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CULTIVATION OF NATURALLY DISTRIBUTED MOUNTAIN TEA (*Sideritis* spp.) TAXA IN ISPARTA (TURKIYE) AND DETERMINATION OF THEIR CHEMICAL AND AGRICULTURAL TRAITS

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ABSTRACT

The aim of this study was to cultivate *Sideritis* spp. taxa that are naturally distributed in the province of Isparta, Türkiye and evaluate agricultural performance. The taxa investigated included *Sideritis perfoliata* L., *Sideritis hispita* P.H.Davis, *Sideritis libanotica* Labill. subsp. *linearis* ((Benth.) Bornm., *Sideritis libanotica* subsp. *libanotica, Sideritis condensata* Boiss. & Heldr., *Sideritis cilicica* Boiss. & Balansa, *Sideritis congesta* P.H.Davis & Hub.-Mor., *Sideritis stricta* Boiss. & Heldr., *Sideritis leptoclada* O.Schwarz & P.H.Davis, *Sideritis syriaca* subsp. *nusairiensis* (Post) Hub-Mor., *Sideritis pisidica* Boiss. & Heldr., *Sideritis phrygia* Bornm., *Sideritis dichotoma* Huter and *Sideritis erythrantha* var. *erythrantha*. Twelve of these taxa are endemic to the region. Successful cultivation was achieved in nine species among these taxa: *S. perfoliata*, *S. hispita*, *S. libanotica* subsp. *linearis*, *S. libanotica* subsp. *libanotica*, *S. condensata*, *S. congesta*, *S. stricta*, *S. leptoclada*, and *S. syriaca* subsp. *nusairiensis*. These species showed high total phenolic content values and high antioxidant activity in both wild and cultivated conditions. The highest total phenolic content (mg GAE/g dry sample) values were found in *Sideritis libanotica* subsp. *Linearis*, with 14.06 mg/g GAE in wild conditions and 12.56 mg/g GAE under cultivation conditions. Among all taxa, the highest antioxidant activity was for *Sideritis leptoclada* in wild conditions. SPME analyses showed the main volatile compounds under wild conditions were: *β*-pinene (18.12-5.66%), trans-caryophyllene (12.77-0.83%), and germacrene-D (10.59-0.67%) in *Sideritis condensata*. In *Sideritis perfoliata*, the primary compounds were *α*-pinene (51.72-43.36%), *β*-pinene (14.07-12.25%), and limonene (10.96-14.09%), while in *Sideritis hispita*, they were *α*-pinene (22.86-13.74%), *β*-pinene (28.31-16.39%), and trans-caryophyllene (11.24-14.49%). Other species such as *Sideritis libanotica* subsp. *linearis*, *Sideritis libanotica* subsp. *libanotica, Sideritis stricta, Sideritis leptoclada*, and *Sideritis syriaca* subsp. *nusairiensis* showed varying dominant compounds including *α*-pinene, *β*-pinene, germacrene-D, caryophyllene, and bicyclogermacrene. For *Sideritis congesta*, the highest compound concentrations were trans(*β*)-caryophyllene (25.03%), *β*-bisabolene (13.24%), and bicyclogermacrene (9.47%), while other compounds varied between wild conditions and cultivated conditions, including *β*-pinene, dl-limonene, *α*-pinene, (Z)-2-heptenal, Z-3-hexenyl 2-methylbutanoate, and benzoate<isobutyl>. Cuttings were successfully cultivated for *S. perfoliata*, *S. hispita*, *S. libanotica* subsp. *linearis*, *S. libanotica* subsp. *libanotica*, *S. condensata*, *S. congesta*, *S. stricta*, *S. leptoclada*, and *S. syriaca* subsp. *nusairiensis*. In addition, seed germination was successful for *S. perfoliata*, *S. libanotica* subsp. *libanotica*, *S. condensata*, *S. congesta*, and *S. stricta*. The remaining species were not suitable for cultivation through seed germination. These findings highlight the potential for domestication and commercial cultivation of select *Sideritis* species. Further long-term studies are recommended to evaluate agricultural productivity and quality throughout the life cycles of species that showed successful outcomes in cultivation trials.

Keywords: *Sideritis*, Culture studies, Agricultural performance, Antioxidant-phenolic, Volatile compound, Türkiye

INTRODUCTION

Sideritis species are widely used in folk medicine due to their anti-inflammatory, antimicrobial, diuretic, and antispasmodic properties (Aydın *et al.*, 2023). The experimental validation of the anti-inflammatory and cytotoxic activities of certain compounds of *Sideritis* demonstrated that virtual drug screening and molecular docking are suitable tools for identifying potential drug candidates (Yücer *et al.*, 2025).

The genus *Sideritis* is found in various habitats and at various altitudes in the North Pole, the Himalayas, Southeast Asia, Hawaii, Australia, Africa, and the Americas. Its main habitat is the Mediterranean region

