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FIELD PERFORMANCE AND FRUIT QUALITY OF PRIMOCANE FRUITING RASPBERRY CULTIVARS GROWN IN SERBIA

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Abstract

The main focus of our study was to investigate differences in ripening time, vegetative and generative potential (number of canes per meter of hedgerow, cane height and diameter, number of fruiting laterals per primocane, yield per primocane and per meter of hedgerow) as well as fruit quality traits (fruit weight, index of fruit shape, number of drupelets per fruit, soluble solids content, total acids, total and inverted sugars, and sucrose content) in four newly introduced primocane fruiting raspberry cultivars ('Erika', 'Paris', 'Versailles', 'Satine') that are internationally competitive to both growers and marketers in the fresh markets. Studies were conducted at a commercial raspberry plantation located near Kraljevo (Serbia), in the period of 2015-2016. Results from this study showed that the average earliest harvest time was observed in 'Versailles' (11th August), whereas 'Paris' was the latest cultivar (10th September). Significantly higher cane height was registered in cvs. 'Erika' and 'Paris' (213 and 204 cm, respectively) in comparison to the two other tested cultivars. 'Erika' expressed the lowest values of all generative characteristics, while 'Paris' yielded much higher per primocane (840 g), followed by 'Versailles' (805 g). The latter one is also characterized by the highest average fruit weight (4.93 g) and the lowest level of soluble solids, total and inverted sugars (10.9%, 8.18% and 6.94%, respectively), whereas 'Satine' had significantly higher total acids content of the fruit (2.18%) compared to the rest cultivars. In general, cvs. 'Versailles' and 'Paris' demonstrated the best productivity and outer or inner fruit quality.

Keywords: *Rubus idaeus* L., vegetative potential, productivity, physical and chemical fruit traits.

Introduction

Primocane-fruiting raspberries have many advantages over traditional summer-fruiting florican raspberries. Most notably, they provide an opportunity to extend the season from late summer into fall (Pritts, 2008; Gwozdecki, 2004). Whereas the summer raspberry harvest lasts 5 weeks, fall fruiting can add an additional 3 months or longer to the season. These cultivars are usually grown in the form of a hedgerow system with annual removal of all canes after fall fruiting which decreases pruning costs and prevents winter injury (Milivojević et al., 2011a). Because of these advantages, primocane-fruiting raspberries were rapidly and widely planted in Republic of Serbia over the last several years (Milivojević et al., 2017; Milivojević et al., 2011b). Currently, primocane cultivars 'Polka' and 'Polana' are the most common in commercial raspberry plantings. These cultivars cover an area of about 500 ha in Serbia, mostly spreading in flat regions of the province of Vojvodina (Milivojević et al., 2017). However, some newer cultivars have large and flavorful fruit, earlier or later cropping, and exhibit higher yields. Certain new introduced cultivars also perform extremely well characteristics in specific locations. Hence the present study was undertaken over a 2-year period to describe vegetative potential, productivity, and physico-chemical fruit traits of four newly introduced primocane fruiting raspberry cultivars grown in South-Western Serbia.

Material and methods

Experimental work was performed in commercial raspberry plantation located near Kraljevo (Serbia), in the period of 2015-2016. The orchard was planted in the spring of 2014 in the form of a hedgerow system at spacing of 3.0 m × 0.5 m. Canes were simply mowed down early each spring and

the crop was only born on the primocanes during the summer and fall. Four newly introduced primocane fruiting raspberry cultivars ('Erika', 'Paris', 'Versailles' and 'Satine') were evaluated for their ripening time, vegetative and generative potential (number of canes per meter of hedgerow, cane height and diameter, number of fruiting laterals per primocane, yield per primocane and per meter of hedgerow) as well as fruit quality traits (fruit weight, index of fruit shape, number of drupelets per fruit, soluble solids content - SSC, titratable acidity - TA, total and inverted sugars, and sucrose content). Investigation of vegetative and generative characteristics was carried out on samples of 30 canes in 3 replications. Each replicate consisted of 10 canes selected for their uniformity. The cane height (cm) and diameter (mm) were measured after its growth was stopped using the PVC tape and caliper, respectively. Generative characteristics were investigated by counting the number of fruiting laterals per cane and weighing the harvested fruit to determine yield per cane (g). Yield per meter of hedgerow (kg) was calculated as a product of cane number per meter of hedgerow and yield obtained per cane for each harvest date. The date of the first harvest was considered as being the beginning of ripening when approximately 8 to 10% of fruits were technologically mature, whereas the end of ripening was recorded as being the date of the last harvest. Fruit samples were collected in triplicate at the commercial maturity stage of each cultivar to investigate the physical fruit properties (fruit weight, index of fruit shape and number of drupelets per fruit). Fruit weight was determined by weighing 30 fruit (± 0.1) per replication (90 per cultivar) and expressed in grams. For drupelets counting, the same fruit samples were used within each replication. An index of fruit shape was calculated as the ratio of the maximum height and width. Each sample consisted of 30 fruits pooled to obtain a composite sample and analyzed for soluble solids content using a digital refractometer (Pocket PAL-1, Atago, Japan). Titratable acidity was measured using a digital buret and 0.1 M NaOH, to titrate samples to an endpoint of 8.1, and acidity based as percent of malic acid equivalent. Determination of total and inverted sugars was done following the Luff – Schoorl method (Egan et al., 1981), whereas sucrose was obtained as the difference between the content of total and inverted sugars multiplied by 0.95. Statistical analyses were performed using software Statistica 8.0 for Windows (StatSoft Inc., Tulsa, OK, USA). Data from a 2-year investigation were calculated by ANOVA and significant differences among the means were determined by LSD test at a level of $P \leq 0.05$.

