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INFLUENCE OF DIFFERENT VIGOUR CLONAL ROOTSTOCKS ON THE FRUIT QUALITY OF 'LAPINS' SWEET CHERRY

UTJECAJ VEGETATIVNIH PODLOGA RAZLIČITE BUJNOSTI NA KVALITETU PLODA TREŠNJE SORTE LAPINS

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ABSTRACT

In the experiment, the 'Lapins' cherry variety was grafted on six rootstocks of different vigour (F12 / 1, Maxma14, PiKu1, Gisela 5, Weiroot 13 and Weiroot 158). The orchard was in full production (8 years after planting) and was planted at a distance of 5 x 3.5 m. The orchard was not irrigated. Samples were analyzed at full maturity. The study showed a significant impact on almost all parameters of fruit quality. The largest fruits were on the rootstock F12 / 1 and Gisela 5. The color indicators of the skin and flesh depended relatively little on the rootstocks. In the chemical composition, greater differences were manifested in the soluble dry matter, on W13 and PiKu 1 being highest, in which the vitamin C content was also higher. The largest differences were found in the content of phenol (199.0 mg / kg on the rootstock PiKu 1, and 68.3 on the rootstock W158) and in the content of neflavanoids (231.7 mg / kg on the rootstock PiKu 1, and 119.5 mg / kg on F12 / 1)

Key words: sweet cherry, rootstock, fruit quality

SAŽETAK

U pokusu je bila trešnja sorte Lapins cijepljena na šest podloga različite bujnosti (: F12/1, Maxma14, PiKu1, Gisela 5, Weiroot 13 and Weiroot 158). Voćnjak je bio u punoj rodnosti (8 godina nakon sadnje) a posađen je na razmaku 5 x 3,5 m. Voćnjak nije navodnjavan. Uzorci su analizirani u punoj zrelosti. Istraživanje je pokazalo značajan utjecaj na gotovo sve parametre kakvoće ploda. Najkrupniji plodovi su bili na podlozi F12/1 i Gisela 5. Pokazatelji boje kožice i mesa su relativno malo ovisili o podlozi. U kemijskom sastavu veće razlike očitovale su se u topivoj suhoj tvari, pri čemu je veća bila W13 i PiKu 1 kod kojih je i sadržaj C vitamina bio veći. Najveće razlike očitovale su se u sadržaju fenola (199,0 mg/kg na podlozi PiKu 1, a 68,3 na podlozi W158) te u sadržaju neflavanoida (231,7 mg/kg na podlozi PiKu 1, a 119,5 mg/kg na podlozi F12/1)

Ključne riječi: trešnja, podloga, kakvoća ploda

INTRODUCTION

In recent decades, a relatively large number of vegetative rootstocks for cherries have been selected. Attention was mainly focused on reducing vigour, adaptable to different soil conditions, precocity and satisfactory yield and quality. The selection of size reduction rootstocks enabled the intensification of cherry cultivation. The mechanisms of vigour control have not yet been fully elucidated, but are mainly attributed to hormonal interaction of rootstock and variety (Webster, 1998). However, a complex of factors involved in the effects of the rootstock on water and nutrient uptake, flowering time and fruit ripening time, fruit quality (fruit size, sugar and acid content, physical properties of the fruit, antioxidant content, etc.) as well as the mechanisms influencing early entry into productive age and yield efficiency were also only partially explained in numerous studies (Schmitt et al., 1989; Nielsen & Kappel, 1996; Gonçalves et al., 2005). The chemical composition of cherries greatly affects the sensory quality of fruits. The sweetness and color of the skin affect the acceptance of consumers of cherry varieties as well as fruit size and firmness. According to Kappel et al. (1996) ideal cherry weighs 11.6 g, color corresponding to code number 6 of the CTIFL scale, firmness 0.5-0.6 kg / cm2, contains 19.5% soluble solids content (SSC), pH 3.76, while the ratio of SSC to total acids ranges between 1.5 to 2. Many studies have investigated the influence of rootstocks on the physical, chemical and nutritional properties of cherries (Usenik & Štampar, 2000; Cmelik et al., 2004; Spinardi et al., 2005; Sitarek & Grzyb, 2010; Usenik et al., 2010; Sitarek & Bartosiewicz, 2012; Milinović et al., 2016.).

