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Chemical composition of endemic *Prangos* species essential oils and multivariate analyses

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ABSTRACT: In the present study, the chemical composition of the essential oils of the endemic *Prangos meliocarpoides* Boiss. var. *meliocarpoides* and *Prangos uechtritzii* Boiss & Hausskn aerial parts (Karaman and Kayseri) were analysed by GC-FID and GC/MS, respectively. The main constituents of the *P. meliocarpoides* var. *meliocarpoides* oil were *α*-phellandrene (16.9%), sabinene (16.2%), and *γ*-terpinene (13.2%). *P. uechtritzii* oils (localities Karaman and Kayseri) were characterized with *p*-cymene (19.4 and 18.4%), 7-*epi*-1,2-dehydrosesquicineole (8.7 and 9.0%) and spathulenol (8.3 and 10.3%) as main compounds, respectively. The essential oil compositions of *P. uechtritzii* were compared to the essential oil components in the literature. Multivariate statistical techniques, including principal component analysis and hierarchical clustering, were utilized to investigate the chemotaxonomic variations in the composition of *P. uechtritzii* essential oils across diverse geographical locations.

KEYWORDS: Essential oil; *Prangos meliocarpoides* var. *meliocarpoides; Prangos uechtritzii;* statical analyses.

1. INTRODUCTION

The Apiaceae (Umbelliferae) family, which includes about 434 genera and 3780 species in the world, is among the families' rich in taxa. In our country, it contains more than 100 genera and more than 420 taxa. The ***Prangos*** genus has a global distribution of approximately 45 species, it comprises 22 taxa, 12 of which are endemic to Türkiye. The Irano-Turanian region is recognized as the gene center of *Prangos* species. Notably, the Taurus Mountains and the Kurdistan region of Iraq found a high diversity, hosting 14 and 7 species, respectively [1-3].

Prangos species have long been recognized for their significant role in the traditional medicine and culinary practices of various Asian countries, particularly Iran, Türkiye, and Iraq. These plants have a rich history of use, with their medicinal and aromatic properties being valued for centuries. The primary medicinal application of these *Prangos* species is the alleviation of various gastrointestinal ailments, though they have been documented to serve additional therapeutic purposes. In Türkiye, *Prangos* species are employed as tonic, anthelmintic, and carminative remedies, to alleviate issues such as external bleeding, gastrointestinal disorders, wounds, scarring, and leukoplakia. In addition, *Prangos* species have been utilized as stimulants, sexual enhancement agents, and organic fertilizers. Furthermore, certain members of this genus are incorporated as food ingredients or culinary spices [1].

Different parts of *Prangos* genus containing seeds, flowers, and fruits were subjected to analysis of the profiles of their essential oils. Monoterpene hydrocarbons (*p*-cymene, *γ*-terpinene, and *β*-phellandrene) and sesquiterpene hydrocarbons (*β*-elemene, *β*-bisabolene germacrene D, and *γ*-cadinene) were reported as the major essential oil constituents [1].

P. meliocarpoides Boiss. is represented by two varieties in Türkiye, var. *meliocarpoides* is an endemic species that locals refer to as "sultanteresi" and the root, fruit and leaf of the plant are used as aphrodisiacs in Türkiye [4,5]. It typically features reaching heights between 15 to 30 centimeters and is native to the Inner

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Anatolia region of Turkey, thriving at elevations up to 2000 meters. Petals are yellow and glabrous (smooth and hairless). Fruit is pyriform and the wings of mericarp are usually straight [2].

Prangos species are referred by locals as "çakşır otu" in Türkiye [1,3]. *Prangos uechtritzii* Boiss & Hausskn is known locally by name "deli çakşır" and *Prangos* species, such as *P. uechtritzii* and have been described as purported sexual enhancement agent in some traditions. Furthermore, the aerial parts of *P. uechtritzii* are incorporated into traditional Anatolian medicinal practices to address hemorrhoidal condition [6]. *P. uechtritzii* is similar to *P. ferulacea* and is a perennial plant. The flowers are yellow, and fruiting umbels are 12-20 rayed [2].

In our research, endemic *P. meliocarpoides* var. *meliocarpoides* and *P. uechtritzii* were investigated. *P. uechtritzii* plant was acquired from two different localities and the chemical composition of their essential oils were elucidated. The essential oils were compared with literature studies and tested by statistically analysis.

