

Variation of the Chemical Properties of Rosehip (*Rosa canina* L.) Fruits According to Aspect Conditions

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Abstract: This study aimed to determine the chemical variations of volatile oil components in *Rosa canina* L. fruits across different slope aspects and to evaluate their relationship with environmental factors such as temperature, precipitation, and soil properties. The research was conducted in the Sarıveliler district of Karaman Province, Türkiye. Fruit samples collected from four different aspects were analyzed using a Shimadzu 2010 Plus GC-MS system, and compound identification was performed by comparing retention time (RT) and mass spectral (MS) data with literature references. Relationships between compounds and environmental variables were assessed using Pearson correlation analysis and temperature-precipitation maps generated by the Co-Kriging method. The findings revealed significant aspect-dependent differences in both the composition and relative abundance of volatile compounds. (E)-2-Hexenal dominated in the eastern and northern aspects, while Limonene prevailed in the western aspect. Positive correlations were observed among terpenoids, whereas negative correlations were found between terpenoids and oxygenated compounds. The region's temperature (10–12 °C), precipitation (600–800 mm), and calcareous brown forest soils provide favorable ecological conditions for *Rosa canina*.

Kuşburnu (*Rosa canina* L.) Meyvelerinin Kimyasal Özelliklerinin Bakı Koşullarına Göre Değişimi

Anahtar Kelimeler

Rosa canina,
Bakı,
Uçucu Bileşen,
Karaman,
Türkiye

Öz: Bu çalışma, *Rosa canina* L. meyvelerinin farklı bakı yönlerine göre uçucu yağ bileşenlerindeki kimyasal varyasyonları belirlemek ve bu varyasyonların yetiştirme ortamı koşulları (sıcaklık, yağış, toprak özellikleri) ile ilişkisini değerlendirmek amacıyla yürütülmüştür. Araştırma, Türkiye'nin Karaman ili Sarıveliler ilçesinde gerçekleştirilmiştir. Dört farklı bakıdan toplanan meyve örnekleri Shimadzu 2010 Plus GC-MS cihazı ile analiz edilmiş, bileşen tanımlamaları alıkonma zamanı (RT) ve kütle spektral (MS) verilerinin literatürle karşılaştırılmasıyla yapılmıştır. Pearson korelasyon analizi ve Co-Kriging yöntemiyle elde edilen sıcaklık-yağış haritaları kullanılarak bileşen-çevre ilişkileri değerlendirilmiştir. Bulgular, uçucu bileşenlerin bileşim ve oranlarının bakıya göre anlamlı farklılık gösterdiğini ortaya koymuştur. Doğu ve kuzey bakılarda (E)-2-Hexenal, batı bakıda Limonene baskın bileşenlerdir. Terpenoid bileşikler arasında pozitif, oksijenli bileşiklerle arasında ise negatif korelasyonlar belirlenmiştir. Çalışma alanındaki 10–12 °C sıcaklık, 600–800 mm yağış ve kireçsiz kahverengi orman toprakları *Rosa canina* için elverişli ekolojik koşullar sunmaktadır.

1. Introduction

Rosa canina L., commonly known as rosehip, is a perennial shrub species that can reach heights between 1.5 and 3.5 meters, typically exhibiting an upright, bushy growth form. This species has a broad natural distribution, occurring not only across many European countries—including Russia, Poland, Germany, France, Switzerland, and Bulgaria—but also in regions of North Africa and Western Asia. In Turkey, *R. canina* holds a significant position within the native flora and is widely distributed throughout various regions of the country. A total of nine different *Rosa* species that are traditionally collected and utilized by local communities have been identified [1]. As of 2019, *R. canina* was recorded across 102,113 hectares in Turkey, with approximately 113 tons harvested from the wild [2]. Owing to its high content of ascorbic acid (vitamin C), the species is recognized for its considerable nutritional value. Traditionally, it has been used as a tonic and is also employed as a supportive treatment in diseases such as diabetes [3], [4]. Furthermore, several Eastern European countries have initiated its agricultural cultivation [5].

The fruits of *R. canina* are rich in a variety of biologically active compounds, including minerals, carotenoids, tocopherols, bioflavonoids, organic acids, tannins, pectins, amino acids, and various volatile oils [6]. Among these, mineral elements are of critical nutritional importance for human health, positioning rosehip as a valuable natural source. Research has shown that rosehip fruits are particularly rich in phosphorus and potassium, and also contain appreciable levels of other essential minerals such as manganese, calcium, and magnesium [7].