MATERIALS AND METHODS

Materials

Research was performed at the experimental station "Jazbina" located in Zagreb, Croatia. At this location the soil is rather heavy and poorly aerated. In the research, a self-fertile sweet cherry variety 'Lapins' was grafted on the following vegetative rootstocks: F12/1, Maxma14, PiKu1, Gisela 5, Weiroot 13 and Weiroot 158. The experimental design was randomly complete block with 5 blocks. Planting density was 5.0. × 3.5 m. Trees were trained as Zhan spindle

(Zahn, 1990). The orchard was not irrigated. Sweet cherry fruits, collected from the orchard, were immediately analysed. They were kept in cooled bags during transportation to the laboratory. The moisture content was immediately measured on arrival. All of the analyses were carried out at a room temperature of 23°C.

METHODS

Chemical analyses

The total titratable acidity was assessed by titration with sodium hydroxide and expressed as a % of malic acid. The pH value was measured using a digital pH-meter (Metler Toledo, Germany). Total soluble solids were measured as °Brix (Krüss refractometer- Germany). Ascorbic acid was determined using 2.6-dichlorophenolindophenol by visual titration (Ough and Amerine, 1998).

Total phenolics and nonflavonoids were determined using the Folin-Ciocalteu colorimetric method described by Amerine and Ough (Amerine and Ough, 1981). Results were expressed as mg gallic acid equivalents (GAE)/kg fresh weight of the edible part of fruits. Formaldehyde precipitation was used to determine nonflavonoids in fruit samples (Kramling and Singleton, 1969). Results were expressed as mg gallic acid equivalents (GAE)/kg fresh weight of the edible part of fruits. The extract of total phenolics was used for the DPPH assay.

Total anthocyanin content in extracts from selected fruits was determined using the bisulphite bleaching method (Ough and Amerine, 1998).

The molar absorbance value for cyanidin-3,5-diglucoside was used as a standard value. Results were expressed as mg cyanidin-3,5-diglucoside equivalents/kg fresh weight of the edible part of fruits.

The free radical scavenging capacity of fruit extracts was determined according to the previously reported procedure using the stable DPPH radical (Brand-Williams et al., 1995). The method is based on reduction of stable DPPH nitrogen radicals in the presence of antioxidants. Results were expressed as mmol Trolox equivalents per kg of fresh weight of the edible part of fruits.

Physical analyses

From the physical parameters: dry matter, fruit dimensions (length, width, thickness), fruit weight, surface and fruit sphericity were determined. Total dry matter was conducted by drying of fruits at 105ºC until constant mass (AOAC

1995). To determine the average size of fruit, for 100 randomly picked fruits their three linear dimensions namely, length (L), width (W) and thickness (T) were measured using a digital calliper (sensitivity of 0.01 mm). Fruit mass was measured with electronic balance (0.01g sensitivity). Surface area (S) and sphericity (Φ) were calculated according Vursavuş et al. (2006).

The fruit colour was represented by Hue angle (H), Chroma (C), Lightness (L), a (red-greenness), and b (blue-yellowness) values, according to CIE Lab system on colorimeter (Colortec PCM, USA). L defines the lightness, while a and b define the red-greenness and blue-yellowness, respectively. Hue angle (H) was calculated as H=arctan b/a.

Statistical analysis

Statistical analyses were performed using the SAS® version 9.1 Data were subjected to the one-way analysis of variance (ANOVA) according to the treatment structure. Mean values were compared by t-test (LSD), and they are considered significantly different at $p \leq 0.05$. Regression analyses were performed in order to investigate the nature and intensity of relationships between compounds with antioxidative activity, and antioxidative capacity in vitro. Correlation coefficients with p values ≤ 0.05 were considered significant.

