Morphological and Volatile Profiles of *Phlomis russeliana* and *Phlomis armeniaca* from Uludağ, Türkiye

Ayse Gul Sarikaya ,[a,]* and Betul Ilhan ,[b]

The medicinal and aromatic plant species naturally found in Türkiye are particularly noteworthy. Among them, *Phlomis* L., a genus within the Lamiaceae family, stands out for its numerous species. This study, conducted in Uludağ (Bursa), aimed to analyze the morphological traits, volatile components, ratios, and molecules present in the leaves and flowers of *Phlomis russeliana* (Sims) Bentham and *P. armeniaca* Willd. Samples were collected during their flowering period using a random sampling method. Their morphological characteristics were analyzed using Microsoft Excel and IBM SPSS software, while the volatile components of the leaf and flower samples were identified through the HS-SPME/GC-MS method. The morphological characteristics of *Phlomis russeliana* and *P. armeniaca* were examined in detail. The leaf widths and lengths, petiole lengths, number of flowers, petal lengths, sepal lengths were measured. 32 different components were identified in *P. russeliana* and 43 different components in *P. armeniaca*, summing up to 56 different components. The main components identified were caryophyllene (31.6%; 26.4%), (E)-β-farnesene (19.6%; 25.2%), and germacrene-D (25.7%; 16.5%), respectively. Such studies are crucial for enhancing the protection and sustainable management of non-wood forest products, which significantly contribute to our country's economy and play a pivotal role, especially in rural economies.

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Contact information: a: Bursa Technical University, Faculty of Forestry, Bursa-Türkiye;
b: Bursa Technical University, Graduate School, Bursa-Türkiye;
** Corresponding author: aysegul.sarikaya@btu.edu.tr*

INTRODUCTION

The share of Non-Wood Herbal Products (NWFPs) within the broader category of non-wood forest products is highly significant. In contemporary times, medicinal and aromatic plants occupy a prominent place in Türkiye. The country not only serves as a genetic center for numerous plant species but also harbors a rich diversity of endemic species across its varied geographical regions. Situated at the crossroads of three phytogeographical regions, Türkiye acts as a bridge between the floras of Southern Europe and Southwest Asia. Anatolia, in particular, is recognized as a center of origin and diversification for many plant genera and sections. Furthermore, ecological and phytogeographical variations have contributed to a high level of species endemism (Tan 1992).

Of the approximately 11,466 plant taxa that grow naturally in Türkiye, around 3,649 are endemic (Guner 2012). Beyond these endemic species, hundreds of naturally occurring plants in Türkiye possess significant medicinal and aromatic properties (Baydar 2009). Medicinal and aromatic plants have historically been utilized in both traditional and modern medical practices for disease prevention and the promotion of health. Additionally, they play an important role in nutrition as dietary supplements, herbal teas, flavorings, and spices. These plants are also extensively employed in the fragrance and cosmetics industries for perfumes and personal care products, as well as in various industrial applications, including use as brighteners and insecticides. In recent years, the global demand for these natural resources has increased markedly and continues to rise (BAKA 2012).

Among medicinal and aromatic plants, those with high volatile components hold particular significance. Essential oils (also known as essences or ethereal oils) and their aromatic extracts are extensively used in the fragrance and flavor industries to create perfumes, food additives, cleaning products, cosmetics, and pharmaceuticals. These oils serve as a source of aroma chemicals or as raw materials for synthesizing both natural and semi-synthetic aroma chemicals (Weiss 1997). Essential oils and aromatic extracts are utilized by the fragrance and flavor industries as a source of flavor chemicals. They also serve as raw materials for the synthesis of both natural and semi-synthetic flavor chemicals (Baser 1998). Today, obtaining and analyzing the pure, particularly the main active ingredients of medicinal plants and their volatile components, holds significant scientific and economic value. It is believed that studying the pharmacological properties of volatile components and their components could reveal their potential applications in medicine, cosmetics, and various industrial fields (Kirbag and Bagci 2000). Essential oils have been used as remedies in the treatment of various diseases since ancient times (Kubeczka 1973). Some of their biological effects have been scientifically demonstrated as a result of pharmacological studies on these drugs by taking into account the purposes of their use in folk medicine (Kivanc and Akgul 1986; Sarer 1991).

Since the 1990s, the discovery of new applications for medicinal and aromatic plants, along with a growing interest in natural products, has driven a steady increase in their usage (Kumar 2009). Public interest and consumption of medicinal and aromatic plants have also risen significantly. Among the species traditionally used by local populations is “Çalba,” belonging to the genus *Phlomis* L.