2. RESULTS and DISCUSSION

2.1. Chemical Investigation of Essential Oil

The chemical composition of the essential oils (EOs) extracted from *Prangos meliocarpoides* var. *meliocarpoides* and *P. uechtritzii* was thoroughly and systematically analyzed through the concurrent utilization of both GC-FID detection and GC-MS analytical techniques. This comprehensive investigation allowed the detailed characterization of the diverse chemical constituents of these essential oil samples. The oil yields of *P. meliocarpoides* var. *meliocarpoides* and *P. uechtritzii* (Karaman) were determined as 1.63% and 0.65%, respectively. However, the EO yield of *P. uechtritzii* from Kayseri couldn't be calculated due to the lack of defining the plant part (Table 1).

Table 1. The locations of *Prangos* species

Plant material	Location	Herbarium code	Date
Prangos meliocarpoides var. *meliocarpoides*	Karaman (Türkiye) at an altitude of 1050 m	S.D. 2850	June 2014
Prangos uechtritzii	Karaman province (Türkiye) at an altitude of 1650 m	S.D. 3030	July 2018
	Kayseri province at an altitude of 1750 m	S.D. 3031	July 2018

As shown in Table 2, 64 and 57 components were identified in the aerial parts of *P. uechtritzii* collected from Karaman (SD 3030) and Kayseri (SD 3031) provinces of Türkiye, respectively. The relative percentage amounts of *P. uechtritzii* EOs in Karaman and Kayseri were constituted 85.2% and 87.7%, respectively. Fifty-seven components were identified comprising 97.6% of *P. meliocarpoides* var. *meliocarpoides* was oil.

The EO of *Prangos* species is composed of six major classes of compounds: monoterpenes (hydrocarbons and oxygenated hydrocarbons), sesquiterpenes (hydrocarbons and oxygenated hydrocarbons), and other minor substances. The oil of *P. meliocarpoides* var. *meliocarpoides* was characterized by a high amount of monoterpene hydrocarbons (82.5%). The main components were characterized as α-phellandrene (16.9%), sabinene (16.2%), *γ*-terpinene (13.2%), *β*-phellandrene (8.9%) and *p*-cymene (8.1%), respectively.

The oils of *P. uechtritzii* in from Karaman and Kayseri were characterized by a notable abundance of monoterpene hydrocarbons (33.9 and 30.4%), oxygenated sesquiterpenes (26.5 and 28.8%) and sesquiterpene hydrocarbons (18.1 and 21.9%), respectively. Conversely, the essential oil of *P. meliocarpoides* var. *meliocarpoides* was dominated by monoterpenes hydrocarbons and oxygenated monoterpenes. The main constituents of *P. uechtritzii* EOs in from Karaman and Kayseri were characterized as *p*-cymene (19.4 and 18.4%), 7-*epi*-1,2-dehydrosesquicineole (8.7 and 9.0%) and spathulenol (8.3 and 10.3%), respectively.

Table 2. The Profile of the Essential Oils of *P. meliocarpoides* var. *meliocarpoides* and *P. uechritzii*