(Kırımer *et al.*, 2001). In a revision study conducted in Türkiye by Duman *et al.* (2005), it was determined that this genus was represented by 44 *Sideritis* species (55 taxa in total). Forty of these taxa (74%) are endemic (Güner *et al.*, 2012). In folk medicine, infusions prepared from teas made with *Sideritis* spp. species (Selvi *et al.*, 2013) are used for their analgesic (painkiller)(Piozzi *et al.*, 2006), antirheumatic, digestive (Çelik *et al.*, 2008), and antimicrobial effects. They are commonly consumed by people due to their antioxidant effects (Arabacı *et al.*, 2014). In scientific studies, extracts of some *Sideritis* spp. species have been found to show antistress, antiulcer (Günbatan *et al.*, 2023), analgesic, antioxidant (Krckovska 2022; Uysal *et al.*, 2023), antibacterial (Temel *et al.*, 2014), antifungal (Tunalier *et al.*, 2004), anti-inflammatory (inflammation reduction), sedative (Maksimovic *et al.*, 2005), common cold treatment (Güvenç and Duman 2010), antimicrobial (Günbatan *et al.*, 2023; Yıldırım and Felek 2023), antipyretic, anticarcinogenic (Seifried *et al.*, 2004), immunomodulatory, antispasmodic, carminative, antitussive, and dyspeptic (indigestion) (Saraç and Uğur 2007), stomachic and anticonvulsant (antiepileptic), antifeedant, and insecticidal (Çarıkçı *et al.*, 2012) effects. Five *Sideritis* species growing in Türkiye have antidepressant and antistress activities. Volatile components also offer potential applications in areas such as perfumery and aromatherapy (Sarıkaya *et al.*, 2025). Various potential positive effects of *S. libanotica* on colon cancer have been observed. It is predicted that populations of *Juniperus drupacea* resistant to future drought conditions caused by climate change will gradually decrease, putting the species at risk (Turkmenoglu *et al*., 2024). When undesirable properties such as color and waxy structures are eliminated in *Helichrysum italicum*, the absolue has the potential to be used directly in perfume and cosmetic formulations (Erbaş *et al*., 2023). The *Sideritis* species are also widely used in various fields such as cosmetics, fragrance, and medicine. The market volume of *Sideritis* species in Türkiye is increasing and excessive foraging has emerged, similar to many other medicinal and aromatic plants. Irresponsible foraging and animal grazing activities has led to a significant decline in the population of these plants. The commercial cultivation of *Sideritis* species in Türkiye is limited, and most plants are collected from the wild due to ecological and propagation challenges. Cultivation helps reduce pressure on wild populations, improve plant quality, support local economies, and promote biodiversity and sustainability. The aim of this study is to cultivate naturally distributed *Sideritis* species in the Isparta region of Türkiye and then identify and compare the concentrations of volatile compounds, antioxidant properties, and total phenolic contents of plants in wild habitats and cultivated environments. The innovative aspect of this study is the successful identification and cultivation of *Sideritis* spp. species under cultivation conditions in Türkiye using both cuttings and seeds. Furthermore, three different propagation methods were investigated: only cuttings, only seed germination, and a combination of both. The results expand our knowledge of effective cultivation techniques for these plants. In addition, the study provides a comprehensive comparison of the phytochemical profiles of wild and cultivated plants. Cluster analysis of volatile compound data classified the species into five distinct groups. This integrated approach offers valuable insights for the sustainable cultivation and conservation of *Sideritis* species.

MATERIALS AND METHODS

Materials: The study materials consisted of 14 *Sideritis* spp. samples collected between 2020 and 2023 in the province of Isparta, Türkiye (Figure 1). *Sideritis* taxon samples were collected at two different times of the year, during the flowering period and during the post-flowering seed formation period. Cultivation field soil conditions were set according to the recommendations of Rowell (1996). The soil had a clayey-loamy texture, its organic matter content was at 1.1% as determined by the Walkley-Black method, lime content was 7.20% using a Schiebler calcimeter, salt concentration was 0.38%, available phosphorus was 3.9 mg/kg, and available potassium was 119.0 mg/kg in 1N NH_4OAc. The soil had a mildly acidic pH (6.5).

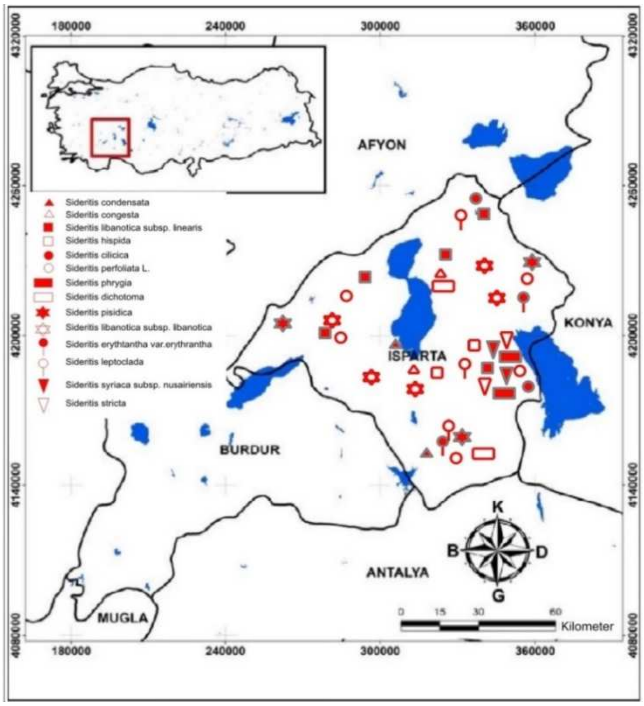

Figure 1- Sampling areas of *Sideritis* taxa in Isparta Province

Methods: The study was conducted in two phases. In the first phase, taxa were collected in 2020-2023 throughout their vegetation process from their identified distribution areas based on a field study program and were prepared as herbarium samples. The collected samples were brought to the Herbarium of the Faculty of Forestry at Isparta University of Applied Sciences in paper bags. In the second phase of the study, the seeds of the taxa were collected in their seed maturation period in 2020-2023, and were used to produce seedlings in the same period in the greenhouses of the Arable Plants Department of the Faculty of Agriculture. The seedlings were transferred to the field environment and studies were conducted throughout a two-year period.