The genus *Phlomis* L., an important member of the Lamiaceae (mint) family, comprises approximately 100 species and is broadly distributed across the Mediterranean Basin, Central Asia, and China (Amor *et al*. 2009; Eruygur *et al*. 2022). Recent molecular phylogenetic research has indicated that traditional morphological classifications are often inadequate, suggesting the need for a taxonomic revision of the *Phlomis* genus (Will and Claßen-Bockhoff 2017). In addition, ecological studies have underscored the important roles *Phlomis* species play in drought resistance and in supporting pollinator networks (Özdemir and Kaya 2021).

Various parts of certain *Phlomis* species — including the leaves, flowers, seeds, and roots — are traditionally consumed. These plant parts are utilized through methods such as boiling, infusion, and extraction of plant sap (Limem-Ben Amor *et al*. 2009a). Numerous *Phlomis* species are employed in traditional medicine, particularly as herbal teas, serving as stimulants, tonics, diuretics, and in the treatment of ulcers and hemorrhoids (Zhang and Wang 2008). Additionally, they are used externally as herbal remedies for respiratory disorders and wound healing (Marina *et al*. 2002).

Herbal teas (prepared through decoction or infusion) made from *Phlomis* species are commonly used to support digestion and to treat conditions such as gastritis, ulcers, and various types of pain in countries including Türkiye, Spain, Iran, Syria, Greece, and Portugal (Limem-Ben Amor *et al*. 2009b). Beyond their recognized medicinal applications, certain *Phlomis* species are also utilized in Anatolian folk medicine for their antidiarrheal, immunosuppressive, antimutagenic, antipyretic, and free radical scavenging properties (Borchardt *et al*. 2008; Parisa *et al*. 2006).

There are approximately 100 species worldwide, and this genus is found across Asia, Southern Europe, and Northern Europe (Mathiesen *et al.* 2011). The height of the species can range between 30 cm and 2 m. The edges of the leaves are serrated, arranged oppositely, and not lobed. The hairs covering the plant surface are star-shaped. The flowers are purple, pink, white or yellow (Huber-Morath 1982). The members of the genus *Phlomis*, represented by 40 species and subspecies, 10 hybrids and 50 taxa in total in Davis' (1982) Flora of Turkey, were evaluated as 39 species and subspecies, 19 hybrids and 58 taxa in total in Dadandi's revision of the *Phlomis* genus of Türkiye. In the list of Plants of Türkiye, it is represented by 39 taxa and 13 hybrids with a total of 52 taxa (Dadandi 2002). Many *Phlomis* species are used in traditional medicine as herbal tea as stimulant, tonic, diuretic, ulcer, and haemorrhoid treatments (Zhang and Wang 2008). It is used externally as an herbal medicine for respiratory system disorders or for the treatment of wounds (Marina *et al*. 2002; Limem-Ben *et al*. 2009a).

Herbal teas (decoctions and infusions) made from *Phlomis* species are commonly used in Türkiye, Spain, Iran, Syria, Greece, and Portugal as digestive aids and for treating conditions such as gastritis, ulcers, and pain. Beyond their well-known medicinal uses, certain *Phlomis* species are also employed in Anatolian folk medicine for their antidiuretic, immunosuppressive, antimutagenic, antifebrile, and free radical scavenging properties (Parisa *et al*. 2006; Borchardt *et al*. 2008).

Volatile components from various *Phlomis* species have been shown to exhibit antibacterial activity against a broad spectrum of pathogenic bacteria. Previous studies have also revealed that the *Phlomis* genus possesses antiparasitic properties (Limem-Ben *et al*. 2009b). Although it has many uses, there have been very few studies on *Phlomis* taxa in Türkiye. In addition, there has been a need for studies on the volatile components of the leaves of these species. For this purpose, morphological characteristics, volatile components, ratios and molecules of *Phlomis russeliana* (Sims) Bentham and *P. armeniaca* Willd., which are distributed in Uludağ (Bursa), were determined.

Volatile components were identified using the Headspace Solid-Phase Microextraction (HS-SPME) technique combined with Gas Chromatography/Mass Spectrometry (GC-MS). The environmentally friendly Solid-Phase Microextraction (SPME) technique significantly reduces processing time and costs due to being a solvent-free analysis method (Vas and Vekey 2004; Araujo *et al*. 2007; Dönmez and Salman 2017; Dönmez 2024). For this reason, it was preferred as the analysis technique in the present work. The study contributed to the formation of a scientific infrastructure on the usage possibilities of *Phlomis* species and their raw materials for the industrial sector.

The aim of this study was to determine the morphological characteristics and volatile components of *Phlomis* taxa distributed in Uludağ. The components, particles and molecules of leaf and flower shaped samples from the field were determined.