RRI	Compound	A %	B %	C %	IM
1032	*α*-Pinene	4.5	4.4	2.9	RRI, MS
1035	*α*-Thujene	0.8	0.4	0.3	MS
1076	Camphene	0.1	0.1	-	RRI, MS
1118	*β*-Pinene	0.7	3.0	2.2	RRI, MS
1132	Sabinene	**16.2**	2.0	1.4	RRI, MS
1159	*δ*-3-Carene	2.1	0.1	-	MS
1176	*α*-Phellandrene	**16.9**	-	-	RRI, MS
1174	Myrcene	-	0.3	tr	RRI, MS
1183	*p*-Mentha-1,7(8)-diene (=*Pseudolimonene*)	0.1	0.1	-	MS
1188	*α*-Terpinene	1.2	-	-	RRI, MS
1195	Dehydro-1,8-cineole	tr	-	-	MS
1203	Limonene	-	3.2	3.0	RRI, MS
1213	1,8-Cineole	4.5	-	-	RRI, MS
1218	*β*-Phellandrene	**8.9**	0.8	2.2	RRI, MS
1246	(Z)-*β*-Ocimene	4.7	-	-	MS
1255	*γ*-Terpinene	**13.2**	0.1	tr	RRI, MS
1266	(*E*)-*β*-Ocimene	3.7	-	-	MS
1280	*p*-Cymene	**8.1**	**19.4**	**18.4**	RRI, MS
1286	Isoterpinolene	0.1	-	-	MS
1290	Terpinolene	1.2	-	-	RRI, MS
1299	2-Methylbutyl isovalerate	-	0.1	-	MS
1348	6-Methyl-5-hepten-2-one	-	0.1	1.0	MS
1438	Hexyl 2-methyl butyrate	-	tr	tr	MS
1446	3,5-Nonadiyne	0.3	-	-	MS
1452	*α*,*p*-Dimethylstyrene	-	0.1	-	MS
1457	Hexyl-3-methyl butyrate	-	tr	tr	MS
1466	*α*-Cubebene	-	tr	tr	RRI, MS
1474	*trans*-Sabinene hydrate	0.1	0.1	tr	MS
1477	4,8-Epoxyterpinolene	0.1	-	-	MS
1497	*α*-Copaene	0.1	1.2	1.4	RRI, MS
1509	(Z)-3,5-nonadiyne-7-ene	0.2	-	-	MS
1535	*β*-Bourbonene	-	tr	tr	MS
1544	*α*-Gurjunene	-	0.1	-	MS
1556	*cis*-Sabinene hydrate	0.1	0.2	tr	MS
1571	*trans*-*p*-Menth-2-en-1-ol	0.2	0.2	tr	MS
1586	Pinocarvone	-	0.1	tr	RRI, MS
1600	*β*-Elemene	0.1	0.6	0.6	MS
1611	Terpinen-4-ol	2.3	2.2	2.3	RRI, MS
1612	*β*-Caryophyllene	0.3	0.2	tr	RRI, MS
1638	*cis*-*p*-Menth-2-en-1-ol	0.1	0.2	tr	MS
1650	γ-Elemene	tr	-	-	RRI, MS
1661	Alloaromadendrene	0.5	2.6	3.2	MS
1668	*(Z)*-*β*-Farnesene	tr	0.1	tr	MS
1670	*trans*-Pinocarveol	-	0.3	0.4	RRI, MS
1683	*trans*-Verbenol	-	0.3	0.5	RRI, MS
1687	*α*-Humulene	0.3	0.3	0.4	RRI, MS
1689	*trans*-Piperitol	0.1	-	-	RRI, MS
1690	Cryptone	0.1	1.5	1.7	MS
1704	*γ*-Muurolene	0.1	1.8	2.1	MS
1706	*α*-Terpineol	0.1	-	-	RRI, MS
1726	Germacrene D	0.4	-	-	MS
1727	7-*epi*-1,2-Dehydrosesquicineole	1.0	**8.7**	**9.0**	RRI, MS, NMR*
1740	*α*-Muurolene	-	0.4	0.7	MS
1751	Carvone	-	0.1	tr	RRI, MS
1755	Bicyclogermacrene	0.1	-	-	MS
1758	*cis*-Piperitol	0.1	0.2	-	RRI, MS

1773	*δ*-Cadinene	0.6	0.5	0.8	MS
1776	*γ*-Cadinene	-	0.3	0.5	MS
1784	*(E)*-*α*-Bisabolene	tr	-	-	MS
1786	*ar*-Curcumene	0.1	0.5	0.9	MS
1823	*p*-Mentha-1(7),5-dien-2-ol	0.2	-	-	MS
1830	2,6-Dimethyl-3(*E*),5(*E*),7-octatriene-2-ol	0.1	-	-	MS
1849	Calamenene	-	0.3	0.5	MS
1864	*p*-Cymen-8-ol	0.1	0.7	0.6	RRI, MS
1900	*epi*-Cubebol		0.1	tr	MS
1921	*α*-Phellandrene epoxide	0.1	-	-	MS
1941	*α*-Calacorene	-	0.4	1.2	MS
1984	*γ*-Calacorene	-	0.1	0.6	MS
2008	Caryophyllene oxide	-	3.9	3.4	RRI, MS
2037	Salvial-4(14)-en-1-one	-	0.2	tr	MS
2057	Ledol	0.6	2.8	3.1	MS
2071	Humulene epoxide-II	0.1	1.8	1.6	MS
2094	*p*-Cresol	0.1	-	-	RRI, MS
2098	Globulol	0.1	-	-	MS
2104	Viridiflorol	0.2	1.9	1.8	MS
2130	Salviadienol	-	0.3	tr	MS
2144	Spathulenol	0.3	**8.3**	**10.3**	MS
2161	Muurola-4,10(14)-dien-1-ol	-	0.3	tr	MS
2187	*T*-Cadinol	-	0.5	0.8	MS
2209	*T*-Muurolol	0.3	0.8	1.0	MS
2219	*δ*-Cadinol	-	0.2	0.2	MS
2232	*α*-Bisabolol	0.7	1.8	1.5	RRI, MS
2255	*α*-Cadinol	-	2.7	3.7	MS
2256	Cadalene	-	0.3	0.5	MS
2389	Caryophylla-2(12),6-dien-5 *α*-ol (=Caryophyllenol I)	-	0.6	0.9	MS
2931	Hexadecanoic acid	0.3	0.3	0.1	RRI, MS
	Monoterpene Hydrocarbons	82.5	33.9	30.4	
	Oxygenated Monoterpenes	8.0	4.6	3.8	
	Sesquiterpene Hydrocarbons	3.6	18.1	21.9	
	Oxygenated Sesquiterpenes	2.4	26.5	28.8	
	Fatty acids	0.3	0.3	0.1	
	Others	0.8	1.8	2.7	
	Oil Yield (%)	**1.63**	**0.65**	**nd**	
	Total	**97.6**	**85.2**	**87.7**	