Numerous scientific studies have been conducted to determine the chemical composition of *R. canina* fruits. These studies have identified the presence of fundamental phytochemicals including minerals, bioflavonoids, organic acids, tannins, pectins, and amino acids [8]. Moreover, rosehip fruits have been found to contain significant amounts of carotenoids, contributing to their high antioxidant capacity [8], [3], [9]. In addition, various other bioactive components such as phenolic compounds [10], [11], folic acid [12], α -tocopherol (vitamin E), and γ -tocopherol [9], [13], [14] have also been identified. The presence of malic acid and fructose [15], as well as unsaturated fatty acids such as oleic, linoleic, and linolenic acids [13], [16], [17], further enhances the nutritional value of the fruit. Additionally, phenolic compounds such as catechin, chlorogenic acid, caffeic acid, and apigenin-7-O-glucoside have also been reported in rosehip [13], [18].

Species of *Rosa* are widely distributed across Turkey, particularly in regions characterized by cool and cold climates. Their range extends from sea level to elevations as high as 2,500 meters in the northern Aegean, Marmara, and Black Sea regions. In the Mediterranean coastal areas, their distribution

typically begins at elevations around 500–600 meters. In the Aegean and Mediterranean regions, *Rosa* species often grow in shrubby forms and show a preference for habitats such as riverbanks, streambeds, field and roadside margins, and forest clearings [2].

Ecological factors significantly influence both the fruit maturation period and the size of rosehip fruits. In interior regions and at higher elevations, pronounced diurnal temperature fluctuations positively affect fruit size and pigmentation, resulting in larger and more vividly colored fruits. Moreover, fruit maturation tends to occur earlier under such conditions. While *Rosa* spp. can grow in diverse soil types, they demonstrate optimal development in calcareous, nutrient-rich, and well-drained soils [2], [19].

Despite variations in environmental factors such as altitude, climate, and site conditions, one of the most striking features of rosehip is its consistently high vitamin C content. This characteristic has led to its widespread use as a raw material in the pharmaceutical industry, especially across many European countries [18].

Traditionally, *R. canina* fruits have been harvested from the wild by local communities. However, in recent years, increasing interest from the private sector in agricultural production has driven the development of large-scale enterprises and the industrial evaluation of rosehip products. Nevertheless, because the majority of the production still relies on wild populations, challenges persist regarding supply continuity and the standardization of product quality. This, in turn, hampers the ability to meet the growing demand from the herbal tea, food, and cosmetics industries, occasionally necessitating imports to compensate for domestic shortfalls. Therefore, to ensure the sustainability of production and the consistency of product quality, wild collection must be complemented with controlled agricultural cultivation. In Turkey, rosehip fruits are still primarily collected from the wild and processed mainly for household consumption.

With this context in mind, the present study was conducted in Sarıveliler district (Karaman, Turkey), where *R. canina* grows naturally. The primary aim of the study was to determine the chemical variation of volatile components in rosehip fruits depending on slope aspect and to evaluate the relationship of these variations with environmental factors such as temperature, precipitation, and soil properties.

2. Material and Method

2.1. Study area

The plant samples used in this study were collected from the Sarıveliler district, located in the southern part of Karaman Province within the Central Anatolia Region of Turkey (Figure 1). Sarıveliler is situated on the southern slopes of the Central Taurus Mountains,

specifically on the Taşeli Plateau. It is bordered by the district of Taşkent to the north, Başyayla to the northeast, Ermenek to the east, Gazipaşa to the south, and Alanya to the southwest [20].