EXPERIMENTAL

Materials

The study material consisted of populations of *Phlomis russeliana* and *Phlomis armeniaca* naturally distributed in Uludağ (Bursa) (Fig. 1). During field expeditions conducted in the study areas, the coordinates of the locations where *Phlomis* species were identified were recorded. Based on these findings, sampling sites were selected. *Phlomis russeliana* samples were collected from a site located at 40° 07' 5.26" N, 29° 01' 28.96" E, at an elevation of 1,031 meters. Similarly, *Phlomis armeniaca* samples were collected at 39° 53' 53.82" N, 29° 20' 10.72" E, at an elevation of 1,055 meters. Sampling plots measuring 20 × 20 meters were established.

It was also considered that the individuals of the species had reached a certain maturity, were healthy, represented different growing environments, and were as far away from human influence as possible. The area where *Phlomis russeliana* was collected is partly arid, rocky, and filled with stones, located at the forest edge and clearings within the forest. In contrast, the areas where *P. armeniaca* was collected are rocky, along the road leading to Mount Uludağ, and in open areas.

Tools and equipment such as field bag, loop, steel shovel, compass, topographical and elevation curve map, stand map, pruning shears, field notebook, altimeter, press, blotting paper, camera, steel meter were used while collecting the samples. The collected plant specimens were deposited in the herbarium and identified at Bursa Technical University, Faculty of Forestry.

Fig. 1. Plant taxa constituting the material of the study (A-1. habitus of *Phlomis russeliana*; A-2. Inflorescence of *Phlomis russeliana* and B-1. habitus of *Phlomis armeniaca*; B-2. Inflorescence of *Phlomis armeniaca*)

Methods

Leaf, flower, and calyx samples were collected from the designated areas using the simple random sampling method to identify the morphological characteristics of the respective taxa. In their natural distribution areas within Türkiye, *Phlomis russeliana* flowers between May and September, whereas *P. armeniaca* flowers between June and August. Based on these field observations, sample collection was carried out in July.

Morphometric analyses were conducted on *Phlomis russeliana* and *P. armeniaca* based on the collected specimens. For each species, the length and width of 50 leaf samples, petiole length, and the calyx width, calyx length, and calyx tooth length from 50 calyx samples were measured. Additionally, the floral architecture was characterized by determining the inflorescence type and the number of flowers per inflorescence. The minimum, maximum and arithmetic mean values of the morphological measurements were calculated using Microsoft Excel (Microsoft Corp., USA). The standard deviations and variations of the data were calculated using the IBM SPSS Statistics 23 software package.

The areas determined at the time of maturation of the leaves and flowers of *Phlomis russeliana* and *P. armeniaca* during the vegetation period were visited, and leaf and flower samples were collected from the plants. The collected leaf and flower samples were placed in packages and transported to the laboratory on the same day without waiting or exposure to sunlight. The collected plant materials were dried at room temperature (25 °C) until they achieved a constant weight after one week. The floral aroma components of the flowers and leaves were together identified using the headspace-solid phase microextraction (HS-SPME) technique, combined with gas chromatography/mass spectrometry (GC-MS). Approximately 2 g of leaf and flower samples from each species were placed into a 10 mL vial and incubated at 60 °C for 30 min to allow the volatile components to be released into the vial’s headspace. The volatile components were then absorbed from the headspace using a 75 µm Carboxene/polydimethylsiloxane (CAR/PDMS) coated fused silica fiber. Immediately after, the volatile compounds were transferred to the capillary column (Restek Rx-5 Sil MS, 30 m x 0.25 mm, 0.25 µm) of an HS-SPME-compatible GC-MS (Shimadzu 2010 PLUS). The oven temperature was programmed to reach 250 ºC after 2 min at 40 °C with an increase of 4 °C per min. Injector and detector temperatures were set to 250 °C and EI (70 eV) was used as the ionization type and helium (1.61 mL/min) as the carrier gas. Wiley, NIST, and FFNSC spectral libraries were used to identify volatile components. The applied method was performed in three replicates and the results were averaged.

RESULTS AND DISCUSSION

Flowers, leaves and bracts of *Phlomis russeliana* were examined and necessary measurements were made to determine morphological characteristics. The results of morphological measurements are given in Table 1. The ovate-lanceolate, acuminate, greenish tomentose leaves of *Phlomis russeliana* had the following dimensions: width: 0.677 to 12.152 cm; and length: 1.8 to 17.091. The length of petiole was 0.113 to 15.782 cm. The flower cluster has 12 to 20 flowers and flowers bloom in May to September. The corolla is yellow, 0.4 to 2.4 cm, and the upper lip is helmet-shaped. Bracts are 0.8 to 2.4 cm; the calyx is 1.1 to 2.2 cm long with dense stellate-tomentose pubescence and spreading calyx tooth 0.3 to 07 cm long (Table 1). Nut-like fruits are glabrous.

