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INFLUENCE OF PLANTING MATERIAL ORIGIN ON THE FRUIT QUALITY OF TWO RASPBERRY CULTIVARS ACROSS DIFFERENT HARVEST PERIODS

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Abstract: This research investigated the influence of propagation methods and harvesting time on the fruit quality of two raspberry cultivars, 'Meeker' and 'Willamette'. The plants were propagated through tissue cultre and root suckering, and the fruits were picked during three harvest in 2020. The study analyzed soluble solids content (SSC), total sugars (TS), titratable acidity (TA), total phenolic and anthocyanin content (TPC and TAC), as well as antioxidant activity (AA). The results showed that SSC and TS increased as harvest progressed, while TA decreased. The 'Meeker' showed higher TS and SSC values, indicating a naturally sweeter fruit profile. Fruit of 'Willamette' cultivar propagated throught tissue culture had higher TAC and AA values. These findings highlight the impact of propagation technique on the accumulation of bioactive compounds in raspberry fruit. The results suggest that later harvests fruit with higher sugar content and antioxidant propertist, can be advantageous for both fresh consumption and processing.

Key words: 'Meeker', 'Willamette', tissue culture, harvest time, antioxidative activity

Introduction

Red raspberries are the fourth most important fruit product in the world (Bojkovska et al., 2021). In 2023, total annual production of raspberries in Republic of Serbia reached 98,674 tons, placing our country among the top three global producers, alongside Russia and Mexico (FAOSTAT, 2025). In

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commercial raspberry plantations, the most common floricane-fruiting cultivars are 'Willamette' and 'Meeker', whose fruits are intended for freezing/processing and export to the foreign market as various frozen products (Milivojević et al., 2012; Karaklajić-Stajić et al., 2024).

In raspberry production virus-infected plants pose a major challenge, reducing yield and fruit quality. Using healthy, virus-free, and genetically pure planting material is crucial for successful commercial production. Plant tissue culture, especially micropropagation, is a reliable method for producing high-quality plants. According to Georgieva et al. (2020), the availability of certified planting material is essential for successful raspberry cultivation.

Red raspberry (*Rubus idaeus* L.) is an economically important berry crop that contains numerous phenolic compounds with potential health benefits. The consumers are attracted to raspberry fruit because of its pleasant aroma and hue, high nutritive value and low caloric value, with health advantages represented by a high concentration of antioxidants. It is known that the content of phenolics is affected by processing factors, but limited information is available on the influence of environmental factors or genotype (Anttonen and Karjalainen, 2005). During the fruit ripenning, weight increases, mainly due to increased water content, a significant dilution of all soluble fruit constituents is also taking place during fruit ripening. As the fruits mature, the concentration of titratable acids decreases, whereas the concentrations of anthocyanins and the sugar/acid ratio increase in parallel with colour development (Stavang et al., 2015).

The aim of this study is to evaluate variations in fruit quality between two raspberry cultivars, 'Meeker' and 'Willamette', and to assess the influence of planting material origin on fruit quality. Furthermore, by analyzing different harvest times, the study seeks to gain insights into how harvest timing affects the overall quality of the fruit.

Material and methods

Plant material and experimental design

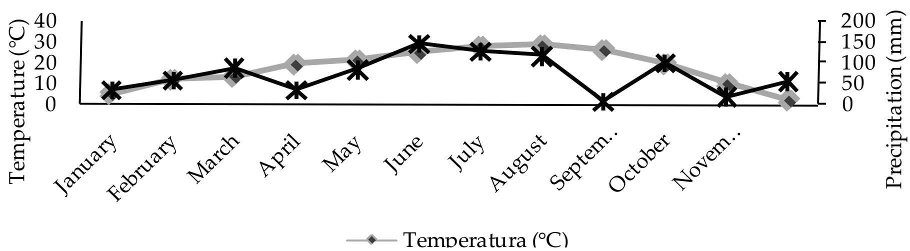
The trial was conducted at the experimental field of the Fruit Research Institute in Čačak (43°54′ N latitude, 20°22′ E longitude, 225 m altitude) in 2020 year. The research aimed to assess the fruit quality of two raspberry cultivars, 'Meeker' and 'Willamette', by comparing *in vitro* (IvPl) and conventionaly propagated – by root suckering (CpPl) plants. Given that the raspberry fruits ripen successively, harvest of fully matured raspberry samples is conducted on several occasions (early season, middle season, late season). The start of ripening occurred on June 15th for the ‘Meeker’ and June 7th for ‘Willamette’. The middle harvest took place at the end of June, while the late harvest was on July 27th for ‘Meeker’ and July 18th for the ‘Willamette’ (Table 1). After each harvest, the fruits were frozen at −18 °C and stored until chemical analyses.