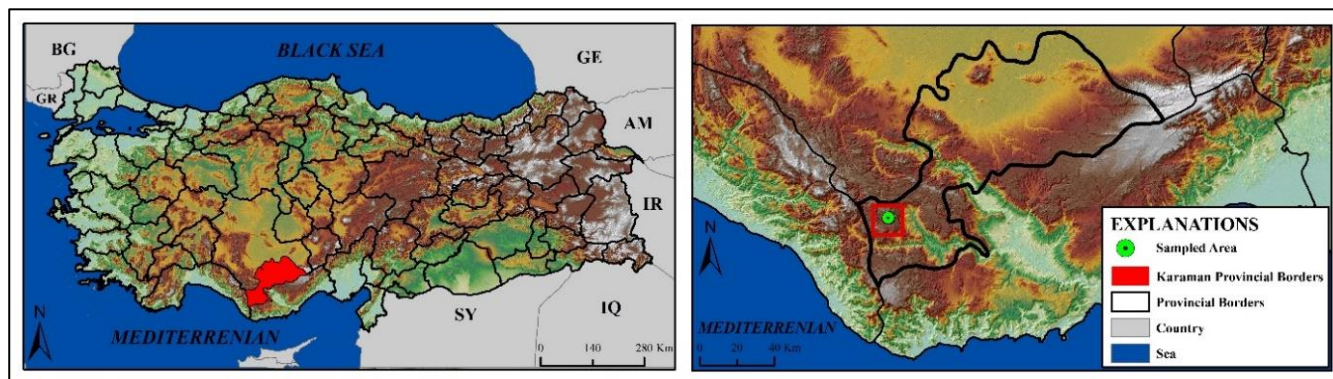


Figure 1. Location of the Study Area

2.2. Plant material

The plant material used in this study comprised *Rosa canina* fruits naturally growing in the Sarıveliler district of Karaman Province. Samples were collected from multiple locations surrounding a central reference point (36.6968° N, 32.610196° E; 1496 m a.s.l.) in order to represent spatial variability within the study area. These sampling points were selected to reflect microhabitat differences rather than strictly directional positions. Fruit samples were collected from 30 different individual plants (n = 30) within the study area. To ensure comparability among samples, all fruits were collected at a similar ripening stage (full maturity) and were selected to be uniform in terms of color and size. Species identification was conducted using the taxonomic key described in *Flora of Turkey and the East Aegean Islands* by Peter Hadland Davis (1982) [21].

2.3. Method for volatile compounds

In September 2024 (during the fruiting period), fruit samples of the species were collected from natural habitats. All fruits were collected at the full maturity stage, based on uniform external characteristics such as color, size, and texture, to ensure comparability among samples. The samples were placed in paper bags and delivered to the laboratory on the same day without delay and without exposure to direct sunlight. The plant materials were air-dried at room temperature (25°C) until a constant weight was achieved. The fruit volatile compounds were determined using a combined gas chromatography/mass spectrometry (GC/MS) system integrated with the Headspace Solid-Phase Microextraction (HS-SPME) technique.

According to the solid-phase microextraction procedure, fruit samples were cleaned by removing external plant residues (including pedicel and calyx

tissues). Then, 2 g of fruit material from each sample was placed into a 10 mL glass vial sealed with a silicone cap and incubated at 60°C for 30 min. To absorb volatile compounds, a fused silica fiber coated with 75 µm Carboxen/Polydimethylsiloxane (CAR/PDMS) was used. The fiber was then injected into the capillary column (Restek Rx-5 Sil MS, 30 m × 0.25 mm, 0.25 µm) of an HS-SPME-compatible GC-MS system (Shimadzu 2010 PLUS). Each analysis was performed in triplicate, and mean values were calculated. The oven temperature was initially held at 40°C for 2 min and then increased at a rate of 4°C/min to 250°C. The injector and detector temperatures were set at 250°C. Electron impact (EI) ionization at 70 eV was applied, with helium used as the carrier gas at a flow rate of 1.61 mL/min. Compound identification was carried out using Wiley, NIST, Tutor, and FFNSC spectral libraries.

2.4. Determination of ecological parameters

To identify climatic characteristics, long-term average temperature and precipitation data were obtained from meteorological stations in the provinces of Antalya (Alanya, Gazipaşa, Manavgat), Karaman (Karaman), Konya (Beyşehir, Ereğli, Hadım, Karapınar, Seydişehir), Mersin (Anamur, Erdemli, Mersin, Mut, Silifke), and Niğde (Ulukışla), through the Turkish State Meteorological Service. These meteorological datasets were used to generate temperature and precipitation maps using the Co-Kriging interpolation method in ArcGIS software. To assess soil characteristics, reports issued by the former Ministry of Forestry and Village Affairs General Directorate of Soil and Water were utilized. Based on these reports, a 1:100,000 scale soil map of Karaman province, encompassing the study area, was prepared.

2.5. Statistical method

To evaluate the relationships among volatile oil compounds of the *R. Canina* species and to determine

statistically significant correlations between selected components, Pearson correlation analysis was performed using Python software. The resulting correlation matrix was visualized using a heat-map to illustrate the strength and direction of associations among the components.

3. Results and Discussion

3.1. Component analysis of volatile compounds found in fruits

In this study, the volatile compounds of rosehip (*R. canina*) fruits naturally occurring in the Sariveliler district (Karaman) were identified from four aspect directions (north, south, east, and west) using Solid-Phase Microextraction (SPME) analysis. The SPME analysis resulted in the identification of 25 volatile compounds in the east aspect, 32 in the west, 21 in the north, and 41 in the south..