RRI: Relative retention indices calculated against *n*-alkanes; **A:** Essential oil of *Prangos meliocarpoides* var. *meliocarpoides*, **B:** Essential oil of *Prangos uechtritzii* from Karaman, **C:** Essential oil of *Prangos uechtritzii* from Kayseri; **nd:** Not detected; **%:** Calculated from FID data;**tr:** Trace (< 0.1 %); *: Reference [7]; **IM**: Identification method using relative retention indices (RRI) on an HP Innowax column; **MS,** Mass spectra identified through computer matching with Wiley and MassFinder libraries, and comparison with literature data

In earlier studies, the main compounds of various *Prangos* species were reported monoterpenes including *β*-pinene, *α*-pinene, *β*-phellandrene, *γ*-terpinene, and *p*-cymene from the essential oils [1]. In a study by Özcan et al., (2000) [7], *α*-phellandrene (6.3%), *γ*-terpinene (7.0%), *β*-phellandrene (7.8%), and *p*-cymene (10.9%) were reported as the main compunds of the essential oil of *P. uechtritzii*. In another study by Massumi et al., (2007) [8], monoterpene hydrocarbons were identified as the most important compounds (more than 85%) in the EO of *P. ferulacea.*

In a previous research different parts of *Prangos* species like seeds seeds, flowers, and fruits were subjected to analysis of the compositions of their essential oils. Monoterpene hydrocarbons and sesquiterpene hydrocarbons were reported the major essential oil constituents [1].

The EO of *P. meliocarpoides* var. *meliocarpoides* included various components, with bornyl acetate (11.8%) *p*-cymene (13.2%), and sabinene (16.7%) identified as the major components [6].

In a study by Özcan et al., [7] 38 constituents were monitored in *P. uechtritzii*, collected from Kayseri, *α*-phellandrene (6.3%), *γ*-terpinene (7.0%), *β*-phellandrene (7.8%), and *p*-cymene (10.9%) were documented as the main compounds of the EO.

Earlier research determined that 7-*epi*-1,2-dehydrosesquicineole was a predominant constituent in the essential oil derived from the fruits of *P. uechtritzii* [9].

Previous research reported that the essential oil extracted from fruits of *P. uechtritzii* collected from the Malatya region of Türkiye was found to be principally composed of *p*-cymene (4.90%), *δ*-3-carene (7.39%), *β*-phellandrene (11.14%), nonene (17.03%), and *α*-pinene (40.82%), (10). In another study by Zengin et al. (2022) [6], *P. uechtritzii*, collected from Konya, essential oil contained 7-*epi*-1,2-dehydrosesquicineole (12.6%), caryophyllene oxide (19.6%), and *p*-cymene (24.6%) as the most abundant components and they identified 30 constituents in *P. uechtritzii* essential oil. The composition of EOs may alter considerably due to the distinct edaphic (soil-related) and climatic conditions across different geographic habitats. These environmental factors significantly shape the unique chemical profiles of the EOs produced by *Prangos* genus growing in various regions.

2.2. PCA and HCA Analyses

There are insufficient studies to perform statistical analysis on *P. meliocarpoides* var. *meliocarpoides* essential oil. Further research was conducted on the aerial parts of *P. uechtritzii* in different locations. Therefore, the *P. uechtritzii* EOs were analyzed in PCA according to the portions of the major constituents. The major components of our study and the literature were listed in Table 3. In Table 2, the major constituents identified in the EOs of *P. uechtritzii* were *α*-pinene, *α*-bisabolol, *p*-cymene, nonene, *δ*-3-carene, 7-*epi*-1,2-dehydrosesquicineole, *γ*-terpinene, *β*-phellandrene, *α*-phellandrene, and caryophyllene oxide.