Field studies: For production with cuttings, cuttings were collected from fresh *Sideritis* taxa collected in March and April 2020 from the wild conditions flora. The cuttings were obtained from herbaceous and semi-woody shoots, were 8-12 cm long, and had 3-5 nodes. For each cutting, two leaves were left intact only in the top two nodes, and the remaining leaves were removed by breaking them at their base. Before hormone administration, the cuttings were kept in a 15 ml/10 L solution of Previcur Energy SL 840 (Bayer) fungicide for 30 minutes. Next, 1,000 ppm Indole-3-Butyric Acid (IBA) (Merck, CAS No: 133-32-4) hormone was applied through two different routes. After this treatment, the cuttings were planted into 70-cell seedling trays containing a 1:1 agroperlite-peat medium so that two nodes for each cutting would remain above the medium (at a depth of approx. 5 cm). Starting at plantation, throughout the growth period, fogging was performed in the greenhouse depending on the water requirements of the cuttings. At the end of 4 weeks after plantation, intermittent ventilation was initiated to the greenhouse from one direction facing the sun, and the frequency of ventilation gradually increased over the following days. Irrigation continued at gradually reduced levels throughout the following months. Two months after plantation (June 2020), the cuttings were transferred to the field.

For production with seeds, between 2020 and 2023, seeds of mountain tea were collected in the seed maturation period (from taxa collected from the flora of Isparta and the cultivation area on university land) and used to produce shoots in the greenhouses of the Arable Plants Department at the Faculty of Agriculture. The seeds were sown in a peat medium in 104-cell trays under controlled greenhouse conditions, and the plants that turned into seedlings after 45 days within the scope of the fertilization period were transferred to the field at the end of September. Seedlings of taxa that were produced using seeds and cuttings were planted according to a Randomized Complete Block Design (RCBD) with 3 replications in 70 cm interrow spacing and 30 cm Plant x Plant spacing. The length of each plot was 5 m, and each plot included 4 rows. Throughout the trial period, weed control was achieved using mechanical methods, and no irrigation was provided because the annual precipitation of Isparta province is sufficient for the farming of aromatic plants, and Mountain tea (*Sideritis* spp.) is grown without irrigation in other countries where it is farmed. During the study period, the precipitation in Isparta (Türkiye) was between 500 and 700 mm. Each year, the field was fertilized using 5 kg of stock phosphorus (P_2O_5) diammonium phosphate fertilizer (DAP) and 5 kg of stock nitrogen (N) ammonium sulfate fertilizer (AS) per decare (1 decare=0.1 hectare). Stock nitrogen generally refers to the amount of nitrogen accumulated in the soil or ecosystem that can be utilized by plants. It may be nitrogen stored in organic matter or soil minerals and serves as an important nutrient source for plant growth. The DAP fertilizer was provided in the fall months, whereas the AS fertilizer was provided at the beginning of the bolting period of the plants (late April-early June). In 2021 and 2023, flowers (flowers and peduncles) of the *Sideritis* spp. taxa were harvested manually at the leaf level (15 cm above soil level) in the mid-flowering period (June-July) (Sarı *et al*., 2005; Erbaş *et al*., 2017; Yalmanlı *et al*., 2023).

GC-MS analysis of volatile compounds: Volatile compounds in the essential oils, concretes, and absolutes of the *Sideritis* spp. taxa were identified using a GC-MS (Gas chromatography/Mass spectrometry) device (with QP-5050 quadrupole detector Shimadzu 2010 Plus). In the GC-MS analyses where the capillary column was selected as CP-Wax 52 CB (50 m x 0.32 mm. 0.25 µm), the temperature profile of the oven was set at an increment of 10°C per minute from 60°C to 220°C, and a 220°C temperature was maintained for 10 minutes. The analysis settings were adjusted to a total analysis time of 60 minutes, an injector temperature of 240°C, and a detector temperature of 250°C. Helium (20 mL/min, split 1:20) was used as the carrier gas. Wiley, NIST, Tutor, and FFNSC libraries were utilized to identify detected volatile compounds (Baydar *et al*., 2007).

Total phenolic content analysis (mg/g GAE): Dry herb samples from each species were powdered, samples of 1 g were weighed, and each 1-g sample was mixed in a shaker in 10 mL methanol at 100 rpm for 30 minutes. After leaving the mixtures overnight at room temperature, liquid extracts were obtained by filtering (Lu and Foo 2001). All analyses were carried out in three replications. The Folin-Ciocalteu method was used to identify the total phenolic content values of the extracts (Singleton and Rossi 1965). To 100 µl methanolic extract, 2.5 mL deionized water and 100 µl Folin-Ciocalteu solution (2N) were added. The reaction mixture was incubated in the dark for 6 minutes, and then, 500 µl of 20% sodium carbonate was added. To allow the development of color change as a result of the reaction, the mixture was incubated in the dark for 30 minutes, and color changes were measured at a wavelength of 760 nm. The gallic acid standard curve was used to calculate total phenolic content, and the results are expressed as mg of gallic acid equivalent per g of sample (mg/g GAE) (Singleton and Rossi 1965).

Antioxidant analyses (%): Two different methods, DPPH and CUPRAC, were used for antioxidant analyses of the species.

Antiradical activity analysis (DPPH): Antiradical activity was determined using 1,1-diphenyl-2-picryl-hydrazyl (DPPH) (Shimada *et al.*, 1992). To 0.25 mL of the sample (concentration: 250 ppm), 1 mL of 0.2 mM DPPH was added, and the mixture was stirred thoroughly by vortexing. After leaving the mixture at room temperature in a dark environment for 30 minutes, absorbance values were read at 571 nm. The formula for this procedure is given as follows:

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

ƐTR: Molar absorption coefficient of the TR compound in the DPPH method (2.168 × 104 L mol^{-1} cm^{1}); *Vs*: sample volume; *Vm*: total volume of the mixture used in the method (4 mL); *Sf*: dilution factor (if needed); V_E: extract volume, and *m*: extract mass.