Among these compounds, the most abundant in the eastern aspect were (E)-2-Hexenal (52.21%), (Z)-2-Hexen-1-ol (5.40%), and 6-Methyl-5-hepten-2-one (4.82%); in the western aspect, (E)-2-Hexenal (27.65%), Limonene (12.49%), and p-Cymene (9.16%); in the northern aspect, (E)-2-Hexenal (50.14%), Limonene (10.83%), and p-Cymene (6.59%); and in the southern aspect, (E)-2-Hexenal (15.60%), Limonene (14.44%), and p-Cymene (13.32%) were identified as the major constituents (Table 1).

Based on the classification of volatile compounds, the predominant categories were aromatic alcohols (67.18%, 29.90%, 50.55%, and 21.39%), aromatic aldehydes (12.41%, 8.13%, 11.09%, and 16.98%), and monoterpene hydrocarbons (17.43%, 50.44%, 35.29%, and 40.91%) in the east, west, north, and south aspects, respectively (Figure 2).

Table 1. Analysis of volatile compounds in fruits

R.T.	Compounds	East Area %	West Area %	North Area %	South Area %	Formula	Cataegory
1.284	Acetaldehyde	1.62	2.90	1.33	0.82	C ₈ H ₈ O	AAI
1.355	Ethanol	-	0.64	0.41	0.02	C ₂ H ₆ O	AA
1.422	2-Propanone	2.53	1.47	3.11	9.07	C ₃ H ₆ O	AAI
1.487	Dimethyl sulfide	0.67	0.88	1.15	2.51	C ₅ H ₁₀	SH
1.712	2-Bromopropane	-	0.24	-	0.23	C ₃ H ₆ O	AAI
1.781	2-Methylbutanal	-	0.55	-	0.65	C ₅ H ₁₂ O	AA
1.810	2-Methylfuran	-	-	-	0.78	C ₅ H ₆ O	AA
1.889	1-Propenyl bromide	-	-	-	3.03	C ₁₁ H ₁₆ O	AH
1.980	Isobutyl alcohol	-	-	-	0.67	C ₉ H ₁₄	AA
2.525	1-Penten-3-one	-	-	-	0.39	C ₅ H ₈ O	AA
2.664	Pentanal	-	-	-	0.52	C ₅ H ₁₀ O	AA
3.150	Methyl pyruvate	-	-	-	0.30	C ₅ H ₁₀	SH
3.262	3-Methyl-1-butanol	-	-	-	0.44	C ₅ H ₁₀ O	AAI
3.340	2-Methyl-1-butanol	-	-	-	0.26	C ₅ H ₁₀ O	AAI
4.556	Hexanal	3.06	1.01	3.77	1.63	C ₆ H ₁₂ O	AAI
6.016	(E)-2-Hexenal	57.75	27.65	50.14	15.60	C ₆ H ₁₀ O	AA
6.460	(Z)- 2-Hexen-1-ol	5.40	-	-	-	C ₆ H ₁₀ O	AA
6.501	o-Xylene	-	1.93	0.85	0.85	C ₈ H ₁₀	MH
6.579	Hexanol	3.35	0.53	-	0.48	C ₆ H ₁₄ O	AA
7.216	p-Xylene	0.61	0.90	-	-	C ₈ H ₁₀	MH
7.217	Styrene	-	-	-	0.69	C ₈ H ₈	OC
7.610	Heptanal	-	-	-	1.91	C ₇ H ₁₄ O	AA
8.654	α-Pinene	0.51	4.83	4.71	0.85	C ₁₀ H ₁₆	MH

