
	Roxana	86.30 $\pm$ 3.85 a	4.03 $\pm$ 0.31 a	95.26 $\pm$ 0.42 a	57.83 $\pm$ 1.16 a	55.78 $\pm$ 0.77 a	49.95 $\pm$ 1.21 a
	Average	72.00 $\pm$ 14.34 A	3.48 $\pm$ 0.55 A	95.23 $\pm$ 0.02 A	54.45 $\pm$ 3.39 A	51.49 $\pm$ 4.30 A	47.01 $\pm$ 2.94 A
Blackthorn	Harcot	59.38 $\pm$ 2.20 b	2.69 $\pm$ 0.13 b	95.43 $\pm$ 0.24 a	52.66 $\pm$ 1.03 b	47.34 $\pm$ 0.67 b	43.44 $\pm$ 0.54 b
	Roxana	82.70 $\pm$ 3.32 a	3.84 $\pm$ 0.14 a	95.30 $\pm$ 0.23 a	58.22 $\pm$ 1.32 a	55.71 $\pm$ 1.28 a	48.35 $\pm$ 0.87 a
	Average	71.04 $\pm$ 11.69 A	3.26 $\pm$ 0.58 A	95.36 $\pm$ 0.06 A	55.44 $\pm$ 2.79 A	51.52 $\pm$ 4.19 A	45.89 $\pm$ 2.46 B

^a For abbreviations, see section "Materials and Methods".

The same small letters in columns shows insignificant differences ($P \leq 0.05$) by LSD test between cultivars.

The same capital letters in columns shows insignificant differences ($P \leq 0.05$) by LSD test between Myrobalan rootstock and Blackthorn interstem.

significant. Additionally, it is a well-known fact that apricot stones are used in genotype identification (Depypere *et al.*, 2007).

The FP was not affected by rootstock or interstem, and was similar in both cultivars (Table 1). The higher FP is a desired fruit property in apricot, as previously obtained by Mratinić *et al.* (2011). Also, fruit dimensions, except T, were not influenced by rootstock or interstem, but differences between cultivars became evident, 'Roksana' being the most efficient cultivar. In contrast, Hernandez *et al.* (2010) indicated that fruit dimensions were significantly affected by rootstocks and cultivars, partially confirming our results. In general, the present range values were much higher than those for a group of Turkish (Asma *et al.*, 2007) and Iranian cultivars (Jannatizadeh *et al.*, 2008). The differences between the present results and those of the above authors could be due to the different eco-geographical groups of apricot cultivars studied. It seems that fruit dimensions are important features that distinguish apricot cultivars.

According to the reported data (Table 2), D_a and D_g values were not affected by rootstock or interstem. On the other hand, both values significantly differed between cultivars. Higher values were found in 'Roksana' on Myrobalan and Blackthorn, respectively. Jannatizadeh *et al.* (2008) reported that knowledge related to D_g would be valuable in designing the grading process.

The global fruit shape is determined in terms of its ϕ and R_a . Both values were significantly affected by rootstock and/or interstem, and by cultivars (Table 2). The smallest ϕ and R_a were induced by Blackthorn, while higher values belonged to 'Roksana'. Hernandez *et al.* (2010) concluded that ϕ was also rootstock and cultivar dependent. Generally, ϕ is an expression of the shape of a solid related to that of a sphere of the same volume, while the R_a relates the W to the L of the fruit,

Table 2. Arithmetic and geometric diameter, sphericity, aspect ratio, surface area, fruit volume and flesh firmness of Harcot and Roksana apricots grafted on Myrobalan rootstocks and Blackthorn interstem. Data are mean±SE for two successive years.

Stock	Cultivar	D_a (mm) ^b	D_g (mm)	ϕ	R_a	S (mm ²)	V_m (cm ³)	FF (kg cm ⁻²)
Myrobalan	Harcot	31.72±0.36 b	47.36±0.56 b	0.93±0.00 b	138.98±0.56 b	7051.6±165.4 b	56.31±1.74 b	1.29±0.10 a
	Roxana	35.93±0.74 a	54.38±0.84 a	0.94±0.01 a	139.98±1.30 a	9304.4±290.9 a	87.90±3.18 a	1.04±0.10 b
Average		33.82±2.11 A	50.87±3.52 A	0.93±0.00 A	139.48±0.50 A	8178.0±1129.8 A	72.11±15.84 A	1.16±0.12 A
Blackthorn	Harcot	32.03±0.40 b	47.64±0.54 b	0.91±0.01 b	135.70±1.64 b	7134.9±164.4 b	54.42±2.58 b	1.24±0.09 a
	Roxana	35.52±0.59 a	53.89±0.92 a	0.93±0.01 a	136.20±1.88 a	9141.7±315.0 a	84.87±3.01 a	1.01±0.08 b
Average		33.77±1.75 A	50.76±3.13 A	0.92±0.01 B	135.95±0.25 B	8138.3±1006.4 B	69.64±15.27 B	1.12±0.11 B

