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Determination of Volatile Compounds And Antioxidant Properties Of Endemic Natural Mountain Tea (Sideritis spp.) Taxa Of Geyik Dağı (Central Taurides, Türkiye)

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Abstract - In this study, the volatile components and antioxidant properties of the endemic *Sideritis libanotica* subsp. *linearis* (Benth.) Bornm., *Sideritis libanotica* subsp. *libanotica*, and *Sideritis phrygia* Bornm. taxa naturally distributed in Geyik Dağı (Gündoğmuş/Antalya) were determined. Fifty-six, forty-six, and seventy-two volatile components were identified in *S. libanotica* subsp. *linearis*, *S. libanotica* subsp. *libanotica*, and *S. phrygia*, respectively. The main components identified were trans-Caryophyllene (19.33%), Bicyclogermacrene (9.79%), Limonene (9.72%), β-Pinene (8.40%), and α-Pinene (7.88%) in *S. libanotica* subsp. *linearis*; α-Pinene (25.81%), β-Phellandrene (19.73%), β-Myrcene (11.45%), β-Pinene (8.43%), and Bicyclogermacrene (6.18%) in *S. libanotica* subsp. *libanotica*; and trans-Caryophyllene (22.80%), β-Myrcene (10.53%), α-Pinene (9.16%), Limonene (8.06%), and β-Pinene (6.62%) in *S. phrygia*.

As a result of the analysis of variance (ANOVA), the CV values for both DPPH and CUPRAC antioxidant capacities were found to be within the acceptable range. Furthermore, both antioxidant scavenging capacities were found to be statistically significant at the 1% significance level. The *S. libanotica* subsp. *linearis* population had the highest DPPH antioxidant capacity, while the *S. libanotica* subsp. *libanotica* and *S. phrygia* populations were in the same group. The *S. phrygia* population had the highest CUPRAC antioxidant capacity, while the *S. libanotica* subsp. *linearis* and *S. libanotica* subsp. *libanotica* populations were in the same group. The difference in total phenolic content among the genotypes was found to be statistically insignificant, and all genotypes were placed in the same group.

Key Words - *Sideritis,* endemic, volatile components, antioxidant properties, solid phase microextraction, Antalya, Türkiye

I.INTRODUCTION

Türkiye has a highly diverse flora, as well as plant and animal diversity, due to its abundance of natural formations such as mountains, plains, lakes, and rivers, and its extensive coastline resulting from being surrounded by sea on three sides (Duran, 2013; Türkmenoğlu and Fakir, 2023). Furthermore, Türkiye's location at the intersection of three distinct phytogeographic regions namely the Mediterranean, Irano-Turanian, and Euro-Siberian floristic regions is another reason for its high biodiversity. Approximately 11,466 plant taxa are found in the Turkish flora. Of these taxa, 3,649 are endemic (Kaya and Aksakal, 2005; Güner et al., 2012). The Western and Central Taurus Mountains, especially the Taşeli Plateau, are among the richest areas in terms of endemism. The direction of the Taurus Mountains in the Mediterranean and their rise to around 3,500 m above sea level within a short distance are also among the reasons for the area's floristic richness (Avcı, 2014, Tıglı Kaytanlıoglu and Fakir, 2024).

The Lamiaceae family, consisting mostly of annual or perennial herbs or shrubs distributed in the Mediterranean basin, includes taxa that play an important role among medicinal aromatic plants. It is distributed primarily in Mediterranean countries, as well as in Austria, South America, and Southwest Asia. The Lamiaceae family stands out with approximately 245 genera and 7,886 species worldwide (Abdelhalim and Hanrahan, 2021). In Türkiye, it has approximately 45 genera and more than 546 species (Temel and Tokur, 2008). The Lamiaceae family harbors economically valuable species containing essential oils used in medicine and the cosmetic fragrance industry. The Lamiaceae family is a large family representing many beneficial plants such as sage, thyme, and mint (Tıglı et.al., 2023). The *Sideritis* spp. genus within this family is observed in our country as approximately 55 species and infraspecific taxa. Of these species, 44 are endemic. It is also known among the public as mountain tea, sage tea, and plateau tea (Gören, 2011). In addition to its general use as herbal tea, it is also known to have effects such as relieving colds, pain relief, antipyretic (fever-reducing), digestive system relief, and diuretic effects. These plants are also quite rich in essential oils. The essential oils obtained are widely used in the fragrance and flavor industries, in cosmetics as perfumes, food additives, cleaning products, and as a source of aroma chemicals (Erbaş and Fakir, 2012). Among the public, *Sideritis* spp. species are used in the treatment of coughs and gastrointestinal disorders, as an anti-inflammatory, analgesic (pain reliever), antitussive (cough suppressant), and as a stomachic (stomach-strengthening agent) (Kırımer et al., 1999).

Scientific studies have reported that extracts of some *Sideritis* spp. species have antistress (Öztürk et al., 1996), antiulcer (Günbatan et al., 2020), analgesic (Aydın et al., 1996), antioxidant (Uysal et al., 2023), antibacterial (Ezer et al., 1996; Temel et al., 2014), antifungal (Rodriguez-Linde et al., 1994), anti-inflammatory (Ezer et al., 1996), cold treatment (Çarıkçı et al., 2012), antimicrobial (Günbatan et al., 2023), antipyretic (Palomino et al., 1996), and insecticidal (Çarıkçı et al., 2012) effects. Previous studies have shown that *Sideritis* spp. taxa are most frequently used for digestive system disorders and colds (Ertaş, 2005).

Geyik Dağı, located within the boundaries of Gündoğmuş district in Konya-Antalya province in the Mediterranean Region, is a naturally rich area in terms of plant species diversity. This study, conducted on Geyik Dağı, aimed to determine the volatile components and antioxidant properties of naturally growing *Sideritis libanotica* subsp. *linearis* (Benth.) Bornm., *Sideritis libanotica* subsp. *libanotica* Labill., and *Sideritis phrygia* Bornm. taxa.

II.MATERIAL AND METHODS

Field Study Methodology

The research was conducted in the Geyik Dağı region, located within the boundaries of Gündoğmuş district in Antalya province (Figure 1). The material of the research consists of the endemic *S. libanotica* subsp. *linearis*, *S. libanotica* subsp. *libanotica*, and *S. phrygia* taxa belonging to the Lamiaceae family, collected from this area in 2023. General information about the taxa collected from the area is shown in Table 1.

