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Morphological and Biochemical Diversity in Fruits of Unsprayed *Rosa canina* and *Rosa dumalis* Ecotypes Found in Different Agroecological Conditions

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Abstract: The *Rosa* is one of the most diverse genera in the plant kingdom and, in particular, its fruits have been used for multiple purposes in different parts of the world for centuries. Within the genus, *Rosa canina* and *Rosa dumalis* are, economically, the most important species and dominate *Rosa* fruit production. In this study, some important fruit and shrub traits of ten *Rosa canina* and ten *Rosa dumalis* ecotypes collected from rural areas of Kars province, located in the east Anatolia region of Turkey were investigated. We found significant differences among ecotypes in most of the morphological and biochemical traits. The ecotypes were found between 1446–2210 m altitude. Fruit weight and fruit flesh ratio ranged from 2.95 g to 4.72 g and 62.55% to 74.42%, respectively. SSC (Soluble Solid Content), Vitamin C, total phenolic, total flavonoid, total carotenoid, and total anthocyanin content of the ecotypes ranged from 16.9–22.7%, 430–690 mg per 100 g FW (fresh weight), 390–532 mg gallic acid equivalent per 100 g FW, 0.88–2.04 mg per g FW, 6.83–15.17 mg per g FW and 3.62–7.81 mg cyanidin-3-glucoside equivalent per kg, respectively. Antioxidant activity was determined to be between 19.7–34.7 mg ascorbic acid equivalent per g fresh weight. *Rosa* ecotypes contained chlorogenic acid and rutin the most as phenolic compound. Our results indicated great diversity within both *R. canina* and *R. dumalis* fruits.

Keywords: *Rosa canina*; *Rosa dumalis*; ecotype; heterogeneity; morphology; diversity; content

1. Introduction

Wild plants, including edible or less known fruits have unique taste and are easily found in nature. They are an important employment and income sources for rural peoples [1–4].

Opposite to cultivars, wild edible fruits more resistant to adverse soil and climatic conditions. Most wild fruit species had high content of phytochemicals that vital for human health compared with cultivated one [5]. They have rich gene combinations that could be important for breeding new commercial cultivars with improved aroma and resistance to biotic and abiotic stressors [6].

Among wild edible fruits, the *Rosa* species have special importance. The species are treasured mainly for their fruits (rose hips). Apart from edible fruit, seeds, flowers etc. valued and used as food, medicine, fodder, fuel, agriculture, tools, fencing and ritualistic aspects, [7–9].

Over 30 *Rosa* species are found within Turkey's flora, *Rosa canina* and *Rosa dumalis* are the most common and recognized for their better fruit characteristics providing a rich source of *Rosa* products. Native to cold and highland areas in Turkey, *Rosa canina* and *Rosa dumalis* are widely cultivated in Turkey [10]. In the country, it is widespread from east Anatolia to the Aegean region and from the Mediterranean to the Black sea region, revealing high environmental adaptability [7,9]. Previous studies on rose hips in Turkey aimed to describe a certain degree of heterogeneity which is normally present in cross-pollinating plants in any natural population [7–10].

In rural areas rose hip is one of the main sources of income [10]. The hips of *Rosa canina* and *Rosa dumalis* have been traditionally used in Turkey for centuries and, in particular during winter months, they can be processed into several products such as marmalade, syrup, jam, etc. In natural growing conditions, both species show diversity in most of the morphological traits. The fruits of *Rosa canina* and *Rosa dumalis* have been known as medicinal plants for a long time [11,12]. The medicinal potential of *Rosa* species is based on their antioxidant effects, associated with phytochemical content includes high ascorbic acid, carotenoids and phenolic compounds [13–16].

It is obvious that there was an increasing interest in nutraceuticals and functional foods. Wild edible fruits are rich sources of nutraceuticals and studies concentrated on their quality and bioactivity [17–20]. Wild edible fruits exhibit diverse morphology, fruit quality, yield and phytochemicals, compared to cultivated ones, and all those traits can be influenced by environmental conditions and ecotypes [21–25]. Thus, ecotype selection is important task for appropriate varieties' development. Therefore, it is crucial to make detailed comparative studies on rose hip ecotypes related to important plant traits and phytochemical content. Thus, identification of the promising (elite) ecotypes for developing rose hip at a commercial scale is significant.

In the literature, there was limited information about the comparison of morphological and biochemical traits in fruits of *R. canina* and *R. dumalis*. Thus, in this study, we aimed to determine and compare some important morphological and biochemical features of *R. canina* and *R. dumalis* ecotypes, naturally growing in Kars province, located in east Anatolia, due to their potential application in functional foods.