^b For abbreviations, see section "Materials and Methods"The same small letters in columns shows insignificant differences ($P \leq 0.05$) by LSD test between cultivars.The same capital letters in columns shows insignificant differences ($P \leq 0.05$) by LSD test between Myrobalan rootstock and Blackthorn interstem.

being indicative of its tendency toward its oblong shape (Mratinić *et al.*, 2011).

The S and V_m significantly differed between Myrobalan and Blackthorn and between cultivars (Table 2). Higher S and V_m were exhibited with Myrobalan, and lower with Blackthorn. Within cultivars, higher values of both parameters were observed in 'Roksana'. The results for S were due to the differences in values of dimensional features (Maduako and Faborode, 1990). Regarding V_m , it is clear that a large number of 'Harcot' fruits could be packed in the predetermined volume compared with the 'Roksana'. In addition, Jackson and Coombe (1966) reported that apricot fruits varied in volume within and between trees in orchards. In general, our results for S and V_m are superior to those published by Hacisefroğullari *et al.* (2007) for Turkish apricot cultivars and Mratinić *et al.* (2011) for Macedonian genotypes of wild apricot.

Regarding FF, Myrobalan induced higher values than Blackthorn, whereas 'Harcot' exhibited fruits of a higher consistency than 'Roksana' (Table 2). Both of them induced to a firmness > 1.0 kg cm⁻². According to Scandella *et al.* (1998), the quality standard for apricot at harvest maturity is a firmness value between 0.5 and 3.0 kg cm⁻². On this basis, apricots in our study were suitable for consumers and apricot industry.

Fruit Chemical Features

The SSC, TA and RI varied from rootstock to interstem and cultivar to cultivar (Table 3). Myrobalan induced higher SSC and TA, whereas Blackthorn induced higher RI. In relation to cultivar, higher SSC and RI were recorded in 'Harcot', while greater TA was exhibited by 'Roksana'. Similar results for SSC and TA have been found in other studies (Hernandez *et al.*, 2010). Previous studies by several authors on apricot reported that TA > 0.90% and SSC < 12°Brix, consumer acceptance was controlled by the interaction between TA and SSC rather than SSC alone (Crisosto

Table 3. Soluble solids content, titratable acidity, ripening index and content of bioactive compounds Harcot and Roksana apricots grafted on Myrobalan rootstocks and Blackthorn interstem. Data are mean $\pm$ SE for two successive years.

Stock	Cultivar	SSC ($^{\circ}$ Brix) ^a	TA (%)	RI	TPH (mg GAE g ⁻¹)	TFC (mg RU g ⁻¹)	TAC (mg AA g ⁻¹)
Myrobalan	Harcot	18.35 $\pm$ 0.44 a	0.93 $\pm$ 0.02 b	19.73 $\pm$ 0.94 a	23.78 $\pm$ 0.72 a	5.01 $\pm$ 0.04 b	13.10 $\pm$ 0.18 b
	Roksana	15.85 $\pm$ 0.47 b	1.12 $\pm$ 0.04 a	14.15 $\pm$ 0.77 b	3.10 $\pm$ 2.06 b	10.10 $\pm$ 0.89 a	45.02 $\pm$ 4.06 a
	Average	17.10 $\pm$ 1.25 A	1.02 $\pm$ 0.09 A	16.94 $\pm$ 2.79 B	13.44 $\pm$ 10.37 A	7.56 $\pm$ 2.55 A	29.06 $\pm$ 16.01 A
Blackthorn	Harcot	17.20 $\pm$ 0.59 a	0.79 $\pm$ 0.01 b	21.77 $\pm$ 1.01 a	24.01 $\pm$ 0.52 a	5.13 $\pm$ 0.02 b	13.19 $\pm$ 0.22 b
	Roksana	15.74 $\pm$ 0.84 b	0.99 $\pm$ 0.02 a	15.90 $\pm$ 0.64 b	3.02 $\pm$ 1.87 b	9.88 $\pm$ 0.69 a	44.12 $\pm$ 3.77 a
	Average	16.47 $\pm$ 0.73 B	0.89 $\pm$ 0.10 B	18.83 $\pm$ 2.94 A	13.51 $\pm$ 10.53 A	7.50 $\pm$ 2.38 A	28.65 $\pm$ 15.51 A

^a For abbreviations, see section "Materials and Methods".