RESULTS AND DISCUSSION

Physical fruit properties

Our data suggested that vegetative rootstocks of different vigour did keep pace with fruit physical properties of Lapins sweet cherry (Table 1). The highest values of dimensional properties of fruits (length, width and thickness) were measured on F12/1 and Gi5 rootstocks. Fruits grafted on Maxma14 rootstock had the lowest values. The fruits of 'Lapins' grafted on rootstocks W13, PiKu and W158 had similar values. Fruit length varied from 22.8 mm (Maxma14) to 26.1 mm (F12/1 and Gi5). Fruit width varied from 20.7 mm (Maxma14) to 23.3 mm (Gi5). Values for fruit thickness were similar for 'Lapins' grafted on W13, PiKu and F12/1, rootstocks. The fruit surface area was the highest on Gi5 and F12/1 rootstocks. On rootstocks W13, PiKu and W158 values for fruit surface were similar, while the smallest values were observed on Maxma14 rootstock. Fruit sphericity significantly differed only between fruits on PiKu 1 and W158 and F12/1. Fruit mass was similar on rootstocks W13, PiKu i and W158 (7.95, 7.99 and 7.70 g), respectively.

The lowest fruit mass was noted on Maxma 14, and the highest on Gi5 (8.48 g) and F12/1 (8.65 g). In comparison to the other rootstocks, Maxma14 had significantly different influence on almost all of the investigated physical fruit characteristics, among which negative influence of the fruit weight is very important

Table 1 Fruit physical properties of 'Lapins' grafted on six rootstocks of different vigour Values are means of three observation ± standard deviation (SD).

Tablica 1. Fizikalne osobine ploda sorte Lapins cijepljene na šest podloga različite bujnosti

	Physical properties						
Rootstock	Fruit length (mm)	Fruit width (mm)	Fruit thickness (mm)	Fruit surface area (cm^2)	Sphericity (%)	Fruit weight (g)	Stalk length (mm)
Maxma14	22.8±0.51c	20.7±0.91c	19.1±0.21c	20.8±0.08d	91.11±0.02ab	6.19±0.31c	31.6±2.33c
W13	24.9±0.32b	22.4±0.35ab	20.8±0.24b	22.6±0.11bc	91.04±0.01ab	7.95±0.30ab	30.9±1.75c
PiKu 1	24.2±0.87b	22.7±0.52ab	20.8±0.83b	22.5±0.71bc	93.17±0.00a	7.99±0.62ab	38.5±4.28a
W158	24.7±0.52b	21.9±0.72bc	20.8±1.02b	22.4±0.75c	90.73±0.01b	7.70±0.57b	32.9±0.75bc
F12/1	26.1±0.14a	22.4±0.86ab	21.6±0.35ab	23.3±0.25ab	89.29±0.01b	8.65±0.13a	32.1±3.57c
Gi5	26.1±0.25a	23.3±0.74a	21.9±0.27a	23.7±0.43a	90.88±0.01ab	8.48±0.44a	37.5±0.57ab

Different letters within each column indicate significant differences between means at P≤0.05

Our results partially coincide with the results of other researchers (Gonçalves et al., 2005; Sitarek & Grzyb, 2010; Usenik et al., 2010), and the differences were probably due to different growing conditions.

Table 2 Fruit outer and inner colour of 'Lapins' grafted on six rootstocks of different vigour (Values are means of three observation ± standard deviation (*SD*).