Table 1. Phenological phases of two raspberry cultivars depending on origin of planting material in 2020.

Cultivar	Origin of planting material	Flowering time		Flowering duration (in days)	Ripening time		Ripening duration (in days)
		Start	The end		Start	The end	
‘Meeker’	CpPl	08.05.	17.06.	39	16.06.	27.07.	41
	IvPl	09.05.	19.06.	40	14.06.	28.07.	44
‘Willamette’	CpPl	04.05.	16.06.	42	07.06.	18.07.	41
	IvPl	05.05.	15.06.	40	07.06.	17.07.	40

CpPl- conventionaly propagated plants; IvPl- *in vitro* propagated plants.

Meteorological data for 2020 is shown in the Graph 1. The temperature was lower at the beginning of the harvest, with the highest precipitation, while during the harvest period, the temperature increased, and precipitation descreased.



Graph 1. Temperature and precipitation in the 2020.

The experiment was arranged in a completely randomized block desing involving two raspberry cultivars and two types of planting material – IvPl plants and CpPl. Total number of plants were 216 for each cultivar, i.e. 108 plants propagated *in vitro*, and the same number for plants propagated by root suckering (36 plants in the three replicates). The spacing between the rows was set at 3 m, with a 0.25 m spacing between plants within each row.

Fruit quality analysis

The fruit chemical analysis included several key measurments. Soluble solids content (SSC) was determined using a digital refractometer (Carl Zeiss, Germany) and expressed as a percentage (%). The content of total sugar (TS) were determined volumetrically using the Luff-Schoorl method described by Egan et al. (1981) and values were presented as a percentage (%). Content of total acids (TA) was measured by neutralization with 0.1 N NaOH, using phenolphthalein as an indicator, and the results were expressed as a percentage of citric acid (%).Total anthocyanin content (TAC) was measured using the pH differential method, with results expressed in milligrams of cyanidin-3-glucoside per 100 grams of fresh weight (mg C3G 100 g^{-1} FW). Total phenolic content (TPC) was determined spectrophotometrically by the modified Folin-Ciocalteu method (Singleton et al., 1999), with results expressed as milligrams of gallic acid equivalents per 100 grams g fresh weight (mg GAE 100 g^{-1} FW). The antioxidant capacity (AA) was assesed using the ABTS test (2,2'-azinobis (3-ethylbenzothiazoline-6-sulfonic acid)). The total antioxidant activity of the samples was calculated as the mg of Trolox equivalent per 100 grams of fresh fruit (mg TE 100 g^{-1}).

Statistical analyses

Experimental data were processed with two-way analyses of variance (ANOVA) with two sources of variation (cultivar and origin of planting material). The data were analyzed using Statgraphic Centurion 18 program (Manugistics. Inc., Rockville, MD, USA). The analyses were performed in three replications and mean values were compared by Least Significant Differences (LSD) test at the 5% level ($p < 0.05$) of probability. Results were expressed as the mean ± standard error.

Results and disscusion

Raspberry fruits are today highly valued by consumers for their aromatic taste. Due to their specific chemical composition, raspberry fruits have significant nutritional, medicinal and dietary effects (Na et al., 2021). One of the most important parameters of fruit maturity is the soluble solids content, which regardless of the origin of the planting material, ranged from 9.72%–12.58% in our study. Levels of SSC increased during the harvest in both cultivars, with higher values observed in the late harvests. The ‘Meeker’ cultivar exhibited higher SSC values, ranging from 10.02% to 12.99%, while the cultivar ‘Willamette’ showed lower values. Our results are confirmed by the study of Yang et al. (2020) who investigated the fruit quality of three raspberry cultivars and indicated that the SSC depends on the degree of raspberry maturity. In the late harvest, the ‘Meeker’ was distincted with higher values of SSC in plants propagated by tissue culture, while in ‘Willamette’ the opposite trend was observed (Graph 2b).