The same small letters in columns shows insignificant differences ($P \leq 0.05$) by LSD test between cultivars.

The same capital letters in columns shows insignificant differences ($P \leq 0.05$) by LSD test between Myrobalan rootstock and Blackthorn interstem.

et al., 2004). In this context, fruits of both cultivars on both stocks had RI values within the limits reported by above authors. Therefore, it can be stated that RI was basically conditioned by the cultivar factor. Generally, the fruit maturity stage at the harvest date is the crucial factor affecting fruit acidity and also the SSC (Ruiz and Egea, 2008).

In relation to TPH, TFC and TAC, differences between Myrobalan and Blackthorn were not observed (Table 3). In contrast, Scalzo *et al.* (2005) reported that Myrobalan induced higher TPH than the other rootstocks evaluated. According to the reported data, the important factor affecting all the three phytochemicals was cultivar. Values of TPH were much lower in 'Roksana' than in 'Harcot'. In contrast, significantly higher TFC and antioxidant power were recorded in fruits of 'Roksana' when compared with 'Harcot'. Previous studies have revealed that cultivar is the crucial factor in determining the apricot fruit TPH, TFC and antioxidant capacity (Drogoudi *et al.*, 2008; Schmitzer *et al.*, 2011), in agreement with our results. Hegedűs *et al.* (2010) reported that, beside cultivar, these features are strongly affected by the type of fruit (species and cultivar within species), but it can also be affected by cultivation conditions of the plant (environmental and cultivation techniques). Besides, according to the above authors, the interaction of these different factors in determining the TPH, TFC and antioxidant capacity of a specific fruit should be established to better characterize agronomic production and information for the consumer. Generally, our range of values, when compared with data from literature, was reasonable and 'Harcot' and 'Roksana' grafted on Myrobalan rootstock and Blackthorn interstem had a good dietary and health values.

CONCLUSIONS

Apricot fruit growth has been obtained as a double sigmoid growth curve with three traditional stages (I, II, III). Average fruit weight of 'Roksana' and 'Harcot' cvs.

significantly increased, but impact of Myrobalan rootstock and Blackthorn interstem was not found, except for length of fruit development period. Myrobalan rootstock induced higher fruit thickness, sphericity, aspect ratio, surface area, fruit volume, flesh firmness, soluble solids content and titratable acidity, whereas Blackthorn interstem induced only higher RI values. The cultivar *per se* (genotype) behaved as the most influencing factor conditioning apricot physico-chemical features; 'Roksana' being the most efficient cultivar, except for flesh firmness, soluble solids content, ripening index and total phenolic content. The assessment of apricot physical features and chemical compositions implies the great potential of both cultivars for both fresh market and fruit processing. Also, the presence of bioactive compounds in apricot fruits may encourage their consumption for potential health benefits. Finally, grown on acidic sandy loam soil, both apricot cultivars grafted directly onto Myrobalan rootstock had better fruit features than when grafted through Blackthorn interstem onto the above rootstock; therefore, direct grafting can be recommended for growers in similar conditions.

ACKNOWLEDGEMENTS

This study was part of a research project TR 31064 funded by the Republic of Serbia, Ministry of Science. Financial assistance from the Ministry is gratefully acknowledged. Also, special thanks to Ms. Aleksandra Milošević for technical support.

