

Changes in various secondary metabolites by crossing modern rose cultivars

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ABSTRACT

The aim of the study was to determine the content and composition of phenolic compounds in autochthonous rose hips (*R. pendulina*, *R. spinosissima* and *R. gallica*) and to compare them with the content of phenolic compounds in their cultivars ('Harstad', 'Bourgogne', 'Mount Everest', 'Poppius', 'Frühlingsduft', 'Single Cherry', 'Frühlingsmorgen', 'Violacea' and 'Splendens') collected in Arboretum Volčji Potok in Slovenia. The total content of phenolic compounds in the flesh with skin was lowest in 'Mount Everest' ($3603.57 \text{ mg} \cdot \text{kg}^{-1} \text{ f.w.}$), which is derived from *R. pendulina*, and highest in 'Splendens' ($68789.39 \text{ mg} \cdot \text{g}^{-1} \text{ f.w.}$), which is derived from *R. gallica*. In seeds, the phenolic compound content was lower, as expected, ranging from $757.02 \text{ mg} \cdot \text{kg}^{-1} \text{ f.w.}$ ('Mount Everest') to $6823.21 \text{ mg} \cdot \text{kg}^{-1} \text{ f.w.}$ ('Single Cherry'). It can be concluded that the cultivars differ significantly from each other due to the content of different bioactive compounds. Based on the obtained results, we cannot determine to which basic rose plant the cultivar belongs based only on the content of one analysed compound. The contents were very different because only one parent plant is known for a given cultivar and breeding programmes in roses were very narrowly focussed on specific targets.

Keywords: extraction, HPLC, hybrids, phenolic compounds, *Rosa gallica*, *Rosa pendulina*, *Rosa spinosissima*

INTRODUCTION

Phenolic compounds are aromatic compounds of the benzene ring that make up a significant portion of plant secondary metabolites. They are extremely diverse and are classified according to the number of carbons. Structural diversity determines their functional properties and distribution in different plant species. In plants, they play a key role in physiological and mechanical activities. Plants produce them primarily for their growth, development and protection against pathogens, including fungi, viruses and bacteria, and as a defence mechanism against major abiotic stresses such as salinity, drought and UV radiation. Plants respond to these stressful abiotic and biotic conditions by accumulating phenolic compounds. Their accumulation

depends on the type of stress and the response of the plant species. In addition to defence mechanisms, they play an important role in the interaction between the plant itself and microbes (Bhattacharya et al., 2010; Dai and Mumper, 2010; Kumar et al., 2020; Chowdhary et al., 2021; Pratyusha, 2022). The main group of natural pigments classified as phenolic compounds responsible for the colours of flowers, fruits and leaves is anthocyanins. Abiotic and biotic stress conditions where changes in the total anthocyanin content were observed were heat, light, water, salt, insect and fungal attack (Mannino et al., 2021).

The main bioactive compounds of roses are phenolic acids (protocatechuic acid, gallic acid, methyl

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gallate, vanillic acid, syringic acid, chlorogenic acid, cichoric acid), anthocyanins (cyanidin-3-*O*-glucoside), tannins, including proanthocyanidins (condensed tannins), flavonoids (flavones (apigenin), flavonols (rutin, catechin, quercetin, quercitrin)), flavanones (hesperidin, eriodictyol, taxifolin), dihydrochalcones (phloridzin), phytosterols (β -sitosterol), pentacyclic triterpenes (ursolic acid and oleanolic acid), organic acids (ascorbic acid, malic acid, citric acid), fatty oils (α -linolenic acid, linoleic acid, palmitic acid), pectins, carotenoids (lycopene, β -carotene), tocopherols and galactolipids (Deliorman Orhan et al., 2012; Dubtsova et al., 2012; Mihaylova et al., 2015; Nadpal et al., 2016). Roses are considered excellent antioxidants due to the antioxidant properties of the listed components, which inhibit or prevent the oxidation of oxidative substances by scavenging free radicals and reducing oxidative stress. Oxidative stress is an imbalanced state in which excessive amounts of reactive oxygen and/or nitrogen species overcome endogenous antioxidant capacity, resulting in the oxidation of various biomacromolecules, such as enzymes, proteins, DNA and lipids (Dai and Mumper, 2010). It is associated with many diseases such as cardiovascular disease, diabetes, obesity and cancer. Some studies could show that foods classified as antioxidants at least partially alleviate diseases associated with oxidative stress (Arts and Hollman, 2005). Cohen (2012) reported that roses have antioxidant, anti-inflammatory, antidiabetic, lipid-lowering and antiobesogenic effects. They have beneficial effects on osteoarthritis, rheumatoid arthritis and back pain. Because of these beneficial effects, foods rich in polyphenolics are increasingly valued and in demand, according to Dai and Mumper (2010). Plant foods are reported to have organoleptic properties (bitterness, astringency), and it is also reported that phenolic compounds are even better antioxidants than vitamins C and E and carotenoids (Dai and Mumper, 2010).

Kunc et al. (2022, 2023b) reported that various roses native to Slovenia, *R. pendulina* L. $\times$ *R. glauca*, *R. corymbifera*, *R. gallica* and *R. subcanina*, as well as the hybrid *R. pendulina* L. $\times$ *R. spinosissima* L., could be a rich source of various secondary metabolites. They found that the content of phenolic compounds was higher in the flesh with skin than in the seeds. The content of cyanidin-3-glucoside was higher in the studied hybrid. Demir et al. (2014) studied the phenolic compounds of five Turkish rose hips (*R. canina*, *R. dumalis*, *R. gallica*, *R. dumalis* subsp. *boissieri* and *R. hirtissima*). They found that *R. dumalis* subsp. *boissieri* contained the most diverse phenolic compounds. *R. canina* is an intensively studied species. Javanmard et al. (2018) found that the different ecotypes of *R. canina* are a rich source of phenolic compounds. Of all the ecotypes studied, the Aghcheh ecotype was the richest in phenolics. Cunja et al. (2015) added that the phenolic compound content was highest in *R. canina* rose hips harvested in late September. Kunc et al. (2023b) found that the content of

phenolics in the flesh with skin was highest in *R. gallica* (as well as the content of cyanidin-3-glucoside) and lowest in the hips of *R. corymbifera*. In seeds, the highest content was in *R. subcanina* and the lowest in *R. \times R. glauca*. The lowest content of cyanidin-3-glucoside was found in *R. subcanina*. Koczka et al. (2018) focussed on studying the phenolic composition and content of *R. canina*, *R. gallica*, *R. rugosa* and *R. spinosissima*, with *R. spinosissima* having the highest content.

To date, very little is known about the effects of hybridisation on the secondary metabolite content. We know that there are approx. 100 cultivars derived from *R. centifolia*, 500 from *R. spinosissima* and >200 from *R. gallica*. The current study will enable a clearer overview of how hybridisation affects the composition and the content of phenolic compounds, which has been very poorly studied until now. The study was based on different original species and several older and modern varieties originating from these species. All original species are also very common in Slovenia. We were interested in how the content of phenolic compounds changes during crossing. We checked whether related varieties derived from the same original species can be assigned to the same chemotype based on the phenolic compound content. Due to the increasing importance of foods with a high content of phenolic compounds, we will additionally try to determine whether the examined rose hips are a rich source of phenolic compounds.

MATERIALS AND METHODS

Plant material

The Rose hips of *R. pendulina*, *R. spinosissima*, *R. gallica* and their cultivars 'Harstad' (deriving from *R. pendulina*), 'Bourgogne' (deriving from *R. pendulina*), 'Mount Everest' (deriving from *R. pendulina*), 'Poppius' (deriving from *R. spinosissima*), 'Frühlingsduft' (deriving from *R. spinosissima*), 'Single Cherry' (deriving from *R. spinosissima*), 'Frühlingsmorgen' (deriving from *R. spinosissima*), 'Violacea' (deriving from *R. gallica*), and 'Splendens' (deriving from *R. gallica*) were collected at the BBCH 88 stage (Meier et al., 2008) in Arboretum Volčji Potok (Slovenia), which was chosen as the research area because it has the largest collection of roses. Arboretum Volčji Potok is a maintenance park located in the Central Slovenian region, approximately 20 km from the capital of Slovenia, Ljubljana. It is located at an altitude of 304 m. The climate is continental, bordering on a subtropical humid climate ('CFA' according to the Köppen climate classification). The region was characterised by warm summers and moderately cold winters. July and August are the warmest months with daily highs usually between 25°C and 30°C, while January is the coldest month with temperatures mostly hovering around 0°C. Precipitation is relatively evenly distributed between the seasons, although winter and spring tend to be slightly drier than summer and autumn. Snow is typical

between December and February (World Maps, 2024). All 12 plants were grown under the same conditions, so we can exclude the influence of environment and cultivation on the number and content of compounds studied. The cultivars 'Violacea', 'Splendens', 'Harstad' and 'Poppius' belong to the old cultivars. The rest of the studied cultivars are modern, having been crossed after 1876 (Table 1). The collected samples were stored at -20°C until the analysis of phenolic compounds.

Rose hip colour analysis

The scale used for fruit colour analysis was established by the Commission Internationale de L'Eclairage. It measures colour in relation to the standard observer and the standard illuminant. Each given colour is located as a point in a three-dimensional space. Skin colour was represented by the coordinates a^* , b^* and L^* ; chroma (C^*); and hue angle (h°). The brightness coefficient L^* ranges from black (0) to white (100), and the coordinates a^* and b^* localise the colour on a rectangular coordinate grid perpendicular to the L^* axis. On the horizontal axis, positive values of the colour parameter a^* indicate red-violet hues and negative a^* values indicate bluish greens. On the vertical axis, a positive b^* indicates yellow colour and a negative b^* indicates blue colour. Hue angle and chroma are measures derived from a^* and b^* and correspond to the basic hue of the fruit colour and the saturation or vividness of the colour (Lancaster et al., 1997).

Extraction and analysis of phenolic compounds

The extraction of rose hips was performed separately for flesh with skin and seeds according to the extraction method described by Kunc et al. (2022). Analyses were performed in triplicate. The material was crushed with a mortar with liquid nitrogen, a measured weight of the sample was placed in a centrifuge tube, and the extraction solution (3% formic acid in methanol with double-distilled water 70/30) was added. The weight of the flesh with skin was 0.5 g and 0.2 g of the seeds. The volume of the extraction solution was 2.5 mL for the flesh with skin and 1 mL for the seeds.

Extraction was then performed using a chilled ultrasonic bath (SONIS 4 GT. Iskra PIO d.o.o., Šentjernej,

Slovenia) on ice for 1 hr, after which the extract was centrifuged at 10000× g for 7 min at 4°C using the Eppendorf Centrifuge 5810 Hamburg, Germany. The supernatant was filtered through a 0.20- μ m polyamide/nylon filter (Macherey–Nagel, Düren, Germany). The vials containing the extracts were stored at -20°C until further analysis of the phenolic compounds.

The analysis of phenolic compounds was performed using a Thermo Scientific Dionex HPLC system with a diode array detector (Thermo Scientific, San Jose, CA, USA) connected to Chromeleon workstation software. The chromatographic method for phenolic analysis was previously described by Mikulic-Petkovsek et al. (2016). The detector was set to three wavelengths (280 nm, 350 nm and 530 nm). The mobile phases were A: 3% acetonitrile/0.1% formic acid/96.9% double-distilled water and B: 3% water/0.1% formic acid/96.9% acetonitrile. Gradient elution of the two mobile phases was described in Mikulic-Petkovsek et al. (2020), and the mobile phase flow was 0.6 mL · min⁻¹. The column used was a Gemini C18 (150 mm × 4.6 mm 3 μ m; Phenomenex, Torrance, CA, USA) heated to 25°C.

Phenolic compounds were identified using a mass spectrometer (LTQ XL Linear Ion Trap Mass Spectrometer, Thermo Fisher Scientific, Waltham, MA, USA) with electrospray ionisation (ESI) in the positive (anthocyanins) or negative (all other phenolics) ionisation mode. All mass spectrometer conditions were set as described by Mikulic-Petkovsek et al. (2020). Spectral data were analysed using Excalibur software (Thermo Scientific). The identification of compounds was confirmed by comparison of their retention times and spectra, addition of the standard solution to the sample and fragmentation and comparison with literature data.

The content of phenolic compounds was calculated from the peak areas of the samples and the corresponding standards. The contents were expressed in mg · kg⁻¹ fresh weight (f.w.) (Kunc et al., 2022).

Statistical analysis

Data were collected using Microsoft Excel 2016 and statistically processed using the R Commander program,

Table 1. Origin data for cultivars used in this study.

Cultivar	Species of the origin	Breeding company	Year of origin
'Violacea'	<i>R. gallica</i>	Unknown (The Netherlands)	1795
'Splendens'	<i>R. gallica</i>	Unknown	1583
'Poppius'	<i>R. spinosissima</i>	Stenberg (Sweden)	1872
'Frühlingsduft'	<i>R. spinosissima</i>	Kordes (Germany)	1941
'Frühlingsmorgen'	<i>R. spinosissima</i>	Kordes (Germany)	1941
'Single Cherry'	<i>R. spinosissima</i>	Unknown	1962
'Harstad'	<i>R. pendulina</i>	Unknown	Unknown (old variety)
'Mount Everest'	<i>R. pendulina</i>	Interplant (The Netherlands)	1956
'Bourgogne'	<i>R. pendulina</i>	Interplant (The Netherlands)	1983

Ri3864.1.2 using one-way analysis of variance (ANOVA). When ANOVA indicated a significant difference between values, Tukey's test was used. Results were expressed as mean $\pm$ standard error (SE) of fresh weight (f.w.). In cases where p -values were <0.05 , the differences between the two genotypes were statistically significant. Results were presented in tables and graphs. Cluster dendrograms using Ward's classification method were used to present the results, comparing the total content of phenolic compounds in all analysed samples.

RESULTS

Colour analysis of hips

Table 2 shows the measured colour parameters of the examined rose hips. The rose hips of *R. pendulina* had higher L^* than their cultivars. L^* of the rose hips of *R. spinosissima* was higher than that of the cultivars 'Frühlingsduft' and 'Single Cherry'. The hips of *R. gallica* had a higher value of the parameter L^* than their cultivars. At the same time, the value of the parameter L^* in the hips of *R. gallica* was the highest measured value among all samples. The lowest value of the parameter a^* was recorded in the rose hips of the cultivar 'Single Cherry', which was conspicuous for its black-purple colour (Figure 1). The cultivar 'Single Cherry' also had the lowest value of the parameters b^* and C^* due to the specific colour of its hips. The highest value of the parameter b^* was measured in *R. gallica*. The value of the parameter C^* was highest in *R. pendulina* and slightly lower in *R. gallica*. The values of the parameter h° were lowest in the hips of *R. spinosissima* and lowest in the hips of 'Single Cherry'. The parameter h° indicates the colour angle in the range from 0° to 360° colour of the fruit, where 0° is red, 90° is yellow, 180° is green and 270° is blue.