2. Materials and Methods

2.1. Plant Material

In this study, ripe fruit of *R. canina* and *R. dumalis* naturally grown in Kars province, located in the east Anatolia of Turkey, were used. Fruits were harvested during September in 2017 and 2018 from 20 pre-selected ecotypes of *R. canina* and *R. dumalis*. They were pre-selected according to their higher yield, being pest and disease free and more attractive bigger fruit characteristics. *Rosa* ecotypes are generally found in rural areas in Turkey, and they were formed as a result of the scattering of seeds naturally. The materials used in this study were also carried out on ecotypes formed from naturally scattering seeds showing a heterogeneity situation.

2.2. Sampling and Morphological Parameters

Samples consisted of 80 randomly harvested fruits from different parts of shrubs. Samples were transferred to the laboratory for measurements of fruit fresh weight, flesh ratio and fruit biochemical analyses, while yield and thorn characteristics of the respective plants were determined by on-site observations. Fruit weight was determined with digital balance. To calculate the fruit–flesh ratio, the fruit flesh weight/fruit weight $\times$ 100 equation was used.

2.3. Biochemical and Bioactive Composition

2.3.1. Sample Preparation and Extraction

For the analyses of biochemical content, the harvested fruit was immediately frozen and stored at -80°C until further analysis. During the analysis, the frozen fruits were

taken and thawed to 24–25 °C. A laboratory blender was used to homogenise the fruit samples (100 g lots of fruits per ecotype) and a single extraction procedure (taking 3 g aliquots transferred inside tubes and extracted for 1 h with 20 mL buffer including acetone, water (deionized), and acetic acid (70:29.5:0.5 *v/v*) [26]) was used.

2.3.2. Total Phenolic Contents

Folin–Ciocalteu method according to Singleton and Rossi [26] was used for determination of total phenolic content (TPC) of the samples. The TPC results was expressed as mg of gallic acid equivalents (GAE) per 100 g of fresh sample.

2.3.3. Total Carotenoid Content

Total carotenoid content was determined according to Lichtenthaler [27] and results of total carotenoid content was expressed as mg per g fresh fruit sample.

2.3.4. Total Flavonoid Content

Total flavonoid content was determined according to Chang et al. [28] and results were expressed as mg quercetin equivalent (QUE) per g FW.

2.3.5. Total Anthocyanin Content

pH differential method of Giusti and Wrolstad [29] was used to determine total anthocyanin amount and results was expressed as mg of cyanidin-3-glucoside equivalent in per kg of fresh sample.

2.3.6. Antioxidant Capacity

According to Nakajima et al. [30], DPPH scavenging activity of rosehip extracts was calculated and given as mg ascorbic acid equivalent (AAE) per g fresh weight.

2.3.7. Phenolic Compounds

Phenolic compounds were detected with a modified HPLC procedure suggested by Rodriguez-Delgado et al. [31]. Phenolic compounds were expressed as µg per g FW.

2.4. Statistical Analysis

The data of both years were pooled because there were no differences between years. SPSS software and procedures used for analysis and Least Significant Difference (LSD) method at $p < 0.05$ was used to analyze of variance tables. In addition, principal component analysis (PCA) was performed to determine the relationships among ecotypes. Furthermore, Pearson analysis was applied to identify the correlation among the measured main morphological and biochemical traits and investigate the relations between them.

3. Results and Discussion

3.1. Morphological Traits of *R. canina* and *R. dumalis* Ecotypes

Location, altitude, thorn, yield, fruit weight and fruit flesh ratio characteristics of 20 *Rosa canina* and *R. dumalis* ecotypes are shown in Table 1. As indicated in Table 1, *Rosa canina* and *Rosa dumalis* ecotypes prefer relatively higher altitudes, which were between 1446 and 2210 m (Table 1). We found a wide variation in thorn, yield, fruit weight and fruit flesh ratio characteristics in ecotypes. In general, the ecotypes used in the present study exhibited low or medium thorn on its shoots. The high thorn causes difficulties in harvesting *Rosa* shrubs. The pre-selected ecotypes had high or very high yield characteristics, which is important for bringing them into cultivation conditions. Fruit weight was quite variable, ranging from 2.95 g (K5, *Rosa dumalis*) to 4.72 g (K12, *Rosa canina*), respectively (Table 1). Previous studies described variability in thorn and yield of *Rosa* ecotypes [32–35]. The fruit weight of rose hip ecotypes belonging to different species that were reported in Turkey ranged from 0.61 to 4.95 g [32,33,35–37].