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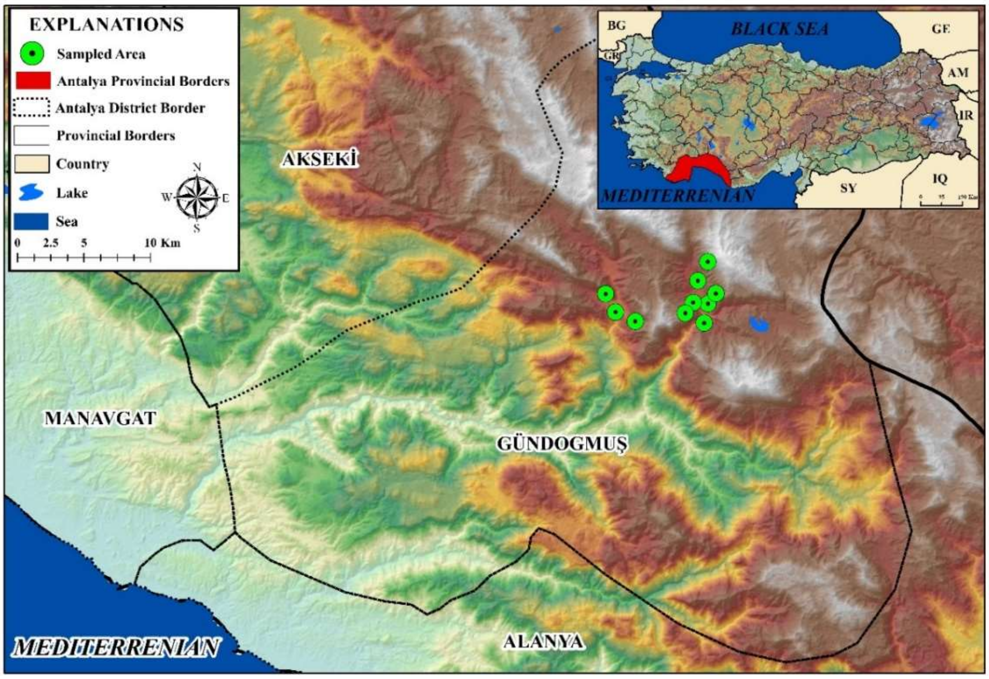

Figure 1. The geographic location of Sideritis spp. taxa

Table 1. Location, Altitude, and Slope Information of the Samples Constituting the Research Material

Taxa	Location	Altitude (m)	Slope (%)
S. libanotica subsp. *linearis*	Oğuz Plateau and surrounding mountain slopes of Malan Valley	1400	30-45
S. libanotica subsp. *libanotica*	Mountain slopes near Pembelik village, Gündoğmuş, Antalya	1300-1500	20-40
S. phrygia	Oğuz Plateau and surrounding mountain slopes of Malan Valley	1800-2200	30-45

Plant specimens used in this study were identified and authenticated at the Herbarium of the Faculty of Forestry, Isparta University of Applied Sciences. Following collection, the specimens were processed according to standard herbarium techniques, including drying, pressing, and numbering, and subsequently incorporated into the Herbarium collection.

A field program was conducted to determine the distribution and collect samples of the endemic *S. libanotica* subsp. *linearis*, *S. libanotica* subsp. *libanotica*, and *S. phrygia* species, which constitute the research material and are distributed in the Geyik Mountains. Technical equipment such as GPS, coordinate maps, compass, and camera, as well as materials such as pruning shears, steel trowel, meter, drying paper, and plant press were prepared for field identification and sample collection. When determining the sampling areas, areas as far away as possible from human and animal disturbance were preferred. Samples were collected during the flowering period for the determination of volatile components (Figure 2).

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Figure 2. Field Collection of Sideritis spp. taxa

Collected plant specimens were transported to the Forest Botany Laboratory of the Faculty of Forestry at Isparta University of Applied Sciences for registration and processing. Following registration, each specimen was labeled with pertinent collection data, including the collector's name, collection locality and collection date. The specimens were then dried under semi-shaded conditions using standard herbarium techniques before being incorporated into the university's herbarium collection

Method for Determination of Leaf and Flower Volatile Components

Following collection from the designated field sites, plant material (flowers, leaves, and stems) was placed in paper bags and transported to the laboratory on the same day, ensuring protection from environmental factors such as direct sunlight, wind exposure, and poor ventilation. Upon arrival at the laboratory, the plant material was air-dried at ambient temperature (25°C). Two grams of each dried sample were weighed and transferred to glass vials, which were subsequently heated at 60°C for 15 minutes. Headspace Solid Phase Microextraction (HS-SPME) was then employed using an appropriate fiber inserted into the vial to adsorb volatile compounds. The adsorbed analytes on the fiber were thermally desorbed in the GC injection port for 5 minutes. Volatile components were identified using a Shimadzu QP 5050 gas chromatograph-mass spectrometer (GC-MS). Floral scent components from the flowers and leaves were analyzed using headspace solid-phase microextraction (HS-SPME) coupled with gas chromatography-mass spectrometry (GC-MS).

Antioxidant activity (%)

Antioxidant activity/capacity of the species was assessed using two distinct assays: the DPPH radical scavenging assay and the CUPRAC assay.

Determination of Antiradical Activity (DPPH)

Antiradical scavenging activity was assessed using the 2,2-diphenyl-1-picrylhydrazyl (DPPH) radical scavenging assay (Shimata et al., 1992). Briefly, 0.25 ml of sample solution (at a concentration of 250 ppm) was mixed with 1 ml of a 0.2 mM DPPH solution using a vortex mixer. The mixture was incubated in the dark at ambient temperature for 30 minutes, and the absorbance was measured at 517 nm using a spectrophotometer. The calculation formula is presented in Equation (3.1) below:"

$$SRS \text{ (mmol TR g}^{-}\text{1 ekstrakt)} = \frac{\Delta A}{\varepsilon_{TR}} \times \frac{V_m}{V_s} \times \text{Sf} \times \frac{V_E}{m} \quad (3.1)$$

ƐTR: The molar absorptivity (ε) of the TR compound in the DPPH assay is 2.168 × 10^4 L mol^{-1} cm^{-1}; Vs: volume of the sample; Vm: total reaction volume of the assay (4 mL); Sf: dilution factor (where applicable); VE: volume of the extract; and m: mass of the extract.