Anthocyanin content

From the anthocyanin group, only cyanidin-3-glucoside was analysed because it was the prevailing anthocyanin

compound in analysed roses. It can be seen from Table 3 that the highest anthocyanin content was measured in the rose hips of the cultivar 'Single Cherry' from the group *R. spinosissima* and the lowest in the rose hips of the cultivar 'Splendens' from the group *R. gallica*. Comparing the contents within each genotype group, it can be seen that in the *R. gallica* group, the anthocyanin content was significantly higher in the rose hips of the cultivar 'Violacea' than in *R. gallica* itself and the cultivar 'Splendens'. The cultivar 'Single Cherry', which was identified as the most anthocyanin-rich plant in terms of its rose hips, was significantly different from all other modern cultivars derived from *R. spinosissima*, as well as from *R. spinosissima* itself. The anthocyanin content in the rose hips of 'Mount Everest' was significantly different from the contents in the rose hips of three other cultivars of the *R. pendulina* group.

Other phenolic compounds

Phenolic compounds in *R. pendulina* and its cultivars

The total content of phenolic compounds (Figure 2) in the studied samples was the highest, with $10504.66 \text{ mg} \cdot \text{kg}^{-1}$ f.w. in the flesh with skin of rose hips of the cultivar 'Harstad'. The values of phenolics in the seeds varied from $757.02 \text{ mg} \cdot \text{kg}^{-1}$ f.w. ('Mount Everest') to $1711.72 \text{ mg} \cdot \text{kg}^{-1}$ f.w. ('Harstad').

Table 4 shows the variations in the content of hydroxybenzoic acid derivatives (HBA), hydroxycinnamic acid derivatives (HCA), gallotannins and ellagitannins in the rose hips of *R. pendulina* and its cultivars. The total HBA content in rose hips of the main *R. pendulina* species was not statistically different from the content in rose hips of cultivar 'Harstad'. There was also no statistically significant difference in the HBA content between cultivars 'Bourgogne', 'Harstad' and 'Mount Everest'. The HBA content in the seeds was

Table 2. Rose hips colour parameters of analysed rose hips.

Species and cultivars	L^*	a^*	b^*	C^*	h°
<i>R. pendulina</i>	$36.70 \pm 1.64 \text{ a}$	$40.98 \pm 1.22 \text{ c}$	$29.66 \pm 1.91 \text{ b}$	$50.58 \pm 2.04 \text{ c}$	$35.75 \pm 1.17 \text{ a}$
'Harstad'	$34.66 \pm 0.69 \text{ a}$	$34.08 \pm 1.08 \text{ b}$	$25.18 \pm 0.87 \text{ b}$	$42.36 \pm 1.35 \text{ b}$	$36.42 \pm 0.37 \text{ a}$
'Bourgogne'	$32.96 \pm 2.76 \text{ a}$	$29.34 \pm 1.15 \text{ ab}$	$21.38 \pm 2.31 \text{ c}$	$37.00 \pm 2.53 \text{ bc}$	$37.16 \pm 3.62 \text{ b}$
'Mount Everest'	$29.66 \pm 1.51 \text{ a}$	$27.36 \pm 1.49 \text{ a}$	$17.20 \pm 2.36 \text{ a}$	$32.42 \pm 2.54 \text{ a}$	$31.58 \pm 1.97 \text{ a}$
<i>R. spinosissima</i>	$27.89 \pm 2.56 \text{ b}$	$23.33 \pm 1.92 \text{ b}$	$14.59 \pm 1.59 \text{ b}$	$22.08 \pm 3.11 \text{ b}$	$22.14 \pm 0.99 \text{ a}$
'Poppius'	$29.38 \pm 2.11 \text{ b}$	$25.26 \pm 2.21 \text{ b}$	$16.26 \pm 3.09 \text{ b}$	$27.76 \pm 4.03 \text{ b}$	$26.04 \pm 1.99 \text{ ab}$
'Frühlingsduft'	$25.08 \pm 1.66 \text{ ab}$	$21.18 \pm 1.14 \text{ ab}$	$15.01 \pm 1.63 \text{ ab}$	$23.84 \pm 1.41 \text{ ab}$	$33.46 \pm 1.59 \text{ bc}$
'Single Cherry'	$20.28 \pm 0.72 \text{ a}$	$2.28 \pm 1.01 \text{ a}$	$3.78 \pm 0.09 \text{ a}$	$4.42 \pm 0.09 \text{ a}$	$59.18 \pm 2.45 \text{ c}$
'Frühlingsmorgen'	$28.28 \pm 0.74 \text{ b}$	$24.36 \pm 1.60 \text{ b}$	$14.28 \pm 0.42 \text{ b}$	$28.02 \pm 1.51 \text{ b}$	$31.46 \pm 1.13 \text{ ab}$
<i>R. gallica</i>	$43.38 \pm 1.77 \text{ b}$	$31.9 \pm 1.65 \text{ a}$	$36.84 \pm 1.27 \text{ b}$	$48.13 \pm 0.73 \text{ b}$	$49.18 \pm 1.79 \text{ b}$
'Violacea'	$31.96 \pm 1.66 \text{ a}$	$32.08 \pm 1.28 \text{ a}$	$21.76 \pm 2.53 \text{ a}$	$38.94 \pm 2.23 \text{ a}$	$33.68 \pm 2.54 \text{ a}$
'Splendens'	$33.78 \pm 1.13 \text{ a}$	$29.59 \pm 1.47 \text{ a}$	$24.20 \pm 1.29 \text{ a}$	$33.33 \pm 1.29 \text{ a}$	$32.90 \pm 1.99 \text{ a}$

Different letters indicate statistically significant differences within the analysed groups.



Figure 1. Rose hips of cultivar 'Single Cherry'.

Table 3. Average contents $\pm$ SE ($\text{mg} \cdot \text{kg}^{-1}$ f.w.) of cyanidin-3-glucoside in all analysed rose hips.

Species and cultivars	Cyanidin-3-glucoside
<i>R. gallica</i>	2.19 ± 0.42 a
'Violacea'	11.51 ± 3.02 b
'Splendens'	0.85 ± 0.13 a
<i>R. spinosissima</i>	20.97 ± 3.31 a
'Poppius'	20.97 ± 3.39 a
'Frühlingsduft'	77.91 ± 10.14 a
'Single Cherry'	3090.36 ± 309.12 b
'Frühlingsmorgen'	134.31 ± 18.61 a
<i>R. pendulina</i>	5.09 ± 0.65 a
'Harstad'	1.59 ± 0.22 a
'Bourgogne'	3.16 ± 1.60 a
'Mount Everest'	56.61 ± 17.38 b

Different letters indicate statistically significant differences within the analysed groups.
SE, standard error.

the highest in the samples of *R. pendulina* and lowest in the hips of 'Bourgogne', the difference was statistically different. HCA content in the flesh with skin and also in the seeds was the lowest in the hips of 'Mount Everest' and the highest in the hips of 'Harstad'. The total HCA content in the 'Harstad' seeds was statistically different from the other samples studied. Only the content of total gallotannins in the flesh with skin of 'Harstad' was statistically different from that of the other samples analysed. There was no statistically significant difference in the total seed content of gallotannins between samples. There was no statistically significant difference between the samples in the content of ellagitannins in flesh with skin and seeds.

The content of total analysed flavonols (Table 5) was the highest in the rose hips of the cultivar 'Harstad', both in the flesh with skin and in the seeds. The rose hips of the cultivar 'Mount Everest' had the lowest values of total flavonols, both in the flesh with skin and in the seeds. There was no statistically significant difference in the content of flavonols in the seeds. Among the flavones, apigenin derivatives 1 and 2 were determined. There was no statistically significant difference in the flavone content between *R. pendulina* genotypes.

Phenolic compounds in R. spinosissima and its cultivars

The content of total phenolic compounds (Figure 3) in the rose hips of *R. spinosissima* and its cultivars was the highest in the flesh with skin in the cultivar 'Single Cherry', with $51980.98 \text{ mg} \cdot \text{kg}^{-1}$ f.w. The contents in the seeds were generally lower than in the flesh with skin. They ranged from $1684.59 \text{ mg} \cdot \text{kg}^{-1}$ f.w. in the hips of the cultivar 'Frühlingsmorgen' to $6823.21 \text{ mg} \cdot \text{kg}^{-1}$ f.w. in the hips of the cultivar 'Single Cherry'.

The HBA content (Table 6) was higher in the seeds than in the hulled flesh of all samples, except for 'Frühlingsmorgen' and 'Frühlingsduft'. The total HCA content (Table 6) was higher than the HBA content

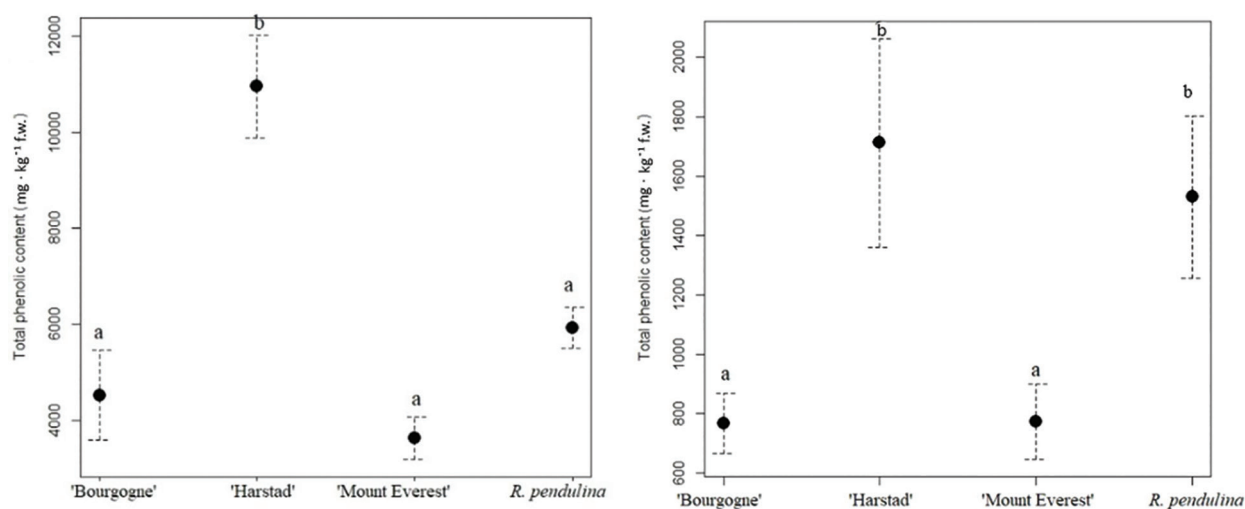


Figure 2. Total phenolic content ($\text{mg} \cdot \text{kg}^{-1}$ f.w.) of *R. pendulina* and its cultivars in flesh with skin (left) and in seeds (right). Different letters indicate statistically significant differences within the analysed groups.

Table 4. The content $\pm$ SE (mg $\cdot$ kg⁻¹ f.w.) of phenolic compounds (HBA, HCA, gallotannins and ellagitannins) in rose hips of *R. pendulina* and its cultivars 'Bourgogne', 'Harstad' and 'Mount Everest'.

