

## Generative and fruit quality characteristics of primocane fruiting red raspberry cultivars

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**Abstract:** Eight primocane fruiting red raspberry cultivars grown at the Experimental station “Radmilovac”, a collective raspberry orchard of the Faculty of Agriculture, Belgrade University, were harvested in 2008 and 2009. The cultivars evaluated were ‘Autumn Bliss’, ‘Lyulin’, ‘Polana’, ‘Polka’, ‘Himbo Top’, ‘Ruby’, ‘Rossana’, and ‘Heritage’. All cultivars were evaluated for their standard parameters of productivity (number of fruiting laterals and fruit per primocane, both yield per primocane and per meter of hedgerow) and fruit quality (fruit weight, number of drupelets per fruit, soluble solids content, and titratable acidity), and also of nutritional value (Total Antioxidant Capacity (TAC) and Total Phenolics (TPH)). The cultivars differed in terms of generative characteristics in both experimental years. In the 1st studied year, ‘Rossana’ expressed the lowest values of all generative characteristics, whereas ‘Heritage’ yielded much higher per primocane and meter of hedgerow (107.2 g and 4.0 kg, respectively). An increase of cropping potential in all studied cultivars was recorded in the 2nd year of the experiment. A similar trend was observed with fruit weight values, although large differences were also found among the cultivars. The highest number of drupelets per fruit as well as the largest fruit in 2009 (4.6 g) was found in ‘Polka’. ‘Polka’ also exhibited the highest level of soluble solids content in 2009 (14.4%), followed by ‘Rossana’ (14.2%). It was found that raspberry cultivars with the smallest fruit size (‘Rossana’ and ‘Autumn Bliss’) showed the highest nutritional value expressed through the highest TPH and TAC levels. However, some of the cultivars represented here may satisfy both producers’ demands and contribute to the improvement of consumers’ health.

**Key words:** Cultivar, fruit quality, primocane fruiting raspberries, productivity

### Introduction

Primocane fruiting raspberry cultivars possess some advantages when compared to floricanes fruiting raspberries, although their presence within the raspberry production is almost negligible in many

countries. Their importance in the season extension, easier growing technology and management practices, as well as the best prices obtained for berries produced late in the season or appearing on the local market in a place where they are not typically found, has been confirmed (Danek 2002;

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Knight 2004; Gwozdecki 2004; Nikolić et al. 2008; Milutinović et al. 2008).

Most of the produced raspberries worldwide are processed, i.e. frozen and sold within different frozen fractions (rollend, gries, block). However, there has been an increasing demand for fresh raspberries out-of-season lately, and so many producers appear to be interested in growing primocane fruiting raspberry cultivars (Milutinović et al. 2008).

The nutritional value of raspberry fruit has been widely studied (Scalzo et al. 2005; Ağaoglu and Eyduran 2006; Pantelidis et al. 2007; Kafkas et al. 2008; Milivojević 2008; Ochmian and Skupień 2008) and is demanded by consumers, especially for protection against cardiovascular disorder, cancer, and other diseases, as well as for general health benefits. These benefits can also be ascribed to the total antioxidant capacity and specific related compounds, such as phenolics, contained in raspberry fruit. A greater consumption of fresh raspberries, by spreading primocane fruiting raspberry cultivars in the production, is considered as one of the ways of increasing the intake of antioxidants.

Numerous studies were conducted to investigate various raspberry cultivars in different locations (Jennings et al. 1990; Eyduran and Ağaoglu 2006; Eyduran et al. 2007; Gercekcioglu 2008). However, there are no published articles estimating the generative potential and fruit quality characteristics of primocane fruiting raspberry cultivars. Therefore, the objective of the present study was to evaluate 8 primocane fruiting raspberry cultivars in terms of their yield components and fruit quality attributes. If nutritional components are combined with high productivity and sensorial fruit quality, these cultivars are considered to be good quality crops with a high market value. Potential differences in expressed antioxidant capacity of analyzed cultivars may be an indicator of improvement of the structure in the assortment in commercial plantings. This means that by the introduction of raspberry cultivars that possess higher nutritive and antioxidant values, besides the standardly sought for high productivity and attractive fruit appearance, it is possible to increase the fruit consumption for beneficial health purposes without decreasing the commercial effect of production.