Cupric reducing antioxidant capacity (CUPRAC): CUPRAC analyses were carried out using the method recommended by (Apak *et al.*, 2004). For this purpose, to 100 ppm extract solution, 0.01 M $CuCl_2$ 7.5 mM neocuproine, 1 M ammonium acetate solution (pH 7.0), and 1 mL distilled water were added. Ethanol was used as the control, and all samples were incubated in the dark for 1 hour. The absorbance values of the samples were read in a spectrophotometer at a wavelength of 450 nm. The results are expressed in units of Trolox equivalent (TE) per dry sample as follows:

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

A: Absorbance of the sample at 450 nm; ε_{TR}: molar absorption coefficient of the Trolox compound in the CUPRAC method (1.67×10^4 L mol^{-1} cm^{-1}); V_m: total volume of the solution measured in the CUPRAC method; V_s: sample volume (mL); D_f: dilution factor; V_E: extract volume (mL), and *m*: dry herb mass (g).

Statistical Analysis: Statistical analyses were performed using the Minitab 19 software package. The characteristics emphasized in the study do not meet the prerequisites of normal distribution and homogeneity of variances, which are prerequisites for parametric tests. The normal distribution assumption was tested using the Anderson-Darling test, while the homogeneity of variances was checked using the Levene test. To determine the difference between wild conditions and cultivated environments for the components studied, the non-parametric Mann-Whitney test was used to assess the significance of the difference between the medians of the two groups. Additionally, the Kruskal-Wallis test was used to determine the differences between species for all components. The Bonferroni-Dunn test, a non-parametric multiple comparison method, was employed to determine the differences between species means. Cluster analysis was applied, taking into account the components without missing data, to identify the species that are most similar or dissimilar to each other. Furthermore, principal component analysis was applied, considering the components without missing data, to identify the components that have the highest load in the total variation. The presence of a linear relationship between components was also determined by calculating the Spearman rank correlation coefficient.

RESULTS

Volatile Compounds: In the study area, *Sideritis* spp. species were collected in the flowering period from their natural growth environment and from field settings, and volatile compounds were identified using SPME. Table 1 presents the results for all the samples.

According to the Kruskal-Wallis test performed on the total phenolic content (TPC) data of the samples collected from their wild conditions environment, the differences among the mean ranks of the species were statistically significant ($p<0.01$). The results of the Bonferroni-Dunn test are provided in the mean rank values in Table 2. *S. perfoliata* had the highest TPC values, and its TPC values were significantly higher than those of all other species ($p<0.05$), except for *S. phrygia*, *S. pisidica,* and *S. cilicica*. The TPC values of the *S. phrygia*, *S. pisidica,* and *S. cilicica* species did not differ significantly from those of *S. syriaca*, while they were significantly higher than the TPC values of others. Moreover, as seen in Table 2, the *S. condensata*, *S. congesta*, *S. libanotica* subsp. *libanotica*, *S. stricta*, *S. leptoclada*, and *S. hispita* species had the same letters, which meant that their values were not significantly different from each other. The lowest TPC values were found respectively in *S. erythrantha* and *S. condensata*.

The Kruskal-Wallis test performed on the DPPH data of the samples collected from their wild conditions, indicated that the differences among the mean ranks of the species were statistically significant ($p<0.01$). The results of the Bonferroni-Dunn test are given using Latin letters on mean rank values in Table 2. The highest DPPH values were in the species *S. hispita*, and the DPPH values of this species were significantly higher than the values of others ($p<0.05$). While the DPPH values of *S. condensata*, *S. erythrantha*, *S. leptoclada*, *S. dichotoma,* and *S. cilicica* did not differ significantly from each other, their values significantly different compared to those of other species ($p<0.05$). Furthermore, while there was no statistically significant difference among the DPPH values of the *S. congesta*, *S. libanotica* subsp. *libanotica*, *S. libanotica* subsp. *linearis*, *S. perfoliata*, and *S. phrygia* species, they had significantly different values compared to the remaining species ($p<0.05$). The lowest DPPH values were seen in *S. stricta* and *S. syriaca*, and these values were significantly lower compared to the values of all other species ($p<0.05$).

Based on the Kruskal-Wallis test performed on the CUPRAC data of the samples collected from their wild conditions, the differences among the mean ranks of the species were statistically significant ($p<0.01$). The results of the Bonferroni-Dunn test are given using Latin letters on mean rank values in Table 2. *S. congesta*, *S. perfoliata*, *S. dichotoma*, *S. phrygia*, *S. pisidica,* and *S. syriaca* showed the highest CUPRAC values, and their values did not significantly differ from each other, whereas they had significantly different values compared to those found in *S. condensata*, *S. libanotica* subsp. *libanotica*, *S. erythrantha*, *S. leptoclada*, *S. libanotica* subsp. *linearis*, *S. hispita,* and *S. cilicica* ($p<0.05$). The lowest CUPRAC values were found in the species *S. congesta* and *S. erythrantha*, which had significantly lower values compared to those in *S. congesta*, *S. stricta*, *S. leptoclada*, *S. perfoliata*, *S. dichotoma*, *S. phrygia*, *S. pisidica*, *S. syriaca*, and *S. cilicica* ($p<0.05$).

Based on the Kruskal-Wallis test performed on the TPC data of the samples collected from the cultivated environment, the differences among the mean ranks of the species were statistically significant ($p<0.01$). The results of the Bonferroni-Dunn test are given using Latin letters on mean rank values in Table 2. The highest TPC values were in the species *S. perfoliata*, which did not have significantly different values compared to those of *S. hispita* and *S. syriaca*, but showed significantly higher values compared to others ($p<0.05$). Furthermore, *S. hispita*, *S. perfoliata*, and *S. syriaca* had significantly higher TPC values compared to *S. congesta*, *S. stricta*, *S. leptoclada,* and *S. libanotica* subsp. *linearis* ($p<0.05$). The lowest TPC values were found in the species *S. leptoclada*, *S. congesta,* and *S. stricta*, respectively.