Phenolic group	Compound		<i>R. pendulina</i>	'Bourgogne'	'Harstad'	'Mount Everest'
HBA	Gallic acid	FS	41.39 $\pm$ 1.86 b	8.69 $\pm$ 3.02 a	42.32 $\pm$ 11.85 b	14.91 $\pm$ 5.58 ab
		S	5.35 $\pm$ 2.05 b	0.95 $\pm$ 0.14 a	5.22 $\pm$ 2.54 b	2.12 $\pm$ 0.97 ab
	Galloylquinic acid	FS	1546.56 $\pm$ 295.70 b	536.17 $\pm$ 97.03 a	1276.72 $\pm$ 237.38 ab	520.65 $\pm$ 177.1 a
		S	965.58 $\pm$ 399.87 b	224.65 $\pm$ 90.54 a	926.54 $\pm$ 416.02 b	254.54 $\pm$ 88.98 a
	Ellagic acid pentoside 1	FS	0.74 $\pm$ 0.28 a	0.53 $\pm$ 0.11 a	0.95 $\pm$ 0.44 a	1.19 $\pm$ 0.44 a
		S	2.36 $\pm$ 1.65 a	2.75 $\pm$ 1.03 a	2.98 $\pm$ 0.98 a	3.41 $\pm$ 1.54 a
	Ellagic acid pentoside 2	FS	2.78 $\pm$ 1.13 a	0.84 $\pm$ 0.28 a	0.71 $\pm$ 0.08 a	1.38 $\pm$ 0.58 a
		S	3.21 $\pm$ 1.19 a	1.03 $\pm$ 0.58 a	0.78 $\pm$ 0.33 a	1.95 $\pm$ 0.65 a
	Taxifolin pentoside 1	FS	0.64 $\pm$ 0.31 a	2.37 $\pm$ 1.00 a	1.07 $\pm$ 0.46 a	4.43 $\pm$ 1.52 a
		S	-	-	-	-
	Taxifolin pentoside 2	FS	0.18 $\pm$ 0.09 a	0.01 $\pm$ 0.005 a	0.11 $\pm$ 0.04 a	0.05 $\pm$ 0.03 a
		S	-	-	-	-
	Taxifolin pentoside 3	FS	0.81 $\pm$ 0.56 a	0.003 $\pm$ 0.002 a	0.22 $\pm$ 0.12 a	0.07 $\pm$ 0.06 a
		S	-	-	-	-
	Total	FS	1593.10 $\pm$ 299.93 b	548.61 $\pm$ 101.45 a	1322.1 $\pm$ 250.37 ab	542.68 $\pm$ 185.32 a
		S	976.50 $\pm$ 404.76 b	229.38 $\pm$ 92.29 a	935.52 $\pm$ 419.87 b	262.02 $\pm$ 92.14 a
HCA	p-coumaric acid hexoside 1	FS	0.39 $\pm$ 0.30 a	0.47 $\pm$ 0.36 a	0.93 $\pm$ 1.31 b	0.54 $\pm$ 0.21 a
		S	-	-	-	-
	p-coumaric acid hexoside 2	FS	3.83 $\pm$ 0.01 a	1.83 $\pm$ 0.12 a	3.94 $\pm$ 0.07 a	1.34 $\pm$ 0.05 a
		S	0.92 $\pm$ 0.54 a	0.41 $\pm$ 0.12 a	0.87 $\pm$ 0.25 a	0.35 $\pm$ 0.18 a
	5-caffeoylquinic acid 1	FS	19.98 $\pm$ 3.94 a	23.43 $\pm$ 8.31 a	77.49 $\pm$ 12.16 b	21.73 $\pm$ 2.93 a
		S	-	-	-	-
	Sinapic acid hexoside 1	FS	5.87 $\pm$ 1.19 a	16.08 $\pm$ 6.43 a	13.89 $\pm$ 1.77 a	3.21 $\pm$ 0.78a
		S	-	-	-	-
	5-caffeoylquinic acid 2	FS	385.29 $\pm$ 9.49 a	544.57 $\pm$ 210.33 a	1530.40 $\pm$ 153.76 b	345.58 $\pm$ 62.90 a
		S	60.54 $\pm$ 22.54 a	71.02 $\pm$ 24.48 ab	96.21 $\pm$ 30.54 b	59.68 $\pm$ 19.88 a
	5-p-coumaroylquinic acid 1	FS	11.28 $\pm$ 0.89 a	5.39 $\pm$ 2.39 a	11.60 $\pm$ 3.86 a	3.96 $\pm$ 0.61 a
		S	2.41 $\pm$ 1.09 a	1.02 $\pm$ 0.35 a	2.39 $\pm$ 1.06 a	0.87 $\pm$ 0.25 a
	5-p-coumaroylquinic acid 2	FS	134.72 $\pm$ 64.05 a	51.39 $\pm$ 27.75 a	170.22 $\pm$ 20.47 a	155.41 $\pm$ 28.42 a
		S	-	-	-	-
	3-p-coumaroylquinic acid	FS	0.62 $\pm$ 0.01 a	0.87 $\pm$ 0.21 a	2.15 $\pm$ 0.48 b	0.59 $\pm$ 0.07 a
		S	0.22 $\pm$ 0.04 a	0.13 $\pm$ 0.03 a	0.24 $\pm$ 0.09 a	0.21 $\pm$ 0.07 a
	Total	FS	561.98 $\pm$ 79.88 a	644.03 $\pm$ 255.90 a	1810.62 $\pm$ 193.82 b	532.36 $\pm$ 95.97 a
		S	64.39 $\pm$ 24.21 a	72.58 $\pm$ 24.98 a	99.71 $\pm$ 31.94 b	61.11 $\pm$ 20.38 a
Gallotannins	Digalloyl hexoside 1	FS	1.83 $\pm$ 0.62 a	0.55 $\pm$ 0.13 a	1.81 $\pm$ 0.53 a	0.83 $\pm$ 0.29 a
		S	5.21 $\pm$ 1.09 b	1.32 $\pm$ 0.98 a	5.42 $\pm$ 1.09 b	2.06 $\pm$ 0.98 a
	Digalloyl hexoside 2	FS	39.45 $\pm$ 25.48 a	32.33 $\pm$ 12.25 a	33.23 $\pm$ 14.51 a	14.57 $\pm$ 5.92 a
		S	0.19 $\pm$ 0.02 a	0.21 $\pm$ 0.07 a	0.17 $\pm$ 0.04 a	0.09 $\pm$ 0.01 a
	Methyl gallate hexoside	FS	182.98 $\pm$ 62.35 a	55.22 $\pm$ 12.75 a	181.00 $\pm$ 53.07 a	82.73 $\pm$ 29.64 a
		S	22.35 $\pm$ 11.45 a	12.47 $\pm$ 2.54 a	21.98 $\pm$ 9.87 a	18.54 $\pm$ 9.42 a
	Digalloylquinic acid 1	FS	121.06 $\pm$ 4.10 a	179.34 $\pm$ 42.58a	353.12 $\pm$ 53.33 b	153.17 $\pm$ 18.24 a
		S	9.21 $\pm$ 4.87 a	9.05 $\pm$ 2.01 a	13.41 $\pm$ 5.87 a	8.96 $\pm$ 3.06 a
	Total	FS	345.32 $\pm$ 36.55 a	267.44 $\pm$ 67.71 a	569.16 $\pm$ 121.44 b	251.30 $\pm$ 82.80 a
		S	36.96 $\pm$ 17.43 a	23.05 $\pm$ 5.6 a	40.98 $\pm$ 16.87 a	29.65 $\pm$ 13.47 a
Ellagitannins	diHHDP hexoside 1	FS	164.32 $\pm$ 102.03 a	145.59 $\pm$ 72.46 a	198.98 $\pm$ 60.19 a	165.69 $\pm$ 36.38 a
		S	32.21 $\pm$ 13.36 a	32.01 $\pm$ 18.54 a	31.85 $\pm$ 16.36 a	30.58 $\pm$ 18.25 a
	diHHDP hexoside 2	FS	-	-	-	-
		S	2.15 $\pm$ 1.03 a	2.32 $\pm$ 0.98 a	2.06 $\pm$ 0.95 a	1.98 $\pm$ 0.78 a
	Digalloyl HHDP hexoside 3	FS	-	-	-	-
		S	0.75 $\pm$ 0.19 a	0.59 $\pm$ 0.14 a	0.71 $\pm$ 0.26 a	0.69 $\pm$ 0.24 a
	HHDP digalloyl hexoside isomer 1	FS	311.37 $\pm$ 24.49 a	149.01 $\pm$ 66.03 a	320.38 $\pm$ 106.58 a	109.35 $\pm$ 16.93 a
		S	2.21 $\pm$ 0.95 a	1.15 $\pm$ 0.98 a	2.34 $\pm$ 1.09 a	0.98 $\pm$ 0.36 a

(Continued)

Table 4. Continued.

Phenolic group	Compound		<i>R. pendulina</i>	'Bourgogne'	'Harstad'	'Mount Everest'
	HHDP digalloyl hexoside isomer 2	FS	19.68 ± 0.48 a	27.82 ± 10.74 a	78.17 ± 7.85 b	17.65 ± 3.21 a
		S	3.54 ± 1.09 a	3.88 ± 1.06 a	5.98 ± 2.44 a	3.65 ± 1.98 a
	HHDP digalloyl hexoside isomer 3	FS	-	-	-	-
		S	0.39 ± 0.11 a	0.52 ± 0.12 a	0.63 ± 0.26 a	0.38 ± 0.14 a
	Galloyl bis HHDP hexoside 1	FS	1.69 ± 0.13 a	0.81 ± 0.36 a	1.74 ± 0.58 a	0.59 ± 0.09 a
		S	0.44 ± 0.19 b	0.24 ± 0.09 a	0.46 ± 0.12 b	0.12 ± 0.06 a
	Galloyl bis HHDP hexoside 2	FS	117.63 ± 28.61 b	54.69 ± 13.75 ab	110.83 ± 1.39 ab	43.22 ± 7.39 a
		S	15.36 ± 5.56 a	12.06 ± 3.65 a	15.88 ± 4.87 a	11.98 ± 3.54 a
	Galloyl bis HHDP hexoside 3	FS	16.90 ± 4.55 a	16.86 ± 5.05 a	13.86 ± 3.90 a	7.84 ± 3.92 a
		S	-	-	-	-
	HHDP galloyl hexoside 1	FS	22.34 ± 0.49 a	31.51 ± 7.65 a	77.76 ± 17.33 b	21.48 ± 2.47 a
		S	-	-	-	-
	Total	FS	653.93 ± 160.78 a	426.29 ± 176.04 a	731.72 ± 197.82 a	365.82 ± 70.39 a
		S	57.05 ± 22.48 a	52.77 ± 25.56 a	59.91 ± 25.40 a	50.36 ± 25.35 a

Different letters indicate statistically significant differences between different genotypes, separately for flesh with skin (FS) and seed (S).

Note: (-) compound was not detected.

HBA, hydroxybenzoic acid derivatives; HCA, hydroxycinnamic acid derivatives; SE, standard error.

Table 5. Contents ± SE (mg · kg⁻¹ f.w.) of flavanols, flavonols, flavones and dihydrochalcone in rose hips of *R. pendulina* and its cultivars 'Bourgogne', 'Harstad' and 'Mount Everest'.

Phenolic group	Compound		<i>R. pendulina</i>	'Bourgogne'	'Harstad'	'Mount Everest'
Flavanols	Procyanidin dimer 1	FS	310.01 ± 75.40 b	144.13 ± 36.23 ab	292.10 ± 3.69 ab	113.91 ± 19.50 a
		S	37.36 ± 19.35 b	23.57 ± 6.37 a	36.98 ± 10.32 b	25.87 ± 8.97 a
	Procyanidin dimer 2	FS	464.64 ± 16.49 a	541.56 ± 140.95 a	1092.39 ± 80.22 b	637.15 ± 60.55 a
		S	85.25 ± 21.74 a	85.99 ± 25.41 a	94.65 ± 25.74 a	91.54 ± 19.74 a
	Procyanidin dimer 3	FS	86.26 ± 17.60 a	236.45 ± 94.54 a	204.15 ± 26.07 a	47.26 ± 11.52 a
		S	6.98 ± 2.14 a	19.87 ± 7.04 b	18.47 ± 8.32 b	4.87 ± 1.09 a
	Procyanidin dimer 4	FS	515.49 ± 11.38 a	759.49 ± 190.75 a	2225.28 ± 465.77 b	467.26 ± 75.16 a
		S	57.05 ± 31.98 a	57.98 ± 24.78 a	90.25 ± 38.76 b	56.98 ± 27.89 a
	Procyanidin trimer 1	FS	78.07 ± 1.73 a	110.11 ± 26.71 a	271.74 ± 60.57 b	75.05 ± 8.63 a
		S	22.54 ± 7.63 a	45.77 ± 19.87 ab	97.87 ± 31.08 b	21.98 ± 9.51 a
	Procyanidin trimer 2	FS	275.79 ± 54.37 a	323.43 ± 114.76 a	1069.74 ± 167.93 b	299.96 ± 40.41 a
		S	11.98 ± 3.15 a	12.15 ± 3.98 a	22.54 ± 12.45 a	12.04 ± 5.78 a
	Procyanidin trimer 3	FS	16.18 ± 0.36 a	23.84 ± 5.99 a	69.85 ± 14.62 b	14.67 ± 2.36 a
		S	87.54 ± 39.87 a	85.66 ± 34.65 a	103.21 ± 45.21 a	88.54 ± 30.01 a
	Epicatechin	FS	65.13 ± 6.45 a	78.48 ± 24.84 a	218.32 ± 18.33 b	48.84 ± 8.85 a
		S	25.77 ± 11.54 a	22.54 ± 9.78 a	44.74 ± 15.87 a	22.87 ± 9.87 a
	Catechin	FS	698.19 ± 1.55 a	98.47 ± 23.89 a	243.02 ± 54.16 b	67.11 ± 7.72 a
		S	23.45 ± 9.36 b	4.87 ± 1.06 a	12.54 ± 3.25 b	2.54 ± 1.21 a
	PA dimer diglycoside	FS	217.12 ± 50.35 a	139.65 ± 48.92 a	232.51 ± 143.72 a	92.21 ± 16.37 a
		S	27.54 ± 12.41 b	19.87 ± 9.24 b	26.98 ± 12.75 b	12.54 ± 6.87 a
	Dimer PA monogallate 1	FS	20.62 ± 0.46 a	30.38 ± 7.63 a	89.01 ± 18.63 b	18.69 ± 3.01 a
		S	3.05 ± 1.39 a	5.98 ± 1.03 a	12.87 ± 3.19 b	1.89 ± 0.97 a
	Dimer PA monogallate 2	FS	22.55 ± 1.77 a	10.79 ± 4.78 a	23.21 ± 7.72 a	7.92 ± 1.23 a
		S	0.45 ± 0.10 b	0.36 ± 0.08 b	0.57 ± 0.14 b	0.19 ± 0.04 a
	Total	FS	2770.05 ± 237.90 a	2496.78 ± 719.99 a	6031.32 ± 1,061.43 b	1890.03 ± 255.31 a
		S	388.87 ± 160.68 a	384.61 ± 143.29 a	561.67 ± 207.08 b	341.85 ± 121.95 a
Flavonols	Quercetin galloyl hexoside 1	FS	0.29 ± 0.11 a	0.20 ± 0.04 a	0.37 ± 0.17 a	0.46 ± 0.17 a
		S	0.78 ± 0.35 a	0.82 ± 0.24 a	0.98 ± 0.37 a	1.25 ± 0.94 a
	Quercetin galloyl hexoside 2	FS	2.65 ± 1.07 a	0.80 ± 0.27 a	0.68 ± 0.08 a	1.31 ± 0.55 a
		S	5.98 ± 2.14 b	1.59 ± 0.75 a	1.63 ± 0.64 a	3.88 ± 1.07 b

(Continued)

Table 5. Continued.

Phenolic group	Compound		<i>R. pendulina</i>	'Bourgogne'	'Harstad'	'Mount Everest'
	Quercetin-3-rutinoside	FS	2.49 ± 1.01 a	0.75 ± 0.25 a	0.64 ± 0.07 a	1.24 ± 0.52 a
		S	0.51 ± 0.16 b	0.14 ± 0.04 a	0.12 ± 0.05 a	0.23 ± 0.09 ab
	Quercetin-3-galactoside	FS	10.97 ± 3.37 ab	0.65 ± 0.22 a	19.30 ± 3.44 b	8.09 ± 6.40 ab
		S	3.54 ± 1.04 a	2.15 ± 0.97 a	3.28 ± 1.01 a	1.05 ± 0.07 a
	Quercetin-3-glucoside	FS	27.26 ± 13.45 a	1.83 ± 0.70 a	15.70 ± 5.36 a	7.22 ± 4.53 a
		S	7.19 ± 2.14 b	1.02 ± 0.21 a	5.84 ± 1.54 b	3.45 ± 1.96 a
	Total	FS	43.66 ± 24.99 b	4.23 ± 1.48 a	36.69 ± 9.12 ab	18.32 ± 12.17 ab
		S	18.00 ± 5.83 a	5.72 ± 2.21 a	11.85 ± 3.61 a	9.86 ± 4.13 a
Flavonols	Apigenin	FS	1.54 ± 0.51 a	0.99 ± 0.30 a	2.15 ± 0.27 a	2.49 ± 0.84 a
	derivative 1	S	0.31 ± 0.09 a	0.12 ± 0.04 a	0.67 ± 0.03 b	0.72 ± 0.16 b
	Apigenin	FS	0.35 ± 0.13 a	0.25 ± 0.05 a	0.45 ± 0.21 a	0.57 ± 0.21 a
	derivative 2	S	1.36 ± 0.57 a	1.02 ± 0.45 a	1.41 ± 0.49 a	1.45 ± 0.87 a
	Total	FS	1.89 ± 0.64 a	1.24 ± 0.35 a	2.60 ± 0.48 a	3.06 ± 1.05 a
		S	1.67 ± 0.66 a	1.14 ± 0.49 a	2.08 ± 0.52 a	2.17 ± 1.03 a

Different letters indicate statistically significant differences between different genotypes, separately for flesh with skin (FS) and seed (S).

Note: (-) Compound was not detected.

SE, standard error.