Tablica 2. Boja kožice i mesa ploda sorte Lapins cijepljene na šest podloga različite bujnosti

	Outer and inner colour					
Rootstock	L outer	C outer	H outer	L inner	C inner	H inner
Maxma14	22.9±1.54a	17.8±2.77ab	29.2±4.64d	33.4±2.91a	22.5±3.11a	35.6±3.21a
W13	20.3±2.72a	17.4±0.52b	33.1±1.86cd	28.7±3.04a	18.1±1.76a	27.2±1.69b
PiKu	21.5±6.55a	17.9±1.94ab	31.5±0.84cd	32.0±8.45a	22.7±6.22a	25.1±3.48b
W158	21.3±2.94a	17.4±0.27b	35.3±5.21bc	30.9±5.41a	19.0±1.48a	18.2±0.37c
F12/1	19.5±3.34a	20.8±2.13a	39.2±1.17ab	33.1±4.32a	22.4±4.62a	24.9±2.01b
Gi5	23.0±2.53a	19.1±1.02ab	42.4±1.42a	34.2±3.56a	22.1±2.16a	34.4±2.87a

Different letters within each column indicate significant differences between means at P≤0.05

Skin colour is considered to be the most important indicator of cherry quality and maturity. As it can be seen in Table 2, there are no significant differences for parameter L, which ranged from 19.5 for fruit grown on F 12/1 to 23.0 for fruits grown on Gi5. Values for parameter C ranged from 17.4 to 20.8, while parameter H ranged from 29.2 to 42.4. In comparison with the data of Bernalte et al. (2003) and Vursavuş et al. (2006), our results were partly similar. These differences can be attributed to the environmental and cultivation conditions.

Chemical fruit properties

Table 3 Fruit chemical properties of ‘Lapins’ grafted on six rootstocks of different vigour Values are means of three observation ± standard deviation (SD)

Tablica 3. Kemijske osobine ploda sorte Lapins cijepljene na šest podloga različite bujnosti

	Chemical properties				
Rootstock	D.M. (%)	T.S.S. (°Brix)	T.A.(%)	T.S.S./T.A.	pH value
Maxma14	18.7±1.01b	18.3±0.31c	0.72±0.03a	25.6±1.61b	3.73±0.03a
W13	21.6±2.12a	19.7±0.55a	0.65±0.09ab	30.4±3.74ab	3.76±0.07a
PiKu	20.3±1.17ab	19.9±0.83a	0.67±0.04ab	29.9±2.83ab	3.74±0.05a
W158	19.9±1.79ab	18.7±0.30bc	0.63±0.09ab	32.0±7.50ab	3.79±0.01a
F12/1	19.1±0.43b	18.5±0.46c	0.71±0.06a	26.1±2.17ab	3.74±0.01a
Gi5	20.0±0.74ab	19.6±0.60ab	0.60±0.03b	32.7±2.81a	3.76±0.01a

D.M. = dry matter; T.S.S. = total soluble solids (°Brix); T.A. = total acids
Different letters within each column indicate significant differences between means at $P \leq 0.05$

Dry matter content varied from 18.7% in fruits to grow on rootstock Maxma14 to 21.6% in fruits grown on rootstock W13. On the other rootstocks dry matter in fruits where similar. Total soluble solids were the lowest on the rootstock Maxma14. Similar values for soluble solids were obtained from fruits grown on rootstocks W13, PiKu i Gi5. Total aciditiy, expressed as malic acid was similar in all analysed fruits. Somewhat lower acidity had fruits grown on rootstock Gi5 and it was 0.60 g/kg f.w. TSS/TA ratio ranged from 25.6 in fruits grown on rootstock Maxma 14 to 32.7 on Gi5. Values of pH in fruits were similar for all rootstocks in the experiment. Our results are to some extent comparable with those obtained by Vursavuş et al. (2006); however in they research they obtained somewhat lower values for TSS (14.20%) and TSS/TA ratio (24.38). In general, our results indicate certain differences in chemical fruit characteristics that are significant for particular combinations of varieties/rootstocks, which may have practical significance.