In *Flora of Turkey* (Davis 1982), the leaf size of *P. russeliana* was given as 6 to 12 x 6 to 20 cm, petiole up to 28 cm, corolla 3.0 to 3.5 cm, bracts 1.0 to 2.0 cm, calyx 2.0 to 2.5 cm, calyx tooth 0.2 to 0.5 cm. In the study of Dadandi (2002), the leaf size of *P. russeliana* was determined as 4.5 to 12 x 6 to 20 cm, petiole up to 15 cm, corolla 2.7 to 3.8 cm, bracts 1 to 2 cm, calyx 1.4 to 2.4 cm. It is seen that the leaf size, petiole, bract, calyx and corolla values in our study differ from the results of the studies in the literature.

Phlomis armeniaca is an herbaceous plant that reaches a maximum height of 60 cm. It is found in the arid southern foothills of Uludağ, growing at elevations between 1000 and 1100 meters in open areas, slopes, and along roadsides. The morphological characteristics of *P. armeniaca* are summarized in Table 2. The leaves of *P. armeniaca* are linear-lanceolate with stellate-tomentose hairs, measuring between 0.619 and 1.215 cm in width and 2.274 to 4.886 cm in length. The petiole length ranged from 0.512 to 7.066 cm. The flower clusters consist of 4 to 10 flowers, which bloom from June to August. The corolla is yellow, with a length ranging from 1.1 to 1.8 cm. The bracts measure between 0.3 and 0.7 cm, while the calyx covered with flattened or spreading stellate hairs, measures 0.8 to 1.5 cm in length. The calyx teeth are lanceolate and acuminate, measuring between 0.3 and 0.5 cm. The fruits are nut-like and glabrous.

The leaf size of *P. armeniaca* was given as 0.8 to 2x2 to 10 cm, petiole up to 7 cm, corolla 2.5 to 3.5 mm, bracts 0.3 to 1.0 cm, calyx 1.3 to 1.7 mm, calyx tooth 0.4 to 0.6 mm in *Flora of Turkey* (Davis 1982). In the study of Dadandi (2002), the leaf size of *P. armeniaca* was determined as 0.6 to 3.5x2 to 12 cm, petiole up to 6 cm, corolla 1.9 to 3.4 cm, bracts 0.05 to 1.5 cm, and calyx 1.0 to 1.6 cm. It is apparent that the leaf sizes determined in the present study differed with respect to the values of petiole, bract, calyx and corolla. It is thought that the morphological characteristics of the species in the present study differed due to reasons such as climate, ecological factors, and different growing places of the plants.

Table 1. Morphology of *Phlomis russeliana*

		Leaf Width	Leaf Length	Leaf Stalk Length	Corolla Size	Bracket Length	Calyx Length	Calyx Tooth Length
N	**Valid**	50	50	50	50	50	50	50
	Missing	0	0	0	0	0	0	0
Min.		0.68	1.80	0.11	0.40	0.80	1.10	0.30
Max.		12.15	17.09	15.78	2.40	2.40	2.20	0.70
Mean		4.68	8.43	2.62	1.42	1.57	1.57	0.44
Std. Deviation		3.43	4.83	4.57	0.40	0.39	0.22	0.11

Table 2. Morphology of *Phlomis armeniaca*

	Leaf Width	Leaf Length	Leaf Stalk Length	Corolla Size	Bracket Length	Calyx Length	Calyx Tooth Length
N Valid	50	50	50	50	50	50	50
Missing	0	0	0	0	0	0	0
Min.	0.62	2.27	0.51	1.10	0.30	0.80	0.30
Max.	1.22	4.89	7.07	1.80	0.70	1.5	0.50
Mean	0.91	3.63	2.80	1.42	0.50	1.10	0.38
Std. Deviation	0.13	0.63	1.98	0.18	0.12	0.18	0.07

Phlomis russeliana was found to be distributed in forest clearings, along forest roads, on roadsides, in maquis habitats, and in rocky, stony regions, typically on slopes ranging from 5 to 20% with southern exposures. The associated flora includes tree and small tree species such as *Quercus cerris* L., *Q. infectoria* Oliv., *Q. coccifera* L., *Juniperus foetidissima* Willd, *Pinus brutia* Ten., *Platanus orientalis* L., *Prunus spinosa* L., *Abies nordmanniana* subsp. *equi-trojani* [Asch. & Sint. ex Boiss] Coode & Cullen, *Cercis* *siliquastrum* L., *Pistacia terebinthus* L., and *Crataegus monogyna* L. Additionally, shrub species such as *Paliurus spina-christi* Mill., *Daphne sericea* Vahl., *Myrtus communis* L., *Vitex agnus-castus* L., *Smilax aspera* L., *Spartium junceum* L., and *Rubus sanctus* Schreber were identified, along with herbaceous species such as *Euphorbia oblongifolia* C. Koch, *Anthemis cretica* L., *Trifolium alpestre* L., *Origanum vulgare* L., *Coronilla varia* L., *Gladiolus italicus* Miller., *Senecio vernalis* Waldst. & Kit., *Astragalus angustifolius* Lam., *A. acutifolius* L., *Salvia viridis* L., and *Lathyrus aureus* (Stev.) Brandza.