REFERENCES

1. Asma, B., Kan, T. and Birhanli, O. 2007. Characterization of Promising Apricot (*Prunus armeniaca* L.) Genetic Resources in Malatya, Turkey. *Genet. Res. Crop Ev.*, **54**: 205-212.
2. Brighente, I. M. C., Dias, M., Verdi, L. G. and Pizzolatti, M. G. 2007. Antioxidant Activity and Total Phenolic Content of Some Brazilian Species. *Pharm. Biol.*, **45**: 156-161.
3. Chahine, H., Gouble, B., Audergon, J. M., Souty, M., Albagnac, G., Jacquemin, G., Reich, M. and Hugues, M. 1999. Effect of Ethylene on Certain Quality Parameters of Apricot Fruit (*Prunus armeniaca* L.) during Maturation and Post Evaluation. *Acta Hort.*, **488**: 577-584.
4. Crisosto, C. H., Garner, D., Crisosto, G. M. and Bowerman, E. 2004. Increasing 'Blackamber' Plum (*Prunus salicina* Lindley) Consumer Acceptance. *Postharvest Biol Technol.*, **34**: 237-244.
5. DeJong, T. M. 2005. Using Physiological Concepts to Understand Early Spring Temperature Effects on Fruit Growth and Anticipating Fruit Size Problems at Harvest. *Summer Fruit*, **3**: 10-13.
6. Depypere, L., Charle, P., Vander-Mijnsbrugge, K. and Goetghebeur, P. 2007. Stony Endocarp Dimension and Shape Variation in *Prunus* Section *Prunus*. *Ann. Bot.*, **100**: 1585-1597.
7. Drogoudi, P. D., Vemmos, S., Pantelidis, G., Petri, E., Tzoutzoukou, C. and Karayannis, I. 2008. Physical Characters and Antioxidant, Sugar, and Mineral Nutrient Contents in Fruit from 29 Apricot (*Prunus armeniaca* L.) Cultivars and Hybrids. *J. Agr. Food Chem.*, **56**: 10754-10760.
8. Durmaz, G., Çam, M., Kutlu, T. and Hişil, Y. 2010. Some Physical and Chemical Changes during Fruit Development of Five Common Apricot (*Prunus armeniaca* L.) Cultivars. *Food Sci. Technol. Res.*, **16**: 71-78.
9. Egea, J., Ruiz, D. and Martínez-Gómez, P. 2004. Influence of Rootstock on the Productive Behaviour of 'Orange Red' Apricot under Mediterranean Conditions. *Fruits*, **59**: 367-373.
10. Egea, M. I., Martinez-Madrid, M. C., Sanchez-Bel, P., Muricia, M. A. and Romojaro, F. 2007. The Influence of Electron-beam Ionization on the Ethylene Metabolism and Quality Parameter in Apricot (*Prunus armeniaca* L., cv. Bulida). *Swiss Soc. Food Sci. Technol.*, **40**: 1027-1035.
11. Giovannoni, J. 2004. Genetic Regulation of Fruit Development and Ripening. *Plant Cell*, **16**: 170-180.
12. Gutfinger, T. 1981. Polyphenols in Olive Oils. *J. Am. Oil Chem. Soc.*, **58**: 966-968.
13. Hacisefroğullari, H., Gezer, I., Özcan, M. M. and Asma, M. B. 2007. Postharvest Chemical and Physical-Mechanical Features of Some