Table 1. Morphological traits of *R. canina* and *R. dumalis* ecotypes.

Ecotypes	Species	Location	Altitude (m)	Thorn	Yield	Fruit Weight (g)	Flesh Ratio (%)
K1	<i>Rosa canina</i>	Arpacay	1765	Medium	High	3.84 ± 0.15	70.55 ± 2.44
K2	<i>Rosa canina</i>	Arpacay	1780	Medium	Very high	4.02 ± 0.20	68.61 ± 3.14
K3	<i>Rosa dumalis</i>	Arpacay	1758	Low	High	3.66 ± 0.11	64.44 ± 2.88
K4	<i>Rosa canina</i>	Digor	1570	Low	High	4.25 ± 0.22	72.25 ± 4.22
K5	<i>Rosa dumalis</i>	Digor	1556	Low	High	2.95 ± 0.12	63.38 ± 4.56
K6	<i>Rosa dumalis</i>	Digor	1548	Medium	High	3.66 ± 0.14	65.11 ± 3.88
K7	<i>Rosa dumalis</i>	Kagizman	1470	Medium	Very high	3.90 ± 0.17	67.22 ± 2.11
K8	<i>Rosa canina</i>	Kagizman	1480	Low	Very high	4.11 ± 0.22	74.42 ± 5.11
K9	<i>Rosa dumalis</i>	Kagizman	1446	Low	High	3.60 ± 0.20	70.55 ± 4.31
K10	<i>Rosa dumalis</i>	Sarikamis	2205	Medium	High	3.44 ± 0.14	72.30 ± 5.51
K11	<i>Rosa canina</i>	Sarikamis	2180	Medium	Very high	4.46 ± 0.23	66.15 ± 4.32
K12	<i>Rosa canina</i>	Sarikamis	2210	Medium	High	4.72 ± 0.21	73.22 ± 5.26
K13	<i>Rosa canina</i>	Selim	1822	Low	High	3.85 ± 0.10	69.56 ± 3.67
K14	<i>Rosa dumalis</i>	Selim	1865	Low	High	3.50 ± 0.09	62.55 ± 4.93
K15	<i>Rosa dumalis</i>	Kars	1828	Low	High	3.10 ± 0.10	67.83 ± 2.93
K16	<i>Rosa dumalis</i>	Kars	1845	Medium	High	3.05 ± 0.09	69.92 ± 4.36
K17	<i>Rosa canina</i>	Kars	1885	Low	High	4.29 ± 0.17	73.34 ± 5.80
K18	<i>Rosa canina</i>	Kars	1910	Medium	Very high	4.38 ± 0.20	67.19 ± 4.55
K19	<i>Rosa dumalis</i>	Kars	1922	Low	High	3.81 ± 0.15	65.44 ± 3.67
K20	<i>Rosa canina</i>	Kars	1968	Low	High	3.57 ± 0.16	70.48 ± 4.67
Significance						**	**
LSD5%						0.21	3.26

**: $p < 0.01$.

At the individual level, promising ecotypes were found in both *R. canina* and *R. dumalis* species. For example, K12, K11, K18, K17 and K4 ecotypes belonging to *R. canina*, and K7 and K19 belonging to *R. dumalis*, had bigger fruits and K8, K17, K12 and K4 within *R. canina*, and K10, K9 and K16 within *R. dumalis*, exhibited a higher percentage of fruit flesh (Table 1). The promising ecotypes can be considered for future research on the rose hip cultivar development. Fruit–flesh ratios were between 62.55% (K-14) and 74.42% (K-8) (Table 1). Previous studies also indicated high diversity within *Rosa* species at the individual level. Ercisli and Esitken [38] reported fruit–flesh ratios between 63.11–73.63% among *Rosa canina* and *Rosa dumalis* ecotypes. Ipek and Balta [39] found fruit–flesh ratios between 62.0–72.0% among 19 rose hip ecotypes naturally grown in middle Anatolia. Ersoy and Ozen [7] found fruit–flesh ratios between 64.8–82.8% among rose hip ecotypes grown in Western Anatolia.

Our results on fruit–flesh ratio was comparable with the above studies. Wild edible fruits had greater gene diversity and they also had unique gene combinations [40–42]. It is well understanding that wild species increase crop genetic diversity [39,43]. Frequent seed propagation of wild fruits and strictly out-crossing nature probably leads to an increase in the genetic diversity of wild fruits [37–39].