Phlomis armeniaca is distributed in areas with slopes ranging from 5 to 20%, including forest clearings, stony and less stony regions, primarily on southern, southwestern, and southeastern aspects. Within the sample areas, tree species identified include *Pinus nigra* Arnold, *P. brutia* Ten., *Juniperus* spp., *Abies nordmanniana* subsp. *equi-trojani* [Asch. & Sint. ex Boiss] Coode & Cullen, and *Quercus cerris* L. var. *cerris*. Shrub species present include *Cistus creticus* L. and *Astragalus* spp., while herbaceous plant species identified include *Artemisia absinthium* L., *Marrubium astracanicum* Jacg., *Cirsium hypoleucum* D.C., *Dorycnium graceum* (L.) Ser., *Euphorbia amygdaloides* L. var. *amygdaloides*, *Geranium pyrenaicum* Burm. F., *Hypericum calycinum* L., and *Thymus praecox* Opiz subsp. *skorpilii*.

The combination of higher sunlight, warmer microclimate, poorer soils, and ecological interactions in these habitats likely causes *Phlomis russeliana* and *P. armeniaca* to increase both the diversity and quantity of its volatile components, enhancing its adaptability and survival. However, while *P. russeliana* is mostly distributed in forest clearings and shrub areas, *P. armeniaca* is predominantly found in open areas and along roadsides. It is thought that, due to the effect of sunlight exposure, the volatile components in *P. armeniaca* have become more complex.

In this study, the floral aroma components of *Phlomis russeliana* and *P. armeniaca* samples, collected from Uludağ during the ripening of their leaves and flowers, were analyzed using the Headspace-Solid Phase Micro Extraction (HS-SPME) technique combined with gas chromatography/mass spectrometry (GC-MS). A total of 32 and 43 different constituents were identified in *Phlomis russeliana* and *P. armeniaca*, respectively. Caryophyllene (31.63%; 26.35%), (E)-β-Farnesene (19.58%; 25.16%) and Germacrene-D (25.71%; 16.54%) were determined as the main components, respectively (Fig. 2). Sesquiterpenes were found to be in high proportion (Table 3; Fig. 3).

Table 3. Leaf and Flower Floral Volatile Constituents *P. russeliana* and *P. armeniaca*

No	LRI	Components	*P. russeliana*	*P. armeniaca*	Class	Formula
1	<700	3-Methylbutanal	0.17	-	AA	$C_5H_{10}O$
2	<700	2-Methylbutanal	0.20	-	AA	$C_5H_{10}O$
3	<700	Sorbaldehyde	0.34	-	AAI	C_6H_8O
4	721	Pentanol	-	0.20	AA	$C_5H_{12}O$
5	819	Hexanal	0.60	0.41	AA	$C_6H_{10}O$
6	870	2-Hexenal	0.19	0.21	AA	$C_6H_{10}O$
7	890	Hexanol	-	0.09	AA	$C_6H_{14}O$
8	920	Heptanal	0.11	-	AA	$C_7H_{14}O$
9	942	α-thujene	-	0.05	MH	$C_{10}H_{16}$
10	949	α-pinene	-	1.07	MH	$C_{10}H_{16}$
11	979	Benzaldehyde	-	0.09	AA	C_7H_6O