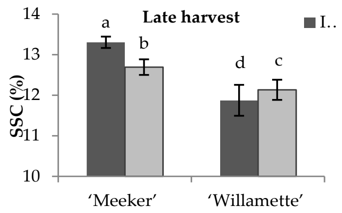
Raspberry cultivar ‘Meeker’ showed better fruit taste parameters, such as a higher sweetness index, sugar content, and lower acidity compared to ‘Willamette’. This highlights the strong influence of genotype (Anđelić et al., 2025). Leposavić et al. (2013) conducted a study in Western Serbia, examined fruit quality of five raspberry cultivars, and recorded the highest content of total sugars in the cultivar ‘Meeker’ (9.68%), while in the cultivar ‘Willamette’ this values were significantly lower, ranging from 6.28% to 6.41%. In our research, the cultivar ‘Meeker’ exhibited higher content of total sugar compared to ‘Willamette’, while the sugars distribution at harvest differed between these two cultivars. Namely, for the cultivar ‘Meeker’, the lowest values were recorded at the beginning of harvest, while this trend was opposite for the ‘Willamette’, with higher content of total sugar observed at the beginning of harvest (Table 2).

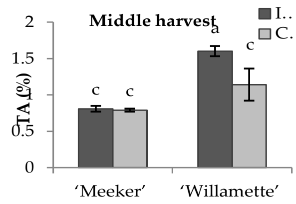
Organis acids play a crucial role in defining the taste and nutrional values of raspberry fruits. Citric and malic acids account for the majority of the total acidity in raspberries. Acid concentrations decrease as fruit ripen, due to respiration and conversion to sugars, while anthocyanin concentrations and the sugar:acid ratio increase in parallel with color development (Batista-Silva et al., 2018). Higher valus of TA in our study were recorded in the early harvest, with a gradual decrese was observed during the harvest. The cultivar ‘Willamette’ exhibited higher TA values (ranging from 1.11% to 1.42%) than ‘Meeker’ (ranging from 0.69% to 0.99%). According to the study of Augšpole et al. (2021), the total acid content in fruit of four raspberry cultivars grown under Latvian conditions ranged from 1.81% to 2.42%. Origin of plant material had significant effect on TA in early and middle harvest. Higher values were recorded in samples of *in vitro* propagated raspberry plants, contrary to Mitrović et al. (2023) who did not observed significant effect of plants origin on TA content in blackberry and raspberry. Interaction between cultivar and origin of plant material has significant influence on the content of total acids in the middle harvest (Graph 2a). In cultivar 'Willamette' *in vitro* propagated plants had higher values of TA compared to conventionaly propagated ones, while in cultivar 'Meeker' no differences were observed between plants of different origin.

Table 2. Effect of raspberry cultivar and origin of planting material on content of soluble solids, total sugars and acids

Factors	SSC (%)			TS (%)			TA (%)		
	Early harvest	Middle harvest	Late harvest	Early harvest	Middle harvest	Late harvest	Early harvest	Middle harvest	Late harvest
Cultivar									
‘Meeker’	10.02±0.22a	10.42±0.1a	12.99±0.14a	7.45±0.25a	8.16±0.18a	8.10±0.27a	0.99±0.02b	0.79±0.02b	0.69±0.03b
‘Willamette’	8.64±0.23b	9.75±0.27b	12.00±0.22b	5.88±0.29b	5.61±0.27b	5.79±0.32b	1.42±0.04a	1.38±0.13a	1.11±0.06a
Origin of planting material									
CpPl	9.94±0.30a	10.50±0.2a	12.41±0.17a	6.62±0.42a	6.95±0.60a	7.17±0.58a	1.07±0.09b	0.96±0.12b	0.85±0.06a
IvPl	9.72±0.42a	10.12±0.2a	12.58±0.26a	6.72±0.46a	6.81±0.63a	6.71±0.60a	1.34±0.07a	1.20±0.11a	0.95±0.07a
ANOVA									
A	*	*	*	*	*	*	*	*	*
B	ns	ns	ns	ns	ns	ns	*	*	ns
A × B	ns	ns	*	ns	ns	ns	ns	*	ns

SSC- soluble solids content; TS- total sugars; TA- titrable acidity; CpPl- traditionally propagated plants; IvPl- *in vitro* plants; *different small letters within the column indicate significant differences ($p \leq 0.05$) according to the LSD test.