Based on the Kruskal-Wallis test performed on the DPPH data of the samples collected from the cultivated plants, the differences among the mean ranks of the species were statistically significant ($p<0.01$). The results of the Bonferroni-Dunn test are given using Latin letters on mean rank values in Table 2. *S. leptoclada* and *S. hispita* had the highest DPPH values; the difference between the mean ranks of these two species was not statistically significant, but the difference between these and other species was significant. The *S. condensata* species had lower DPPH values than those found in *S. leptoclada* and *S. hispita*, while it had significantly higher values compared to all other species. While the differences among the DPPH values of *S. congesta*, *S. libanotica* subsp. *libanotica*, *S. libanotica* subsp. *linearis*, and *S. perfoliata* were not statistically significant, these species had significantly higher DPPH values in comparison to those found in *S. stricta* and *S. syriaca* ($p<0.05$). The lowest DPPH values, which were also significantly lower than the values of all other species, were found in *S. stricta* and *S. syriaca* ($p<0.05$). Based on the Kruskal-Wallis test performed on the CUPRAC data of the samples collected from the cultivated plants, the differences among the mean ranks of the species were statistically significant ($p<0.01$). The results of the Bonferroni-Dunn test are given using Latin letters on mean rank values in Table 2. *S. congesta, S. libanotica* subsp. *libanotica*, and *S. stricta* did not have significantly different CUPRAC values from each other, whereas these three species had significantly greater CUPRAC values than *S. leptoclada* and *S. libanotica* subsp. *linearis* ($p<0.05$). The lowest CUPRAC values were seen in *S. leptoclada*, *S. libanotica* subsp. *linearis,* and *S. perfoliata*.

The results of the volatile compound analyses were first subjected to a cluster analysis. The dendrogram in Figure 2 shows that the species could be divided into five main clusters. The first cluster included the species numbered 1 (*S. condensata*- wild conditions), 2 (*S. condensata*- cultivated), 12 (*S. libanotica* subsp. *libanotica*- cultivated), 14 (*S. stricta*- cultivated), and 13 (*S. stricta*- wild conditions). The second cluster included the species numbered 5 (*S. hispita*- wild conditions), 7 (*S. libanotica* subsp. *linearis*- wild conditions), and 9 (*S. congesta*- wild conditions). The third cluster included the species numbered 6 (*S. hispita*- cultivated) and 8 (*S. libanotica* subsp. *linearis*- cultivated), the fourth cluster included the species numbered 10 (*S. congesta*- cultivated), 15 (*S. leptoclada*- wild conditions), 17 (*S. syriaca* subsp. *nusairiensis*- wild conditions), 18 (*S. syriaca* subsp. *nusairiensis*- cultivated), 16 (*S. leptoclada*- cultivated), and 11 (*S. libanotica* subsp. *libanotica*- wild conditions). Lastly, the fifth cluster included the species numbered 3 (*S. perfoliata*- wild conditions) and 4 (*S. perfoliata*- cultivated).

After clustering analysis was performed, as seen in Figure 2, species 15 (*S. leptoclada*- wild conditions) and 17 (*S. syriaca* subsp. *nusairiensis*- wild conditions) were in the same cluster, and they were 96.33% similar to each other. With a similarity rate of 94.24%, species 2 (*S. condensata*- cultivated) and 12 (*S. libanotica* subsp. *libanotica*- cultivated) were also in the same cluster. In the next step, species 10 (*S. congesta*- cultivated) and 15 (*S. leptoclada*- wild conditions) showed 91.39% similarity, and species 10 joined the previously linked species 15 (*S. leptoclada*- wild conditions) and 17

Table 1. Volatile compound compositions of *Sideritis* spp. species samples collected from wild conditions and cultivated.