## Materials and methods

The 8 primocane fruiting red raspberry cultivars ('Autumn Bliss', 'Lyulin', 'Polana', 'Polka', 'Himbo Top', 'Ruby', 'Rossana', and 'Heritage') were used for detailed analyses. Studies were conducted at the Experimental station "Radmilovac", a collective raspberry orchard of the Faculty of Agriculture, Belgrade University, in the period of 2008–2009. The orchard was established in 2006 in the form of a hedgerow system without trellis. Applied planting distance was 3.0 m between rows and 0.5 m within a row. Canes were simply mowed down early each spring and the crop was only born on the primocanes during the summer and fall.

Investigation of generative characteristics (number of fruiting laterals and fruit per primocane, as well as yield per primocane) was carried out on samples of 30 canes in 3 replications. Each replicate consisted of 10 canes selected for their uniformity. At commercial harvest, fruit were counted from each cane and weighed to determine yield per primocane. Since the examined period is characterized by increasing productivity of studied primocane fruiting raspberry cultivars, the results are shown in tables for each year separately.

Fruit samples were collected in triplicate at the commercial maturity stage of each cultivar to investigate the physical fruit properties (fruit weight and number of drupelets per fruit). Each sample consisted of 30 fruits pooled to obtain a composite sample and analyzed for soluble solids content (SSC) using a digital refractometer (Pocket PAL-1, Atago, Japan). Titratable acidity (TA) 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.

For extraction of phenolics, 5 g of fresh fruit were homogenized in 20 mL of extraction solution containing methanol/water/hydrochloric acid at a ratio of 70:30:5 by volume. The homogenate was filtered through a filter paper and the filtrates were centrifuged at 9500 rpm for 20 min. The methanol supernatant was divided into aliquots and frozen at  $-80^{\circ}\text{C}$  until analyses. Triplicate extractions were prepared for each sample analyzed.

The amount of total phenolics (TPH) in extracts was determined according to the Folin-Ciocalteu

spectrophotometric (2501 PC Shimadzu, Kyoto, Japan) procedure (Singleton and Rossi 1965) using gallic acid (GA) as a standard for the calibration curve. Samples were mixed with 0.25 N Folin-Ciocalteu reagent and after 3 min 0.2 M sodium carbonate solution was added, followed by incubation for 60 min. Results were read at 724 nm and expressed as milligrams of GA equivalent per gram of fresh weight (mg GAE g<sup>-1</sup> FW).

Determination of total antioxidant capacity (TAC) was done following the ABTS method of Arnao et al. (1999). The reaction mixture contained 2 mM ABTS (2,2-azino-bis-3-ethylbenzothiazoline-6-sulfonic acid), 15 µM hydrogen peroxide, and 0.25 µM horse radish peroxidase (HRP) in 50 mM phosphate buffer pH 7.5. The reactions were monitored at 730 nm (2501 PC Shimadzu, Kyoto, Japan) at 25 °C until a stable absorbance was obtained due to ABTS radical formation. Afterwards, different concentrations (0.1-0.8 mM) of ascorbic acid were added for a standard curve set-up. Adding of methanolic extracts of raspberry to the reaction mixture resulted in absorbance decreasing as a consequence of ABTS radical depletion. Absorbance alterations were read from standard curve and results were expressed as

milligrams of ascorbic acid equivalent per gram of fresh weight (mg asc g<sup>-1</sup> FW).

Statistical analyses were performed using software Statistica 6.0 for Windows (StatSoft Inc., Tulsa, OK, USA). Data from a 2-year investigation were calculated by ANOVA for each year separately. Significant differences among the means were determined by Tukey's comparison test at a level of P < 0.05. Regression analyses were conducted to determine the relationship between TPH and TAC. Reported correlation coefficient was significant at a level of P < 0.05.

## Results

One of the most important features determining cultivar suitability for growing is its productivity. In the 1st studied year, 'Rossana' expressed the lowest values of all generative characteristics, especially the lowest yields per primocane and per meter of hedgerow (33.3 g and 1.2 kg, respectively). 'Heritage' yielded much higher compared to the other studied cultivars except 'Lyulin' (Table 1). In 2009, 'Autumn Bliss' exhibited the worst generative characteristics (Table 2), whereas the highest yields per primocane

Table 1. Generative characteristics of primocane fruiting red raspberry cultivars in 2008.