9.232	Camphene	-	2.10	1.65	0.27	C ₁₀ H ₁₆	MH
9.630	(Z)-2-Heptenal,	0.68	0.53	-	-	C ₇ H ₁₂ O	AA
9.790	Benzaldehyde	-	-	-	0.44	C ₇ H ₆ O	AAI
10.279	β-Pinene	-	0.49	0.33	-	C ₁₀ H ₁₆	MH
10.395	1-Octen-3-one	0.72	-	-	-	C ₁₀ H ₁₆	MH
10.530	1-Octen-3-ol	0.22	-	-	0.54	C ₈ H ₁₆ O	AAI
10.658	6-Methyl-5-hepten-2-one	4.82	6.07	4.63	4.65	C ₁₀ H ₁₄	MH
10.820	β-Myrcene	1.63	3.29	2.58	3.24	C ₁₀ H ₁₆	MH
11.492	δ-3-Carene	-	0.53	-	0.35	C ₁₀ H ₁₆	MH
11.377	Octanal	1.31	0.58	0.62	0.92	C ₈ H ₁₆ O	AAI
11.826	α-Terpinene	0.24	0.53	0.38	0.49	C ₁₀ H ₁₆	MH
12.122	p-Cymene	4.04	9.16	6.59	13.32	C ₁₀ H ₁₄	MH
12.302	Limonene	4.21	12.49	10.83	14.44	C ₁₀ H ₁₆	MH
12.406	Eucalyptol	0.54	1.95	1.27	9.86	C ₁₀ H ₁₈ O	OM
13.038	trans-β-Ocimene	-	6.94	-	-	C ₁₀ H ₁₆	MH
13.452	γ-Terpinene	0.65	1.18	1.08	1.80	C ₁₀ H ₁₆	MH
14.507	α-Terpinolene	-	-	-	0.34	C ₁₀ H ₁₈ O	OM
14.600	Fenchone	0.35	-	-	0.59	C ₁₀ H ₁₆ O	OM
15.160	Linalool	0.25	0.64	-	2.32	C ₁₀ H ₁₈ O	OM
15.310	Nonanal	3.67	1.93	2.26	2.63	C ₉ H ₁₈ O	AAI
15.653	Neryl nitrile	-	1.97	-	-	C ₁₀ H ₁₅ N	OC
15.764	Thujone	-	-	-	0.20	C ₁₀ H ₁₆	MH
16.844	Camphor	-	-	-	0.45	C ₁₀ H ₁₆ O	MH
18.183	4-Terpineol	-	-	-	0.37	C ₁₀ H ₁₈ O	AA
22.498	Theaspirane A	-	1.30	0.68	0.33	C ₁₃ H ₂₂ O	SH
23.072	Theaspirane B	0.79	0.81	1.68	0.72	C ₁₃ H ₂₂ O	SH
26.100	Tetradecane	-	0.52	-	-	C ₁₆ H ₃₄	AH
26.674	Caryophyllene	0.38	-	-	-	C ₁₅ H ₂₄ O	OC
29.473	α-Farnesene	-	3.47	-	-	C ₁₅ H ₂₄	SH
	Component Number	25	32	21	41		
	AA:Aromatic Alcohol	67,18	29,9	50,55	21,39		
	AAI:Aromatic Aldehyde	12,41	8,13	11,09	16,98		
	AH:Aromatic Hydrocarbon	-	0,52	-	3,03		
	MH:Monoterpene Hydrocarbon	17,43	50,44	35,29	40,91		
	OM:Oxygenated Monoterpene	1,14	2,59	1,27	13,11		

OC:Other Components	0,38	1,97	-	0,69		
SH: Sesquiterpene Hydrocarbon	1,46	3,51	3,51	3,86		