				S. perfoliata		***S. hispita***		***S. libanotica* subsp. *Linearis***		***S. congesta***		***S. libanotica* subsp. *Libanotica***		***S. stricta***		***S. leptoclada***		***S. syriaca* subsp. *nusairiensis***	
Compounds	**Class**	**Formula**	**LRI[a]**	**wild conditions**	**cultivated**	**wild conditions**	**cultivated**	**wild conditions**	**cultivated**	**wild conditions**	**cultivated**	**wild conditions**	**Cultivated**	**wild conditions**	**cultivated**	**wild conditions**	**cultivated**	**wild conditions**	**cultivated**
Tricyclene	MH	$C_{10}H_{16}$	926	0.05	0.05	0.05	0.02	0.04	0.02	8.42	0.05	-	-	-	-	-	-	-	-
α-Thujene	MH	$C_{10}H_{16}$	927	0.31	0.19	1.06	0.59	0.39	0.25	1.19	0.23	-	-	-	0.14	-	1.86	3.70	6.46
α-Pinene	MH	$C_{10}H_{16}$	933	51.72	43.36	22.86	13.74	25.29	9.29	15.25	1.95	2.10	1.78	0.23	2.84	4.34	11.86	3.49	5.61
Camphene	MH	$C_{10}H_{16}$	953	0.45	0.31	0.37	0.19	0.21	0.11	0.38	0.04	0.03	0.04	-	0.05	-	0.12	-	-
Verbenene	MH	$C_{10}H_{14}$	957	0.02	0.02	-	0.07	-	0.04	-	0.03	-	-	-	-	-	0.08	-	-
(Z)-2-Heptenal	AA	$C_7H_{12}O$	975	-	-	-	-	0.02	-	-	0.02	0.15	-	0.06	-	0.03	-	0.04	0.11
Phenyl methanal	AAI	C_7H_6O	980	-	-	-	-	0.18	-	-	-	0.15	0.14	0.48	0.07	1.13	0.27	0.88	0.35
Benzaldehyde	AAI	C_7H_6O	980	0.35	0.50	0.29	0.16	-	0.18	1.00	0.20	0.15	0.14	0.19	0.02	-	-	0.25	-
Sabinene	MH	$C_{10}H_{16}$	972	0.01	0.67	0.01	0.88	-	0.32	-	0.22	-	0.14	-	0.35	0.09	0.70	-	0.62
β-Phellandrene	MH	$C_{10}H_{16}$	972	0.36	-	1.42	-	0.23	-	2.05	-	0.33	-	0.04	-	0.29	3.64	0.21	-
β-Pinene	MH	$C_{10}H_{16}$	978	14.07	12.25	28.31	16.39	20.14	13.71	34.13	5.74	6.30	5.07	0.68	6.62	3.67	10.76	3.12	3.71
1-Octen-3-ol	AA	$C_8H_{16}O$	1001	-	0.06	0.95	0.12	0.95	0.26	1.06	0.06	-	0.09	0.05	0.02	-	0.04	0.08	0.07
6-Methyl-5-Hepten-2-One B	AAI	C_7H_6O	1003	-	-	-	-	0.08	-	0.00	-	-	-	-	-	0.10	-	0.16	0.11
3-Octanone	AAI	$C_6H_{16}O$	1005	-	0.02	0.09	0.07	-	-	0.11	0.10	1.20	0.08	0.04	0.02	0.17	0.07	0.16	0.11
β-Myrcene	MH	$C_{10}H_{16}$	1009	5.73	6.41	3.18	10.15	2.41	15.96	3.45	0.73	5.17	0.85	1.42	5.15	0.96	1.44	1.24	4.40
(E,E)-2,4-Heptadienal	AAI	$C_7H_{10}O$	1013	0.14	-	0.09	-	0.03	-	0.06	0.25	0.23	-	0.06	-	0.15	-	-	0.06
Octanal	AAI	$C_8H_{16}O$	1023	0.11	0.04	0.03	-	-	0.26	0.08	0.15	0.14	0.05	-	-	-	-	0.10	0.12
l-Phellandrene	MH	$C_{10}H_{16}$	1024	-	1.00	-	-	23.83	-	0.03	-	0.08	-	-	-	0.57	0.86	0.22	0.17
α-Phellandrene	MH	$C_{10}H_{16}$	1024	0.39	-	0.12	0.59	0.15	-	-	-	-	-	-	0.05	-	-	-	-
δ-3-Carene	MH	$C_{10}H_{16}$	1026	2.05	3.52	-	0.64	-	0.12	-	-	-	0.02	-	0.03	0.75	0.48	0.27	0.12
2,4 Heptadienal	AA	$C_7H_{10}O$	1031	-	-	0.04	-	0.03	0.25	-	0.06	0.15	-	0.06	-	0.15	0.07	-	0.06
α-Terpinene	MH	$C_{10}H_{16}$	1035	0.13	0.32	0.08	0.07	0.17	-	-	-	0.05	-	0.06	0.02	-	0.07	-	0.06
p-Cymene	MH	$C_{10}H_{14}$	1042	0.40	0.24	0.26	0.11	2.10	0.03	-	0.03	-	0.02	-	0.01	-	0.27	-	0.24
Limonene	MH	$C_{10}H_{16}$	1048	10.96	14.09	7.69	4.13	0.08	1.69	16.32	16.08	4.72	0.87	0.48	2.16	3.85	4.97	3.18	8.18
1,8-Cineole	OM	$C_{10}H_{18}O$	1050	-	-	-	-	-	-	-	-	0.04	0.02	-	0.04	0.20	-	-	-
cis-Ocimene	MH	$C_{10}H_{16}$	1056	3.40	3.60	0.15	0.12	0.41	2.08	2.51	1.04	6.40	0.71	0.16	0.86	1.35	1.98	1.35	0.27
Benzene acetaldehyde	AAI	C_7H_6O	1062	0.16	0.12	0.13	0.49	0.16	0.06	0.17	-	1.35	0.02	0.74	0.59	0.24	0.39	0.41	0.18
β-Ocimene Y	MH	$C_{10}H_{16}$	1066	0.32	0.44	0.06	0.15	0.28	0.15	2.21	2.32	3.45	1.18	0.30	1.20	0.41	0.50	0.39	0.10
γ-Terpinene	MH	$C_{10}H_{16}$	1077	-	0.56	-	0.23	0.15	0.26	0.18	0.05	0.09	-	0.04	0.03	0.25	0.15	-	0.25
1,4-Cyclohexadiene, 1-methyl-4	MH	$C_{10}H_{14}$	1077	0.29	-	0.15	-	0.06	0.18	-	-	0.13	-	0.05	-	0.21	-	0.16	-
Alloocimene	MH	$C_{10}H_{16}$	1090	-	-	0.01	0.21	-	-	0.04	-	-	-	-	-	-	-	-	-
(*E,E*)-3,5-Octadien-2-one	AAI	$C_8H_{12}O$	1090	-	-	-	-	-	-	-	0.34	-	0.04	0.08	0.07	0.38	0.18	0.28	0.32