No	LRI	Components	*P. russeliana*	*P. armeniaca*	Class	Formula
12	1004	6-methyl-5-hepten-2-one	-	0.10	AA	$C_8H_{14}O$
13	1008	β-Myrcene	-	0.39	MH	$C_{10}H_{16}$
14	1022	Octanal	0.14	*	AA	$C_8H_{16}O$
15	1023	β-phellandrene	-	0.18	MH	$C_{10}H_{16}$
16	1042	para-Cymene	0.09	0.14	MH	$C_{10}H_{14}$
17	1047	Limonene	0.62	2.48	MH	$C_{10}H_{16}$
18	1048	1,8-Cineole	0.20	-	OM	$C_{10}H_{18}O$
19	1089	Fenchone	0.30	-	OM	$C_{10}H_{16}O$
20	1104	α-Terpinolen	-	0.16	MH	$C_{10}H_{16}$
21	1120	Linalool	0.27	0.07	OM	$C_{10}H_{18}O$
22	1124	Nonanal	0.59	0.55	AAI	$C_9H_{18}O$
23	1160	Camphor	0.71	-	OM	$C_{10}H_{16}O$
24	1227	Deconal	-	0.07	OM	$C_{10}H_{20}O$
25	1353	Bicycloelemene	-	0.06	ST	$C_{15}H_{24}$
26	1368	α-Cubebene	0.70	0.32	ST	$C_{15}H_{24}$
27	1390	α-Ylangene	0.14	0.13	ST	$C_{15}H_{24}$
28	1396	α-Copaene	2.52	0.61	ST	$C_{15}H_{24}$
29	1404	β-Bourbonene	1.39	2.11	ST	$C_{15}H_{24}$
30	1409	Epi-bicyclosesquiphellandrene	-	0.43	ST	$C_{15}H_{24}$
31	1410	β-Elemene	0.80	0.55	ST	$C_{15}H_{24}$
32	1432	α-gurjunene	-	0.05	ST	$C_{15}H_{24}$
33	1443	Caryophyllene	31.63	26.35	ST	$C_{15}H_{24}$
34	1445	β-Cubebene	0.93	-	ST	$C_{15}H_{24}$
35	1451	Germacrene-B	0.81	4.04	ST	$C_{15}H_{24}$
36	1456	γ-Gurjunene	-	0.48	ST	$C_{15}H_{24}$
37	1460	Aromadendrene	-	0.18	ST	$C_{15}H_{24}$
38	1463	Cadina-1(6),4-diene <10 β H->	1.08	-	ST	$C_{15}H_{24}$
39	1467	Isoledene	0.17	-	ST	$C_{15}H_{24}$
40	1476	(E)-β-Farnesene	19.58	25.16	ST	$C_{15}H_{24}$
41	1477	α-Humulene	1.76	-	ST	$C_{15}H_{24}$
42	1484	(+)-Epi-bicyclosesquiphellandrene	-	0.94	ST	$C_{15}H_{24}$
43	1497	γ-Muurolene	-	1.26	ST	$C_{15}H_{24}$
44	1504	Germacrene-D	25.71	16.54	ST	$C_{15}H_{24}$
45	1507	2-Isopropenly-4a,8-dimethyl-1,2,3,4,4a,5,6,7-octahydronaphthalene	-	5.78	ST	$C_{15}H_{24}$
46	1511	Eudesma-4(14),11-diene	-	0.53	ST	$C_{15}H_{24}$
47	1515	α-Amorphene	1.35	1.42	ST	$C_{15}H_{24}$
48	1517	β-Guaiene	0.65	-	ST	$C_{15}H_{24}$

No	LRI	Components	*P. russeliana*	*P. armeniaca*	Class	Formula
49	1518	Bicyclogermacrene	-	1.50	ST	$C_{15}H_{24}$
50	1526	Valencene	-	0.38	ST	$C_{15}H_{24}$
51	1530	β-Bisablone	-	0.05	ST	$C_{15}H_{24}$
52	1536	γ-Cadinene	1.64	1.10	ST	$C_{15}H_{24}$
53	1541	δ-Cadinene	3.30	2.30	ST	$C_{15}H_{24}$
54	1555	Naphthalene, 1,2,3,4,4a,7-hexahydro-1,6-dimethyl-4-(1-methylethyl)-	-	0.23	PAC	$C_{15}H_{24}$
55	1559	α-Muurolene	1.31	1.02	ST	$C_{15}H_{24}$
56	1564	Selina-3,7(11)-diene	-	0.22	ST	$C_{15}H_{24}$
	Number of Components		32	43		
	AA: Aromatic Alcohol		1.41	1.10		
	AAI: Aromatic Aldehyde		0.93	0.55		
	MH: Monoterpene Hydrocarbon		0.71	4.47		
	OM: Oxygenated Monoterpene		1.48	0.14		
	ST: Sesquiterpene Hydrocarbon		95.47	93.51		
	PAC: Polycyclic Aliphatic Compound		-	0.23		
	Total		100	100		
	Number of Components		32	43		
LRI: Linear retention index/ **"-":** 0						