Table 4 Fruit antioxidative compounds and antioxidative capacity of 'Lapins' grafted on six rootstocks of different vigour (Average of three observation ± standard deviation (SD)

Tablica 4. Antioksidativne tvari i antioksidativni kapacitet ploda sorte Lapins cijepljene na šest podloga različite bujnosti

	Antioxidative compounds and antioxidative capacity				
Rootstock	Vitamin C (mg/100g f.w.)	Anthocyanins (mg/kg f.w.)	Phenolic compounds (mg/kg f.w.)	Non-flavonoids (mg/kg f.w.)	Antioxidative capacity (mmol TE equivalent / kg f.w.)
Maxma14	21.4±1.13b	38.2±1.04ab	99.5±4.72b	137.2±8.76c	1.63±0.010b
W13	30.0±2.83a	26.7±1.72c	91.2±3.08c	189.2±9.42b	1.51±0.020c
PiKu 1	31.1±3.62a	43.0±2.72a	199.0±3.91a	231.7±11.14a	1.70±0.015a
W158	21.0±0.86b	26.5±4.19c	68.3±2.68d	124.8±5.42cd	1.37±0.015f
F12/1	19.3±2.34b	27.3±3.82c	87.4±3.55c	119.5±3.70d	1.46±0.032d
Gi5	19.7±0.57b	35.2±4.76b	71.2±1.94d	130.0±4.55cd	1.42±0.015e

Different letters within each column indicate significant differences between means at $P \leq 0.05$

Among fruits grown on other rootstocks, fruits on the PiKu 1 rootstock had a significantly higher phenolic (199.0 mg/kg f.w.) and non-flavonoid (231.7 mg/kg f.w.) compounds. It is visible that other antioxidative compounds in cherry fruits grown on PiKu 1 rootstock was higher, but not significantly different from those on W13, and Maxma14. Generally, total antioxidative capacity in fruits on PiKu 1 was significantly higher than in fruits from the other rootstocks. In studies of Vursavuş at al. (2006) total anthocyanins were different, while those for total phenols were similar as in our research.

Regression analyses

Regression between antioxidant capacity measured by DPPH methods and some antioxidant active compounds are presented in Figures 1-4. It was found that the concentration of vitamin C significantly correlates with the antioxidant capacity (DPPH) (Figure 1). In our investigation, the best relationship was observed between antioxidant capacity and total phenolic compounds (r=0.8605), but regression was quadratic and not linear as it was reported by Rousseaux et al. (2005) (Figure 2). However, the relationship between total anthocyanins and antioxidant capacity, and non-flavonoids and antioxidant capacity was linear, similar as reported by Pantelidis et al. (2007), although they obtained to some degree lower values (Figures 3 and 4).

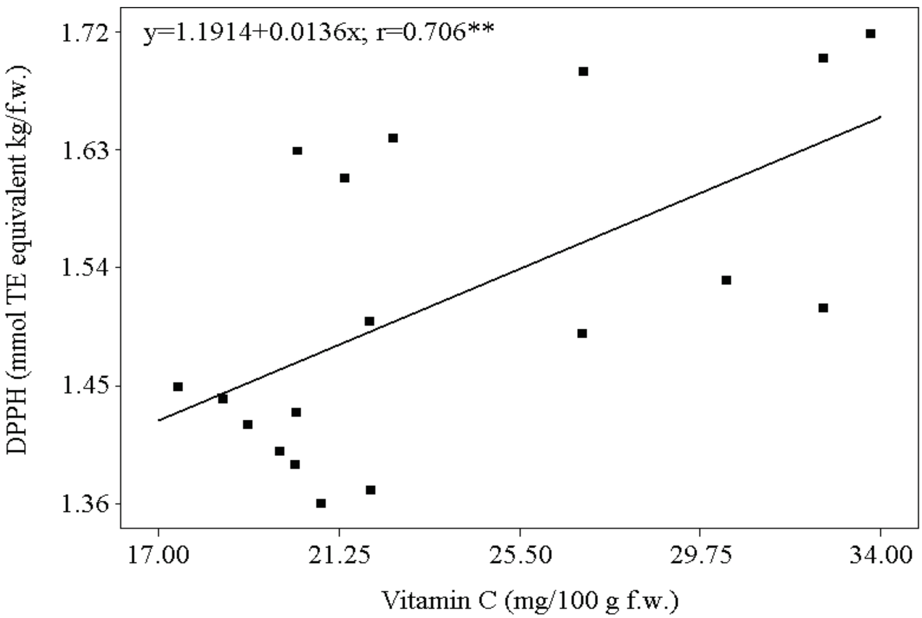

Figure 1 Regression between vitamin C content and antioxidant capacity measured in fruits of 'Lapins' cherry variety. Significance of correlation coefficient (*r*) is marked with asterisks (= significance at p≤0.01)**