3.2. Total Flavonoid, Total Phenolic, Total Carotenoid, Vitamin C, Total Anthocyanin, Antioxidant Capacity and SSC Content

Total flavonoid, total phenolic, total carotenoid, Vitamin C, total anthocyanin, antioxidant capacity and SSC content of *R. canina* and *R. dumalis* ecotypes are shown in Table 2. Total flavonoid content was the highest in K6 (2.04 mg per g FW), which belongs to *R. dumalis*, followed by K3 (1.94 mg per g FW), while it was the lowest in K9 (0.88 mg per g FW) (Table 2). In Iran, total flavonoid content was studied in different *Rosa*

species and reported from 0.70 (*R. hemisphaerica*) to 2.53 mg quercetin equivalent per g FW (*R. canina*) [44]. Flavonoids impact the aroma and color of fruits and against biotic and abiotic stressors [45]. Medveckiene et al. [46] reported that total flavonoid content is species dependent in *Rosa*, and the highest total flavonoid content found as 41.59 mg/100 g DW. Rosehips accumulated a higher amount of total flavonoids ranged from 52 mg/100 g to 56 mg/100 g [20,47].

Table 2. Biochemical content of *rose hip* ecotypes.

Ecotypes	Total Flavonoid (mg QUE/g FW)	Total Phenolic (mg GAE/100 g FW)	Total Carotenoid (mg/g FW)	Vitamin C (mg/100 g FW)	Total Anthocyanin (mg/kg)	DPPH (mg AAE/g FW)	SSC (%)
K1	1.55 ± 0.10	492 ± 16	13.70 ± 0.20	678 ± 21	5.68 ± 0.20	29.8 ± 0.5	20.2 ± 0.4
K2	1.87 ± 0.09	511 ± 13	12.20 ± 0.17	636 ± 27	7.04 ± 0.23	34.4 ± 0.2	19.8 ± 0.4
K3	1.94 ± 0.12	488 ± 14	15.17 ± 0.11	595 ± 24	6.28 ± 0.20	30.5 ± 0.1	20.6 ± 0.5
K4	1.75 ± 0.10	497 ± 09	15.02 ± 0.15	642 ± 29	4.95 ± 0.12	31.4 ± 0.2	19.8 ± 0.3
K5	1.90 ± 0.08	519 ± 20	14.80 ± 0.10	667 ± 23	7.81 ± 0.17	33.3 ± 0.2	20.6 ± 0.2
K6	2.04 ± 0.13	532 ± 13	14.40 ± 0.09	605 ± 30	6.50 ± 0.16	34.7 ± 0.4	19.9 ± 0.4
K7	1.08 ± 0.05	390 ± 10	9.40 ± 0.06	502 ± 13	7.51 ± 0.20	19.7 ± 0.3	17.3 ± 0.1
K8	0.95 ± 0.05	398 ± 09	8.11 ± 0.06	430 ± 10	4.41 ± 0.10	21.3 ± 0.5	16.9 ± 0.1
K9	0.88 ± 0.04	400 ± 14	6.83 ± 0.04	454 ± 09	5.35 ± 0.09	19.9 ± 0.2	17.1 ± 0.3
K10	1.67 ± 0.09	447 ± 10	10.70 ± 0.11	641 ± 14	6.20 ± 0.09	27.4 ± 0.5	22.7 ± 0.2
K11	1.55 ± 0.10	460 ± 08	11.40 ± 0.10	580 ± 12	7.02 ± 0.10	26.9 ± 0.5	21.5 ± 0.4
K12	1.79 ± 0.07	471 ± 07	11.80 ± 0.12	690 ± 16	3.62 ± 0.05	23.8 ± 0.2	22.0 ± 0.3
K13	1.66 ± 0.07	466 ± 10	7.60 ± 0.04	492 ± 10	6.02 ± 0.13	25.4 ± 0.3	20.2 ± 0.1
K14	1.47 ± 0.06	451 ± 12	8.40 ± 0.05	505 ± 13	5.75 ± 0.11	29.2 ± 0.6	20.8 ± 0.2
K15	1.28 ± 0.06	428 ± 14	9.97 ± 0.06	572 ± 11	6.36 ± 0.10	30.1 ± 0.5	19.3 ± 0.3
K16	1.35 ± 0.06	481 ± 10	7.94 ± 0.01	610 ± 14	6.11 ± 0.09	25.5 ± 0.4	21.9 ± 0.1
K17	1.30 ± 0.05	404 ± 09	10.20 ± 0.07	497 ± 08	4.85 ± 0.09	23.8 ± 0.4	20.1 ± 0.4
K18	1.50 ± 0.10	417 ± 11	11.30 ± 0.14	555 ± 10	5.42 ± 0.12	27.0 ± 0.5	21.5 ± 0.6
K19	1.43 ± 0.11	425 ± 15	9.88 ± 0.09	582 ± 12	3.97 ± 0.10	25.6 ± 0.2	20.2 ± 0.5
K20	1.20 ± 0.05	410 ± 14	10.57 ± 0.07	450 ± 11	4.87 ± 0.10	24.4 ± 0.2	19.9 ± 0.3
Significance	**	**	**	**	**	**	**
LSD5%	0.26	45	2.23	120	1.67	2.77	1.40