P-Menth-1-Ene-3.8-DioL	MH	$C_{10}H_{14}$	1093	0.01	-	-	-	-	-	-	-	-	0.05	-	-	0.05	-	-	-
cis-Farnesol	OS	$C_{15}H_{26}O$	1095	-	0.06	-	-	-	-	-	-	-	-	-	-	-	-	-	-
p-Mentha-1,5,8-triene	MH	$C_{10}H_{14}$	1102	0.06	0.03	-	-	-	-	-	-	-	0.06	-	0.05	-	-	-	-
2-Carene	MH	$C_{10}H_{16}$	1102	-	0.09	-	-	-	-	-	-	-	-	-	-	-	-	-	-
α-Terpinolene	MH	$C_{10}H_{14}$	1104	1.63	4.46	0.25	0.39	0.14	0.20	0.13	0.11	0.17	0.04	-	0.18	-	0.26	-	0.18
Linalool	OM	$C_{10}H_{18}O$	1121	-	0.39	0.05	0.04	0.08	-	0.10	0.04	0.82	0.56	0.38	0.33	0.11	0.10	0.22	0.08
n-Nonanal	AAI	$C_9H_{18}O$	1125	0.22	0.01	0.07	0.11	0.13	-	0.18	0.27	0.67	0.17	0.18	0.11	0.58	0.31	0.83	0.77
α-Campholene aldehyde	SH	$C_{15}H_{24}$	1146	-	0.03	0.01	-	0.04	1.05	0.08	0.08	0.09	-	-	-	0.14	-	0.15	0.34
(E,Z)-2,4, 6-Octatriene, 2,6-dimethyl	OM	$C_{10}H_{18}O_2$	1148	-	0.03	-	0.08	0.04	0.94	-	-	0.73	-	-	-	0.11	0.20	-	-
Neoalloocimene	MH	$C_{10}H_{16}$	1149	-	0.34	0.04	-	0.09	0.24	0.03	0.10	-	-	0.03	0.08	-	-	-	0.06
Carveol	OC	$C_{10}H_{16}O$	1167	0.01	0.10	-	0.24	0.17	0.18	-	0.31	0.15	0.15	0.05	-	0.09	0.31	0.06	0.03
Pinocarvone	OM	$C_{10}H_{14}O$	1182	-	0.03	0.04	0.20	0.03	0.14	0.07	0.34	-	-	-	-	0.57	0.51	-	0.08
4-Terpineol	OM	$C_{10}H_{18}O$	1201	-	-	-	0.06	0.02	1.06	-	0.03	0.17	0.04	0.18	0.05	-	0.09	-	0.14
Hex-3(Z)-enyl acetate	FA	$C_8H_{14}O_2$	1206	-	-	-	-	-	0.15	-	0.02	0.03	0.02	0.14	0.17	-	0.37	-	0.19
Methyl salicylate	OC	C_8H_9NO	1212	0.08	0.26	0.07	-	0.08	0.84	-	-	-	-	-	-	0.25	-	-	-
Myrtenal	OM	$C_{10}H_{14}O$	1215	-	-	-	0.13	-	0.18	-	0.35	0.24	0.18	-	-	-	0.36	0.26	-
α-Terpineol	AAI	$C_9H_{18}O$	1216	-	-	-	0.15	-	-	-	-	-	-	-	0.05	-	-	-	0.14
Dodecane	AH	$C_{12}H_{26}$	1222	-	-	0.01	-	0.02	-	-	0.03	0.06	0.02	0.02	-	0.13	-	0.13	0.05
Capraldehyde	MA	$C_{10}H_{20}O$	1227	0.99	-	-	0.16	10.64	0.28	-	-	0.15	-	-	-	-	0.04	-	0.08
Decanal	MA	$C_{10}H_{20}O$	1227	-	0.81	0.02	-	-	-	0.03	0.17	-	0.58	0.08	0.07	0.29	-	0.31	0.38
Z-3-hexenyl 2-methylbutanoate	FA	$C_7H_{12}O_2$	1252	-	-	0.01	0.34	-	0.24	-	-	0.03	1.02	-	-	-	0.39	0.18	-
Hexyl 2-methylbutyrate	SH	C_6H_{12}	1257	-	-	0.36	-	-	0.41	-	0.05	0.10	1.04	0.10	-	0.06	0.11	0.54	0.38
Bornyl acetate	AAI	$C_{12}H_{20}O_2$	1305	-	-	0.04	0.26	0.33	0.95	0.12	0.38	-	0.30	-	0.03	0.24	0.43	0.41	0.33
Tridecane	OC	$C_{13}H_{28}$	1323	-	-	0.10	0.08	0.01	1.08	0.02	0.08	-	1.05	0.11	0.03	0.49	0.07	0.55	0.21
Carvacrol	OM	$C_{10}H_{14}O$	1325	0.01	0.07	0.03	0.61	-	-	-	-	-	-	-	-	-	-	-	0.03
Hexenyl-tiglate	OC	$C_{11}H_{18}O_2$	1345	-	-	-	0.09	0.01	-	0.08	0.11	1.18	0.76	0.06	0.12	0.35	0.05	0.21	0.20
Bicycloelemene	OC	$C_{15}H_{24}$	1354	-	-	0.04	0.73	-	1.08	0.06	0.92	0.41	0.77	0.67	0.74	0.71	0.49	0.49	0.35
α-Cubebene	OC	$C_{15}H_{24}$	1369	0.02	0.02	0.01	0.07	-	1.12	0.12	0.19	0.77	0.41	0.18	0.29	0.05	0.07	-	0.21
Eugenol	PP	$C_{10}H_{12}O_2$	1373	0.07	-	-	-	-	-	-	-	0.16	-	0.11	-	0.73	0.68	0.24	0.12
Ylangene	SH	$C_{15}H_{24}$	1391	-	-	-	-	-	-	1.01	-	0.12	0.13	-	-	0.91	-	0.15	-
Copaene	SH	$C_{15}H_{24}$	1397	0.01	0.04	0.04	0.59	0.03	2.32	0.56	2.80	2.36	1.57	2.50	1.10	4.65	3.68	4.58	2.81
β-Bourbonene	OC	$C_{15}H_{24}$	1405	-	0.19	0.14	1.09	0.08	1.17	0.48	0.28	2.89	1.61	0.92	0.57	1.72	0.84	3.63	2.01
Epi-bicyclosesquiphellandrene	SH	$C_{15}H_{24}$	1410	-	0.05	-	-	-	-	0.24	0.45	1.44	1.51	0.38	0.64	-	0.70	1.06	-
β-Elemene	SH	$C_{15}H_{24}$	1412	-	0.03	0.05	1.25	-	0.38	0.56	0.39	-	1.63	3.14	3.06	0.65	0.18	1.33	1.92
Tricyclo[6.3.0.0(2,4)]undec-8-ene, 3,3,7,11-Tetramethyl	SH	$C_{15}H_{24}$	1417	-	-	0.05	-	-	-	-	-	-	0.06	-	-	-	-	-	-
Sativene	SH	$C_{15}H_{24}$	1417	-	-	0.02	-	-	1.08	-	-	-	-	-	-	0.08	0.46	0.34	0.39
Tetradecane	H	$C_{14}H_{30}$	1424	-	-	0.02	1.03	0.03	0.13	-	0.06	0.16	0.06	0.05	0.06	0.29	0.09	0.14	0.21
α-Gurjunene	SH	$C_{15}H_{24}$	1430	0.09	0.04	0.03	0.15	-	-	-	0.04	-	0.11	0.51	1.01	0.26	0.10	-	1.54
Trans-Caryophyllene	SH	$C_{15}H_{24}$	1444	-	-	11.33	14.49	10.64	1.19	1.02	25.03	18.36	21.20	30.82	23.84	19.81	15.81	27.08	22.49
β-Cubebene	SH	$C_{15}H_{24}$	1452	-	0.03	-	-	-	0.20	-	0.24	-	0.84	0.17	0.58	-	0.10	-	0.31