Slika 1. Regresija između sadržaja vitamina C i antioksidacijskog kapaciteta u plodovima sorte Lapins

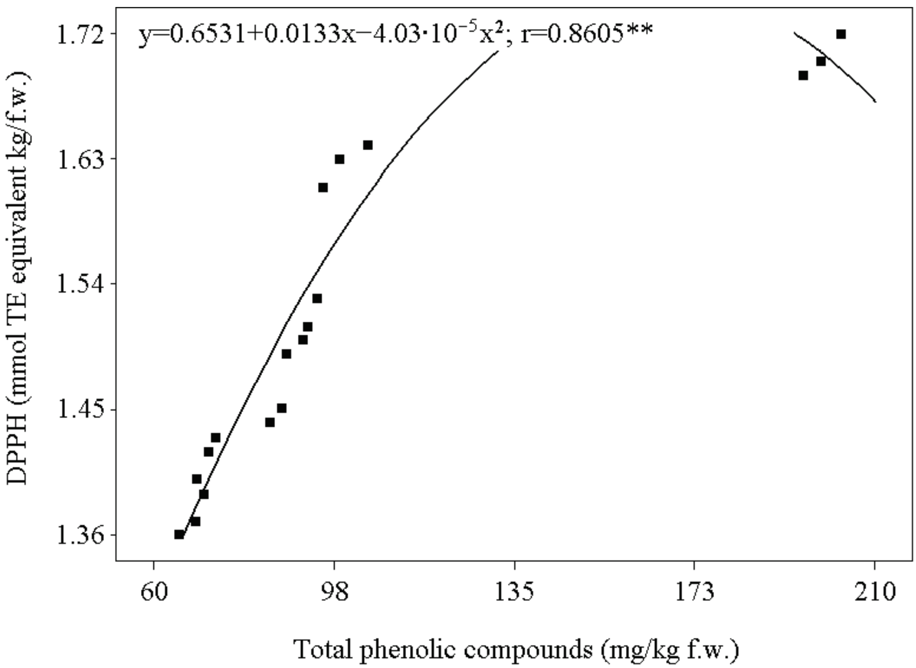

Figure 2 Quadratic regression between total phenolic compounds content and antioxidative capacity measured in fruits of 'Lapins' cherry. Significance of correlation coefficient (*r*) is marked with asterisks (= significance at $p \leq 0.01$)**

Slika 2. Regresija između ukupnih fenola i antioksidacijskog kapaciteta plodova sorte Lapins