QUE: Quercetin equivalent; GAE: Gallic acid equivalent; DPPH: 2,2-diphenyl-1-picrylhydrazyl; AAE: Ascorbic acid equivalent; SSC: Soluble Solid Content; FW: Fresh weight. **: $p < 0.01$.

We found a wide variation in total phenolic content among ecotypes, which varied from 390 mg GAE per 100 g (K7) to 519 mg GAE per 100 g (K5). Previously, total phenolic content was found between 177–816 mg GAE per 100 g fresh samples between *Rosa* species grown in different parts of the world [48–51]. Koczka et al. [52] reported 150–299 mg/100 g DW total polyphenols in fruit flesh of rosehips. Medveckiene et al. [46] used several species of *Rosa* and reported that total polyphenol content in flesh varied from 150 to 299 mg/100 g DW. Fascella et al. [53] showed between 4057 and 6784 mg GAE/100 g DW total phenolic content among *Rosa* species. Alp et al. [54] found that *R. dumalis* fruits had total phenolic content between 297 and 403 mg GAE/100 g FW. The total phenolic content results obtained in our study were comparable with the above studies and indicate total polyphenol richness of rose hips. High polyphenol content of rose hips comparable with high polyphenol fruits such as blueberry, elderberry, black currant, blackberry and raspberry. The differences among studies may be attributed to different species, accessions and ecotypes used. Harvest period, different extraction methods, ecological conditions, etc., could also affect total phenolic content [48–51].

Table 2 shows the total carotenoid contents in the 20 ecotypes of *Rosa* fruits. The total carotenoid content ranged between 6.83 (K9) and 15.17 (K3) mg per g FW. Previously, Shameh et al. [44] reported variable total carotenoid content among 21 *Rosa* ecotypes belonging to different species. Andersson et al. [48] reported total carotenoids between 297 (*R. spinosissima*) and 1020 (*R. dumalis*) µg per g dry weight base in *Rosa*. Medveckiene et al. [46] reported total carotenoid content in the fruits of five *Rosa* species, ranging from 8.67–49.61 mg/100 g DW. Fascella et al. [53] found that hips of *Rosa sempervirens* and *R. canina* showed the highest total carotenoid values (1235 and 1204 mg/100 g DW, respectively), whereas those of *R. corymbifera* and *R. micrantha* had lower values (1072 and 1061 mg/100 g DW, respectively). Al-Yafeai et al. [55] revealed variable carotenoid contents among rosehip species. Previous study is also indicating rich carotenoid content of rosehips than the other fruits [56]. Carotenoids responsible yellow, orange and red pigments in fruits and offers human health benefits [44,57]. Genetic background, cultivars, harvest period, extraction and analytical method etc. affect fruit carotenoid content [48].

Ascorbic acid of the *R. canina* and *R. dumalis* ecotypes are given in Table 2. The ecotypes showed ascorbic acid content between 430 and 690 mg per 100 g of fresh fruit. Ascorbic acid content in rose hip is mainly species and ecotype dependent. Our results are comparable with other investigations. For example, Roman et al. [58] determined that the amount of ascorbic acid ranged between 112–360 mg per 100 g of fresh rose hips belonging to different species grown in Romania. Celik et al. [35] revealed ascorbic acid content in fruits of different *Rosa* species in high altitude (between 1650–1900 m) in the Eastern Anatolia region of Turkey between 604 and 1032 mg/100 g. Medveckiene et al. [46] reported that the ascorbic acid content in flesh of five rosehips species grown in Lithuania ranged between 385 mg to 736 mg/100 g FW. The vitamin C contents of rose hips in Italy were reported between 222–513 mg/100 g [53]. Alp, et al. [54] reported that vitamin C content of hips genotype dependent in *Rosa dumalis* varied from 402 to 511 mg/100 g fresh weight. Ercisli and Esitken [38] found vitamin C content in rose hips between 1222 to 2557 mg/100 g FW, indicating higher values than our samples. Rosu et al. [59] found vitamin C between 616 and 866 mg/100 g FW in fruits of *Rosa caesia* and *R. rubiginosa* in Romania. Rose hip species growing in high altitude regions are rich in ascorbic acid due to higher light exposure and lower oxygen amounts. Light exposure increases the amount of carotene and thus protects ascorbic acid in the fruit, while the lack of oxygen reduces oxidative stress and lessens ascorbic acid breakdown [32]. Vitamin C in fruits specie and genotype dependent and shows high heritability [60,61].