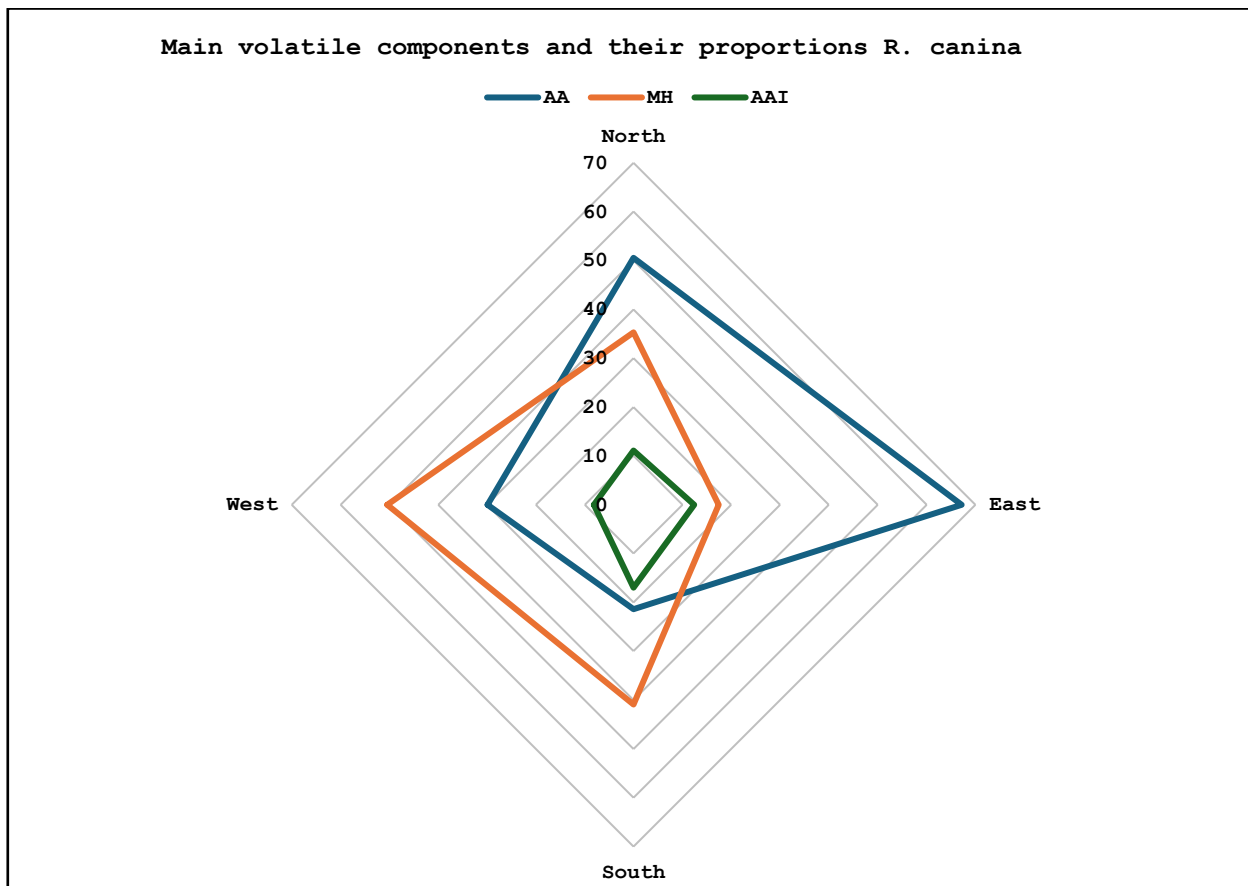


Figure 2. Main volatile components and their proportions *R. Canina*

The results of the correlation analysis indicate that some volatile oil components exhibit strong positive correlations. In particular, very high positive relationships were observed between β -Myrcene and α -Terpinene ($r=0.99$), Octanal and γ -Terpinene ($r=0.98$), Dimethyl sulfide and Eucalyptol ($r=0.98$), and p-Cymene and γ -Terpinene ($r=0.98$). Conversely, strong negative correlations were identified between certain volatile oil components, such as (E)-2-Hexenal

and p-Cymene ($r=-0.97$), (E)-2-Hexenal and Limonene ($r=-0.88$), and Octanal and α -Pinene ($r=-0.91$). Overall, the matrix reveals that while some volatile oil components tend to increase simultaneously, others show an inverse relationship, which may indicate differences in their chemical formation processes and biosynthetic pathways (Figure 3).