Cupric Reducing Antioxidant Capacity (CUPRAC)

Cupric Reducing Antioxidant Capacity (CUPRAC) assay was performed according to the procedure described by Apak et al. (2004). Briefly, to 100 ppm of the extract solution were added 0.01 M $CuCl_2$, 7.5 mM neocuproine solution, 1 M ammonium acetate buffer (pH 7.0), and 1 mL of ultrapure water. Ethanol served as the blank control, and all samples were incubated in the dark for 1 hour at ambient temperature. Absorbance measurements were performed at 450 nm using a spectrophotometer. The results are expressed as Trolox equivalents (TE) per dry weight of the sample, as presented in Equation (3.2).

$$CUPRAC\ (\mu\text{mol TE g}^{-1}) = \frac{A}{\varepsilon_{TR}} \times \frac{V_m}{V_s} \times D_f \times \frac{V_E}{m} \times 1000 \quad (3.2)$$

A: Absorbance value of the sample at 450 nm; εTR: molar absorptivity of Trolox in the CUPRAC assay (1.67 × 10^4 L mol^{-1} cm^{-1}); Vm: total volume of the measured solution in the CUPRAC assay; Vs: sample volume (mL); Df: dilution factor; VE: volume of the prepared extract (mL); and m: dry herb mass (g).

III.RESULTS

Findings on Volatile Components of Leaves and Flowers

In this study, the volatile components of the endemic *S. libanotica* subsp. *linearis*, *S. libanotica* subsp. *libanotica*, and *S. phrygia* species naturally growing in the Geyik Mountains within the boundaries of Gündoğmuş (Antalya) district were determined by SPME analysis. The volatile component ratios of *S. libanotica* subsp. *linearis* in its natural habitat are given in Table 2. SPME analysis of *S. libanotica* subsp. *linearis* identified 56 volatile components. Among these components, the highest proportions were found to be trans-Caryophyllene (19.33%), Bicyclogermacrene (9.79%), Limonene (9.72%), β-Pinene (8.40%), and α-pinene (7.88%), thus establishing them as the main components of *S. libanotica* subsp. *linearis* (Figure 3)."

The volatile component ratios of *S. libanotica subsp. libanotica* in its natural habitat are given in Table 2. SPME analysis of *S. libanotica* subsp. *libanotica* identified 46 volatile components. Among these components, the highest proportions were found to be α-Pinene (25.81%), β-Phellandrene (19.73%), β-Myrcene (11.45%), β-Pinene (8.43%), and Bicyclogermacrene (6.18%), thus establishing them as the main components of *S. libanotica* subsp. *libanotica* (Figure 4).

The volatile component ratios of *S. phrygia* in its natural habitat are given in Table 2. SPME analysis of *S. phrygia* identified 72 volatile components. Among these components, the highest proportions were found to be trans-Caryophyllene (22.80%), β-Myrcene (10.53%), α-Pinene (9.16%), Limonene (8.06%), and β-Pinene (6.62%), thus establishing them as the main components of *S. phrygia* (Figure 5).

According to the categories of volatile components, *S. libanotica* subsp. *linearis*, *S. libanotica* subsp. *libanotica,* and *S. phyrgia* were found to be predominantly composed of Sesquiterpene hydrocarbons (41.48%; 33.61%; 31.92%), Monoterpene hydrocarbons (35.94%; 51.80%; 52.60%), and Aromatic alcohols (3.54%; 0.86%; 4.42%), respectively (Table 2; Figure 6).

Table 2. Volatile component compositions of *S. libanotica* subsp. *linearis*, *S. libanotica* subsp. *libanotica*, and *S. phrygia* in their natural habitats.

RT*	Compounds	*S. libanotica* subsp. *linearis*	*S. libanotica* subsp. *libanotica*	*S. phyrgia*	Formula	Category
1.359	Ethanol	1.37	0.40	2.66	C_2H_6O	AA
1.775	Acetic acid	-	-	0.19	CH_3COOH	AAI
1.882	Ethyl Acetate	0.41	0.18	2.11	$C_4H_8O_2$	AAI
2.309	Butenol	-	-	0.34	C_4H_8O	AA
2.680	Pentenal	-	-	0.15	C_5H_8O	AAI
4.576	Hexanal	0.21	-	0.20	$C_6H_{12}O$	AAI
4.965	Butyl acetate	-	-	0.43	$C_8H_{16}O_2$	MH
6.633	Hexanol	-	-	0.63	$C_6H_{14}O$	AA
8.455	α-Thujene	0.30	0,58	0.62	$C_{10}H_{16}$	MH
8.708	α-Pinene	7.88	25.81	9.16	$C_{10}H_{16}$	MH
9.137	Propenylbenzene	0.26	-	0.09	C_7H_6O	AAI
9.293	Camphene	-	0.14	0.08	$C_{10}H_{16}$	MH
9.434	Verbenene	0.25	0.12	0.31	$C_{10}H_{14}$	MH
10.171	Sabinene	0.45	1.38	0.36	$C_{10}H_{16}$	MH
10.339	β-Pinene	8.40	8.43	6.62	$C_{10}H_{16}$	MH
10.710	3-Octanone	0.15	-	-	$C_8H_{16}O$	AA
10.727	6-Methyl-5-hepten-2-one	-	-	0.37	$C_{10}H_{14}$	MH
10.869	β-Myrcene	3.19	11.45	10.53	$C_{10}H_{16}$	MH
11.166	n-Butyl n-butyrate	-	-	0.15	$C_8H_{16}O_2$	AAI
11.281	Capronate	-	-	0.22	$C_8H_{16}O_2$	AAI
11.379	Pseudolimonene	-	0.08	-	$C_{10}H_{16}$	MH
11.444	α-Phellandrene	0.62	-	1.89	$C_{15}H_{24}$	SH
11.488	Phellandrene	-	2.20	-	$C_{15}H_{24}$	SH
11.543	γ- 3-Carene	1.24	-	2.21	$C_{10}H_{16}$	MH
11.780	Hexyl acetate	0.17	-	1.33	$C_8H_{16}O_2$	AAI
11.894	α-Terpinene	-	-	2.13	$C_{10}H_{16}$	MH
12.170	p-Cymene	0.47	0.43	2.03	$C_{10}H_{14}$	MH