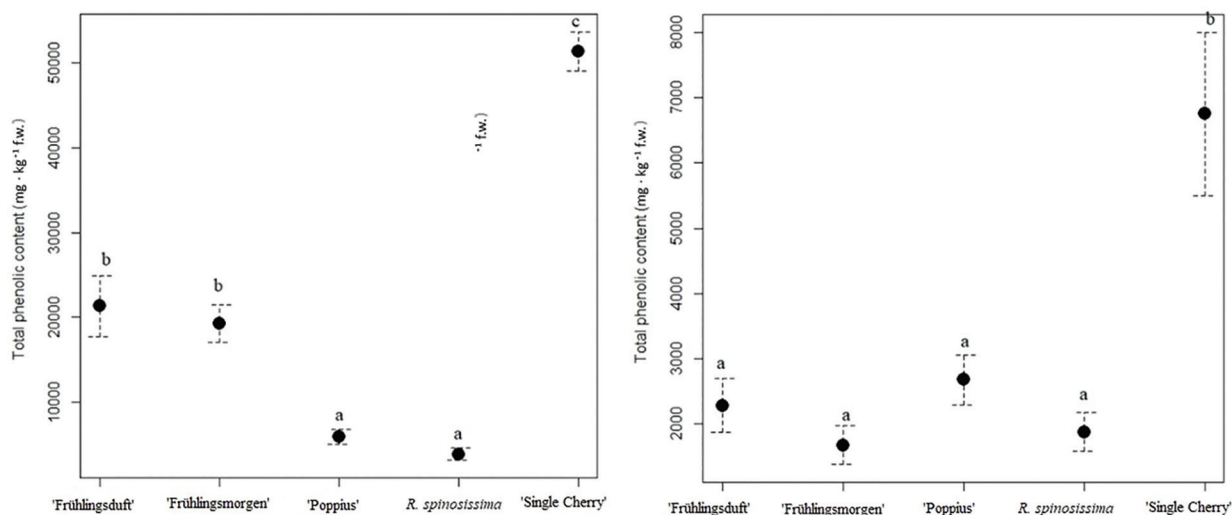


Figure 3. Total phenolic content ($\text{mg} \cdot \text{kg}^{-1}$ f.w.) of *R. spinosissima* and its cultivars in flesh with skin (left) and in seeds (right). Different letters indicate statistically significant differences between genotypes, separately for flesh with skin and seed.

in flesh and skin. HCA contents were also higher in seeds than in the flesh with skin in all samples, except for the hips of the varieties 'Frühlingsmorgen' and 'Frühlingsduft'. Statistically significant differences were analysed in the content of HCA in the hips flesh with skin between the cultivars 'Frühlingsduft', 'Poppus' and *R. spinosissima*. The content of total gallotannins (Table 5) was higher in the flesh with skin than in the seeds. Significant differences between gallotannins were analysed in both cases. The number of compounds classified as ellagitannins was higher in the flesh with skin than in the seeds (Table 5). The total content of ellagitannins in the rose hips of the cultivars 'Poppus' and 'Single Cherry' and in the rose hips of *R. spinosissima* was higher in the seeds than in the flesh with skin. In seeds, the lowest content was analysed for

'Frühlingsmorgen' and the highest for 'Single Cherry'. In all cases, in seeds, a statistically significant difference was observed.

The content of flavanols was higher in the flesh with skin of *R. spinosissima* and its cultivars than in the seeds. The compounds identified only in the seeds were procyanidin trimers 3 to 7, while the dimer diglycoside PA and the dimer monoglycoside 2 PA were determined only in the flesh with the skin. No statistically significant difference was found between the content of total flavonols in the hips flesh with skin and in the seeds of the samples studied. There was a statistically significant difference in the total flavonols content, in the flesh with skin, between 'Frühlingsmorgen' and 'Poppus' and *R. spinosissima*. No statistically significant difference existed in total flavonols in seeds.

Table 6. The content $\pm$ SE (mg $\cdot$ kg⁻¹ f.w.) of phenolic compounds (HBA, HCA, gallotannins and ellagitannins) in rose hips of *R. spinosissima* and its cultivars 'Poppius', 'Single Cherry', 'Frühlingsmorgen' and 'Frühlingsduft'.

Phenolic group	Compound	<i>R. spinosissima</i>	'Poppius'	'Single Cherry'	'Frühlingsmorgen'	'Frühlingsduft'
HBA	Galllic acid	FS	-	-	-	-
		S	45.63 ± 7.62 ab	116.41 ± 10.69 bc	190.84 ± 37.33 c	40.16 ± 22.95 ab
	Ellagic acid pentoside 1	FS	4.64 ± 1.33 a	11.31 ± 3.54 ab	12.64 ± 5.45 ab	101.02 ± 38.43 bc
		S	13.30 ± 3.25 a	4.13 ± 0.84 a	7.62 ± 3.95 a	3.51 ± 1.94 a
	Ellagic acid pentoside 2	FS	1.58 ± 0.36 a	2.66 ± 0.96 a	6.50 ± 3.41 ab	16.23 ± 5.95 bc
		S	1.63 ± 0.46 ab	0.67 ± 0.28 ab	2.27 ± 0.66 b	0.17 ± 0.06 a
	Taxifolin pentoside 1	FS	0.76 ± 0.08 a	2.09 ± 0.65 a	2.34 ± 0.51 a	19.89 ± 7.26 a
		S	-	-	-	-
	Taxifolin pentoside 2	FS	23.98 ± 6.29 a	9.46 ± 3.45 a	38.48 ± 9.32 a	189.33 ± 94.49 b
		S	-	-	-	-
	Taxifolin pentoside 3	FS	0.23 ± 0.02 a	0.27 ± 0.21 a	0.68 ± 0.45 ab	1.64 ± 0.32 bc
		S	-	-	-	-
HCA	Methyl ellagic acid pentoside 1	FS	-	-	-	-
		S	0.05 ± 0.01 a	0.09 ± 0.01 ab	0.04 ± 0.02 a	0.16 ± 0.07 b
	Total	FS	31.19 ± 8.08 a	25.79 ± 8.81 a	60.64 ± 19.14 a	328.11 ± 146.45 a
		S	60.61 ± 11.34 ab	121.30 ± 11.82 bc	200.77 ± 41.96 c	44.00 ± 25.02 ab
	<i>p</i> -coumaric acid hexoside 1	FS	2.69 ± 0.48 a	9.50 ± 1.02 a	20.45 ± 2.03 ab	35.85 ± 8.12 b
		S	45.21 ± 14.87 ab	319.09 ± 101.19 c	534.79 ± 178.29 d	30.0 ± 4.68 a
	<i>p</i> -coumaric acid hexoside 2	FS	0.22 ± 0.06 a	0.59 ± 0.19 a	0.71 ± 0.06 a	2.03 ± 0.29 b
		S	-	-	-	-
	5-caffeoylquinic acid 1	FS	16.55 ± 2.48 a	74.29 ± 22.89 ab	81.14 ± 22.79 ab	148.15 ± 26.08 bc
		S	141.85 ± 52.09 a	159.43 ± 93.72 a	286.42 ± 109.12 a	20.0 ± 8.11 b
	Sinapic acid hexoside 1	FS	94.42 ± 22.52 a	137.39 ± 36.89 a	527.15 ± 32.37 a	1415.02 ± 285.19 b
		S	-	-	-	-
HBA	Sinapic acid hexoside 2	FS	35.26 ± 16.18 a	55.63 ± 21.07 a	100.11 ± 25.38 a	298.62 ± 133.19 b
		S	-	-	-	-
	5-caffeoylquinic acid 2	FS	15.82 ± 2.89 a	9.86 ± 3.63 a	57.05 ± 26.31 a	216.59 ± 105.21 a
		S	-	-	-	-
		FS	-	-	-	-
		S	-	-	-	-
		FS	-	-	-	-
		S	-	-	-	-
		FS	-	-	-	-
		S	-	-	-	-
		FS	-	-	-	-
		S	-	-	-	-

Table 6. Continued.

Phenolic group	Compound	<i>R. spinosissima</i>	'Poppius'	'Single Cherry'	'Frühlingsmorgen'	'Frühlingsduft'	
Gallotannins	5- <i>p</i> -coumaroylquinic acid 1	FS	24.76 ± 9.76 a	30.35 ± 11.49 a	54.61 ± 18.39 a	173.58 ± 99.06 b	289.17 ± 138.59 c
		S	2.26 ± 1.80 a	12.64 ± 1.81 ab	32.73 ± 11.94 b	21.62 ± 7.45 ab	6.68 ± 1.93 a
	5- <i>p</i> -coumaroylquinic acid 2	FS	3.39 ± 1.10 a	9.98 ± 3.35 a	12.01 ± 2.98 a	32.45 ± 13.98 b	74.78 ± 16.39 c
		S	49.72 ± 16.29 a	44.78 ± 13.98 a	111.23 ± 39.27 b	130.25 ± 62.57 b	48.42 ± 18.95 a
	3- <i>p</i> -coumaroylquinic acid	FS	3.00 ± 1.34 a	7.16 ± 1.25 a	12.68 ± 2.24 a	23.65 ± 9.12 b	30.33 ± 12.68 b
		S	112.68 ± 38.42 a	26.31 ± 14.39 a	12.66 ± 3.36 b	46.3 ± 11.55 a	30.06 ± 9.74 a
	3-feruloyquinic acid	FS	0.06 ± 0.04 a	0.06 ± 0.01 a	0.10 ± 0.02 a	0.26 ± 0.19 a	0.26 ± 0.19 a
		S	12.59 ± 4.73 a	41.99 ± 15.55 bc	103.78 ± 46.65 d	21.59 ± 9.86 ab	50.12 ± 16.04 c
	Trigalloylquinic acid	FS	-	-	-	-	-
		S	16.54 ± 5.01 a	6.01 ± 1.03 a	19.32 ± 4.05 a	44.68 ± 14.06 a	12.33 ± 3.62 a
	Total	FS	196.17 ± 56.85 a	334.81 ± 101.79 a	866.01 ± 132.57 ab	2346.20 ± 680.43 ab	3162.12 ± 905.82 b
		S	380.85 ± 133.21 a	610.25 ± 241.67 a	1100.93 ± 392.68 a	314.64 ± 118.28 a	372.72 ± 142.68 a
	Digalloyl hexoside 1	FS	98.41 ± 30.47 a	384.84 ± 154.38 a	1347.62 ± 299.99 b	261.97 ± 135.72 a	237.37 ± 101.92 a
		S	48.89 ± 12.89 b	30.90 ± 9.53 ab	38.68 ± 10.39 ab	93.14 ± 27.56 c	0.24 ± 0.07 a
	Digalloyl hexoside 2	FS	9.67 ± 2.49 a	38.53 ± 14.59 b	114.79 ± 83.03 d	64.93 ± 26.12 c	21.23 ± 3.29 ab
		S	0.19 ± 0.03 b	0.14 ± 0.02 ab	0.26 ± 0.05 b	0.02 ± 0.01 a	0.28 ± 0.05 b
	Methyl gallate hexoside	FS	83.89 ± 27.43 a	321.06 ± 138.24 b	956.62 ± 225.24 d	623.78 ± 243.91 c	262.05 ± 151.99 b
		S	80.35 ± 33.89 ab	68.56 ± 17.90 ab	138.70 ± 38.62 b	32.05 ± 13.72 a	103.40 ± 40.76 ab
	Digalloylquinic acid 1	FS	118.35 ± 35.32 a	229.59 ± 60.72 a	541.28 ± 139.90 bc	478.17 ± 162.57 b	757.77 ± 158.17 c
		S	16.02 ± 6.33 bc	13.65 ± 2.42 ac	24.72 ± 10.94 c	2.77 ± 0.46a b	0.36 ± 0.06 a
Trigalloyl hexoside 1	FS	-	-	-	-	-	
	S	9.04 ± 6.24 a	46.33 ± 16.64 ab	102.28 ± 29.55 b	32.31 ± 10.23 ab	37.44 ± 13.93 ab	
Methyl gallate rutinoside	FS	24.54 ± 11.54 a	12.87 ± 4.14 ab	25.54 ± 19.81 ab	35.62 ± 15.57 ab	47.63 ± 28.92 b	
	S	-	-	-	-	-	
Methyl gallate acetyl dihexoside	FS	-	-	-	-	-	
	S	0.78 ± 0.06 a	1.44 ± 0.77 a	1.57 ± 0.88 a	0.43 ± 0.09 a	1.80 ± 0.18 a	
Total	FS	310.56 ± 107.25 a	986.89 ± 372.07 ab	2985.85 ± 767.97 b	1464.47 ± 583.89 ab	1326.05 ± 444.29 ab	
	S	155.27 ± 59.44 a	161.02 ± 47.28 a	306.21 ± 90.43 b	160.72 ± 52.07 a	143.52 ± 55.05 a	

(Continued)

Table 6. Continued.

Phenolic group	Compound	<i>R. spinosissima</i>	'Poppius'	'Single Cherry'	'Frühlingsmorgen'	'Frühlingsduft'
Ellagitannins	diHHDP hexoside 1	FS	188.89 ± 90.49 a	846.22 ± 253.33 b	435.35 ± 159.26 ab	634.66 ± 191.70 b
		S	337.86 ± 120.95 b	485.41 ± 247.12 c	32.91 ± 15.96 a	241.32 ± 90.27 b
	diHHDP hexoside 2	FS	55.25 ± 19.97 a	136.65 ± 40.17 b	179.10 ± 85.64 b	54.21 ± 16.94 a
Digalloyl HHDP hexoside 3		S	97.55 ± 28.32 ab	605.36 ± 379.67 c	38.69 ± 14.04 a	273.86 ± 169.35 b
		FS	37.15 ± 12.54 a	53.01 ± 19.05 ab	46.18 ± 13.54 a	78.35 ± 23.05 b
		S	9.21 ± 3.46 ab	16.48 ± 5.03 b	1.84 ± 0.95 a	1.03 ± 0.72 a
HHDP digalloyl hexoside isomer 1		FS	33.27 ± 13.59 a	71.58 ± 27.10 a	71.87 ± 20.03 a	321.05 ± 170.33 a
		S	-	-	-	-
		FS	27.74 ± 18.95 a	154.36 ± 69.02 b	378.43 ± 142.98 c	193.66 ± 77.44 b
HHDP digalloyl hexoside isomer 2		S	-	-	-	-
		FS	75.95 ± 26.21 a	439.26 ± 180.54 b	372.92 ± 126.87 b	499.12 ± 30.39 b
		S	-	-	-	-
Galloyl bis HHDP hexoside 1		FS	11.29 ± 3.79 a	13.59 ± 6.11 a	39.93 ± 12.63 b	84.93 ± 27.16 c
		S	-	-	-	-
		FS	11.31 ± 4.67 a	36.79 ± 11.32 a	273.38 ± 93.95 b	465.07 ± 138.81 c
Galloyl bis HHDP hexoside 2		S	-	-	-	-
		FS	17.90 ± 3.12 a	31.70 ± 15.61 ab	50.35 ± 18.36 bc	74.96 ± 26.59 c
		S	289.23 ± 104.96 b	1261.13 ± 427.95 c	30.93 ± 13.67 ab	1.07 ± 0.09 a
HHDP galloyl hexoside 1		FS	458.75 ± 193.33 a	1783.16 ± 622.25 ab	1847.51 ± 673.26 ab	2406.01 ± 672.02 b
		S	733.85 ± 257.69 ab	2368.38 ± 1,059.77 b	104.37 ± 44.62 a	517.28 ± 260.43 ab
		FS	286.39 ± 130.62 a	-	-	-
Total						

Different letters indicate statistically significant differences between different genotypes, separately for flesh with skin (FS) and seed (S).

Note: (-) compound was not detected.

HBA, hydroxybenzoic acid derivatives; HCA, hydroxycinnamic acid derivatives; SE, standard error.