The total anthocyanin content of ecotypes ranged from 3.62 mg (K12) to 7.81 (K5) mg cyanidin-3-glucoside equivalent per kg of fresh fruit (Table 2). Previous studies reported that the major anthocyanin in the Caninae section including *R. canina* and *R. dumalis* fruits was cyanidin-3-glucoside and was mostly found in seed coat and fruit peel [12]. Guerrero et al. [62] found that the total anthocyanin content in over matured rose hip fruit was 0.38 mg/100 g. Cyanidin-3-glucoside was previously reported to have the highest oxygen radical scavenging effect [63]. Shameh et al. [44] reported that the total anthocyanin content in the various species of *Rosa* was between 1.80 and 15.86 mg per kg. In Italy, anthocyanins content was found between 0.55 mg CGE/100 g DW in *R. corymbifera* fruits and 3.66 mg CGE/100 g DW in *R. canina* fruits. Murathan et al. [64] reported that total anthocyanin specie dependent in *Rosa* and varied from 2.45 to 3.72 mg CGE/100 g. Yildiz and Alpaslan [65] found total anthocyanins in *Rosa* fruits as 28.2 mg per kg. Anthocyanins give red to blue colors of many plants. Environment, specie, cultivar, altitude, cultivation techniques etc. strongly effect its concentration in fruits [62,64,66].

DPPH values of ecotypes are shown in Table 2 and the results indicate differences among ecotypes in the antioxidant capacities. Antioxidant capacity was the lowest for the K7 ecotype as 19.7 mg ascorbic acid equivalent per g FW and was the highest for K6 ecotype as 34.7 mg ascorbic acid equivalent per g FW (Table 2). Shameh et al. [44] showed significant differences in antioxidant activity among *Rosa* ecotypes. They reported that *R. hemisphaerica* fruits had the lowest (3.80 mg AAE per g FW), and *R. canina* fruits had the

highest (37.60 mg AAE per g FW), antioxidant capacity. These differences may be caused by factors such as sample type used, the species differences, geographical area, the degree of ripening, climate and experimental conditions. Cunha et al. [67] reported that the highest antioxidant capacity was observed in *R. canina* fruit harvested in September and after that antioxidant capacity decreased. Okatan et al. [37] reported significant variability in DPPH scavenging activity of rosehip ecotypes ranging from 98.1 to 254.8 µg/mL. Demir et al. [13] found that DPPH scavenging activities of five *Rosa* species between 161 and 278 µg/mL. Soare et al. [68] reported that rose hip ecotypes show great diversity in DPPH values in Romania.

Soluble solid content (SSC) of ecotypes varied from 16.9% (K8) to 22.7% (K10), respectively (Table 2). Previously, SSC contents of rose hip fruits were very variable and reported between 12–36% [33,34,69]. For rose hip (*Rosa* spp.) genotypes from different areas, SSC were reported as 31–36.7% [38], 24.1–30.5% [7], 10–18% [68] and 17.6–22.8% [54]. Our results on SSC were in agreement with the above literature. Consumers not only emphasis on external quality criteria such as color, shape, size, but also on internal quality of fruits, including taste, sugar degree, acidity, etc. [69].

3.3. Phenolic Compounds

Table 3 shows phenolic compounds of 20 *Rosa* ecotypes. The major phenolic compounds in fruits of *R. canina* and *R. dumalis* ecotypes were chlorogenic acid, and followed by gallic acid, rutin, *p*-coumaric acid and caffeic acid, respectively (Table 3).

Table 3. Phenolic compounds in rosehip fruits (µg per g FW).