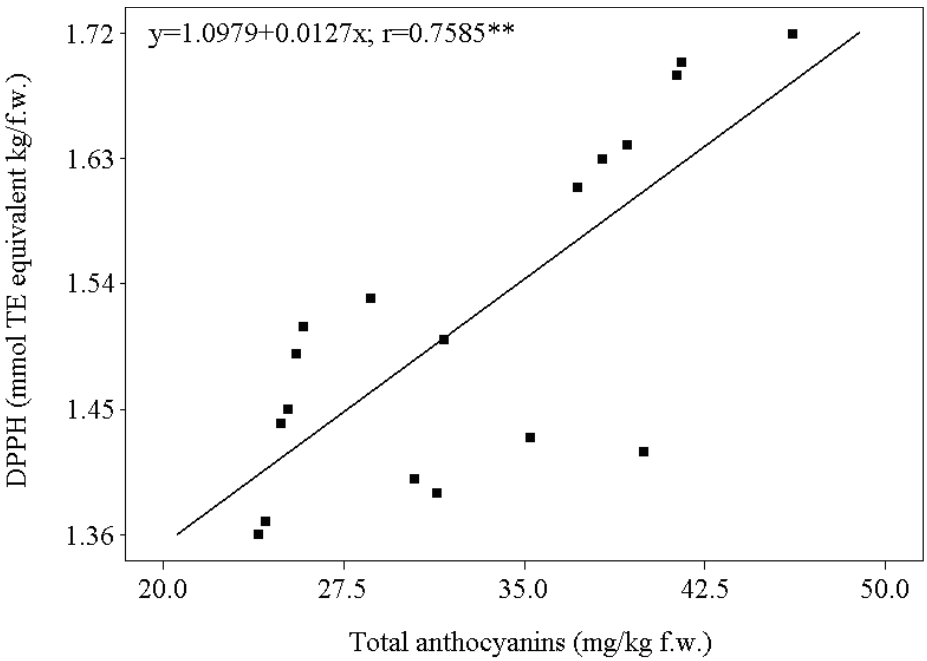

Figure 3 Linear regression between total anthocyanins content and antioxidative capacity measured in fruits of 'Lapins' cherry. Significance of correlation coefficient (*r*) is marked with asterisks (= significance at $p \leq 0.01$)**

Slika 3. Regresija između ukupnih antocijanina i antioksidativnnog kapaciteta plodova sorte Lapins

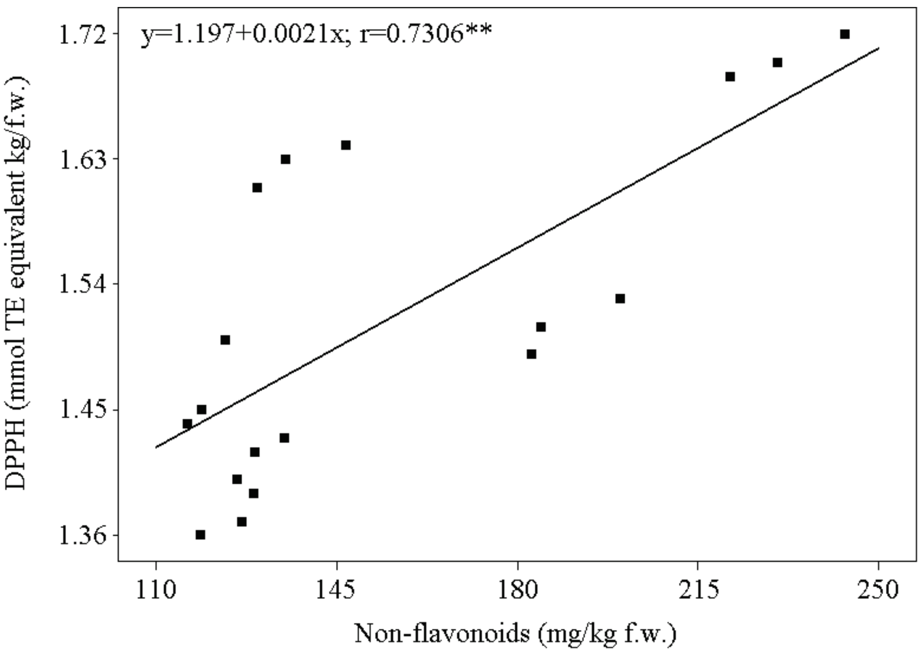

Figure 4 Linear regression between non-flavonoids content and antioxidative capacity measured in fruits of ‘Lapins’ cherry. Significance of correlation coefficient (*r*) is marked with asterisks (= significance at $p \leq 0.01$)**

Slika 4. Regresija između neflavonoida i antioksidativnog kapaciteta plodova sorte Lapins

CONCLUSION

It is well known that there is an interaction between rootstocks and varieties, which is primarily manifested in vegetative growth, time of entry into productive age, yield and fruit quality (primarily in size). Recent research has shown that the rootstock can affect virtually all fruit quality parameters (physical and chemical). Furthermore, research has shown a significant agroecological impact on fruit characteristics, so the results of research cannot be universally applied.

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