Table 7. Contents $\pm$ SE (mg $\cdot$ kg⁻¹ f.w.) of flavanols, flavonols, flavones and dihydrochalcone in rose hips of *R. spinosissima* and its cultivars 'Poppus', 'Single Cherry', 'Frühlingsmorgen' and 'Frühlingsduft'.

Phenolic group	Compound		<i>R. spinosissima</i>	'Poppus'	'Single Cherry'	'Frühlingsmorgen'	'Frühlingsduft'
Flavanols	Procyanidin dimer 1	FS	624.11 ± 198.54 ab	298.81 ± 181.73 a	555.59 ± 299.72 ab	464.99 ± 133.42 ab	783.54 ± 259.96 b
		S	227.30 ± 24.41 a	81.38 ± 29.51 a	255.06 ± 95.24 a	80.01 ± 32.60 a	55.44 ± 11.35 a
	Procyanidin dimer 2	FS	3.51 ± 1.03 a	12.43 ± 3.87 a	22.89 ± 13.01 a	28.63 ± 15.16 a	63.69 ± 19.93 b
		S	8.42 ± 2.19 a	13.44 ± 6.16 ab	23.68 ± 3.25 b	18.36 ± 3.65 ab	17.15 ± 2.19 ab
	Procyanidin dimer 3	FS	48.05 ± 19.78 a	140.32 ± 47.71 a	168.86 ± 91.75 a	480.38 ± 152.04 b	1050.27 ± 352.29 c
		S	6.68 ± 1.41 a	11.14 ± 5.69 a	41.10 ± 18.87 b	2.34 ± 0.71 a	0.02 ± 0.01 a
	Procyanidin dimer 4	FS	763.20 ± 258.03 a	915.33 ± 224.39 a	2263.83 ± 938.62 b	2798.91 ± 798.77 b	898.13 ± 244.72 a
		S	0.10 ± 0.08 a	0.56 ± 0.08 a	2.05 ± 0.63a	1.39 ± 0.92 a	0.25 ± 0.03 a
	Procyanidin dimer 5	FS	358.04 ± 102.45 a	205.18 ± 107.08 a	37604.18 ± 1,103.86 b	1054.83 ± 552.07 a	1314.54 ± 365.47 a
		S	58.22 ± 13.54 ab	228.32 ± 81.51 bc	276.98 ± 63.31 c	45.48 ± 28.73 ab	37.76 ± 11.24 a
	Procyanidin trimer 1	FS	22.79 ± 6.98 a	42.67 ± 17.42 a	75.56 ± 23.37 ab	174.64 ± 69.58 bc	197.24 ± 47.38 c
		S	2.76 ± 1.85 a	4.23 ± 1.27 a	11.61 ± 4.62 a	4.01 ± 0.55 a	39.18 ± 12.05 a
	Procyanidin trimer 2	FS	556.081 ± 176.26 a	679.47 ± 209.38 a	742.12 ± 208.39 a	1055.67 ± 506.25 ab	2052.13 ± 554.44 b
		S	2.86 ± 0.37 a	1.79 ± 0.39 a	3.24 ± 0.34 a	2.65 ± 0.39 a	1.84 ± 0.74 a
	Procyanidin trimer 3	FS	-	-	-	-	-
	Procyanidin trimer 4	S	0.18 ± 0.08 a	1.12 ± 0.55 b	1.95 ± 0.45 c	0.20 ± 0.13 a	0.59 ± 0.35 ab
		FS	-	-	-	-	-
	Procyanidin trimer 5	S	2.02 ± 1.06 a	2.19 ± 0.74 a	18.94 ± 8.71 a	0.39 ± 0.13 a	0.20 ± 0.05 a
		FS	-	-	-	-	-
	Procyanidin trimer 6	S	48.91 ± 22.31 a	81.68 ± 37.21 a	385.93 ± 145.92 b	158.45 ± 54.04 ab	262.84 ± 107.92 ab
		FS	-	-	-	-	-
	Procyanidin trimer 7	S	229.27 ± 53.28 a	14.59 ± 6.35 a	412.32 ± 201.98 a	160.1 ± 29.86 a	223.18 ± 54.41 a
		FS	-	-	-	-	-
	Catechin	S	33.15 ± 16.38 a	10.23 ± 4.68 a	221.00 ± 39.87 b	367.28 ± 141.91 c	24.47 ± 11.54 a
		FS	291.77 ± 198.25 a	741.39 ± 129.03 ab	1312.92 ± 232.34 b	2061.68 ± 538.86 c	2661.29 ± 1,092.08 c
	Epicatechin	S	0.99 ± 0.16 a	0.19 ± 0.11 a	13.85 ± 6.13 a	0.36 ± 0.06 a	8.62 ± 2.38 a
		FS	22.50 ± 9.45 a	72.69 ± 22.79 a	133.85 ± 56.90 a	147.96 ± 43.96 a	572.56 ± 141.82 b
	PA dimer diglycoside	S	68.71 ± 24.04 a	125.08 ± 69.71 a	357.15 ± 150.65 a	63.36 ± 28.62 a	243.87 ± 91.14 a
FS		70.35 ± 25.89 a	416.42 ± 152.89 ab	936.35 ± 233.66 c	288.22 ± 97.93 ab	711.98 ± 275.98b c	
	S	-	-	-	-	-	

(Continued)

Table 7. Continued.

Phenolic group	Compound	<i>R. spinosissima</i>	'Poppius'	'Single Cherry'	'Frühlingsmorgen'	'Frühlingsduft'
Flavanols	Dimer PA monogallate 1	FS	93.11 ± 26.05 a	275.26 ± 91.79 a	1249.47 ± 375.94 c	695.19 ± 197.06 b
		S	50.32 ± 19.32 ab	609.44 ± 375.15 b	18.59 ± 9.07 a	24.86 ± 5.28 a
	Dimer PA monogallate 2	FS	17.49 ± 5.07 a	259.42 ± 152.15 b	702.67 ± 241.54 c	282.55 ± 96.08 b
		S	108.72 ± 71.27 b	31.19 ± 7.92 a	54.03 ± 21.29 ab	59.21 ± 17.11 ab
	PA dimer monoglycoside 1	FS	76.49 ± 17.98 a	1112.50 ± 237.81 b	1073.39 ± 240.35 b	1076.45 ± 370.16 b
		S	32.05 ± 19.62 a	90.34 ± 25.06 c	44.93 ± 18.06 ab	74.17 ± 24.03 bc
	PA dimer monoglycoside 2	FS	7.53 ± 2.94 a	38.04 ± 14.92 b	46.66 ± 19.84 b	94.82 ± 34.82 c
		S	-	-	-	-
	Total	FS	2955.02 ± 1,048.70 a	3911.04 ± 1,168.50 a	45501.37 ± 3,698.29 a	11628.10 ± 3,767.71 a
		S	880.66 ± 271.37 a	1094.05 ± 430.07 a	2753.88 ± 1,148.10 a	1021.98 ± 370.72 a
	Quercetin galloyl hexoside 1	FS	1.30 ± 0.31 a	1.83 ± 0.32 a	4.64 ± 1.91 a	11.58 ± 2.91 ab
		S	-	-	-	-
	Quercetin galloyl hexoside 2	FS	0.47 ± 0.16 a	1.15 ± 0.11 a	1.28 ± 0.25 a	11.29 ± 3.31 b
		S	-	-	-	-
	Quercetin-3-rutinoside	FS	3.00 ± 0.82 a	5.90 ± 2.58 a	6.59 ± 3.28 a	54.20 ± 20.12 b
Flavanols		S	41.41 ± 27.05 a	7.48 ± 3.17 a	25.32 ± 7.31 a	1.71 ± 0.73 a
	Quercetin-3-galactoside	FS	4.01 ± 1.45 a	24.63 ± 2.67 b	17.86 ± 3.02 ab	42.85 ± 25.98 c
		S	27.95 ± 13.64 a	18.84 ± 2.38 a	27.20 ± 10.97 a	20.98 ± 10.47 a
	Quercetin-3-glucoside	FS	3.77 ± 0.36 a	23.19 ± 2.46 a	10.26 ± 1.39 a	215.75 ± 124.74 b
		S	-	-	-	-
	Kaempferol hexoside 1	FS	0.25 ± 0.02 a	1.47 ± 0.16 a	0.65 ± 0.09 a	16.05 ± 8.16 b
		S	3.06 ± 0.87 a	2.38 ± 0.65 a	2.08 ± 0.71 a	3.16 ± 1.25 a
	Kaempferol hexoside 2	FS	-	-	-	-
		S	0.68 ± 0.32 a	0.28 ± 0.09 a	0.27 ± 0.11 a	0.31 ± 0.15 a
	Phloretin pentosyl hexoside 1	FS	4.27 ± 2.49 a	14.55 ± 6.21 a	98.34 ± 9.59 ab	28.39 ± 9.92 a
		S	-	-	-	-
	Phloretin pentosyl hexoside 2	FS	16.96 ± 2.45 a	17.04 ± 1.28 a	69.32 ± 13.22 a	322.74 ± 104.80 b
		S	-	-	-	-
	Quercetin-3-glucuronide	FS	5.68 ± 2.02 a	13.77 ± 1.21 a	93.04 ± 12.50 bc	28.43 ± 14.36 ab
		S	21.26 ± 12.89 a	3.12 ± 0.57 b	22.71 ± 10.52 a	0.29 ± 0.12 c

(Continued)

Table 7. Continued.

Phenolic group	Compound		<i>R. spinosissima</i>	'Poppius'	'Single Cherry'	'Frühlingsmorgen'	'Frühlingsduft'
Flavones	Quercetin-3-arabinopyranoside	FS	0.003 ± 0.001 a	0.01 ± 0.001 a	0.06 ± 0.01 ab	0.02 ± 0.01 a	0.13 ± 0.04 b
		S	0.77 ± 0.09 a	0.13 ± 0.02 a	0.94 ± 0.45 a	0.01 ± 0.004 a	0.003 ± 0.001 a
	Quercetin-3-arabinofuranoside	FS	0.57 ± 0.25 a	0.97 ± 0.23 a	0.75 ± 0.16 a	4.91 ± 0.96 b	2.36 ± 0.69 ab
		S	1.54 ± 0.31 b	0.96 ± 0.17 ab	0.84 ± 0.41 ab	0.76 ± 0.48 ab	0.27 ± 0.09 a
	Isorhamnetin-3-rhamnoside	FS	0.31 ± 1.20 a	0.79 ± 0.06 b	0.29 ± 0.05 a	0.31 ± 0.04 a	0.72 ± 0.19 ab
		S	1.26 ± 0.20 ac	1.58 ± 0.14b c	0.62 ± 0.29 a	1.85 ± 0.29 c	0.71 ± 0.17 ab
	Isorhamnetin-3-hexoside	FS	0.52 ± 0.12 a	1.25 ± 0.11 ab	1.20a ± 0.12 b	2.61 ± 0.36 b	4.44 ± 1.54 c
		S	0.21 ± 0.03 a	0.32 ± 0.03 a	0.13 ± 0.06 a	0.32 ± 0.06 a	0.25 ± 0.06 a
	Isorhamnetin pentoside 1	FS	4.28 ± 1.20 a	6.15 ± 1.45 a	4.78 ± 1.03 a	244.12 ± 120.95 a	34.07 ± 16.96 a
		S	7.58 ± 1.19 a	5.88 ± 2.00 a	8.41 ± 5.20 a	4.59 ± 2.41 a	2.26 ± 0.31 a
	Isorhamnetin pentoside 2	FS	3.98 ± 1.21 a	10.80 ± 0.87 ab	3.94 ± 0.69 a	4.99 ± 0.89 a	22.64 ± 7.04 b
		S	0.19 ± 0.03 a	0.07 ± 0.01 a	0.25 ± 0.14 a	0.07 ± 0.02 a	0.24 ± 0.02 a
	Quercetin-3-rhamnoside	FS	7.36 ± 1.23 a	15.89 ± 1.38 a	15.31 ± 1.52 a	25.60 ± 6.10 ab	47.39 ± 12.41 b
		S	-	-	-	-	-
	Quercetin-acetylhexoside	FS	0.36 ± 0.06 ab	0.78 ± 0.06 b	0.29 ± 0.05 a	0.32 ± 0.03 a	0.46 ± 0.18 ab
		S	0.05 ± 0.009 a	0.10 ± 0.05 a	0.11 ± 0.06 a	0.02 ± 0.006 a	0.19 ± 0.07 a
	Quercetin galloyl pentoside 1	FS	0.28 ± 0.06 a	0.52 ± 0.04 a	0.19 ± 0.03 a	0.62 ± 0.33 a	0.39 ± 0.08a
		S	-	-	-	-	-
	Quercetin galloyl pentoside 2	FS	0.29 ± 0.09 a	0.48 ± 0.03 a	1.43 ± 0.64 a	1.07 ± 0.25 a	4.22 ± 0.84 b
		S	-	-	-	-	-
	Quercetin galloyl pentoside 3	FS	0.01 ± 0.006 a	0.51 ± 0.09 ab	1.02 ± 0.79 ab	2.29 ± 0.52 b	1.91 ± 0.25 ab
		S	-	-	-	-	-
	Quercetin-3-xyloside	FS	8.28 ± 3.96 a	8.11 ± 2.96 a	32.97 ± 4.56 a	165.21 ± 16.67 b	144.23 ± 28.71 b
		S	3.28 ± 0.57 a	1.51 ± 0.11 a	2.47 ± 0.39 a	3.52 ± 0.95 a	13.95 ± 0.79 a
	Total	FS	65.95 ± 19.47 a	149.79 ± 24.28 a	364.21 ± 54.90 ab	1210.35 ± 461.41 b	947.52 ± 351.51 ab
		S	109.24 ± 57.02 a	42.65 ± 9.39 a	91.35 ± 36.51 a	37.59 ± 16.94 a	65.20 ± 29.71 a
Flavones	Apigenin derivative 1	FS	0.56 ± 0.07 a	3.57 ± 1.52 a	4.87 ± 2.36 a	38.19 ± 18.17 a	29.6 ± 3.47 a
		S	2.21 ± 0.24 a	1.17 ± 0.09 a	1.69 ± 0.66 a	1.29 ± 0.62 a	2.57 ± 0.48 a

(Continued)

Table 7. Continued.

Phenolic group	Compound		<i>R. spinosissima</i>	'Poppius'	'Single Cherry'	'Frühlingsmorgen'	'Frühlingsduft'
Apigenin derivative 2		FS	0.003 ± 0 a	0.001 ± 0.0001 a	0.002 ± 0.001 a	0.02 ± 0.016 a	0.01 ± 0.003 a
		S	-	-	-	-	-
Total		FS	0.56 ± 0.07 a	3.57 ± 1.52 ab	4.87 ± 2.36 ab	38.21 ± 18.12 b	29.61 ± 3.47 ab
		S	2.21 ± 0.24 a	1.17 ± 0.09 a	1.69 ± 0.66 a	1.29 ± 0.62 a	2.57 ± 0.48 a
Dihydrochalcone	Phloridzin	FS	117.31 ± 29.81 a	140.04 ± 9.59 a	414.87 ± 186.71 a	261.26 ± 52.16 a	964.13 ± 33.32 b
		S	-	-	-	-	-

Different letters indicate statistically significant differences between genotypes, separately for flesh with skin (FS) and seed (S).