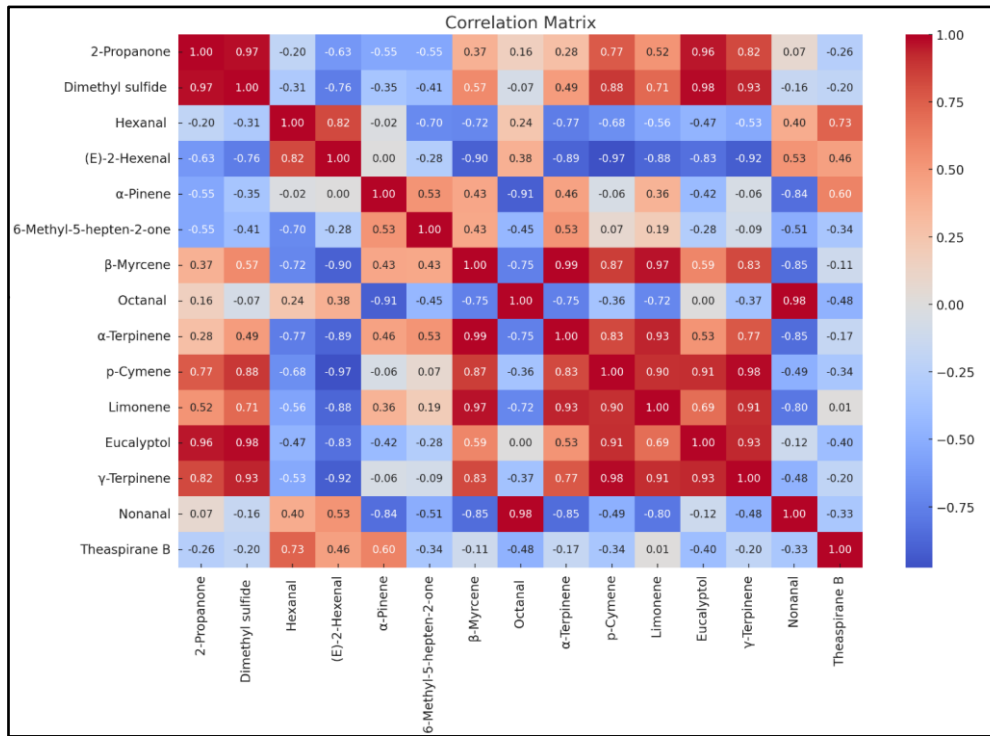


Figure 3. Correlation matrix heatmap

3.2. Climate–soil relationship

The Sariveliler district is located in the southeastern part of Karaman Province, situated on the north-facing slopes of the Taurus Mountains, and exhibits transitional climatic characteristics between the Mediterranean and continental climates. The region’s high elevation (~1555 m), annual precipitation ranging from 600 to 800 mm (Figure 5), and average temperature values of 10–12°C (Figure 4) contribute to the formation of a humid microclimate. These ecological conditions provide a favorable environment for the development of *R. canina*, a species with high tolerance to extreme temperatures and broad adaptive capacity. Due to its resistance to low temperatures down to -40°C, it is commonly found in mountainous and high-altitude areas [2].

The dominant soil type in the study area is non-calcareous brown forest soil (Figure 6), which offers suitable conditions for the productive growth of rosehip plants. Therefore, the ecological structure of the Sariveliler district constitutes a significant habitat in terms of the natural distribution and developmental dynamics of *R. canina*.