Table 3. The comparison of EOs of *Prangos uechtritzii* between literature and current study

PCA No*	Plant parts	Location	Major compounds	%	Ref
1	Aerial parts	Karaman	*p*-cymene 7-epi-1,2-Dehydrosesquicineole	19.4 8.7	Our study
2	Aerial parts	Kayseri	*p*-cymene 7-epi-1,2-Dehydrosesquicineole	18.4 9.0	Our study
3	Fruit	Konya	7-epi-1,2-Dehydrosesquicineole *α*-Pinene *β*-Phellandrene	13.4 7.8 6.8	[9]
4	Fruit	Kayseri	*α*-Pinene *β*-Phellandrene *α*-Bisabolol	11.2 8.3 7.0	[9]
5	Fruit	Malatya	*α*-Pinene Nonene *β*-Phellandrene	40.8 17.0 11.1	[10]
6	Aerial parts	Konya	*p*-Cymene *β*-Phellandrene *α*-Pinene	10.9 7.8 6.1	[7]
7	Aerial parts	Konya	*p*-Cymene 7-epi-1,2-Dehydrosesquicineole	24.6 12.6	[6]

***PCA No:** Principal component analysis number

PCA and HCA were analyzed to describe the compounds of essential oils. PCA and HCA were conducted on ten main constituents of our study (7-*epi*-1,2-dehydrosesquicineole, *α*-pinene, *p*-cymene, *β*-phellandrene, *α*-bisabolol, nonene, *δ*-3-carene, *γ*-terpinene, *α*-phellandrene and caryophyllene oxide) and literature studies. PCA Numbers (PCA No) of EOs for statistical analysis were listed in Table 3. The PCA no 1 and 2 are our study's essential oils from Karaman and Kayseri. PCA was used to show interrelationships among the EOs of the *P. uechtritzii* from different locations and plant parts. The resulting clusters were further confirmed using PCA analysis to determine the accuracy of this classification. Also, to assess the accuracy of this classification, the cluster obtained was confirmed with the other multivariate analysis (HCA), as well. Figures 1 and 2 depicted PCA analysis, whereas Figures 3 and 4 depicted HCA analysis.

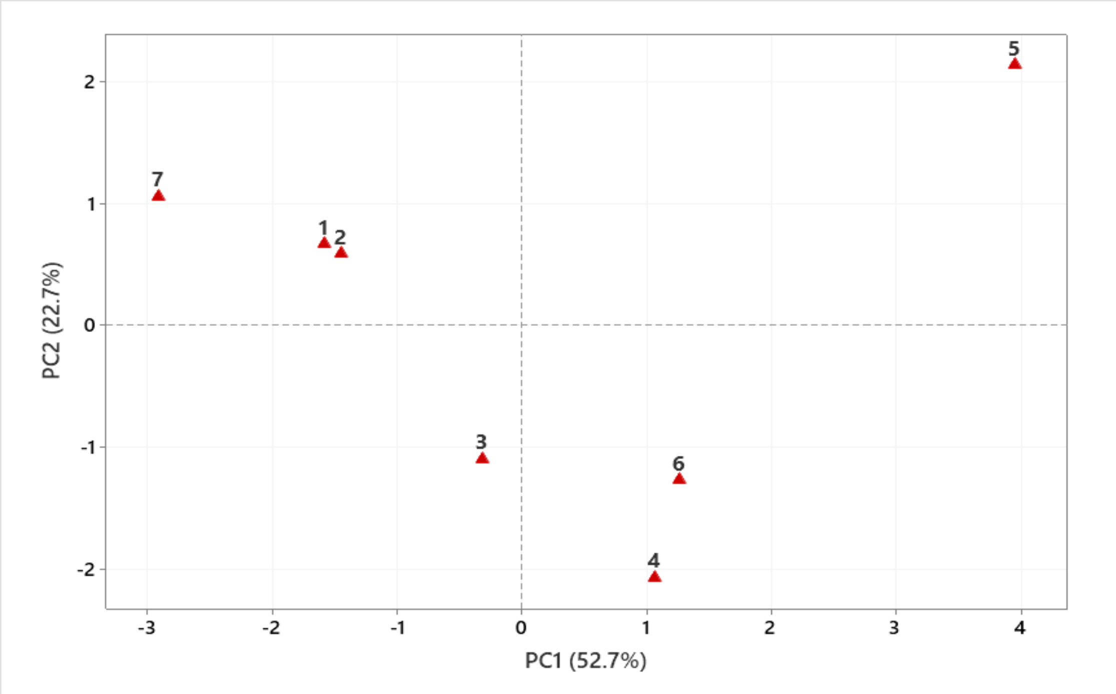

Figure 1. PCA analysis of the main compounds of the essential oils in Table 3; **1:** The aerial parts of EO in Karaman; **2:** The aerial parts of EO in Kayseri; **3:** The fruit of EO in Konya; **4:** The fruit of EO in Kayseri; **5:** The fruit of EO in Malatya; **6:** The aerial parts of EO in Konya; **7:** The aerial parts of EO in Konya

The principal component evaluation of the EOs from *P. uechtritzii*, as illustrated in Figure 2, revealed that the first two principal components (PC1 (52.7%) and PC2 (22.7%)), clarified 75.4% of the accumulated variation of the data analyzed.