Note: (-) compound was not detected.

SE, standard error.

There was a statistically significant difference in the total flavone content in the flesh with skin between 'Frühlingsmorgen' and *R. spinosissima*. However, no statistically significant difference was found in the total flavone content in the seeds. Among dihydrochalcones, only phloridzin was determined, which was present in the flesh with the skin. The content of phloridzin in 'Frühlingsmorgen' was statistically different from that of the other samples (Table 7).

Phenolic compounds in *R. gallica* and its cultivars

The total content of phenolic compounds (Figure 4) in the flesh with skin of rose hips of *R. gallica* was 20443.00 mg · kg⁻¹ f.w., while the content in the seeds of rose hips was only 1713.90 mg · kg⁻¹ f.w.

There was no significant differences in the HBA content (Table 8) in flesh with skin and in seeds. Gallic acid was determined only in the hips flesh with skin. Methyl ellagic acid pentosides 1 and 2, which were detected only in the seeds, showed no significant differences between samples. The total content of HCA was higher in the flesh with skin than in the seeds, also without significant differences between seeds and between flesh with skin. Digalloylquinic acid 1 was determined only in the flesh with skin, while trigalloyl hexosides 1 and 2 and methyl gallate acetyl dihexoside were present only in the seeds. Di-HHDP-hexosides 1 and 2 and HHDP-digalloyl hexoside isomer 3 compounds were present only in the hips with skin. Galloyl-bis-HHDP-hexoside 2 was present only in the seeds. No significant differences were analysed between ellagitannins in flesh with skin and in seeds.

Table 9 shows the content of flavanols, flavanones, flavonols, flavones and dihydrochalcone in rose hips of *R. gallica* and its cultivars 'Violacea' and 'Splendens', separated by fruit flesh and skin, and seeds. There was no statistically significant difference between the content of flavanols and the flesh with skin. We also did not find a statistically significant difference in the content of flavanols in the seeds. There were statistically significant differences in flavanones between treatments. We did not detect any statistically significant difference between the content of flavanones in the seeds. The content of flavonols was not statistically different between the samples studied, both in the flesh with skin and in the seeds. There was no statistically significant difference in phloridzin, which is classified as a dihydrochalcone, between the samples.

Hierarchical cluster analysis

Figure 5 shows the cluster dendrogram for the total phenolic compound content in the flesh with skin and in the seeds for all 12 *Rosa* genotypes analysed. From the left panel, it can be seen that one group of samples differs from the others in terms of total phenolic compound content in the flesh with skin. The cultivars 'Single Cherry' (group *R. spinosissima*) and 'Splendens' (group *R. gallica*) belong to this group. The rest genotypes are divided into two larger groups. In the first group, there are five genotypes: 'Frühlingsduft' (group *R. spinosissima*),

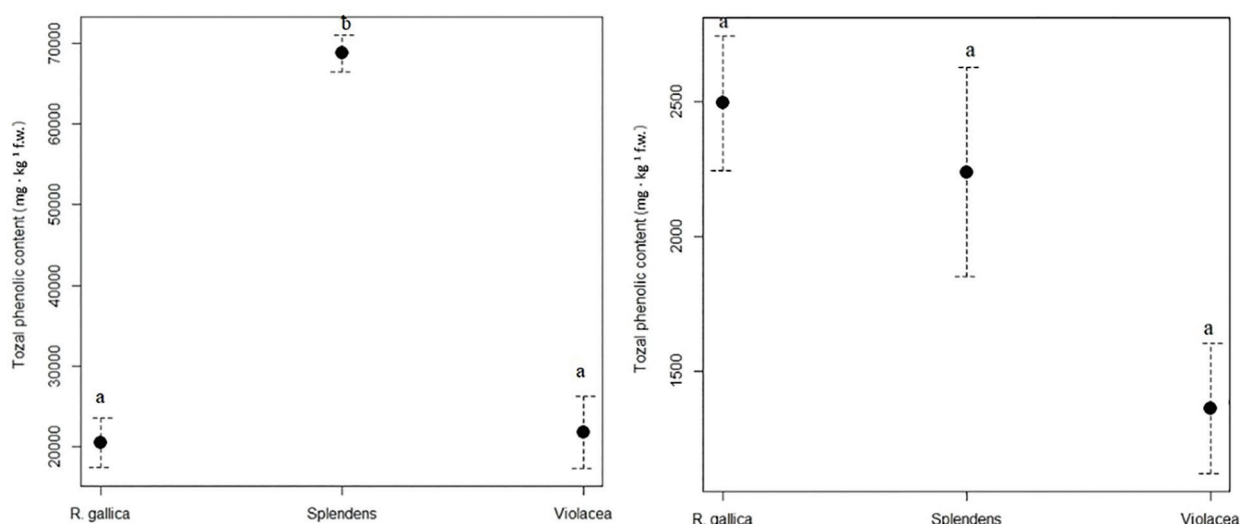


Figure 4. Total phenolic content ($\text{mg} \cdot \text{kg}^{-1}$ f.w.) of *R. gallica* and its cultivars in flesh with skin (left) and in seeds (right). Different letters indicate statistically significant differences between analysed genotypes, separately for flesh with skin and seed.

'Viola cea' (group *R. gallica*), 'Frühlingsmorgen' (group *R. spinosissima*) and *R. gallica*. The second group includes six genotypes: 'Harstad' (group *R. pendulina*), *R. pendulina*, 'Poppius' (group *R. spinosissima*), 'Bourgogne' (group *R. pendulina*), 'Mount Everest' (group *R. pendulina*) and *R. spinosissima*. The right image shows the cluster dendrogram of the total phenolic compound content in the seeds of the rose hips studied. It can be seen that one group with the cultivar 'Single Cherry' (group *R. spinosissima*) deviates strongly from the others. The other rose hips are further divided into two groups. The first group belongs only to the varieties 'Bourgogne' (group *R. pendulina*) and 'Mount Everest' (group *R. pendulina*). Within the second group, two other groups are formed. The first includes *R. pendulina*, 'Viola cea' (group *R. gallica*), *R. spinosissima*, 'Frühlingsmorgen' (group *R. spinosissima*), 'Harstad' (group *R. pendulina*) and *R. gallica*. The second consists of 'Poppius' (group *R. spinosissima*), 'Frühlingsduft' (group *R. spinosissima*) and 'Splendens' (group *R. gallica*).

Examining the classification based on the content of cyanidin-3-glucoside, it can be seen (Figure 6) that the genotypes are divided into two groups. The first group with the cultivar 'Single Cherry' (*R. spinosissima* group) stands out strongly. The second group consists of 'Splendens' (group *R. gallica*), 'Harstad' (group *R. pendulina*), *R. gallica*, 'Bourgogne' (group *R. pendulina*), *R. pendulina*, 'Viola cea' (group *R. gallica*), 'Poppius' (group *R. spinosissima*), *R. spinosissima*, 'Frühlingsmorgen' (group *R. spinosissima*), 'Mount Everest' (group *R. pendulina*) and 'Frühlingsduft' (group *R. spinosissima*).

DISCUSSION

As part of research work, we determined the colour parameters and the content of bioactive compounds

in the rose hips of three native Slovenian roses and cultivars derived from them, growing in Arboretum Volčji Potok (Slovenia).

Lancaster et al. (1997) reported that fruit skin colour results from several parameters, among which pigments, chlorophyll and carotenoids in the chloroplast and chromoplast, and phenolic pigments (anthocyanins, flavonols and proanthocyanidins) in the vacuole are of great importance. The expression of pigment colour also depends on physical factors such as the presence of cuticular growth, epidermal hairs, the shape and orientation of cells in the epidermis and subepidermis. They concluded that pigments and surface topography selectively absorb and refract incident visible light to produce a reflectance spectrum characteristic of the particular fruit skin. Comparing the Hunter Lab colour content determined in the current study (Sahingil and Hayaloglu, 2022) with the results of the study by Cunja et al. (2015), who measured the colour parameters of *R. canina* in six different periods, it is noticeable that the value of the parameter L^* was quite similar to the values measured in the current study (20.28 to 43.38). Cunja et al. (2015) reported that in the value was 43.1 the initial stage of harvesting, followed by 35.0, 32.6, 29.4 and 28.9, and the value was 28.2 in the last stage. It was reported that the analysis of the parameter L^* showed significant differences between the ripening of the rose hips and the increase in the darkness of the fruits in the last sampling. The values were highest (43.1) at the first sampling in September and lowest after fruit freezing. The decrease in the a^* value was measured at the last sampling after freezing (Cunja et al., 2015). The parameter b^* also decreased as the rose hip gradually lost its yellow colouration. Similar values and a significant decrease in the above parameters are also reported by Ugglja et al. (2005), who observed the ripening of *R. dumalis* and *R. rubiginosa*. Ercişli (2007)

Table 8. The content $\pm$ SE (mg $\cdot$ kg⁻¹ f.w.) of phenolic compounds (HBA, HCA, gallotannins and ellagitannins) in rose hips of *R. gallica* and its cultivars 'Violacea' and 'Splendens'.

Phenolic group	Compound		<i>R. gallica</i>	'Violacea'	'Splendens'
HBA	Gallic acid	FS	72.13 $\pm$ 11.03 ab	54.78 $\pm$ 18.81 a	127.40 $\pm$ 17.48 b
		S	-	-	-
	Ellagic acid pentoside 1	FS	9.45 $\pm$ 3.44 a	5.67 $\pm$ 2.29 a	5.03 $\pm$ 2.69 a
		S	5.43 $\pm$ 2.03 a	11.64 $\pm$ 5.39 a	4.15 $\pm$ 0.18 a
	Ellagic acid pentoside 2	FS	1.23 $\pm$ 0.37 a	2.91 $\pm$ 1.37 a	1.53 $\pm$ 0.24 a
		S	1.32 $\pm$ 0.44 a	0.84 $\pm$ 0.31 a	0.82 $\pm$ 0.32 a
	Methyl ellagic acid pentoside 1	FS	-	-	-
		S	1.22 $\pm$ 0.35 a	1.22 $\pm$ 0.41 a	0.58 $\pm$ 0.12 a
	Methyl ellagic acid pentoside 2	FS	-	-	-
		S	1.26 $\pm$ 0.36 a	0.78 $\pm$ 0.49 a	0.47 $\pm$ 0.39 a
HCA	Total	FS	82.80 $\pm$ 14.84 a	63.36 $\pm$ 22.47 a	134.54 $\pm$ 20.41 a
		S	9.23 $\pm$ 3.18 a	14.48 $\pm$ 6.30 a	5.44 $\pm$ 1.01 a
	<i>p</i> -coumaric acid hexoside 1	FS	636.74 $\pm$ 119.49 a	1111.94 $\pm$ 697.73 a	1314.25 $\pm$ 263.63 a
		S	1.45 $\pm$ 0.35 a	1.57 $\pm$ 0.43 a	2.15 $\pm$ 0.53 a
	<i>p</i> -coumaric acid hexoside 2	FS	-	-	-
		S	4.66 $\pm$ 1.41 b	1.28 $\pm$ 0.38 ab	1.01 $\pm$ 0.35 a
	5-caffeoylquinic acid 1	FS	6.55 $\pm$ 3.36 a	53.36 $\pm$ 25.88 a	23.34 $\pm$ 4.74 b
		S	1.02 $\pm$ 0.25 a	1.26 $\pm$ 0.43 a	0.80 $\pm$ 0.45 a
	5-caffeoylquinic acid 2	FS	52.81 $\pm$ 12.72 a	2.17 $\pm$ 1.04 a	61.24 $\pm$ 26.61 a
		S	6.85 $\pm$ 2.03 a	7.02 $\pm$ 1.51 a	6.09 $\pm$ 3.18 a
	Sinapic acid hexoside 1	FS	256.49 $\pm$ 55.18 a	320.10 $\pm$ 103.97 a	557.87 $\pm$ 116.94 a
		S	0.18 $\pm$ 0.05 a	0.22 $\pm$ 0.08 a	0.14 $\pm$ 0.07 a
	Sinapic acid hexoside 2	FS	0.48 $\pm$ 0.11 a	1.69 $\pm$ 0.71 a	2.16 $\pm$ 0.45 a
		S	-	-	-
	3-caffeoylquinic acid 1	FS	326.12 $\pm$ 191.43 a	235.82 $\pm$ 157.48 a	395.29 $\pm$ 136.67 a
		S	-	-	-
	3-caffeoylquinic acid 2	FS	38.56 $\pm$ 19.27 a	137.03 $\pm$ 80.39 a	174.68 $\pm$ 73.67 a
		S	-	-	-
	4-caffeoylquinic acid	FS	0.07 $\pm$ 0.02 a	0.25 $\pm$ 0.10 a	0.32 $\pm$ 0.07 a
		S	-	-	-
	5- <i>p</i> -coumaroylquinic acid 1	FS	83.77 $\pm$ 32.76 a	61.37 $\pm$ 26.12 a	92.80 $\pm$ 44.70 a
		S	14.54 $\pm$ 4.33 a	12.41 $\pm$ 5.61 a	16.99 $\pm$ 2.61 a
	5- <i>p</i> -coumaroylquinic acid 2	FS	334.81 $\pm$ 162.66 a	179.39 $\pm$ 93.52 a	219.31 $\pm$ 143.98 a
		S	3.51 $\pm$ 2.18 a	1.99 $\pm$ 0.71 a	2.81 $\pm$ 0.37 a
	3- <i>p</i> -coumaroylquinic acid	FS	10.34 $\pm$ 1.94 a	18.06 $\pm$ 7.13 a	21.34 $\pm$ 9.28 a
		S	0.02 $\pm$ 0.008 a	0.014 $\pm$ 0.006 a	0.04 $\pm$ 0.001 a
	4- <i>p</i> -coumaroylquinic acid	FS	26.56 $\pm$ 16.39 a	36.30 $\pm$ 19.93 a	30.80 $\pm$ 18.35 a
		S	-	-	-
	Total	FS	1773.30 $\pm$ 615.33 a	2227.48 $\pm$ 1,214.00 a	2893.40 $\pm$ 839.27 a
		S	32.23 $\pm$ 10.61 a	25.89 $\pm$ 9.16 a	30.03 $\pm$ 7.56 a
Gallotannins	Digalloyl hexoside 1	FS	67.04 $\pm$ 22.74 a	87.20 $\pm$ 36.43 a	205.58 $\pm$ 146.16 a
		S	75.01 $\pm$ 25.98 a	53.02 $\pm$ 26.18 a	69.88 $\pm$ 31.97 a
	Digalloyl hexoside 2	FS	144.73 $\pm$ 40.24 a	153.85 $\pm$ 70.31 a	289.52 $\pm$ 144.26 a
		S	97.57 $\pm$ 29.68 a	44.31 $\pm$ 26.99 a	97.01 $\pm$ 41.48 a

(Continued)

Table 8. Continued.