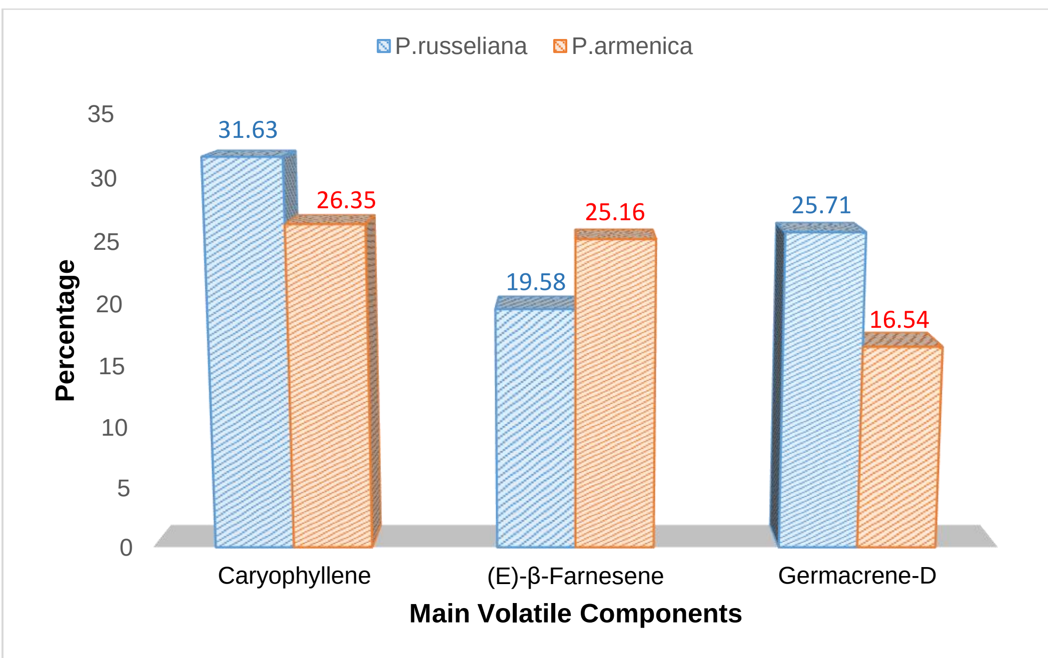

Fig. 2. Leaf and flower floral volatile main constituents of *Phlomis russeliana* and *P. armeniaca*

Sesquiterpenes are chemically stable, biologically useful, structurally diverse, and efficiently produced — making them dominate volatile profiles when conditions favor it. Also, the higher content of MH (monoterpene hydrocarbons) such as limonene and α-pinene in *P. armeniaca* compared to *P. russeliana* is likely due to genetic, environmental, and ecological factors that influence terpene production differently in each species. The growth conditions of each species can influence terpene synthesis. Factors such as soil composition, climate, temperature, and exposure can affect the production of terpenes. *P. armeniaca* might be growing in conditions under exposure that promote the biosynthesis of limonene and α-pinene, while *P. russeliana* may not have the same environmental factors driving the production of these compounds.

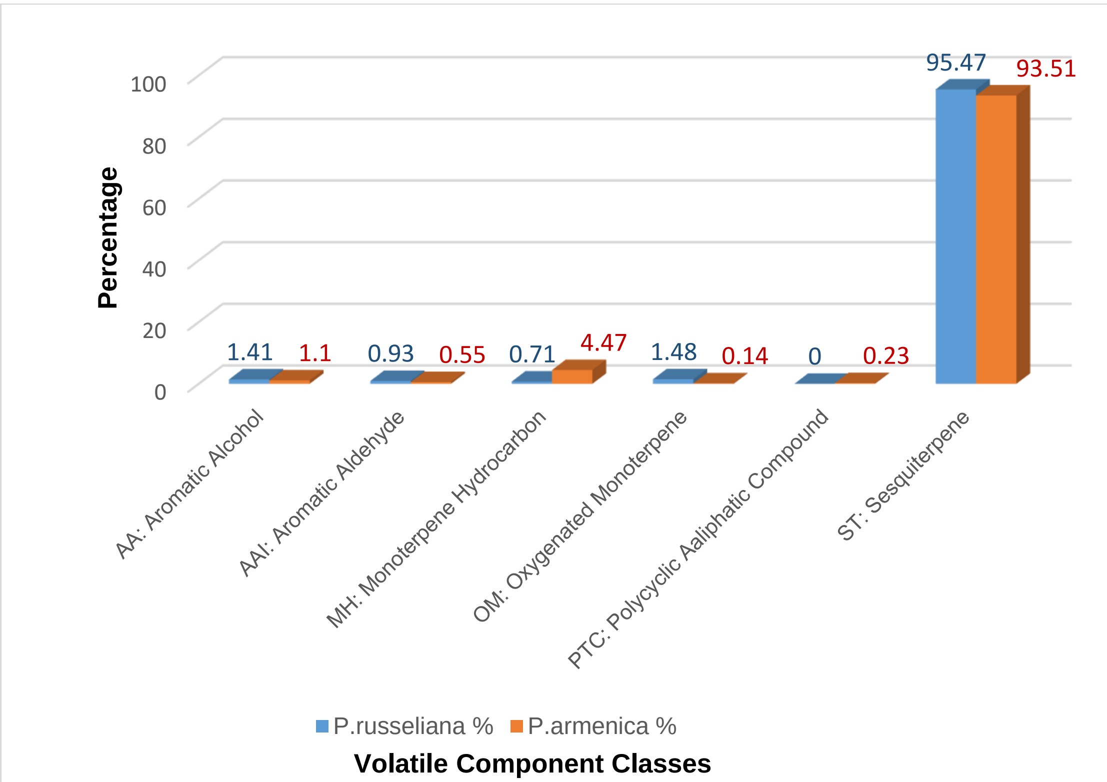

Fig. 3. Classes of leaf and flower floral volatile constituents of *Phlomis russeliana* and *P. armeniaca*