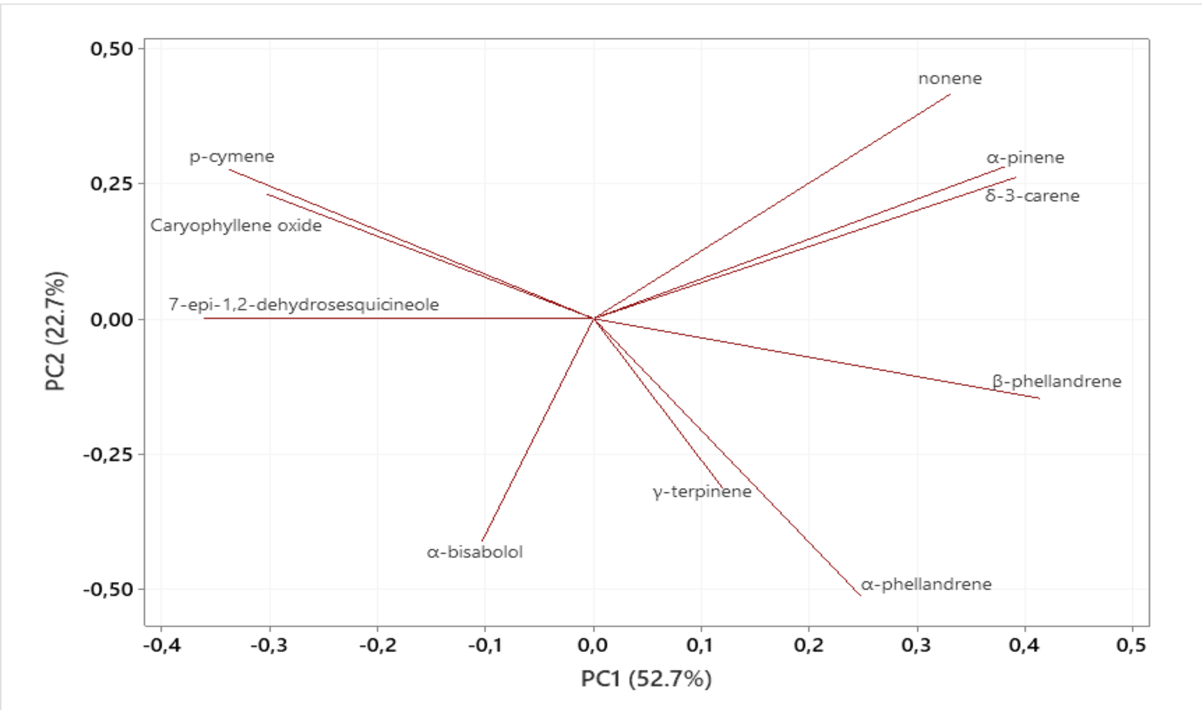

Figure 2. Eigeanalysis of the correlation matrix of main compounds of the essential oils in Table 3; **1:** The aerial parts of EO in Karaman; **2:** The aerial parts of EO in Kayseri; **3:** The fruit of EO in Konya; **4:** The fruit of EO in Kayseri; **5:** The fruit of EO in Malatya; **6:** The aerial parts of EO in Konya; **7:** The aerial parts of EO in Konya

The first principal component (PC1) (22.7%) was predominantly influenced by the positive scores of six other compounds (*α*-pinene, *β*-phellandrene, nonene, *δ*-3-carene, *γ*-terpinene, and *α*-phellandrene),

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along with a minor contribution from four compounds (7-*epi*-1,2-dehydrosesquicineole, *p*-cymene, *α*-bisabolol, and caryophyllene oxide), with negative scores. Conversely, the second principal component (52.7%) was primarily represented by the negative scores of *α*-phellandrene, *β*-phellandrene, and *γ*-terpinene, as well as the positive scores of the remaining five compounds.

The hierarchical clustering evaluation of the ten main EO compounds demonstrated the existence of three distinct primary groupings (clades) characterized by similar levels ranging from 25.91% to 99.24% (Figure 3). Apart from 7-*epi*-1,2-dehydrosesquicineole, *p*-cymene, and caryophyllene oxide, the other seven compounds were clustered in the same clade. The hierarchical clustering analysis revealed that the two main compounds of essential oil constituents, *α*-pinene and *δ*-3-carene, which share a close structural relationship, were categorized within the same cluster (99.24%). The compounds *γ*-terpinene and *α*-phellandrene can be classified as monoterpene hydrocarbons, part of the same chemical groups as the other essential oil constituents identified in the analysis. Therefore, this analysis does not merely indicate differences but rather organizes the compounds based on their chemical similarities and relationships, providing a better understanding of the essential oil's compositional structure.