Ecotypes	Chlorogenic	Gallic	Rutin	<i>p</i> -Coumaric	Caffeic
K1	28.2 ± 0.06	25.8 ± 0.05	21.7 ± 0.04	30.7 ± 0.04	8.7 ± 0.02
K2	55.8 ± 0.03	30.1 ± 0.03	30.8 ± 0.02	25.8 ± 0.02	10.1 ± 0.01
K3	67.4 ± 0.03	49.3 ± 0.02	25.5 ± 0.04	19.6 ± 0.03	ND
K4	60.3 ± 0.02	40.2 ± 0.02	30.1 ± 0.01	27.3 ± 0.03	13.7 ± 0.01
K5	81.3 ± 0.06	44.3 ± 0.01	38.6 ± 0.03	ND	10.9 ± 0.01
K6	50.2 ± 0.06	32.1 ± 0.03	26.2 ± 0.05	14.9 ± 0.02	ND
K7	73.7 ± 0.05	24.8 ± 0.01	24.4 ± 0.02	16.2 ± 0.03	9.4 ± 0.02
K8	48.8 ± 0.04	29.3 ± 0.04	33.6 ± 0.03	21.3 ± 0.03	11.6 ± 0.02
K9	69.8 ± 0.04	34.6 ± 0.05	28.6 ± 0.04	27.4 ± 0.02	ND
K10	27.8 ± 0.03	33.1 ± 0.05	20.9 ± 0.04	18.4 ± 0.02	8.3 ± 0.01
K11	56.1 ± 0.02	19.2 ± 0.05	22.5 ± 0.06	11.6 ± 0.01	14.2 ± 0.01
K12	51.4 ± 0.06	10.9 ± 0.03	24.7 ± 0.01	ND	13.1 ± 0.03
K13	29.3 ± 0.04	28.3 ± 0.05	18.5 ± 0.03	12.0 ± 0.01	ND
K14	77.8 ± 0.03	27.6 ± 0.04	33.2 ± 0.04	13.2 ± 0.01	ND
K15	44.2 ± 0.02	30.9 ± 0.02	35.4 ± 0.06	16.1 ± 0.02	13.9 ± 0.02
K16	39.6 ± 0.03	24.2 ± 0.05	19.9 ± 0.02	15.0 ± 0.02	12.6 ± 0.01
K17	35.2 ± 0.02	30.4 ± 0.06	22.6 ± 0.02	33.2 ± 0.02	11.5 ± 0.01
K18	51.8 ± 0.04	21.6 ± 0.05	24.4 ± 0.03	ND	14.0 ± 0.05
K19	69.1 ± 0.06	32.1 ± 0.02	30.2 ± 0.05	14.7 ± 0.01	ND
K20	42.2 ± 0.06	22.3 ± 0.04	19.2 ± 0.04	14.2 ± 0.02	13.3 ± 0.04
Significance	**	**	**	**	**
LSD5%	3.2	2.8	2.4	1.9	0.9

ND: Non determined. **: $p < 0.01$.

Those phenolic acids are highly variable in fruits of different ecotypes of *R. canina* and *R. dumalis*. The highest chlorogenic acid content was found in ecotype K5 as 81.3 µg per g FW, while the lowest value was observed in fruits of K10 ecotypes as 27.8 µg per g FW, respectively (Table 3).

Gallic acid and rutin content were between 10.9 (K12)–49.3 (K3) µg per g FW and 18.5 (K13)–38.6 (K5) µg per g FW, respectively, indicating high variability among ecotypes. The highest *p*-coumaric acid content was observed in K17 ecotypes as 33.2 µg per g FW. Three ecotypes, K5, K12 and K18, did not show any *p*-coumaric acid in their fruits (Table 3). The highest caffeic acid content was found in fruits K11 ecotypes as 14.2 µg per g FW. The caffeic acid was not detected in the fruits of K3, K6, K9, K13, K14 and K19 ecotypes (Table 3). In Iran, Shameh et al. [44] revealed that *Rosa* species mostly include chlorogenic acid and gallic acid in their fruits, and they determined high variability in those compounds among species. They found that chlorogenic acid and gallic acid levels were in the ranges of 5.7–186 and 4.1–164 µg per g FW, respectively. Demir et al. [13] reported that five *Rosa* species grown in Turkey mostly included chlorogenic acid, gallic acid, *p*-coumaric acid and caffeic acid. Ozturk et al. [70] reported that the *R. canina* fruits included mostly protocatechuic acid, vanillic acid, catechin, chlorogenic acid, *p*-coumaric acid and ferulic acid, and concentrations of those phenolic compounds in rosehips were 1.4, 6.9, 3.1, 8.5, 24.9 and 23.9 mg/100 g, respectively. Similar ranges of phenolic compounds in *R. canina* genotypes were determined by Okatan et al. [37], Nowak [71] and Fecka [72]. Chlorogenic acids reduce oxidative and inflammatory stress conditions [73]. Rutin, has antioxidant, cytoprotective, vasoprotective, anticarcinogenic, neuroprotective and cardioprotective properties [74].