12.382	Limonene	9.72	-	8.06	$C_{10}H_{16}$	MH
12.480	1,8-Cineole	-	-	0.01	$C_{10}H_{18}O$	OM
12.550	β-Phellandrene	-	19.73	-	$C_{15}H_{24}$	SH
12.674	cis-Ocimene	0.35	2.07	1.58	$C_{10}H_{16}$	MH
13.096	trans-β-Ocimene	-	0.13	0.34	$C_{10}H_{16}$	MH
13.496	δ-Terpinene	0.12	0.08	0.82	$C_{10}H_{16}$	MH
13.990	cis-Sabinene hydrate	-	0.15	-	$C_{10}H_{16}$	MH
14.556	α-Terpinolen	0.91	0.32	0.57	$C_{10}H_{18}O$	OM
14.911	Methyl benzoate	-	0.11	-	$C_8H_8O_2$	AH
15.176	Linalool	0.19	2.18	0.68	$C_{10}H_{18}O$	OM
15.373	Nonanal	-	-	0.35	$C_9H_{18}O$	AAI
16.140	Campholaldehyde	0.50	0.24	0.49	$C_{15}H_{24}$	SH
16.257	(4E,6Z)-Alloocimene	-	0.09	-	$C_{10}H_{16}$	MH
16.558	Limonene oxide	0.11	-	-	$C_{10}H_{16}$	MH
16.580	(1R)-(+)-Norinone	-	-	0.08	$C_{10}H_{16}$	MH
16.678	trans-Pinocarveol	0.42	-	0.25	$C_{10}H_{16}O$	OC
17.187	Citronellal	-	-	0.25	$C_{10}H_{16}O$	OC
17.486	Pinocarvone	0.47	0.13	0.51	$C_{12}H_{14}O$	OM
18.058	(3E,5Z)-,3,5-undecatriene	-	0.18	-	$C_{11}H_{18}$	MH
18.437	Crptone	-	0.24	-	$C_{10}H_{16}$	MH
18.664	Methyl salicylate	-	0.23		C_8H_9NO	OC
18.679	Butyl caproate	-	-	0.36	$C_{10}H_{20}O_2$	MH
18.750	Myrtenal	0.66	-	0.75	$C_{10}H_{14}O$	OM
18.802	α-Terpineol		0.75	-	$C_{10}H_{18}O$	OM
19.207	Berbenone	0.38	0.21	0.47	$C_{10}H_{14}O$	OM
20.116	Butanoic acid	0.35	-	-	$C_{11}H_{22}O_2$	MH
20.337	hexyl 2-methylbutanoate	-	-	0.12	$C_{11}H_{22}O_2$	MH
20.518	Cuminaldehyde	-	0.08		$C_{10}H1_2O$	AAI
20.572	1,1'-Bicyclohexyl	0.67	-	-	$C_{15}H_{28}$	OC
20.611	Carvone	-	-	0.16	$C_{10}H_{14}O$	OM
20.861	Linalyl acetate	-	-	0.10	$C_{12}H_{20}O_2$	MH

22.058	Bomyl acetate	-	0.34	-	$C_6H_{12}O_2$	MH
23.421	Tiglate <3(Z)-hexenyl->	0.32	-	-	$C_{11}H_{20}O_2$	OC
23.610	Benzoate	-	0.10	-	$C_{11}H_{14}O_2$	MH
23.753	Bicycloelemene	1.00	0.69	0.14	$C_{15}H_{24}$	OC
23.832	Citronellyl acetate	2.71	-	0.19	$C_{12}H_{22}O_2$	MH
24.291	α-Cubebene	-	-	0.07	$C_{15}H_{24}$	OC
24.921	β-Bisabolane	-	0.41	-	$C_{15}H_{24}$	SH
25.271	α-Copaene	2.83	0.09	0.73	$C_{15}H_{24}$	SH
25.534	β-Bourbonene	0.42	1.14	0.21	$C_{15}H_{24}$	OC
25.747	β-Elemene	-	1.36	-	$C_{15}H_{24}$	SH
25.900	β-Dihydroionone	1.32	-	0.11	$C_{13}H_{22}O$	AA
26.819	trans-Caryophyllene	19.33	1.38	22.80	$C_{15}H_{24}$	SH
27.226	Selina-3,7(11)-diene	0.32	-	-	$C_{15}H_{24}$	SH
27.087	β-Cubebene	-	0.14	0.16	$C_{15}H_{24}$	OC
27.372	Aromadendrene	1.95	0.20	0.55	$C_{15}H_{24}$	SH
27.372	Isoamyl benzoate	-	1.54	-	$C_{12}H_{16}O_2$	AAI
27.601	δ-Gurjunene	0.43	0.13	0.10	$C_{15}H_{24}$	SH
27.742	α-Himachalene	0.36	-	0.23	$C_{15}H_{24}$	SH
27.866	β-Farnesene	4.92	0.72	1.21	$C_{15}H_{24}$	SH
27.930	α-Humulene	-	-	0.42	$C_{15}H_{24}$	SH
28.200	Acoradiene	0.68	-		$C_{15}H_{24}$	SH
28.418	trans-β-Caryophyllene	-	6.02	-	$C_{15}H_{24}$	SH
28.570	δ-Muurolene	0.18	-	0.09	$C_{15}H_{24}$	SH
28.673	Himachalene	1.18	-	0.26	$C_{15}H_{24}$	SH
28.772	ar-Curcumene	3.35	-	-	$C_{15}H_{24}$	SH
28.777	Germacrene D	-	0.87	0.99	$C_{15}H_{24}$	SH
29.093	Ledene	1.51	-	-	$C_{15}H_{24}$	SH
29.097	α-Bergamotene	-	-	0.62	$C_{15}H_{24}$	SH
29.284	Bicyclogermacrene	9.79	6.18	1.85	$C_{15}H_{24}$	SH
29.400	β-Himachalene	0.58	-	0.19	$C_{15}H_{24}$	SH
29.514	α-Farnesene	0.63	0.13	0.36	$C_{15}H_{24}$	SH