Phenolic group	Compound		<i>R. gallica</i>	'Violacea'	'Splendens'
	Methyl gallate hexoside	FS	268.34 ± 153.01 a	114.97 ± 86.74 a	859.74 ± 353.67 b
		S	166.63 ± 47.99 a	61.23 ± 28.79 a	167.63 ± 75.79 a
	Digalloylquinic acid 1	FS	196.67 ± 92.76 a	157.35 ± 63.74 a	375.45 ± 169.14 a
		S	-	-	-
	Trigalloyl hexoside 1	FS	-	-	-
		S	171.25 ± 51.67 a	133.92 ± 37.81 a	137.53 ± 37.69 a
	Trigalloyl hexoside 2	FS	-	-	-
		S	4.78 ± 1.21 a	5.84 ± 2.51 a	6.22 ± 2.14 a
	Methyl gallate rutinoside	FS	3.41 ± 0.15 a	4.72 ± 1.95 a	6.95 ± 1.49 a
		S	0.0004 ± 0.0 a	0.0002 ± 0.0 a	0.0001 ± 0.00 a
	Methyl gallate acetyl dihexoside	FS	-	-	-
		S	0.82 ± 0.19 a	0.81 ± 0.67 a	0.39 ± 0.04 a
	Total	FS	680.19 ± 308.90 a	518.09 ± 259.17 a	1737.24 ± 814.72 a
		S	516.06 ± 156.72 a	299.13 ± 122.95 a	478.66 ± 189.11 a
Ellagitannins	diHHDP hexoside 1	FS	-	-	-
		S	299.13 ± 102.62 a	60.85 ± 25.35 a	102.65 ± 54.16 a
	diHHDP hexoside 2	FS	-	-	-
		S	5.21 ± 1.35 a	8.14 ± 3.76 ab	16.48 ± 6.14 b
	HHDP digalloyl hexoside isomer 1	FS	24.89 ± 15.08 a	32.24 ± 12.85 ab	69.63 ± 31.19 b
		S	25.34 ± 6.08 a	27.36 ± 7.42 a	37.45 ± 10.34 a
	HHDP digalloyl hexoside isomer 2	FS	311.24 ± 116.63 a	403.00 ± 210.69 ab	870.41 ± 321.98 b
		S	12.71 ± 3.16 a	15.60 ± 5.32 a	9.97 ± 5.65 a
	HHDP digalloyl hexoside isomer 3	FS	30.16 ± 18.36 a	15.66 ± 7.79 a	48.84 ± 28.06 a
		S	-	-	-
	Galloyl bis HHDP hexoside 1	FS	18.63 ± 4.75 a	30.29 ± 16.74 a	46.32 ± 13.75 a
		S	0.87 ± 0.42 a	0.42 ± 0.25 a	0.39 ± 0.21 a
	Galloyl bis HHDP hexoside 2	FS	-	-	-
		S	0.23 ± 0.14 b	0.06 ± 0.01 ab	0.05 ± 0.03 a
	HHDP galloyl hexoside 1	FS	16.53 ± 6.97 a	17.38 ± 4.47 a	11.64 ± 4.18 a
		S	26.97 ± 8.14 a	21.09 ± 5.96 a	21.66 ± 5.93 a
	HHDP galloyl hexoside 2	FS	-	-	-
		S	0.05 ± 0.02 a	0.04 ± 0.02 a	0.11 ± 0.02 a
	Total	FS	401.45 ± 161.79 a	498.57 ± 252.54 a	1046.84 ± 399.19 a
		S	370.51 ± 122.20 a	72.71 ± 48.09 a	188.76 ± 82.48 a

Different letters indicate statistically significant differences between different genotypes, separately for flesh with skin (FS) and seed (S).

Note: (-) compound was not detected.

HBA, hydroxybenzoic acid derivatives; HCA, hydroxycinnamic acid derivatives; SE, standard error.

found similar results but also reported a decrease in the parameter h° during maturation, which Cunja et al. (2015) could not confirm. In their case, h° initially decreased until the fourth sampling date and increased again in the last two sampling dates. The values of the mentioned parameter ranged from 19.5 to 34.2 in the results of Cunja et al. (2015). In our samples, the parameter h° was slightly higher and ranged from 22.14 (*R. spinosissima*) to 59.18 ('Single Cherry'), which means the hips of *R. spinosissima* were more red than 'Single Cherry' hips, which were more red and yellow.

Goztepe et al. (2022) measured the colour of fresh fruit of *R. canina* and reported that the values of the parameters L^* , a^* and b^* were 42.5, 24.7 and 13.3, respectively. Their results are comparable to ours. The parameter L^* corresponds most closely to the value we determined for *R. gallica* and a^* and b^* for the cultivar 'Frühlingsmorgen'.

The total analysed phenolic content (excluding anthocyanins) in the flesh with skin was lowest in the modern cultivar of *R. pendulina*, 'Mount Everest', 3603.57 mg · kg⁻¹ f.w. The highest total content

Table 9. Contents $\pm$ SE (mg $\cdot$ kg⁻¹ f.w.) of flavanols, flavanones, flavonols, flavones and dihydrochalcone in rose hips of *R. gallica* and its cultivars 'Violacea' and 'Splendens'

Phenolic group	Compound		<i>R. gallica</i>	'Violacea'	'Splendens'
Flavanols	Procyanidin dimer 1	FS	3126.14 $\pm$ 752.27 a	1361.77 $\pm$ 338.39 a	3401.99 $\pm$ 1562.04 a
		S	1.27 $\pm$ 0.41 a	0.53 $\pm$ 0.24 a	0.32 $\pm$ 0.21 a
	Procyanidin dimer 2	FS	896.30 $\pm$ 162.67 a	704.06 $\pm$ 186.69 a	776.21 $\pm$ 140.02 a
		S	359.41 $\pm$ 193.31 a	562.13 $\pm$ 259.37 ab	1137.43 $\pm$ 413.09 b
	Procyanidin dimer 3	FS	0.003 $\pm$ 0.001 a	0.004 $\pm$ 0.001 a	0.005 $\pm$ 0.001 a
		S	0.07 $\pm$ 0.02 a	0.08 $\pm$ 0.02 a	0.11 $\pm$ 0.02 a
	Procyanidin dimer 4	FS	321.68 $\pm$ 168.16 a	157.21 $\pm$ 48.47 a	268.21 $\pm$ 161.94 a
		S	13.65 $\pm$ 3.46 a	16.69 $\pm$ 7.12 a	17.76 $\pm$ 9.08 a
	Procyanidin dimer 5	FS	0.25 $\pm$ 0.09 a	0.39 $\pm$ 0.18 a	0.33 $\pm$ 0.18 a
		S	-	-	-
	Epicatechin	FS	7.70 $\pm$ 1.86 a	10.52 $\pm$ 2.56 a	8.93 $\pm$ 3.42 a
		S	-	-	-
	Catechin	FS	195.79 $\pm$ 39.76 a	276.17 $\pm$ 30.62 a	631.35 $\pm$ 256.12 b
		S	-	-	-
	Catechin hexoside	FS	-	-	-
		S	236.22 $\pm$ 57.93 a	193.09 $\pm$ 64.69 a	146.45 $\pm$ 74.25 a
	Procyanidin trimer 1	FS	0.04 $\pm$ 0.02 a	0.06 $\pm$ 0.02 a	0.13 $\pm$ 0.09 b
		S	17.87 $\pm$ 5.39 a	13.97 $\pm$ 3.95 a	14.35 $\pm$ 3.93 a
	Procyanidin trimer 2	FS	706.44 $\pm$ 262.14 a	414.42 $\pm$ 168.13 a	1985.02 $\pm$ 696.19 b
		S	1.06 $\pm$ 0.45 a	0.83 $\pm$ 0.36 a	2.19 $\pm$ 0.84 a
	Procyanidin trimer 3	FS	14.28 $\pm$ 6.25 a	18.49 $\pm$ 9.24 ab	39.93 $\pm$ 23.06 b
		S	3.36 $\pm$ 0.84 a	4.13 $\pm$ 1.41a	2.64 $\pm$ 0.15 a
	Procyanidin trimer 4	FS	621.06 $\pm$ 216.47 a	652.65 $\pm$ 209.54 a	437.19 $\pm$ 185.76 a
		S	3.94 $\pm$ 1.22 a	3.43 $\pm$ 1.52 a	3.92 $\pm$ 0.39 a
	Procyanidin trimer 5	FS	1391.21 $\pm$ 487.65 a	1247.21 $\pm$ 442.01 a	2709.28 $\pm$ 730.14 b
		S	-	-	-
	Procyanidin trimer 6	FS	22.16 $\pm$ 9.16 a	31.78 $\pm$ 18.45 a	50.99 $\pm$ 24.07 a
		S	-	-	-
	Procyanidin tetramer 1	FS	0.88 $\pm$ 0.16 a	1.53 $\pm$ 0.96 a	1.81 $\pm$ 0.36 a
		S	-	-	-
	Procyanidin tetramer 2	FS	0.06 $\pm$ 0.02 a	0.08 $\pm$ 0.01 a	0.19 $\pm$ 0.02 b
		S	-	-	-
	Procyanidin tetramer 3	FS	6.99 $\pm$ 1.48 a	3.42 $\pm$ 1.05 a	5.84 $\pm$ 1.35 a
		S	-	-	-
	Procyanidin tetramer 5	FS	242.38 $\pm$ 106.21 a	221.99 $\pm$ 99.87 a	312.46 $\pm$ 162.14 a
		S	-	-	-
	Dimer PA monogallate 1	FS	77.65 $\pm$ 17.67 a	111.36 $\pm$ 43.94 a	178.68 $\pm$ 37.95 a
		S	65.98 $\pm$ 10.92 a	65.69 $\pm$ 8.46 a	63.32 $\pm$ 18.36 a
	Dimer PA monogallate 2	FS	0.15 $\pm$ 0.05 a	0.24 $\pm$ 0.11 a	0.19 $\pm$ 0.05 a
		S	39.43 $\pm$ 15.71 a	19.32 $\pm$ 15.06 a	17.60 $\pm$ 4.30 a
	Dimer PA monogallate 3	FS	-	-	-
		S	1.17 $\pm$ 0.51 a	0.66 $\pm$ 0.34 a	0.92 $\pm$ 0.49 a
	PA dimer monoglycoside 1	FS	7874.00 $\pm$ 1,699.11 a	12317.33 $\pm$ 4,413.33 a	49035.33 $\pm$ 9560.51 b
		S	7.81 $\pm$ 2.46 a	12.22 $\pm$ 5.08 ab	24.72 $\pm$ 11.36 b

(Continued)

Table 9. Continued.

Phenolic group	Compound		<i>R. gallica</i>	'Violacea'	'Splendens'
	PA dimer monoglycoside 2	FS	1834.54 ± 368.39 ab	842.22 ± 395.60 a	3003.20 ± 627.29 b
		S	-	-	-
	Total	FS	17340.065 ± 4,299.589 a	18372.908 ± 6,409.199 a	62848.269 ± 14172.699 a
		S	750.79 ± 292.635 a	892.87 ± 367.62 a	1431.73 ± 536.47 a
Flavanones	Naringenin hexoside 1	FS	0.46 ± 0.12 a	0.26 ± 0.01 b	-
		S	0.46 ± 0.14 a	0.21 ± 0.01 a	0.15 ± 0.04 a
	Naringenin hexoside 2	FS	0.30 ± 0.28 a	0.44 ± 0.18 a	0.33 ± 0.32 a
		S	0.02 ± 0.01 a	0.02 ± 0.01 a	0.03 ± 0.01 a
	Naringenin hexoside 3	FS	0.005 ± 0.001 ab	0.002 ± 0.001 a	0.001 ± 0.001 b
		S	0.02 ± 0.005 a	0.02 ± 0.01 a	0.03 ± 0.02 a
	Naringenin hexoside 4	FS	2.64 ± 0.06 a	5.48 ± 1.15 a	0.86 ± 0.03 a
		S	0.67 ± 0.55 a	0.32 ± 0.09 a	0.46 ± 0.08 a
	Naringenin hexoside 5	FS	0.59 ± 0.18 a	0.37 ± 0.13 a	0.03 ± 0.01 a
		S	-	-	-
	Total	FS	3.995 ± 0.641 b	6.552 ± 1.441 c	1.221 ± 0.361 a
		S	1.17 ± 0.705 a	0.47 ± 0.12 a	0.67 ± 0.15 a
Flavonoles	Quercetin galloyl hexoside 1	FS	2.09 ± 0.70 b	4.44 ± 1.27 a	-
		S	0.18 ± 0.15 a	0.17 ± 0.07 a	0.26 ± 0.13 a
	Quercetin galloyl hexoside 2	FS	0.59 ± 0.13 ab	0.27 ± 0.14 a	1.28 ± 0.34 b
		S	0.34 ± 0.04 a	0.22 ± 0.01 a	0.21 ± 0.19 a
	Quercetin-3-rutinoside	FS	0.0006 ± 0.0002 b	0.001 ± 0.0004 a	-
		S	1.02 ± 0.44 a	0.65 ± 0.19 a	0.63 ± 0.38 a
	Quercetin-3-galactoside	FS	4.48 ± 1.04 a	6.40 ± 3.08 a	4.75 ± 0.54 a
		S	0.79 ± 0.29 a	2.15 ± 0.34 a	2.31 ± 0.85 a
	Quercetin-3-glucoside	FS	24.44 ± 15.15 a	1.80 ± 0.29 a	3.93 ± 0.49 a
		S	1.74 ± 0.13 b	1.32 ± 0.13 ab	0.77 ± 0.31 a
	Kaempferol hexoside 1	FS	1.08 ± 0.34 a	0.08 ± 0.02 a	0.17 ± 0.06 a
		S	0.34 ± 0.15 a	0.22 ± 0.07 a	0.21 ± 0.13 a
	Kaempferol hexoside 2	FS	1.01 ± 0.07 a	2.22 ± 0.91 a	0.35 ± 0.02 a
		S	9.48 ± 5.02 a	22.73 ± 7.87 a	9.98 ± 0.24 a
	Kaempferol derivate	FS	0.96 ± 0.38 a	0.98 ± 0.39 a	0.71 ± 0.27 a
		S	-	-	-
	Phloretin pentosyl hexoside 1	FS	1.04 ± 0.42 a	0.22 ± 0.14 a	0.41 ± 0.08 a
		S	-	-	-
	Quercetin-3-glucuronide	FS	3.35 ± 1.35 a	0.69 ± 0.46 a	1.31 ± 0.25 a
		S	0.02 ± 0.01 a	0.05 ± 0.02 a	0.02 ± 0.0006 a
	Quercetin-3-arabinopyranoside	FS	13.09 ± 2.89 a	18.98 ± 9.19 a	16.96 ± 4.22 a
		S	6.02 ± 3.79 a	4.89 ± 1.95 a	1.31 ± 0.56 a
	Quercetin-3-arabinofuranoside	FS	10.85 ± 7.98 a	23.99 ± 4.45 a	3.82 ± 3.78 a
		S	1.04 ± 0.55 a	2.49 ± 0.86 a	1.09 ± 0.03 a
	Isorhamnetin pentoside 1	FS	0.07 ± 0.05 a	0.16 ± 0.03 a	0.03 ± 0.02 a
		S	6.31 ± 3.98 a	5.12 ± 2.04 a	1.38 ± 0.59 a
	Isorhamnetin pentoside 2	FS	-	-	-
		S	0.21 ± 0.05 a	0.28 ± 0.23 a	0.05 ± 0.008 a

(Continued)

Table 9. Continued.