- Apricot Varieties Cultivated in Turkey. *J. Food Engin.*, **79**: 364-373.
14. Hegedűs, A., Engel, R., Abrankó, L., Balogh, E., Blázkovics, A., Hermán, R., Halász J., Ercisli, S., Pedryc, A. and Stefanovits-Bányai, E. 2010. Antioxidant and Antiradical Capacities in Apricot (*Prunus armeniaca* L.) Fruits: Variations from Genotypes, Years, and Analytical Methods. *J. Food Sci.*, **75**: 722-730.
 15. Hernández, F., Pinochet, J., Moreno, M. A., Martínez, J. J. and Legua, P. 2010. Performance of *Prunus* Rootstocks for Apricot in Mediterranean Conditions. *Sci. Hortic.*, **124**: 354-359.
 16. Jackson, D. I. and Coombe, B. G. 1966. The growth of apricot fruit. I. Morphological Changes during Development and the Effects of Various Tree Factors. *Aust. J. Agr. Res.*, **17**: 465-477.
 17. James, H., LaRue, R. and Scott, J. 1989. *Peaches, Plums, and Nectarines - Growing and Handling for Fresh Market*. Postharvest Technology Research and Information Center, UC Davis-Department of Plant Sciences, Davis, CA, PP. 32-38.
 18. Jannatizadeh, A., Naderi-Boldaji, M., Fatahi, R., Ghasemi-Varnamkhasti, M. and Tabatabaeefar, A. 2008. Some Postharvest Physical Features of Iranian Apricot (*Prunus armeniaca* L.) Fruit. *Int. Agrophys.*, **22**: 125-131.
 19. Maduako, J. N. and Faborode, M. O. 1990. Some Physical Features of Cocoa Pods in Relation to Primary Processing. *IFE J. Tech.*, **2**: 1-7.
 20. Milošević, T., Milošević, N., Glišić, I. and Krška, B. 2010. Characteristics of Promising Apricot (*Prunus armeniaca* L.) Genetic Resources in Central Serbia Based on Blossoming Period and Fruit Quality. *Hortic. Sci.*, **37**: 46-55.
 21. Milošević, T. and Milošević N. 2011. Diagnose Apricot Nutritional Status According to Foliar Analysis. *Plant Soil Environ.*, **57**: 301-306.
 22. Milošević, T., Milošević, N. and Glišić, I. 2012. Effect of Tree Conduite on the Precocity, Yield and Fruit Quality in Apricot on Acidic Soil. *Rev. Ciênc. Agrôn.*, **43**: 177-183.
 23. Mohsenin, N. N. 1986. *Physical Properties of Plant and Animal Materials*. Gordon and Breach Science Publishers, New York, USA, PP. 80-85.
 24. Mratinić, E., Popovski, B., Milošević, T. and Popovska, M. 2011. Analysis of Morphological and Pomological Characteristics of Apricot Germplasm in FYR Macedonia. *J. Agr. Sci. Tech.*, **13**: 1121-1134.
 25. Pérez-Pastor, A., Ruiz-Sánchez, M. C., Domingo, R. and Torrecillas, A. 2004. Growth and Phenological Stages of Búlida Apricot Trees in South-East Spain. *Agronomie*, **24**: 93-100.
 26. Prieto, P., Pineda, M. and Aguilar, M. 1999. Spectrophotometric Quantification of Antioxidant Capacity Through the Formation of a Phosphomolybdenum Complex: Specific Application of Vitamin E. *Anal. Biochem.*, **269**: 337-341.
 27. Ruiz, D. and Egea, J. 2008. Phenotypic Diversity and Relationships of Fruit Quality Traits in Apricot (*Prunus armeniaca* L.) Germplasm. *Euphytica*, **163**: 143-158.
 28. Scalzo, J., Politi, A., Pellegrini N., Mezzetti, B. and Battino, M. 2005. Plant Genotype Affects Total Antioxidant Capacity and Phenolic Contents in Fruit. *Nutrition*, **21**: 207-213.
 29. Scandella, D., Sibille, I., Venien, S., Lichou, J. and Jay, M. 1998. Abricot: Evaluation des Atouts Organoleptiques. *Infos-Ctifl*, **141**: 22-25.
 30. Schmitzer, V., Slatnar, A., Mikulic-Petkovsek, M., Veberic, R., Krska, B. and Stampar, F. 2011. Comparative Study of Primary and Secondary Metabolites in Apricot (*Prunus armeniaca* L.) Cultivars. *J. Sci. Food Agric.*, **91**: 860-866.
 31. Serafimov, S. S., Borisov, N. 1980. The New Apricot Cultivar Roksana. *Grad. Loz. Nauka*, **17**: 54-58.
 32. Wertheim, S. J. 1996. Methods for Cross Pollination and Flowering Assessment and Their Interpretation. *Acta Hort.*, **423**: 237-241.

دینامیک (تحولات) رشد میوه و کیفیت درونی میوه درختان زرد آلو پیوند شده روی پایه یا میانپایه

ت. میلوسویچ، ن. میلوسویچ، و ی. گلیسیچ

چکیده

این بررسی برای تحقیق در باره اثر پایه مایروبالان و میانپایه بلکهورن روی رشد، خواص فیزیکی شیمیایی و ترکیبات زی فعال دو کالتیوار "هارکوت" و "رکسانا" زرد آلو در سالهای ۲۰۱۰ و ۲۰۱۱ انجام شد. پیشرفت رشد میوه های هر دو کالتیوار از مرحله گل دهی کامل تا برداشت روی پایه مایروبالان و میانپایه بلکهورن به شکل کلاسیک یک منحنی با سیگمویید دوگانه بود. در طی دوره رشد و تکامل، میانگین وزن میوه هر دو کالتیوار از نظر آماری به طور معنی داری افزایش یافت ولی تفاوتی بین پایه و میانپایه دیده نشد. پایه مایروبالان منجر به القای ارزش های بالاتر در جنبه های فیزیکی میوه (ضخامت میوه، کروی بودن میوه، aspect ratio، مساحت رویه میوه، حجم میوه، و سفتی گوشت) و بعضی صفات شیمیایی (محتوی جامدات محلول، اسیدیته قابل سنجش) گردید در حالی که بلاکهورن فقط منجر به افزایش شاخص رسیدگی میوه شد. در مورد کالتیوارها، "رکسانا" دارای صفات فیزیکی بهتری بود، به جز در مورد سفتی گوشت میوه، و نیز مقدار بیشتری از مواد جامد محلول، شاخص رسیدگی بزرگتر، محتوی افزونتر فلاونوئید و ظرفیت بیشتر آنتی اکسیدان کل را به دست داد. نتایج به دست آمده در این تحقیق تایید میکنند که در یک خاک اسیدی با بافت لوم شنی، سازگاری پایه مایروبالان با پیوندک کالتیوارهای "رکسانا" و "هارکوت" بهتر از سازگاری میانپایه بلکهورن با آنهاست.