Demirci *et al.* (2008) identified β-caryophyllene (23%), Germacrene-D (15%), and caryophyllene oxide (8%) as the primary components of *Phlomis russeliana*. Both studies agree on the prominence of caryophyllene and germacrene-D as major components. However, in the present study, the presence of (E)-β-farnesene was detected, a component not reported by Demirci *et al.* (2008). In a separate study, Sarikaya (2015) identified 54 volatile compounds in *P. armeniaca* through SPME analysis, with (E)-2-hexenal (12.1%), β-caryophyllene (16.6%), and germacrene-D (27.2%) as the dominant components. Similarly, Yasar *et al.* (2010) detected 12 volatile components in *P. armeniaca*, with germacrene-D (35.7%), β-caryophyllene (18.1%), caryophyllene oxide (13.4%), (E)-β-farnesene (7.2%), and hexahydrofarnesyl acetone (7.0%) as the major constituents. Germacrene-D was found to be the most abundant and characteristic compound in *P. armeniaca*. The results from these studies are consistent with our findings.

Moreover, studies have demonstrated that environmental factors and growth conditions significantly influence the essential oil compositions of *Phlomis* species. For example, it has been shown that ecological variations cause changes in the proportions of compounds such as borneol, camphor, and 1,8-cineole in *Phlomis fruticosa* samples (Tzakou and Pitarokili 2019).

In a study on the essential oil components of *Phlomis kurdica*, the main constituents were reported as spathulenol (22.1%), caryophyllene oxide (17.8%), and Germacrene D (14.5%) (Mohammadi *et al*. 2022). Similarly, analyses of *Phlomis olivieri* revealed that sesquiterpenes such as β-caryophyllene, germacrene D, and bicyclogermacrene were predominant (Sharifi-Rad *et al*. 2021).

Characterization of the volatile compound profiles has also been carried out for species such as *Phlomis armeniaca* and *Phlomis pungens*, which have a wide distribution in the flora of Türkiye. These species were found to be particularly rich in monoterpenes (α-pinene, β-pinene) and oxygenated sesquiterpenes (Goren and Kupeli Akkol 2020).

CONCLUSIONS

1. This study revealed significant differences in the morphological and aromatic characteristics of *Phlomis russeliana* and *P. armeniaca*. These differences can be explained by the geographical and climatic conditions in which each species grows. Additionally, volatile component analyses showed that both species possess rich sesquiterpene hydrocarbon component profiles. Notably, the detection of (E)-β-farnesene as the dominant component in *P. russeliana* suggests that these species hold potential value for the pharmaceutical and cosmetic industries. In the future, testing the biological activities of these components could provide more information about the therapeutic and aromatic properties of the species.
2. The study confirmed that both species are found in specific ecological areas, particularly along forest roads, clearings, and rocky regions. It is important to protect their habitats and carry out restoration efforts for their conservation. Additionally, to enhance the cultural and economic value of these species, it is recommended that these plants be cultivated within the framework of sustainable agricultural practices.
3. Considering the impact of global climate change and environmental factors on plant development, long-term ecological monitoring programs could be initiated to track the future distribution and biochemical components of *P. russeliana* and *P. armeniaca*. This would be important for understanding how these species adapt to climate changes.
4. Molecular biological analyses on the genetic diversity of these species will allow for a deeper examination of their relationships with environmental factors. The use of the obtained aromatic components in the pharmaceutical and cosmetic industries could enhance the potential benefits of these species, especially in the production of skincare products and natural medicines. Finally, cultivating these species with sustainable agricultural practices, without causing harm to the environment, presents a significant economic opportunity. Studies on the best cultivation techniques suitable for the climatic and soil conditions of the species to be cultivated are recommended.
5. Some types of *Phlomis* L. are consumed as tea for haemorrhoids and digestive disorders among the people and it is also used externally in the treatment of wounds. Studies should be increased for the public to consume and use *Phlomis* consciously. Detailed studies on antibacterial, antiseptic, antimicrobial and deterrent properties of *Phlomis*

taxa should be carried out. Dyestuffs can be obtained from the yellow flowers and used as natural colorants in food, health, *etc*. industrial sectors; a detailed study on this subject is recommended. Such studies are important in order to show that plants can be used as pharmaceutical raw materials or as natural preservatives in food and cosmetic products and to collect and use plants more consciously.

6. Non-wood forest products are resources that make significant contributions to our country's economy and play a vital role, especially in rural areas. More work needs to be done to protect and sustainably use these resources. These studies should include increasing protected areas, restoring natural habitats, and developing policies that will enable local communities to benefit from these resources in a fair and sustainable manner.

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