Cultivar	Number of fruiting laterals per primocane	Fruit number per primocane	Yield per primocane (g)	Yield per meter of hedgerow (kg)
Autumn Bliss	10.3 ± 2.47 a	39.1 ± 3.09 ab	47.5 ± 1.70 d	1.6 ± 0.25 cd
Lyulin	11.2 ± 2.08 a	42.5 ± 3.91 a	105.0 ± 2.89 a	3.9 ± 0.82 a
Polana	13.2 ± 1.89 a	45.8 ± 3.56 a	59.4 ± 2.61 cd	2.0 ± 0.37 bcd
Polka	12.7 ± 1.76 a	52.2 ± 8.47 a	91.0 ± 12.01 ab	2.9 ± 0.64 abc
Himbo Top	8.8 ± 0.76 a	44.3 ± 11.85 a	83.8 ± 24.42 abc	3.3 ± 0.08 ab
Ruby	9.5 ± 1.00 a	42.8 ± 1.89 a	61.5 ± 6.38 bcd	2.2 ± 0.25 bcd
Rossana	3.7 ± 0.76 b	25.3 ± 2.84 b	33.3 ± 5.01 d	1.2 ± 0.28 d
Heritage	9.8 ± 1.44 a	50.0 ± 4.58 a	107.2 ± 8.51 a	4.0 ± 0.91 a

\* Data are the means of 3 replications ± standard deviation. Values within column followed by the same letter are not significantly different at P = 0.05 (Tukey honest significant difference test).

Table 2. Generative characteristics of primocane fruiting red raspberry cultivars in 2009.

Cultivar	Number of fruiting laterals per primocane	Fruit number per primocane	Yield per primocane (g)	Yield per meter of hedgerow (kg)
Autumn Bliss	15.0 ± 2.31 b	47.1 ± 12.51 b	88.9 ± 16.63 c	2.51 ± 0.65 d
Lyulin	19.0 ± 3.46 ab	62.7 ± 17.74 ab	182.0 ± 47.21 bc	5.5 ± 1.50 cd
Polana	18.9 ± 2.71 ab	57.7 ± 8.40 ab	183.2 ± 30.28 b	4.6 ± 0.55 cd
Polka	17.6 ± 4.12 ab	73.2 ± 4.51 ab	336.1 ± 33.96 a	14.8 ± 2.65 a
Himbo Top	16.3 ± 2.22 ab	61.9 ± 13.52 ab	245.1 ± 52.96 ab	12.1 ± 3.14 ab
Ruby	21.6 ± 1.03 ab	64.2 ± 9.40 ab	205.4 ± 34.31 b	6.23 ± 1.66 cd
Rossana	18.1 ± 0.19 ab	72.8 ± 2.92 ab	196.5 ± 13.39 b	8.67 ± 1.17 bc
Heritage	22.7 ± 1.00 a	85.6 ± 4.69 a	265.1 ± 11.69 ab	13.23 ± 0.13ab

\* Data are the means of 3 replications ± standard deviation. Values within column followed by the same letter are not significantly different at P = 0.05 (Tukey honest significant difference test).

and per meter of hedgerow were recorded in 'Polka' (336.1 g and 14.8 kg, respectively).

Large differences were also found among cultivars in terms of fruit quality characteristics in both investigated years. 'Autumn Bliss' had the lowest values of all fruit quality parameters in 2008 (Table 3) and similar traits were observed in 2009 (Table

4). Conversely, 'Polka' expressed the highest number of drupelets per fruit ranging from 101.9 in 2008 to 111.4 in 2009, as well as the largest fruit in 2009 (4.6 g).

Great variability existed among the examined cultivars regarding their SSC in 2008 with the highest value observed in 'Rossana' (19.4%), whereas no

Table 3. Fruit quality characteristics of primocane fruiting red raspberry cultivars in 2008.

Cultivar	Fruit weight (g)	No. of drupelets per fruit	Soluble solids content (%)	Titrateable acidity (%)
Autumn Bliss	1.2 ± 0.07 e	30.9 ± 1.62 e	10.2 ± 0.31 e	0.80 ± 0.04 c
Lyulin	2.5 ± 0.16 a	49.7 ± 0.58 d	11.8 ± 0.36 d	1.10 ± 0.06 a
Polana	1.3 ± 0.09 e	71.2 ± 1.51 b	11.1 ± 0.51 de	0.94 ± 0.04 b
Polka	1.8 ± 0.05 cd	101.9 ± 4.23 a	14.0 ± 0.47 b	0.80 ± 0.05 c
Himbo Top	1.9 ± 0.05 bc	50.1 ± 2.23 d	13.5 ± 0.50 b	0.99 ± 0.05 ab
Ruby	1.4 ± 0.17 de	54.7 ± 4.70 cd	13.1 ± 0.42 bc	1.00 ± 0.07 ab
Rossana	1.3 ± 0.05 e	56.1 ± 1.62 cd	19.4 ± 0.49 a	0.94 ± 0.05 b
Heritage	2.2 ± 0.17 b	58.1 ± 1.03 c	12.2 ± 0.40 cd	0.91 ± 0.05 bc

\* Data are the means of 3 replications ± standard deviation. Values within column followed by the same letter are not significantly different at P = 0.05 (Tukey honest significant difference test).