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29.630	β-Bisabolene	0.18	-	0.21	$C_{15}H_{24}$	SH
29.685	α-Duprezianene	0.48	-	0.11	$C_{15}H_{24}$	SH
29.792	δ-Cadinene	0.19	-	0.07	$C_{15}H_{24}$	SH
29.970	γ-Cadinene	2.14	-	0.24	$C_{15}H_{24}$	SH
31.482	Citronellyl propionate	0.18	-	-	$C_{13}H_{24}O_2$	MH
31.793	Spathulenol	0.70	0.46	0.88	$C_{15}H_{24}O$	AA
31.940	Caryophyllene oxide	1.87		0.39	$C_{15}H_{24}O$	OC
34.085	Triethyl citrate	-	-	0.41	$C_{12}H_{20}O_7$	MH
38.287	2-Ethylhexyl salicylate	0.22	-	3.26	$C_{15}H_{22}O_3$	MH
39.472	Dioctyl sebacate	-	-	2.43	$C_{26}H_{50}O_4$	MH
Total		100	100	100		
Number of compounds		56	46	72		
AA: Aromatic Alcohol		3.54	0.86	4.62		
AAI: Aromatic Aldehyde		1.05	1.80	4.79		
AH: Aromatic Hydrocarbon		-	-	-		
MH: Monoterpene Hydrocarbon		35.94	51.80	52.60		
OM: Oxygenated Monoterpene		2.61	3.59	3.15		
SH: Sesquiterpene Hydrocarbon		41.48	33.61	31.92		
OC: Other Components		4.70	2.20	1.47		

*RT: Retention Time

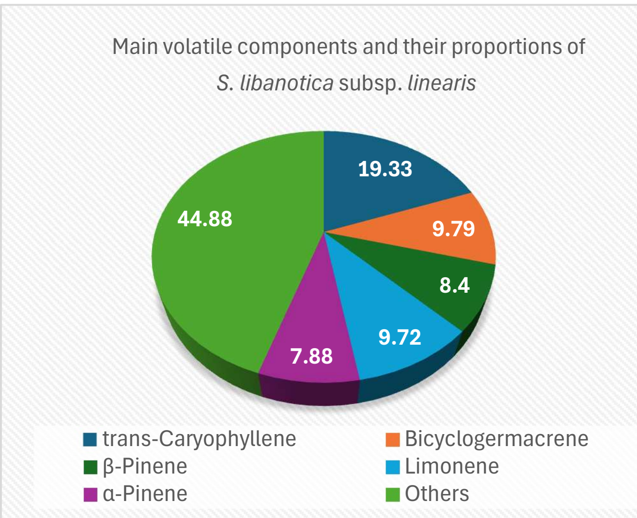

Figure 3. Main volatile components and their proportions of *S. libanotica* subsp. *linearis*

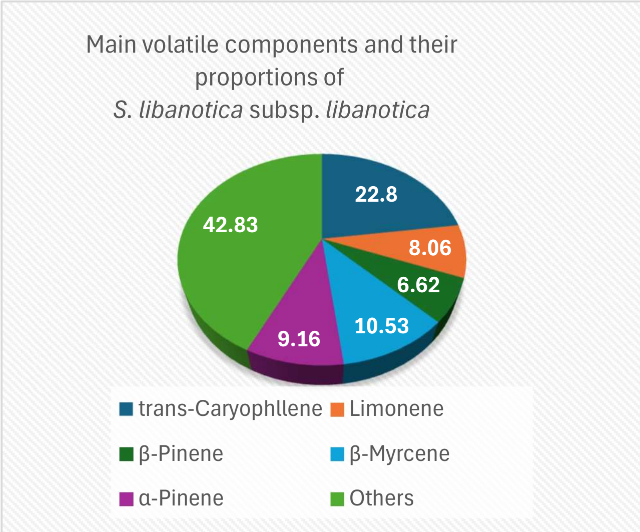

Figure 4. Main volatile components and their proportions of *S. libanotica* subsp. *libanotica*