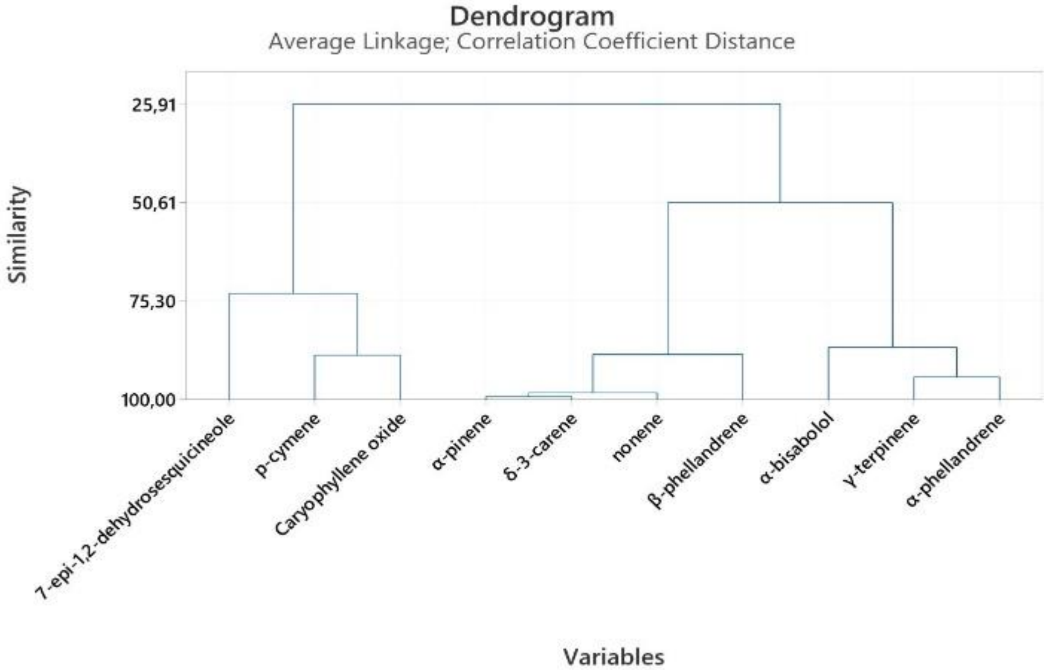

Figure 3. Dendrogram obtained by HCA based on the Euclidian distances between groups of main compounds of the essential oils in Table 3; **1:** The aerial parts of EO in Karaman; **2:** The aerial parts of EO in Kayseri; **3:** The fruit of EO in Konya; **4:** The fruit of EO in Kayseri; **5:** The fruit of EO in Malatya; **6:** The aerial parts of EO in Konya; **7:** The aerial parts of EO in Konya

The hierarchical cluster analysis of the *P. uechtritzii* EO samples (Figure 4) indicated the existence of two primary clades, exhibiting similar levels ranging from 35.01% to 99.82%. The EO profiles of *Prangos uechtritzii* collected from the Karaman (PCA no: 1) and Kayseri (PCA no: 2) were closely aligned within the hierarchical cluster analysis, indicating a strong relationship between these plant samples and their corresponding environmental habitats. The EO of *P. uechtritzii* fruit in Malatya (PCA no: 5) had various chemical profile. Therefore, the HCA similarity of this essential oil was calculated as 35.01%. Except for PCA no 5, all EOs of aerial parts were observed in the same cluster. Despite being obtained through different methods, the fruit essential oils of PCA No. 3 and 4 fell into the same group and had closely matching chemical profiles (89.62%). According to the HCA analysis, the essential oil composition of the fruits collected from Kayseri (PCA: 4) exhibited a 96.13% similarity to that of the aerial parts collected from Konya (PCA: 6). The essential oil composition of the aerial parts collected from Konya (PCA: 7) was clustered together with those of the aerial parts collected from Kayseri (PCA: 2) and Karaman (PCA: 1) in the same cluster.