Table 4. Fruit quality characteristics of primocane fruiting red raspberry cultivars in 2009.

Cultivar	Fruit weight (g)	No. of drupelets per fruit	Soluble solids content (%)	Titrateable acidity (%)
Autumn Bliss	1.9 ± 0.24 d	40.6 ± 4.73 d	9.5 ± 0.50 c	1.07 ± 0.06 a
Lyulin	2.9 ± 0.15 c	110.4 ± 7.31 ab	10.7 ± 0.42 c	0.94 ± 0.05 abc
Polana	3.2 ± 0.19 c	99.3 ± 3.70 b	9.7 ± 0.21 c	0.80 ± 0.05 de
Polka	4.6 ± 0.18 a	111.4 ± 2.08 a	14.4 ± 0.46 a	0.82 ± 0.06 cde
Himbo Top	4.0 ± 0.13 b	99.1 ± 1.72 b	10.0 ± 0.32 c	0.96 ± 0.05 ab
Ruby	3.2 ± 0.13 c	107.5 ± 3.22 ab	12.3 ± 0.27 b	0.80 ± 0.03 de
Rossana	2.7 ± 0.08 c	71.2 ± 4.29 c	14.2 ± 0.89 a	0.91 ± 0.03 bcd
Heritage	3.1 ± 0.26 c	102.1 ± 2.31 ab	13.2 ± 0.36 ab	0.75 ± 0.04 e

\* Data are the means of 3 replications ± standard deviation. Values within column followed by the same letter are not significantly different at P = 0.05 (Tukey honest significant difference test).

statistically significant differences were recorded in most of the studied cultivars in 2009. 'Polka' exhibited the highest level of SSC in 2009 (14.4%), followed by 'Rossana' (14.2%). The lowest SSC was obtained in 'Autumn Bliss', with somewhat higher levels being achieved in 2008 (10.2%), accompanied by smallest fruit size.

Titrateable acidity values in raspberry cultivars were different between the 2 years of the investigation and most studied cultivars were characterized by lower values in 2009, similar to those obtained for SSC (Table 4). Relatively low and close TA values in both studied years were recorded in 'Polka', whereas

the highest levels of acidity observed in 'Lyulin' in 2008 (1.10%) and 'Autumn Bliss' in 2009 (1.07%).

Regarding the nutritional value of primocane fruiting red raspberry cultivars, only a few of them differed in their higher total phenolic content and total antioxidant capacity (Figure 1).

'Rossana' and 'Autumn Bliss' displayed higher values of TPH in comparison to other cultivars, and consequently the highest levels of TAC were recorded in the mentioned cultivars (5.08 mg asc g<sup>-1</sup> FW and 3.59 mg asc g<sup>-1</sup> FW, respectively). 'Lyulin' was characterized by the lowest average values of TPH and TAC (2.34 mg GA g<sup>-1</sup> FW and 2.41 mg asc

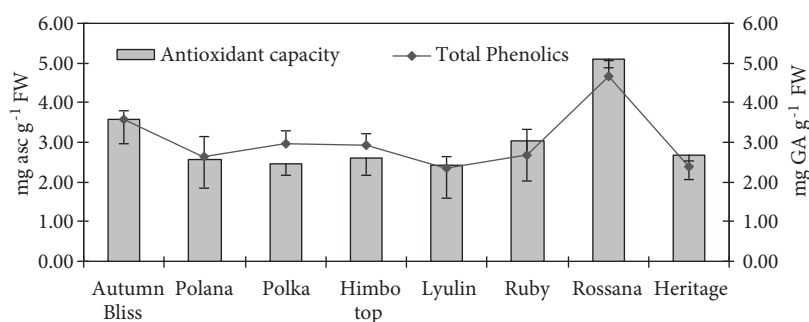


Figure. Survey of antioxidant capacity (TAC) and total phenolic content (TPH) in fruit of primocane fruiting red raspberry cultivars. Data represent average values for studied period (2008-2009). FW is fresh weight.

$\text{g}^{-1}$  FW, respectively). Generally, a significant linear correlation existed between TPH and TAC in the studied cultivars (correlation coefficient  $r = 0.87$ ).