(a) **(b)**

Graph 2. Interaction effect of cultivar/plant origin on soluble solids content (SSC) in raspberry fruits in the late harvest (a) and total acids (TA) in the middle harvest (b);

Berries' phenolic compounds have been reported to have antioxidant, anticancer, antiinflammatory, and antineurodegenerative activities (Kong et al., 2003; Seeram et al., 2006; Seeram, 2008). Our results showed that the average content of TPC for the two raspberry cultivars ranged from 111.13 to 240.54 mg GAE 100 g^{-1} FW (Table 3). The TPC increased over the course of the harvest period, as did the anthocyanin content. During the early and middle harvest, the TPC was higher in the 'Meeker' cultivar, but in the late harvest opposite trend was observed. The origin of planting material significantly influenced TPC during the middle harvest, with higher values recorded in the samples collected from *in vitro* plants. The interaction between cultivar and origin of planting material has significant influence on TPC during the early and late harvests. In cultivar 'Meeker', no differences were observed between the harvest times, but TPC values were consistently higher in plants propagated by traditional method. Cultivar 'Willamette' had higher values of the TPC in the late harvest compared to the early harvest, with no significant differences observed between the fruits sampled from plants of different origin (Graph 3a).

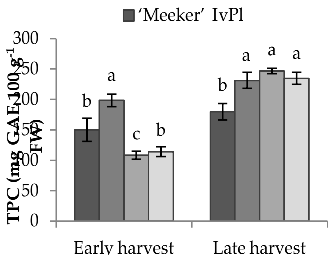
Anthocyanin levels in fruits are significantly influenced by the harvest time, as highlighted by Giné Bordonaba et al. (2010). According to Miletić et al. (2012) total anthocyanin content in the cultivar 'Meeker' primarily increases from 35.07 to 59.70 mg C3G 100 g^{-1} FW, and subsequently decreases to 43.00 mg C3G 100 g^{-1} FW. In our study higher TAC was recorded in the 'Meeker' during the early harvest. However, in the middle and late harvests, the opposite trend was observed. The TAC increase during the harvests, with the higher values recorded in 'Willamette' (64.62 mg C3G 100 g^{-1} FW). During the late harvest, interaction between cultivar and origin of planting material had significant effect on TAC. Notably, *in vitro* propagated plants of 'Willamette' displayed higher TAC then those propagated by traditional method. Conversely, in the cultivar 'Meeker', plants propagated by traditional methods exhibited higher TAC values (Graph 3b). According to Irshad et al. (2023), strawberry plants propagated by tissue culture have higher levels of anthocyanins and vitamin C which aligns with our results.

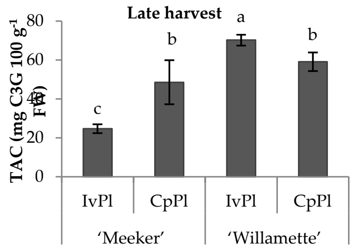
Fruit and vegetables are reach sources of phytochemicals, phytonutrients, bioactive compounds, and other substances with strong high antioxidant potential (Gansch et al., 2009). According to Grisebach (1982), light is the most crucial factor influencing anthocyanin biosynthesis in plants, paticularly in vegetative tissues. In our study, the cultivar had a significant impact on antioxidant activity, except during the late harvest. The higher antioxidant activity observed in 'Meeker' compared to 'Willamette' during early and middle harvests can be attributed to elevated levels of phenolic compounds. Additionally, a notable difference in antioxidant activity was observed between plants propagated *in vitro* and those propagated conventionally during these harvest phases. Antioxidant activity was significantly higher in CpPl compared to IvPl. In open- field conditions, *in vitro* propagated plants of 'Willamette' exhibited higher anthocyanin levels, whereas in 'Meeker' this propagation method resulted in the lowest anthocyanin levels (Graph 3c). Considerable data suggest that higher levels of total phenolics, flavonoids, and anthocyanins in red raspberry fruits contribute to their increased antioxidant activity (Anttonen and Karjalainen, 2005). These findings align with our results, which demonstrated that during the final harvest, the total phenolic and anthocyanin contents reached the highest levels, correlating with increased of antioxidant activity.