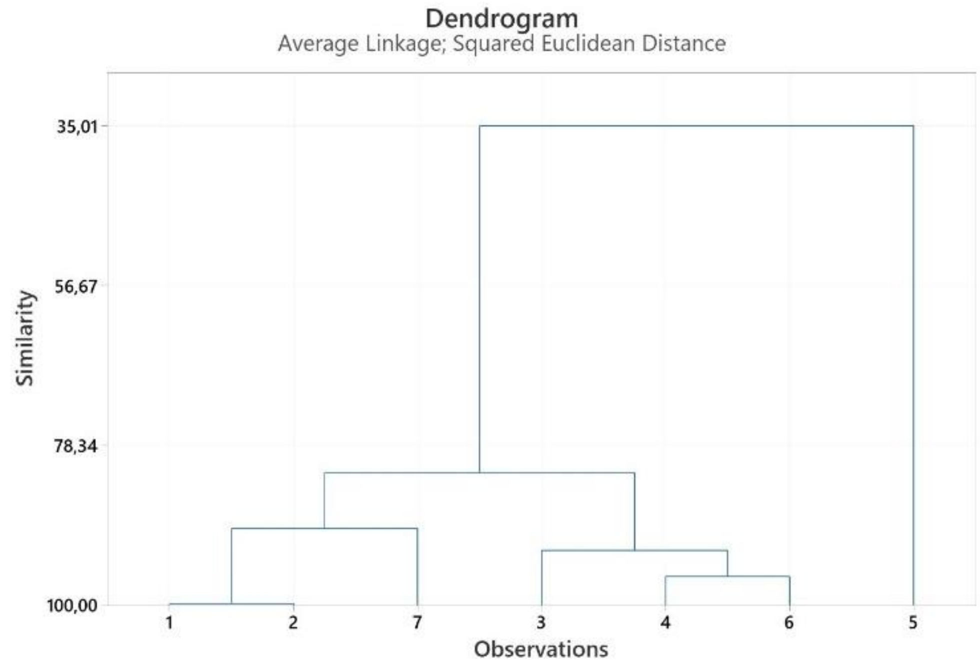

Figure 4. Dendrogram acquired by HCA based on Euclidian distances between groups of main compounds of the essential oils in Table 3; **1:** The aerial parts of EO in Karaman; **2:** The aerial parts of EO in Kayseri; **3:** The fruit of EO in Konya; **4:** The fruit of EO in Kayseri; **5:** The fruit of EO in Malatya; **6:** The aerial parts of EO in Konya; **7:** The aerial parts of EO in Konya

3. CONCLUSION

The essential oil compositions of endemic *P. meliocarpoides* var. *meliocarpoides* and *P. uechtritzii* aerial parts were determined. In addition, our study reports *P. uechtritzii* EOs and a review of different locations and plant parts of *P. uechtritzii* EOs variability employing statistical analysis. The chemical and statistical analysis of *P. uechtritzii,* combined with previous research on the *Prangos* genus, can provide valuable chemotaxonomic insights. This can lead to a more comprehensive understanding of the diversity within the *Prangos* genus.

4. MATERIALS AND METHODS

4.1. Plant Samples and Essential Oil Extraction Process

The aerial parts of *Prangos meliocarpoides* var. *meliocarpoides* and *P. uechtritzii* were collected (Table 1). Voucher specimens of the plant material have been deposited and preserved at the Herbarium within the Department of Biology at Necmettin Erbakan University.

The essential oils were extracted from the air-dried plant materials through the process of hydrodistillation for a duration of 3 hours employing a Clevenger-type apparatus.

The extracted oils were subsequently preserved at a temperature of 4°C in a dark environment until they were subjected to concurrent analysis utilizing both GC-FID and GC-MS techniques.

4.2. Chemical Analysis

The essential oil compositions were characterized using GC-FID and GC-MS methods. An Agilent 5975 GC-MSD instrument was used for the GC-MS analysis, with helium as the carrier gas. The temperature was set from 60°C to 240°C at a ramp of 1°C per minute, and the mass spectrometer scanned a mass-to-charge ratio range of 35 to 450.

The GC analysis was conducted employing an Agilent 6890N GC instrument. Simultaneous automated injections were carried out on the same analytical column under consistent operating parameters to guarantee the constant elution order between the GC-MS and GC analyses. The relative compositions of the separated components were computed using the FID chromatograms.

The volatile compounds were identified by comparing their relative retention times to those of known reference specimens or their retention index values relative to a series of n-alkanes. Computer-assisted database searches (Wiley GC-MS and MassFinder 4.0 Libraries) [11, 12], including the in-house "Başer's Essential Oil Constituents Library," which contains authentic compounds and components of well-characterized essential oils, were also used for identification purposes.

4.3. **Statistical Analysis**

The essential oil constituents comprising at least 10.0% of the total composition in any *Prangos* species were selected as the primary variables for analysis. Subsequently, cluster analysis and principal component analysis were executed. The statistical analysis was conducted using Minitab 19. The appropriate number of clusters was selected by analyzing the rescaled distances shown in the dendrogram and identifying a threshold that established stable, coherent cluster structures. To assess the resemblance within the essential oils based on their chemical constituent contents, PCA and HCA were employed [13, 14].

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