Results and discussion

The average earliest harvest time was observed in 'Versailles' (11th of August), whereas 'Paris' was the latest cultivar (10th of September). 'Versailles' expressed three days longer harvest duration compared to data registered in 'Erika', i.e. for four days compared to 'Satine' (Table 1). The shortest harvest duration was recorded in late cultivar 'Paris' (58 days).

Table 1. Ripening season of newly introduced primocane fruiting raspberry cultivars during 2015-2016

Cultivar	Beginning	End	Duration (days)
Erika	August 17	November 7	82
Paris	September 10	November 7	58
Versailles	August 11	November 4	85
Satine	August 15	November 4	81

Primocane growth was significantly affected by cultivar in our study, whereby primocanes of 'Versailles' and 'Satine' were shorter at the end of the season than those of 'Erika' and 'Paris' (Table 2). Cultivars with shorter canes also produced significantly lower number of canes per meter of hedgerow, while no significant differences in cane diameter among the tested cultivars were observed. Carew et al. (2000) reported that short canes produced larger berries and a higher yield. Interestingly, no effect in number of the fruiting nodes was found in their studies suggesting that the short canes were able to produce the same and even more number of fruiting laterals as the tall canes. In our study, 'Erika' had the highest primocane height with the lowest number of fruiting

laterals (213 cm and 7.47/cane, respectively), while ‘Versailles’ with significantly shorter canes produced much higher fruiting laterals (152 cm and 10.78/cane, respectively). Sønsteby and Heide (2009) reported that rate of growth in primocane-fruiting red raspberry was increased with temperature, but also cultivar and primocane management treatment may have a significant effect.

Table 2. Vegetative potential of newly introduced primocane fruiting raspberry cultivars

Cultivar	Number of canes per meter of hedgerow	Cane height (cm)	Cane diameter (mm)
Erika	6.17±0.20b	213±13.6a	0.99±0.04
Paris	6.10±0.21b	204±10.2a	1.12±0.04
Versailles	7.57±0.07a	152±13.7b	1.06±0.03
Satine	6.97±0.27a	159±12.1b	1.11±0.03
<i>P</i>	***	**	ns

Data are the means of 3 replications ± standard errors. Different letters in column denote significant differences (LSD test, $P \leq 0.05$). Statistically significant differences at ** $P \leq 0.01$, *** $P \leq 0.001$; ns=not significant.

Yield is a complex trait and also depends on cultural practices, environmental conditions and resistance to pest and diseases (Graham et al., 2007). This comparative study indicates that a wide variability in yield components occurs among the tested primocane fruiting raspberry cultivars (Table 3). The highest number of fruiting laterals per cane and consequently the highest yield were registered in ‘Paris’ (12.07/cane and 840 g/cane, respectively), whereby ‘Erika’ was the least productive cultivar (561 g/cane and 3.46 kg per meter of hedgerow). The yield per primocane obtained in our experiment was generally greater than that previously reported by Milivojević et al. (2011a), who found 2- to 4-fold lower values for eight primocane fruiting raspberry cultivars grown in Belgrade region (Serbia).

Table 3. Generative characteristics of newly introduced primocane fruiting raspberry cultivars

Cultivar	Number of fruiting laterals per primocane	Yield per primocane (g)	Yield per meter of hedgerow (kg)
Erika	7.47±0.73b	561±13.0c	3.46±0.12c
Paris	12.07±0.60a	840±22.1a	5.13±0.27b
Versailles	10.78±0.15a	805±32.1a	6.09±0.22a
Satine	11.57±0.52a	681±22.8b	4.73±0.14b
<i>P</i>	***	***	***

Data are the means of 3 replications ± standard errors. Different letters in column denote significant differences (LSD test, $P \leq 0.05$). Statistically significant differences at *** $P \leq 0.001$.