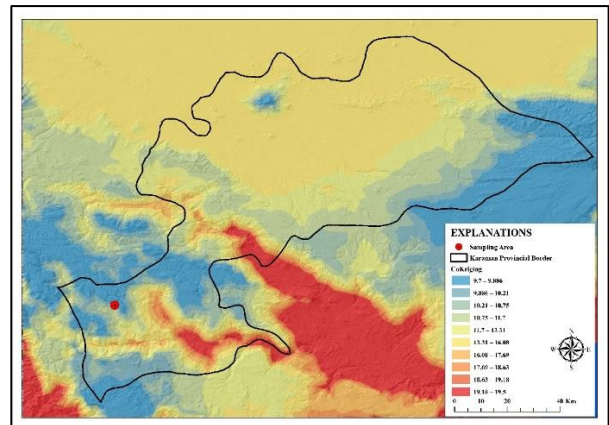


Figure 4. Temperature map of the study area

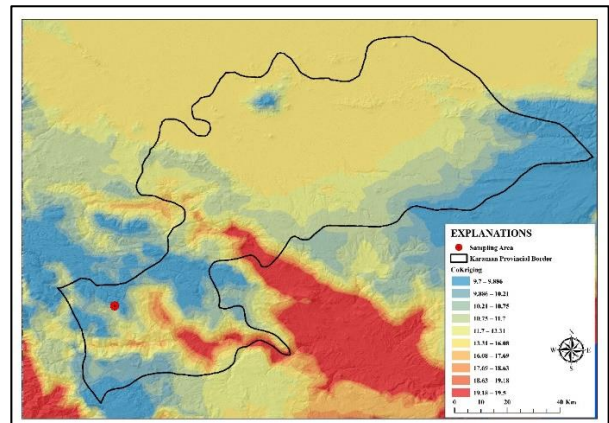


Figure 5. Precipitation map of the study area

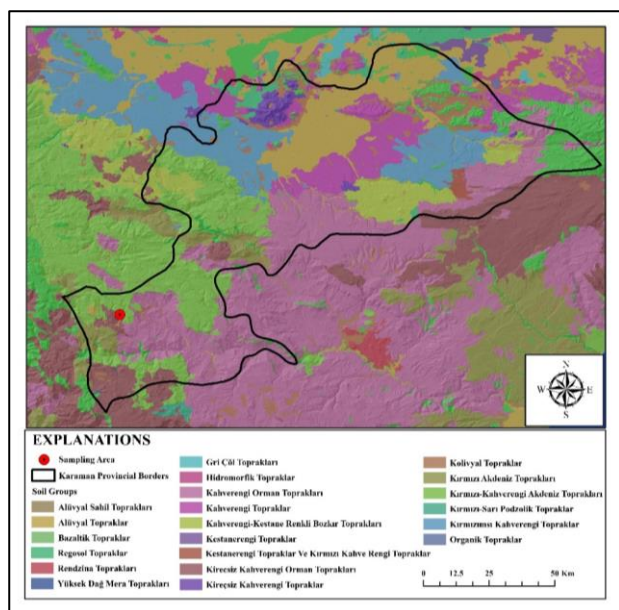


Figure 6. Soil map of the study area

In this study, fruit samples of *R. canina* were collected from different aspect directions (north, south, east, and west) in the Sarıveliler (Karaman) region, and their volatile compound profiles were compared based on aspect. Although the findings indicated the presence of similar types of compounds in all four aspects, significant differences were observed in both the number and relative proportions of these compounds. Notably, (E)-2-Hexenal was identified at the highest proportion in the eastern aspect (52.21%), whereas this compound was not detected in the southern aspect. Limonene and p-Cymene were found at 12.49%, 10.83%, and 14.44%, and 9.16%, 6.59%, and 13.32%, respectively, in the western, northern, and southern aspects, while their levels were markedly lower in the eastern aspect. Additionally, ethanol was detected in high proportion (15.62%) only in the southern aspect but was entirely absent in the eastern aspect; its levels in the western (0.64%) and northern (0.41%) aspects were found to be quite low. These results suggest that variation in volatile compound composition may be associated not only with ecological factors but also with genetic diversity. Since different aspect directions alter microclimatic parameters such as light intensity, humidity, temperature, and wind, their influence on metabolite biosynthesis may constitute one of the primary drivers of variation in volatile profiles.

Orhan and Hartevioğlu (2013) identified benzyl alcohol, phenylethyl alcohol, 2,6,11-trimethyl dodecane, eicosane, benzaldehyde, α -pinene, limonene, and tetrahydroionol in *R. canina* fruits. Özel and Clifford (2004) reported 2-furancarboxaldehyde (35.08%), capric acid (15.85%), phthalic acid (13.74%), and cyclohexanone (4.76%) among the main constituents. Koeduka et al. (2006) identified eugenol as a major bioactive compound, while Pichersky and Gershenzon (2002) reported linalool; Luan and Wüst (2002) and Dudareva & Negre (2005)

reported 1,8-cineole and (Z)-3-hexenol; and Sabulal et al. (2006) and Khan et al. (2008) identified β -caryophyllene. When compared with the findings of the present study, some differences in compound diversity and relative proportions were noted [22], [23], [24], [25], [26], [27], [28], [29]. These differences may be attributed to environmental conditions, aspect orientation, genetic variability, and methodological differences.

In the study area, the annual average temperature ranges between 10–12°C, and the annual precipitation varies between 600 and 800 mm, indicating that the region provides a suitable growing environment in terms of the ecological requirements of *R. canina*. This species possesses a broad ecological tolerance and is capable of surviving even in high mountainous regions where temperatures occasionally fall below –40 °C. It exhibits high resistance not only to low-temperature stress but also to water scarcity [2].

In general, the temperature and precipitation conditions in the study area are favorable for *R. canina*; however, additional ecological variables such as microclimatic factors, soil structure, and water-holding capacity should also be considered for the species' long-term development and adaptation.

The dominant soil type in the study area, identified as non-calcareous brown forest soil, constitutes one of the significant ecological factors influencing the development of *R. canina*. Although this species is capable of adapting to various soil types, it is typically associated with calcareous soils. Nevertheless, it can be encountered across a wide range of edaphic conditions [2]. *R. canina* has the ability to thrive under challenging ecological conditions, including rocky terrains, sloped areas, nutrient-poor soils, and arid environments [30]. When compared with the findings reported in the literature, the results of the present study suggest that the non-calcareous brown forest soil in the study area generally provides favorable conditions for the growth of *R. canina*. However, for long-term adaptation, it is essential to consider additional ecological factors such as soil nutrient dynamics, organic matter cycling, and moisture regime.

4. Conclusion

This study demonstrated that the volatile compound composition of *R. canina* varies depending on environmental conditions, indicating that the quality parameters of this species in agricultural production may differ according to habitat characteristics. Furthermore, rosehip fruits rich in volatile constituents present a strategic potential for the development of value-added products, particularly in the food, pharmaceutical, and cosmetic industries. To effectively harness this potential, it is essential to support local producer associations and cooperatives, and to promote rural industrial activities such as processing and packaging.

Additionally, initiating geographical indication and ecological branding initiatives in regions such as Sarıveliler, where the species grows naturally, would represent a significant step toward enhancing the competitiveness of local products in national and international markets. For the successful implementation of these processes, technical training programs should be organized for producers on topics such as harvesting, post-harvest processing, quality control, and organic production. Moreover, research and development activities should be encouraged within the framework of university-village collaborations, thereby enhancing local innovation capacity.

These recommendations not only aim to expand the industrial applications of *R. canina* but also contribute to achieving the region's sustainable rural development objectives.

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Declaration of Ethical Code

In this study, we undertake that all the rules required to be followed within the scope of the "Higher Education Institutions Scientific Research and Publication Ethics Directive" are complied with, and that none of the actions stated under the heading "Actions Against Scientific Research and Publication Ethics" are not carried out.

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