3.4. Correlations between Traits

In the study, correlation analysis was performed to determine the relationships between fruit characteristics in rose hip ecotypes (Table 4). Correlation analysis showed that FW had positive relationships with FFR ($r = 0.34$), Vit. C ($r = 0.57^*$), TPC ($r = 0.07$) and DPPH ($r = 0.13$), and negative relationships with SSC ($r = -0.25$), TFC ($r = -0.09$), TC ($r = -0.03$) and TA ($r = -0.04$), respectively (Table 4).

Table 4. Pearson's correlations of fruit characteristics of rosehip ecotypes.

	FW	FFR	SSC	Vit. C	TPC	TFC	TC	TA	DPPH
FW	1.00								
FFR	0.34	1.00							
SSC	−0.25	−0.18	1.00						
Vit. C	0.57 *	−0.17	0.63 *	1.00					
TPC	0.07	−0.04	−0.07	0.43	1.00				
TFC	−0.09	−0.07	−0.14	0.21	0.74 **	1.00			
TC	−0.03	−0.09	−0.11	0.33	0.61 *	0.55	1.00		
TA	−0.04	−0.17	−0.23	−0.08	0.44	0.52	0.04	1.00	
DPPH	0.13	−0.21	−0.08	0.55	0.84 **	0.69 *	0.58	0.61 *	1.00

FW: Fruit weight; FFR: Fruit flesh ratio; SSC: Soluble Solid Content; Vit. C: Vitamin C; TPC: Total phenolic Content; TFC: Total flavonoid content; TC: Total carotenoid; TA: Total anthocyanin; DPPH: 2,2-diphenyl-1-picrylhydrazyl; *: $p < 0.05$; **: $p < 0.01$.

FFR was negatively related to SSC ($r = -0.18$), Vit. C ($r = -0.17$), TPC ($r = -0.04$), TFC ($r = -0.07$), TC ($r = -0.09$), TA ($r = -0.17$) and DPPH ($r = -0.21$). SSC had a positive correlation with Vit. C ($r = 0.63^*$) but had negative correlation with TPC, TFC, TC, TA and DPPH. Vit. C had a positive correlation with TPC, TFC, TC and DPPH, but was negatively related to TA. TPC showed strong relationships with TFC ($r = 0.74^{**}$) and DPPH ($r = 0.84^{**}$) (Table 4). Previously, Guler et al. [9] used a number of rose hips and reported negative

relationships between fruit SSC content and flesh weight, and positive correlation with FW and FFR. Cosmulescu et al. [75] reported that there was strong relationship between antioxidant activity and total phenolic content in *Rosa* fruits.

3.5. Principal Component Analysis (PCA)

In the PCA analysis we found 75.68% variability in the traits. First three components namely PC1, PC2 and PC3 explained 40.11%, 23.42% and 8.15% of variations, respectively. PC1 is identified with the fruit weight, fruit flesh ratio and vitamin C, while PC2 is related to the SSC, total carotenoids and total phenolics. The analysis clearly grouped wild grown rose hip into bigger fruited ones, sweeter ones or those with a higher content of polyphenolic compounds (Figure 1). Previous studies also indicated large diversity among ecotypes in wild and cultivated plants by using PCA analysis [76–82].

Figure 1. Distribution of rose hip ecotypes according to morphological and biochemical characteristics determined by principal component analysis.

4. Conclusions

As a result, we identified valuable rose hip ecotypes belonging to *R. canina* and *R. dumalis* among natural rose hip populations in Kars province where no previous studies were conducted on rose hip ecotypes. At present study, especially K2, K8, K11 and K18 were found promising, with high fruit weight (over 4 g), K1, K8 and K10 with a high fruit–flesh ratio (over 70%), and K4, K12 and K17 with both high fruit weight and a fruit–flesh ratio. It is also thought that these promising ecotypes can be cultivar candidates and can be produced economically in Turkey. The data showed that the analysed naturally grown hips, particularly K1, K2, K3, K4, K5, K6, K11 and K15, have good nutritional quality, making them suitable as functional foods.

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