## Discussion

This comparative study indicates that a wide variability in productivity and fruit quality occurs among primocane fruiting raspberry cultivars. 'Heritage' yielded much better compared to the other studied cultivars in 2008, whereas in 2009 slightly lower yields per primocane and per meter of hedgerow were recorded in this cultivar in comparison to 'Polka'. The yield per primocane observed in our experiments was generally greater than that reported by Eyduran et al. (2008), who found 2- to 4-fold lower values for 'Heritage' grown in Turkey. An increase of cropping potential observed in the 2nd year of the investigation was expected, taking into account that the primocane fruiting raspberry cultivars were in the period of initial yielding.

A similar trend was observed with fruit weight values, which were much lower in 2008 than those obtained in the 2nd year of investigation. 'Polka' exhibited the highest number of drupelets per fruit in both years tested, as well as the largest fruit in 2009. These results are similar to those reported by Danek (2002). The lowest fruit weight recorded in 'Autumn Bliss' is almost 2-fold lower compared to that which was reported by Bononi et al. (2006). However, Eyduran and Aġaoġlu (2006) found lower values of fruit weight for 'Heritage' grown in Turkey, when compared to our results. Environmental factors (light, temperature, and rainfall) and agronomy practice may have contributed to the differences in physical fruit characteristics between the various studies.

The evaluation of raspberry fruit nutritional quality represents an important task to better identify the commercial exploitation of primocane fruiting raspberry cultivars. This study demonstrates that a high variation of chemical fruit composition exist among cultivars tested. The lowest SSC in both studied years were obtained in 'Autumn Bliss'. Moore et al. (2008) found slightly higher SSC in 'Autumn Bliss' grown in the USA, which can be explained by environmental effect of different growing areas as seen with physical fruit properties. In contrast,

'Polka' was the richest in SSC achieving the highest level in 2009. As noted before (Milutinović et al. 2008), 'Polka' is also known for its harmonious SSC/TA ratio, confirming relatively low and close TA values recorded in both studied years.

Raspberry fruit is well known for its food and flavor qualities, but it is less known for its content of nutraceuticals such as polyphenols (Benvenuti et al. 2004). It is difficult to estimate the concentrations of phenolic compounds in raspberry. There is no method that only detects the phenolics; however, the Folin-Ciocalteu method is probably the best method so far devised to estimate TPH in plant extracts. This method has limited interference from other plant components such as sugars and amino acids, and has been used widely in estimating total phenolic content.

Our results showed that an average content of TPH for 8 primocane fruiting raspberry cultivars ranged from 2.34 to 4.66 mg GA  $\text{g}^{-1}$  FW. Two cultivars ('Rossana' and 'Autumn Bliss') were found to be higher in TPH than the other cultivars tested. Moore et al. (2008) evaluated the content of TPH in 10 raspberry cultivars, and they found an average amount of 3.04 mg GA  $\text{g}^{-1}$  FW in 'Autumn Bliss', which is slightly lower than our result obtained for this cultivar. In general, the amount of TPH is within the range of the values reported by Wang and Lin (2000) and Weber and Liu (2002). It was observed that the highest yielding cultivar 'Heritage' exhibited TPH values similar to those obtained in Italy (Plessi et al. 2007), but these are 2-fold lower compared to the values recorded in 'Heritage' grown in the USA (Weber and Liu 2002).

The average values of TAC varied greatly among the cultivars used in this study and expressed a similar trend to those of TPH. These data underline the importance of phenolic compounds in expressed antioxidant capacity, as reported by Halvorsen et al. (2002), Proteggente et al. (2002), and Scalzo et al. (2005). Furthermore, accumulating evidence exists, suggesting that genotype may have a profound influence on the content of bioactive compounds in berries (Anttonen and Karjalainen 2005). Unfortunately, quality of the fruit is often associated with negative agronomic traits and, in this study (data not shown), a negative correlation was found

between fruit size and most of the nutritional quality parameters. In particular, raspberry cultivars with the smallest fruit size ('Rossana' and 'Autumn Bliss') showed the highest nutritional value expressed through high TPH and TAC levels. Similar results have been reported by Remberg (2006), who found a negative correlation between fruit weight and its antioxidant capacity in other berries.

The present study indicates that 'Polka', 'Heritage', and 'Rossana' demonstrated the best results based on their generative characteristics and nutritional fruit quality. These cultivars may satisfy producers'

demands and contribute to the improvement of consumers' health in accordance with high levels of TPH and TAC recorded in their fruit. Besides these, 'Autumn Bliss' also occupies a high position in the group of studied raspberry cultivars and could be considered a good and natural source of antioxidants.

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