Large differences were also found among cultivars in terms of fruit quality characteristics (Table 4). Average fruit weight varied from 3.69 g (‘Erika’) to 4.93 g (‘Versailles’). Since fruit size has been discussed as one of the main components of yield, large size is preferred for the fresh market and improves hand-harvest efficiency.

Table 4. Physical fruit properties of newly introduced primocane fruiting raspberry cultivars

Cultivar	Fruit weight (g)	Index of fruit shape	Number of drupelets per fruit
Erika	3.69±0.03c	1.10±0.04a	90.0±3.76
Paris	4.49±0.13b	0.91±0.01b	97.3±3.26
Versailles	4.93±0.14a	1.05±0.02a	99.8±2.52
Satine	3.32±0.08d	0.85±0.02b	88.6±1.33
<i>P</i>	***	***	ns

Data are the means of 3 replications ± standard errors. Different letters in column denote significant differences (LSD test, $P \leq 0.05$). Statistically significant differences at *** $P \leq 0.001$; ns=not significant.

Raspberry cv. 'Versailles' grown in a soilless system under a polyethylene 'umbrellas' in Switzerland gave higher average fruit weight of 6.16 g, but yield per plant was slightly lower than those obtained in our study (Andrianjaka-Camps et al., 2016). Great variability in the fruit weight of five tested primocane fruiting cultivars affected by the harvest date was also found by Milivojević et al. (2011b), i.e. significantly higher values were recorded in fruits of summer harvest than in autumn harvest. In our study, 'Erika' expressed the highest index of fruit shape (1.10), followed by 'Versailles' (1.05) corresponding to long conical fruit shape. 'Paris' and 'Satine' with lower values of fruit shape index than 1.00 mostly had broad conical and round forms. Without regard to differences in the fruit size, no significant differences were observed in number of drupelets per fruit among the tested cultivars. The obtained results of chemical fruit composition (Table 5) indicated that 'Versailles' yielded the lowest amounts of soluble solids, total and inverted sugars (10.9%, 8.18% and 6.94%, respectively). Probably, larger crop load of this cultivar had a negative effect on the sugar content. Beside crop load, weather conditions also may play a crucial role in the amount of primary metabolites in raspberry fruit (Milivojević et al., 2013). Conversely, the highest contents of soluble solids, total and inverted sugars, as well as sucrose were recorded in the late ripened cultivar 'Paris' (13.7%, 10.37%, 9.05% and 1.25%, respectively).

Table 5. Chemical fruit properties of newly introduced primocane fruiting raspberry cultivars

Cultivar	Soluble solids content (%)	Total acids (%)	Total sugars (%)	Inverted sugars (%)	Sucrose (%)
Erika	12.4±0.52b	1.92±0.06b	9.50±0.53ab	8.41±0.47ab	1.04±0.05c
Paris	13.7±0.30a	1.88±0.04b	10.37±0.31a	9.05±0.30a	1.25±0.01a
Versailles	10.9±0.18c	1.72±0.08b	8.18±0.22c	6.94±0.21c	1.18±0.01ab
Satine	13.0±0.30ab	2.18±0.07a	9.09±0.06bc	7.90±0.05bc	1.13±0.01bc
<i>P</i>	**	**	**	**	**

Data are the means of 3 replications ± standard errors. Different letters in column denote significant differences (LSD test, $P \leq 0.05$). Statistically significant differences at ** $P \leq 0.01$.

Results from this study are comparable with the published data by Milivojević et al. (2011a) who evaluate the other eight primocane fruiting raspberry cultivars grown in Serbia. Since fruit taste depends not only on the total sugars, but also on organic acids content, their composition may reflect changes in fruit quality. This trait is generally desirable for both fresh and processed fruit, but without a proper balance of acids, a fruit may be perceived as bland and lacking fullness of flavor for fresh consumption. According to Milivojević et al. (2013), raspberries showed citric acid quantities three times higher than malic acid, which could present valuable information for the consumers. Among the tested cultivars in our study, the lowest sized fruit of cultivar 'Satine' had significantly higher total acids content (2.18%) compared to the rest cultivars.

Conclusions

These findings could meet the preference of demanding consumers for fresh raspberries out-of-season. Moreover, farmers who are focused on nearby and niche markets could have interest in these new cultivars to promote their further spreading in commercial raspberry production. All cultivars evaluated herein were acceptable based on their agronomic properties, but only the two cultivars, 'Versailles' and 'Paris', were clearly superior according to their productivity and outer or inner fruit quality. Further research on the impact of cultural practices is needed in order to provide high yields of raspberry fruit with undiminished amounts of phytochemicals, especially with an increasing trend of fresh raspberry consumption.

Acknowledgements

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