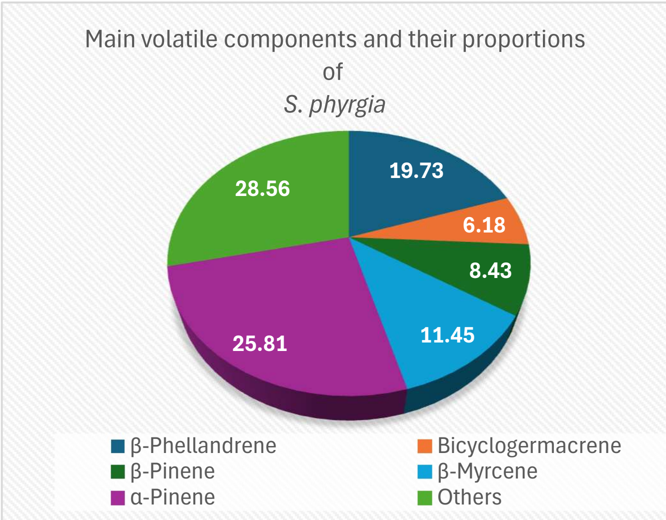

Figure 5. Main volatile components and their proportions of *S. phyrgia*

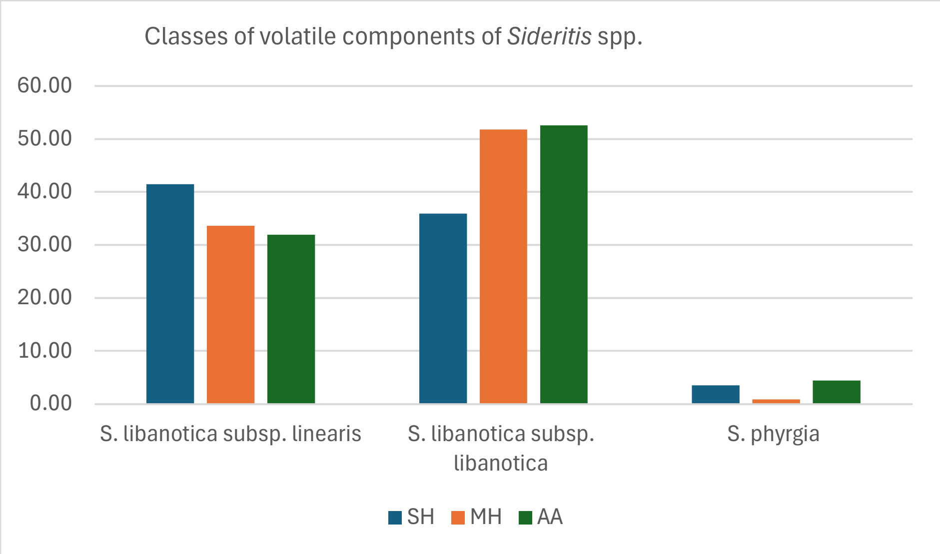

Figure 6. Categories of volatile components of *Sideritis* spp. taxa

Findings of the Study on Total Phenolic Content and Antioxidant Activity

The variance analysis results concerning the 2,2-diphenyl-1-picrylhydrazyl (DPPH) and Cuprac antioxidant capacities and total phenolic content of the studied *Sideritis spp.* taxa are shown in Table 3, with the corresponding mean values presented in Table 4. The analysis of variance indicated statistically significant differences ($p<0.01$) between taxa for both DPPH and Cuprac antioxidant capacities. In contrast, no statistically significant difference was observed among the genotypes regarding their total phenolic content.

Analysis of variance showed that the coefficient of variation (CV) values for DPPH and Cuprac antioxidant capacities were within the acceptable range (1.26% and 1.58%, respectively). Furthermore, both antioxidant scavenging capacities exhibited statistically significant differences at the $p<0.01$ level (Table 3). Among the studied populations, *S. libanotica* subsp. *linearis* displayed the highest DPPH antioxidant capacity, whereas *S. libanotica* subsp. *libanotica* and *S. phrygia* populations clustered in the same statistical group. Conversely, *S. phrygia* exhibited the highest Cuprac antioxidant capacity, with *S. libanotica* subsp. *linearis* and *S. libanotica* subsp. *libanotica* populations forming a separate, statistically indistinguishable group. Regarding total phenolic content, no statistically significant differences were observed among the genotypes, with all taxa grouped together statistically (Table 4).

Table 3. Variance analysis table of biochemical analyses of *Sideritis* spp. taxa

	SD	DPPH (mmolTE/ dry sample)			PHENOLIC (mg/g (dry sample))			CUPRAC (mmolTE/dry sample)		
		SS	MS	F	SS	MS	F	SS	MS	F
Taxa	2	3.55	1.77	16.00**	0.12	0.063	1.63	0.00009	0.00004	16.15**
Error	6	6.66	1.11		0.23	0.038		0.00001	0.000003	
General	8	4.22			0.36			0.00011		
CV		1.26			0,35			1.58		

Table 4. Mean values of biochemical analyses of *Sideritis* spp. taxa

Taxa	DPPH	PHENOLIC	CUPRAC
S. libanotica subsp. *linearis*	0.00273 a	11.20 a	0.105 b
S. libanotica subsp. *libanotica*	0.00260 b	11.23 a	0.108 b
S. phrygia	0.00260 b	11.46 a	0.113 a

IV. DISCUSSION AND CONCLUSION

Sideritis spp. taxa are commonly known as mountain tea and have widespread use in folk medicine. Teas prepared from *Sideritis* spp. taxa are used in the treatment of various diseases, and it has been determined that extracts obtained from these species have antistress, antiulcer, analgesic, antioxidant, antibacterial, anti-inflammatory, antifeedant, and insecticidal effects (Topal and Palabaş Uzun, 2020). In this study conducted within the boundaries of Antalya province, the volatile components of the endemic *S. libanotica* subsp. *linearis*, *S. libanotica* subsp. *libanotica*, and *S. phrygia* taxa, collected from the Geyik Mountains, were determined by SPME analysis.

Among the main components identified by SPME analysis of the samples, the volatile component α-Pinene was found to be the most abundant component in *S. libanotica* subsp. *libanotica* at a rate of 25.81%, while it was the 5th component in *S. libanotica* subsp. *linearis* at a rate of 7.88% and the 3rd component in *S. phrygia* at a rate of 9.16%. The volatile component trans-Caryophyllene shows a difference in that it is found at a rate of 19.33% in *S. libanotica* subsp. *linearis* and 22.80% in *S. phrygia*, where it is a main component, while it is found at a lower rate of 1.38% in *S. libanotica* subsp. *libanotica* compared to the others. The volatile component Limonene was found at a rate of 9.72% in *S. libanotica* subsp. *linearis* and 8.06% in *S. phrygia*, while it was not detected at all in *S. libanotica* subsp. *libanotica*. The volatile component Bicyclogermacrene was found as a main component at a rate of 9.79% in *S. libanotica* subsp. *linearis* and 6.18% in *S. libanotica* subsp. *libanotica*, while it was found at a lower rate of 1.8% in *S. phrygia* compared to the others. The volatile component β-Phellandrene, while being found as a main component at a rate of 19.73% in *S. libanotica* subsp. *libanotica*, was not detected at all in *S. libanotica* subsp. *linearis* and *S. phrygia*.

In their study, Erbaş and Fakir determined the three most effective volatile components in *S. libanotica* subsp. *liearis* as α-bisabolol (30.85%), β-phellandrene (25.29%), and germacrene-D (8.68%). In his master's thesis, Demir (2019) identified (E)-2-Hexenal, 3-Octanol, and Limonene as the main components in *S. libanotica* subsp. *linearis*. When the present study is compared with these studies, it is observed that the three most effective volatile components of *S. libanotica* subsp. *liearis* are different. It is thought that the reasons for these differences may originate from ecological factors (climate, altitude, and soil properties, etc.), genetic factors, and collection time and analysis methods.

In the study conducted by Özderin (2010), myrcene, linalool, β-pinene, α-cadinene, and caryophyllene were identified as the main components in *Sideritis libanoitica* subsp. *linearis*. In this study, the presence of β-pinene and caryophyllene among the most effective volatile components and the similarity of their proportions are also observed.