Table 3. Effect of raspberry cultivar and origin of planting material on content of total phenols, anthocyanins, and antioxidant activity in raspberry fruits

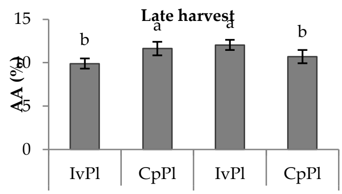
Factors	TPC (mg GAE 100 g^{-1} FW)			TAC (mg C3G 100 g^{-1} FW)			AA (%)		
	Early harvest	Middle harvest	Late harvest	Early harvest	Middle harvest	Late harvest	Early harvest	Middle harvest	Late harvest
Cultivar									
'Meeker'	174.13±12.14 a	200.68±8.42a	205.45±10.9 9b	20.44±2.02a	23.22±1.92b	36.64±6.30a	10.29±0.63a	10.59±0.47a	10.76±0.52 a
'Willamette'	111.13±5.09 b	154.62±9.67b	240.54±6.23 a	13.31±1.36b	33.58±2.29a	64.62±3.02a	7.49±0.44b	7.76±0.66b	11.36±0.49 a
Origin of planting material									
CpPl	156.24±12.11 a	183.52±10.32a	225.92±9.03 a	16.25±2.30a	27.46±2.22a	53.81±6.09a	9.54±0.57a	9.45±0.72a	11.16±0.54 a
IvPl	129.03±11.03 b	171.78±12.78a	220.07±10.6 4a	17.50±3.01a	29.34±1.85a	47.46±5.79a	8.24±0.67b	8.90±0.72b	10.96±0.48 a
ANOVA									
A	*	*	*	*	*	*	*	*	ns
B	*	ns	*	ns	ns	ns	*	*	ns
A x B	*	ns	*	ns	ns	*	ns	ns	*

TPC- total phenols; TAC- total antocyanin content; AA- antioxidant activity; CpPl- traditionally propagated plants; IvPl- *in vitro* plants; * different letters within the column indicate significant differences (₽ 0.05) according to the LSD test.





(a) **(b)**



(c)

Graph 3. Interaction effect of cultivar/plant origin on total phenolic content (TPC) in the early and late harvests (a); content of total anthocyanins (TAC) in raspberry fruits in the late harvest (b); and antioxidant activity (AA) in the late harvest (c).

Conclusion

Our study demonstrated that cultivar has significant impact on the soluble solids content, total sugars and total acids in raspberry fruit. The cultivar ‘Meeker’ exhibited higher values of soluble solids content and total sugars, along with lower acidity, indicating superior fruit quality compared to ‘Willamette’.

During the late harvest, both total anthocyanin and antioxidant activity showed a significant increase. This trend can be attributed to environmental factors, particularly higher temperatures and precipitation levels, which likely induced stress in the plants. As a response, the fruit may have enhanced the production of phenolic compounds, including anthocyanins, as part of its defense mechanism. Such environmental stressors are known to influence secondary metabolite accumulation, ultimately affecting fruit quality and bioactive potential.

In addition to cultivar, the origin of planting material also had an impact on fruit quality traits. The cultivar 'Willamette' propagated through tissue culture stood out with high values of total phenolic and anthocyanin content.

These fundings highlight the importance of cultivar selection and harvest time in optimizing fruit quality and bioactive compound accumulation, which are crucial factors for commercial raspberry production. However, a one-year study is not sufficient to determine the long-term effects on different propagation methods on raspberry fruit quality.

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YIELD AND QUALITY OF THE GRAPEVINE VARIETY RED TRAMINAC IN THE NIŠ WINE-GROWING REGION

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Abstract: This paper presents the results of a study on some production and technological characteristics of the Red Traminac grapevine variety in the Niš wine-growing region. The study was conducted in the collection vineyard of the "Center for Viticulture and Oenology" in Niš. During the research period, favorable conditions prevailed for the manifestation of production and technological characteristics of the Red Traminac variety. The yield level and its variation over the years indicate high and stable fertility of the examined variety. The sugar content in the grape must was 22.51%, and the total acid content was 7.86 g/L. Chemical analysis of the wine determined that the wine obtained from the Red Traminac variety was of good quality. Alcohol content in the wine ranged from 13.50% to 14.01% by volume. The sensory evaluation of this variety's wine scored 73 points. The research results confirm the justification for growing the Red Traminac grapevine variety in the Niš wine-growing region.

Keywords: phenological observations, yield potential, grape yield, quality of grapes and wine.

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