Phenolic group	Compound		<i>R. gallica</i>	'Violacea'	'Splendens'
	Quercetin-3-rhamnoside	FS	4.71 ± 1.01 a	6.85 ± 2.29 a	5.22 ± 0.51 a
		S	0.69 ± 0.42 a	1.25 ± 0.27 a	0.35 ± 0.06 a
	Quercetin-3-xyloside	FS	14.87 ± 6.19 a	23.83 ± 4.19 a	11.09 ± 2.69 a
		S	5.01 ± 1.92 a	0.66 ± 0.18 a	1.58 ± 0.45 a
	Total	FS	82.63 ± 37.70 a	90.91 ± 26.71 a	50.03 ± 13.27 a
		S	33.19 ± 16.94 a	42.20 ± 14.23 a	20.15 ± 3.93 a
Flavones	Apigenin derivative 1	FS	0.05 ± 0.01 ab	0.02 ± 0.01 a	0.12 ± 0.03 b
		S	-	-	-
	Total	FS	0.05 ± 0.01 ab	0.02 ± 0.01 a	0.12 ± 0.03 b
		S	-	-	-
Dihydrochalcone	Phloridzin	FS	78.52 ± 13.88 a	97.56 ± 31.62 a	78.73 ± 10.33 a

Different letters indicate statistically significant differences between genotypes, separately for flesh with skin (FS) and seed (S).

Note: (-) compound was not detected.

SE, standard error.

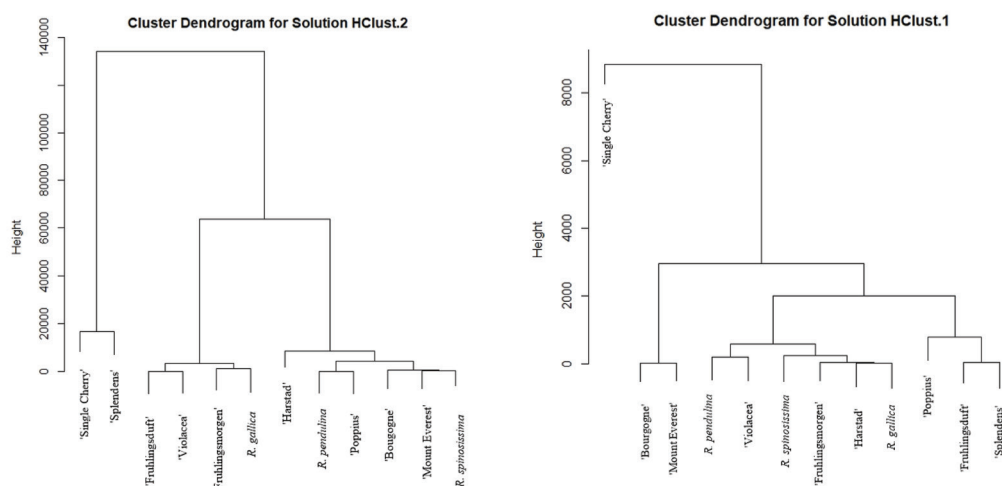


Figure 5. Hierarchical cluster analysis of the content of total phenolic compounds in flesh with skin (left) and in seeds (right) for all 12 analysed rose hips.

in the flesh with skin was found in the cultivar 'Splendens', which is derived from *R. gallica*, with 68789.39 mg · kg⁻¹ f.w.. From the dendrograms, it can be concluded that the cultivars 'Single Cherry' and 'Splendens' are similar and also characterised by a high total phenolic compound content. Based on the total phenolic compound content in the hips, 'Frühlingsduft' and 'Violacea', 'Frühlingsmorgen' and *R. gallica*, *R. pendulina* and 'Poppus', 'Bourgogne' and 'Mount Everest', and *R. spinosissima* are also similar. The only cultivar that differed from all others was 'Harstad'.

When the compounds present were examined, it was found that 45 phenolic compounds were determined in the flesh with the skin of *R. pendulina* and its cultivars, 76 in *R. spinosissima* and 67 in *R. gallica*. *R. pendulina* and its cultivars differ from the others by their extremely low composition of flavanols and flavonols, quite the opposite of *R. gallica*, where quite a lot of compounds

belonging to the mentioned group of phenolics were present. In *R. pendulina*, on the other hand, compounds such as quercetin-3-arabinopyranoside, quercetin-3-rhamnoside, quercetin-3-furanoside, isorhamnetin-pentoside 1–2, quercetin-galloyl-pentoside 1–3 were absent. The same was true for the content in the seeds, with the difference that the contents of compounds and total content in seeds were lower. They were also the lowest in 'Mount Everest', 757.02 mg · kg⁻¹ f.w. and the highest in 'Single Cherry', 6823.21 mg · kg⁻¹ f.w. When comparing our results with the literature, it can be seen that Kunc et al. (2023c) reported that the total phenolic content in the flesh with skin of *R. gallica* was 15800 mg · kg⁻¹ f.w. and 5310 mg · kg⁻¹ f.w. in *R. subcanina*, which is also comparable with our results. Najda and Buczkowska (2013) reported the total content in the hips of *R. villosa*, *R. californica*, *R. spinosissima*, *R. rugosa* and *R. × damascena*, where

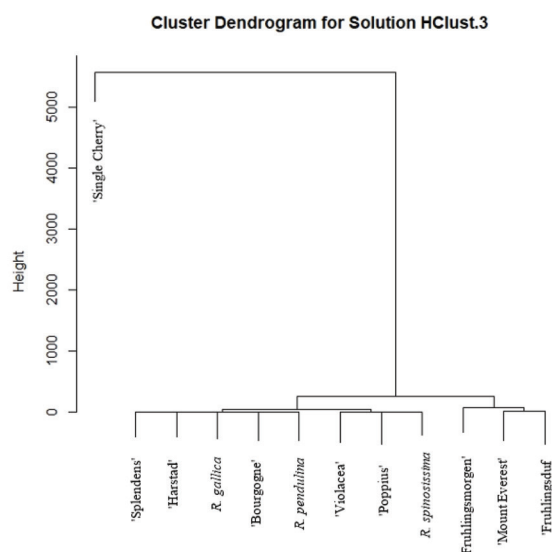


Figure 6. Hierarchical cluster analysis for the total content of cyanidin-3-glucoside in flesh with skin for all 12 analysed rose hips.

the lowest content was determined in *R. × damascena* ($1096.7 \text{ mg} \cdot \text{kg}^{-1} \text{ f.w.}$) and the highest in *R. rugosa* ($2151.4 \text{ mg} \cdot \text{kg}^{-1} \text{ f.w.}$), which was, on average, lower than that determined in the current study. As reported by Roman et al. (2013), there are differences in the phenolic composition of rose hips due to genetic variations, growth location, cultivation techniques and altitude. Olsson et al. (2004) found that the predominant phenolic compounds were quercetin and catechin. The phenolic acids identified by Demir et al. (2014) and Elmastas et al. (2017) were gallic acid, 4-hydroxybenzoic acid, caftaric acid, 2,5-dihydroxybenzoic acid, chlorogenic acid, caffeic acid, *p*-coumaric acid and ferulic acid. Nadpal et al. (2016) listed methyl gallate, catechin, epicatechin, rutin, eriocitrin, quercetin, apigenin-7-*O*-glucoside, kaempferol, quercitrin and quinic acid as the major flavonoids. In our samples of *R. pendulina*, the predominant HBA was galloylquinic acid, from the HCAs, 5-caffeoylquinic acid 2 was predominant, and among the gallotannins, digalloylquinic acid 1 and HHDP digalloylhexoside isomer 1 (ellagitannins) were predominant. The predominant flavanols were procyanidins. The high content of procyanidins, catechin and PA dimer diglycoside in *R. spinosissima* should be emphasised. *R. gallica* was very rich in *p*-coumaric acid hexoside 1. From the flavanols, procyanidins and PA dimer monoglycosides should be mentioned. The total content of phenolic compounds in the seeds of the studied rose hips ranged from $757.02 \text{ mg} \cdot \text{kg}^{-1} \text{ f.w.}$ ('Mount Everest') to $1714.72 \text{ mg} \cdot \text{kg}^{-1} \text{ f.w.}$ ('Harstad') for *R. pendulina* and cultivars and from $1684.59 \text{ mg} \cdot \text{kg}^{-1} \text{ f.w.}$ for *R. spinosissima* ('Frühlingsmorgen') to $6823.21 \text{ mg} \cdot \text{kg}^{-1} \text{ f.w.}$ ('Single Cherry'). In contrast, for *R. gallica*, these levels ranged from $1347.75 \text{ mg} \cdot \text{kg}^{-1} \text{ f.w.}$ ('Violacea') to $2155.44 \text{ mg} \cdot \text{kg}^{-1} \text{ f.w.}$ ('Splendens'). Kunc et al.

(2023a) found that the total phenolic content in seeds of selected native-grown Slovenian roses ranged from $1263.08 \text{ mg} \cdot \text{kg}^{-1} \text{ f.w.}$ to $3247.89 \text{ mg} \cdot \text{kg}^{-1} \text{ f.w.}$ Kunc et al. (2022) reported that the content of flavanols in the seeds of *R. pendulina* was $391.4 \text{ mg} \cdot \text{kg}^{-1} \text{ f.w.}$ and that of flavonols was $39.4 \text{ mg} \cdot \text{kg}^{-1} \text{ f.w.}$ They listed phloridzin as the dominant compound. In the seeds of 'Harstad' and *R. pendulina*, HBA dominated ($935.52 \text{ mg} \cdot \text{kg}^{-1} \text{ f.w.}$ and $976.50 \text{ mg} \cdot \text{kg}^{-1} \text{ f.w.}$), while in 'Bourgogne' and 'Mount Everest', flavanols were present ($384.61 \text{ mg} \cdot \text{kg}^{-1} \text{ f.w.}$ and $341.85 \text{ mg} \cdot \text{kg}^{-1} \text{ f.w.}$). In the samples of *R. spinosissima* and its cultivars, the content of ellagitannins dominated, ranging from $880.66 \text{ mg} \cdot \text{kg}^{-1} \text{ f.w.}$ (*R. spinosissima*) to $2753.88 \text{ mg} \cdot \text{kg}^{-1} \text{ f.w.}$ ('Single Cherry'). In *R. gallica* and its cultivars, the content of flavanols dominated, ranging from $751.96 \text{ mg} \cdot \text{kg}^{-1} \text{ f.w.}$ (*R. gallica*) to $1432.40 \text{ mg} \cdot \text{kg}^{-1} \text{ f.w.}$ ('Splendens').

In the study, we included roses that were grown in the park, which means that they were regularly maintained (irrigation, fertilisation, treatments against pests and diseases), unlike some other, similar studies (Kunc et al., 2022), where the plants were grown in a natural environment and not maintained and were also highly exposed to stress factors. Despite all this, from the results obtained, it appears that the content of the compounds analysed is extremely higher. This also indicates a great influence of the genotype to the phenolic picture of the hips.

The content of the anthocyanin cyanidin-3-glucoside was determined in rose hips. The cultivar 'Single Cherry' derived from *R. spinosissima* had the highest content ($3090.36 \text{ mg} \cdot \text{kg}^{-1} \text{ f.w.}$). The extremely high content of the mentioned anthocyanin is the result of the pronounced dark purple colour. In all the samples studied, it is noted that *R. spinosissima* and its cultivar 'Poppius' have identical anthocyanin content ($20.97 \text{ mg} \cdot \text{kg}^{-1} \text{ f.w.}$). However, in the other samples, there is no obvious link between the original rose hip and its cultivars. Kunc et al. (2022) reported that the content of cyanidin-3-glucoside in the hips of wild *R. pendulina* was $19.3 \text{ mg} \cdot \text{kg}^{-1} \text{ f.w.}$ In comparison to *R. pendulina* grown in Arboretum Volčji Potok, the content is significantly lower ($5.09 \text{ mg} \cdot \text{kg}^{-1} \text{ f.w.}$). All varieties derived from *R. pendulina* had a lower content of cyanidin-3-glucoside, except for 'Mount Everest', whose content was even $56.61 \text{ mg} \cdot \text{kg}^{-1} \text{ f.w.}$ The content of cyanidin-3-glucoside in the cultivar 'Splendens' was only $0.85 \text{ mg} \cdot \text{kg}^{-1} \text{ f.w.}$, and its content in the cultivar 'Violacea' was higher than that in *R. gallica*, with $11.51 \text{ mg} \cdot \text{kg}^{-1} \text{ f.w.}$ The dendrogram of the classification of the samples according to the content of cyanidin-3-glucoside shows that the samples are quite similar to each other. There are three groups of species and cultivars. Cultivars 'Splendens', 'Harstad' and 'Bourgogne' and species *R. gallica* and *R. pendulina* form the first group; cultivars 'Violacea' and 'Poppius' and species *R. spinosissima* form the second group; and the cultivars 'Mount Everest' and 'Frühlingsduft'

form the third group. Only 'Frühlingsmorgen' stands out, not fitting into any of the listed groups. It can be seen that the content of constituents in the cultivars does not often correspond to the content in the species from which they are derived. This indicates that modern breeding has other objectives than increasing the content of polyphenolic compounds in hips of new cultivars.

CONCLUSIONS

The phenolic compounds of rose hips from 12 different roses (*R. pendulina*, *R. spinosissima*, *R. gallica*, 'Violacea', 'Splendens', 'Poppius', 'Frühlingsmorgen', 'Frühlingsduft', 'Single Cherry', 'Harstad', 'Bourgogne' and 'Mount Everest') from Slovenia were studied. Research findings showed that the total phenolic content was higher in the flesh with skin than in the seeds. Due to the dark purple colour of rose hips, the variety 'Single Cherry' stood out, in which we found the highest content of cyanidin-3-glucoside. We can conclude that most of the samples studied are a rich source of phenolic compounds. Based on the composition of the phenolic compounds, the original species can be clearly distinguished from each other. However, we cannot say that a particular cultivar is derived from it solely based on its content, without knowing the original cultivar from which it is derived. The contents of studied phenolic compounds are very different, and we have found that some cultivars derived from different parent species are even more similar than those derived from the same species. We attribute this to the fact that only one known species of the origin (parent species) was considered in the ingredient and composition analysis, that the plants are subject to mutations and that the breeding houses have different breeding objectives, which is then reflected in the composition of phenolic compounds and their content. We suggest that further research studies should focus on investigating different new hybrids and modern cultivars to find out how different locations affect the content and composition of bioactive compounds in these genotypes. With this information, we would obtain information on which area is best suited for the growth of the varieties under study to obtain the highest content of bioactive substances useful for humans.

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AUTHOR CONTRIBUTIONS

N.K., G.O. and M.M.P. developed the concept and wrote the manuscript. N.K. and M.M.P. designed experiments, wrote code, ran the model, conducted analyses and analysed output data. M.H. gave technical support.

CONFLICT OF INTEREST

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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