In the study conducted by Sağır (2016), limonene (10.6%) was identified as one of the main components of the essential oil in *Sideritis phrygia*. In our study, the limonene component is also among the most effective volatile components, and their proportions show similarity.

In their study, Tunalier et al. (2004) determined the total phenolic content in the species as 328.9±4.9 mgGAE/g extract for *S. phrygia* obtained from the Afyon region and 265.2±7.0 mgGAE/g extract for *S. libanotica* subsp. *linearis* obtained from the Karaman region. In the present study, the IC50 values of the DPPH antioxidant capacities of the genotypes were determined as 5.3 µg/ml and 6.7 µg/ml, respectively. Plants play an important role in their natural fight against biotic (e.g., bacteria, fungi, etc.) and abiotic (e.g., high temperature, drought, etc.) stresses. Plants use secondary metabolites to attract insects for pollination and seed setting. These include compounds such as essential oils, colored flavonoids, and phenolics. In this way, metabolites help plants attract organisms in their environment as signaling compounds (Pagare et al., 2015). Almost all of these secondary metabolites are synthesized by the plant as a defense mechanism against stress. These compounds play important roles in stress adaptation and various physiological functions, which makes them essential for the plant's survival and defense (Jan et al., 2021). Accordingly, the parallel or different results obtained after the biochemical analyses in the study and the studies conducted are caused by the harvest times of the taxa, the regions where they grow, altitudes, and the biotic or abiotic stresses experienced by the plants in their environmental conditions.

Studies on the volatile components of *Sideritis* spp. taxa have been conducted in different regions of Türkiye. However, the determination of volatile components and antioxidant properties of *Sideritis* spp. taxa in Geyik Dağı for the first time increases the significance of this study. It is believed that the data obtained as a result of the study will contribute to practitioners and researchers working in the field.

EXPLANATION

This study was produced from the Master's thesis titled "Determination of Volatile Components and Antioxidant Properties of Endemic Natural Mountain Tea (Sideritis spp.) Taxa of Geyik Dağı (Gündoğmuş/Antalya)" at Isparta University of Applied Sciences, Graduate Education Institute.

REFERENCES

[1]. Abdelhalim, A., & Hanrahan, J. (2021). Biologically active compounds from Lamiaceae family: Central nervous system effects. *Studies in Natural Products Chemistry*, *68*, 255-315.

[2]. Avcı, M. (2014). Türkiye’nin flora bölgeleri ve “Anadolu Diagonali”ne coğrafi bir yaklaşım. *Türk Coğrafya Dergisi, 28*, 225-248.

[3]. Apak, R., Güçlü, K., Özyürek, M. and Karademir, S. E. (2004). A novel total antioxidant capacity index for dietary polyphenols, vitamin C and E using their cupric ion reducing capability in the presence of neocuproine: CUPRAC method. *Journal of Agricultural and Food Chemistry*, 52: 7970-7981.

[4]. Aydın, S., Yücel, Ö., Beis, R., & Başer, K. H. C. (1996). Investigation of *Origanum onites*, *Sideritis conge*sta and *Satureja cuneifolia* essential oils for analgesic activity. *Phytotherapy Research, 10*(4), 342-344.

[5]. Çarıkçı, S., Sağır, Z., & Kılıç, T. (2012). Mineral Contents of Two Endemic *Sideritis* Species for Turkey, *Medicinal and Aromatic Plants Symposium*, September 13-15, Tokat, 81-87.

[6]. Demir, S. (2019). Determination to leaf and flower volatile components of some natural sage taxa (sideritis spp.) of Davraz mountain (Isparta), *Master's Thesis,* Isparta University of Applied Sciences Graduate School of Education.

[7]. Duran, C. (2013). The Role of Mountainous Areas on Plant Diversity of Turkey, *Research Journal of Biological Sciences, 6*(1), 72-77.

[8]. Erbaş, S., & Fakir, H. (2012). Determination of contents and components of essential oils of *Sideritis libanotica* Labill. subsp. *linearis* (Bentham) Bornm. and *Origanum sipyleum* L. grown wild in Western Mediterranean Region of Turkey, *Süleyman Demirel Universiy, Faculty of Forestry Journal*, *13*, 119-122.

[9]. Ertaş, A. (2005). Isolation of Diterpenic Constituents and Biologıcal Activity Studies of two Endemic Sideritis Species, *Sideritis arguta* and *Sideritis congesta*, *Master's Thesis,* Istanbul University Institute of Science.

[10]. Ezer, N., Vila, R., Cañigueral, S., & Adzet, T. (1996). Essential oil composition of four Turkish species of Sideritis. *Phytochemistry*, *41*(1), 203-205.

[11]. Gören, G. (2011). Molecular Systematic Analysis of *Hesiodia* and *Burgsdorfia* Sections of the Genus *Sideritis* L. (Lamiaceae) Growing in Turkey with ITS nrDNA, *trnl-F*, and *ndhF* cpDNA Sequences, *Master's Thesis,* Balıkesir University Institute of Science.

[12]. Günbatan, T., Gürbüz, İ., Bedir, E., Özkan, A. M. G., & Özçınar, Ö. (2020). Investigations on the anti-ulcerogenic activity of Sideritis caesarea H. Duman, Aytaç & Başer. *Journal of Ethnopharmacology*, *258*, 112920.

[13]. Günbatan, T., Gürbüz, İ., Karaca, N., & Demirci, F. (2023). In vitro antioxidant, enzyme ınhibitory and antimicrobial evaluation of sideritis caesarea H. Duman, Aytaç & Başer Extracts. *Natural Product Communications*, *18*(4), 1-11.

[14]. Güner, A., Aslan, S., Ekim, T., Vural, M., & Babaç, M. T. (2012). List of Turkish Plants, *Publication of Nezahat Gökyiğit Botanical Garden and Flora Research Society*.

[15]. Jan, R., Asaf, S., Numan, M., Lubna, & Kim, K. M. (2021). Plant secondary metabolite biosynthesis and transcriptional regulation in response to biotic and abiotic stress conditions. *Agronomy*, *11*(5), 968.

[16]. Kaya, Y., & Aksakal, Ö. (2005). Distribution of endemic plants in the world and Turkey, *Erzincan University Journal of Faculty of Education*, 7(1), 85-99.

[17]. Kıtıkı, A., M. Nakiboğlu, A. Tan, T. Kesercioğlu, H. Otan, A. O. Sarı, B. Oğuz ve H. Aydın. (1998). Collection of some Sideritis L. species distributed in South-West Anatolia and biosystematic studies on them,. Anadolu, J. of AARI, 8 (1): 26-54.

[18]. Kirimer, N., Tabanca, N., Tümen, G., Duman, H., & Başer, K. H. C. (1999). Composition of the essential oils of four endemic Sideritis species from Turkey. *Flavour and Fragrance Journal*, *14*(6), 421-425.

[19]. Kirimer, N., Başer, K.H.C., Demirci, B., & Duman, H. (2004). Essential oils of sideritis species of turkey belonging to the section empedoclia. *Chemistry of Natural Componds, 40*(1), 19-23.

[20]. Koyuncu, O., Yaylacı, Ö. K., Öztürk, D., Erkara, İ. P., Savaroğlu, F., Akcoşkun, Ö., & Ardıç, M. (2010). Risk categories and ethnobotanical features of the Lamiaceae taxa growing naturally in Osmaneli (Bilecik/Turkey) and environs. *Biological Diversity and Conservation*, 3(3), 31-45.

[21]. Pagare, S., Bhatia, M., Tripathi, N., Pagare, S., & Bansal, Y. K. (2015). Secondary metabolites of plants and their role: Overview. *Current Trends in Biotechnology and Pharmacy*, *9*(3), 293-304.

[22]. Palomino, O. M., Söllhuber, M., Carretero, E., & Villar, A. (1996). Isoscutellarein 7-glucosyl (1→ 2) xyloside from sixteen species of Sideritis. *Phytochemistry*, *42*(1), 101-102.

[23]. Rodriguez-Linde, M. E., Diaz, R. M., Garcia-Granados, A., Quevedo-Sarmiento, J., Moreno, E., Onorato, M. R., & Ramos-Cormenzana, A. (1994). Antimicrobial activity of natural and semisynthetic diterpenoids from Sideritis spp. *Microbios*, *77*(310), 7-13.

[24]. Sağır, Z. (2016). Phytochemical Analysis of Endemic Sıderitis L. Species from Türkiye *(Sideritis pisidica* Boiss. et Heldr. *Apud Bentham, S. phrygia* Bornm.*, S. brevibracteata* P.H. Davis)*. PhD Thesis*, Balıkesir University Institute of Science.

[25]. Shimata K, Fujikawa K, Yahara K & Nakamura T (1992). Antioxidative properties of xanthan on the autoxidation of soybean oil in cyclodextrin emulsion. *Journal of Agricultural and Food Chemistry* 40: 945- 948.

[26]. Temel, M., & Tokur, S. (2008). Palynological Properties of Western Anatolian Origanum L. (Lamiaceae) Taxa, Afyon Kocatepe University Journal of Science*,* 8(1), 1-6.

[27]. Temel, M., Kara, R., Müdüroğlu, R., & Akkaya, L. (2014). Antibacterial activity of turkish endemic sideritis akmanii (Lamiaceae). *Global Research Analysis, 3*(4), 83-84.

[28]. Tığlı K. E. H., Özderin S., Fakir, H., Erbaş S. (2023). Determination of The Essential Oil Components of Some Sage (Salvia Sp.) Species Naturally Distributed in The Isparta Province. *Kastamonu Univ., Journal of Forestry Faculty*, 23, 1-10.

[29]. Tıglı Kaytanlıoglu, E.H.T, Fakir, H. (2024). Morphological And Distribution Area Characteristics Of Orchis L. Taxa Naturally Distributed In Isparta Region, *International Journal of Progressive Sciences and Technologies* (IJPSAT), Vol. 48 No. 1 December 2024, pp. 83-96.

[30]. Topal, A., & Palabaş Uzun, S. (2020). Seed and Morphological Characteristics of Three Endemic Sideritis L. Taxa, *Turkish Journal of Forest Science,* 4(1), 1-10.

[31]. Tunalier, Z., Kosar, M., Ozturk, N., Baser, K. H. C., Duman, H., & Kirimer, N. (2004). Antioxidant properties and phenolic composition of Sideritis species. *Chemistry of Natural Compounds, 40*, 206-210.

[32]. Türkmenoğlu, G., Fakir, H. (2023). Determination of Volatile Components in Mountain Tea (Sideritis condensata Boiss. Et. Heldr. Apud Bentham) Grown in its Natural and Agricultural Field Environment, *Journal of Bartin Faculty of Forestry*, 2023, 25(3): 411 – 420.

[33]. Uysal, İ., Mohammed, F. S., Koçer, O., Doğan, M., & Sevindik, M. (2023). Antioxidant and oxidant status, DPPH activity, total phenolic and flavonoid contents of mountain tea (Sideritis libanotica subsp. kurdica (Bornm.) Hub.-Mor). *International Journal of Chemistry and Technology, 7*(1), 82-85.

[34]. Özderin, S. (2010). Natural tea plants and essential oil constituents of Muğla-Ula province, *Master's Thesis*, Süleyman Demirel University Institute of Science.

[35]. Öztürk, Y., Aydin, S., Öztürk, N., & Can Başer, K. H. (1996). Effects of extracts from certain *Sideritis* species on swimming performance in mice. *Phytotherapy Research*, *10*(1), 70-73.

[36]. Özhatay, N., Byfield, A., & Atay, S. (2005). Important Plant Areas in Turkey, 122 Key Botanical Sites, İstanbul: WWF Türkiye.

[37]. Öztürk, Y., Aydin, S., Öztürk, N., & Can Başer, K. H. (1996). Effects of extracts from certain Sideritis species on swimming performance in mice. *Phytotherapy Research*, *10*(1), 70-73.

[38]. Şahin, M. (2010). Screening of Antioksidant Ativities of Methanol Extract of *Sideritis libanotica* Labill. ssp. *linearis* (Bentham) Bornm., *Master's Thesis*, Fırat University Institute of Science.

[39]. Şanda, M. A. (2006). The Forest and Subalpine Vegetation of Geyik Dağı and Surroundings (Antalya). *Selçuk University Faculty of Science Journal of Science, 2*(27), 99-116.