β-Gurjunene	SH	$C_{15}H_{24}$	1457	-	-	0.04	-	-	-	-	0.12	-	-	-	-	-	-	0.25	-
α-Cedrol	OS	$C_{15}H_{26}O$	1457	-	-	-	-	-	0.14	-	0.29	0.11	0.38	-	0.28	-	0.09	-	0.13
Aromadendrene	SH	$C_{15}H_{24}$	1461	-	-	0.59	0.97	-	1.53	0.13	0.58	0.53	0.67	0.32	0.50	0.66	0.57	3.85	5.76
δ-Guaiene	SH	$C_{15}H_{24}$	1467	-	-	0.17	-	-	-	0.12	-	0.22	-	-	-	-	-	-	0.04
γ-Gurjunene	SH	$C_{15}H_{24}$	1468	-	-	0.02	1.12	-	0.24	-	0.22	-	0.57	-	0.39	-	1.06	-	0.26
Cadina-1(6),4-diene <10- *β* -H->	SH	$C_{15}H_{24}$	1472	0.01	-	0.04	-	-	1.15	-	-	1.99	-	-	0.14	0.53	0.08	-	0.23
α-Humulene	SH	$C_{15}H_{24}$	1478	0.14	0.08	-	-	-	-	0.20	0.76	0.58	-	-	0.64	0.53	0.48	0.69	0.78
(*E*)-*β*-Farnesene	SH	$C_{15}H_{24}$	1478	-	-	-	-	-	10.04	1.03	1.07	1.74	4.42	2.26	3.45	7.53	7.30	7.37	1.45
Cycloisosativene	SH	$C_{15}H_{24}$	1488	0.04	0.02	0.01	-	-	-	-	0.11	1.19	-	-	-	0.39	1.30	0.38	0.23
Germacrene-D	SH	$C_{15}H_{24}$	1492	0.00	0.61	0.28	1.44	-	1.45	2.16	6.75	16.01	29.24	33.85	26.45	2.73	0.76	4.80	6.93
δ-Cadinene	SH	$C_{15}H_{24}$	1496	-	0.04	0.08	0.66	-	2.47	0.32	0.30	0.91	-	3.29	1.63	5.69	3.79	4.99	3.75
γ-Muurolene	SH	$C_{15}H_{24}$	1498	-	-	-	-	-	1.10	-	-	0.36	1.32	-	1.23	-	1.06	-	-
α-Amorphene	SH	$C_{15}H_{24}$	1498	-	-	0.03	-	-	-	-	-	-	-	0.09	-	-	-	0.38	1.07
γ-Cadinene	SH	$C_{15}H_{24}$	1498	-	0.06	0.02	1.09	-	1.12	0.34	0.40	1.17	1.46	0.49	-	4.23	4.80	-	0.85
α-Bergamotene	SH	$C_{15}H_{24}$	1514	-	0.02	2.13	-	-	2.99	-	0.06	-	-	-	0.07	0.77	3.47	0.52	2.16
Bicyclogermacrene	SH	$C_{15}H_{24}$	1520	-	-	4.45	6.22	-	7.69	1.04	9.47	3.67	7.17	7.23	6.96	7.90	-	6.78	4.68
α-Muurolene	SH	$C_{15}H_{24}$	1523	-	-	-	-	-	-	0.14	-	1.51	-	-	-	0.47	-	0.07	-
(*E,E*)-*α* Farnesene	SH	$C_{15}H_{24}$	1528	0.21	0.17	9.49	12.63	-	2.38	0.29	0.54	0.50	2.53	1.94	1.55	4.62	3.70	-	-
β-Bisabolene	SH	$C_{15}H_{24}$	1531	-	-	0.87	1.98	-	0.30	0.04	13.24	-	0.37	-	-	3.28	1.27	1.45	0.30
Cadina-1,4-diene	SH	$C_{15}H_{24}$	1556	0.41	0.75	0.02	0.98	-	-	-	0.32	0.25	-	-	-	1.16	-	1.37	0.17
Calamenene	SH	$C_{15}H_{22}$	1557	-	-	0.96	-	-	0.43	-	0.14	1.40	1.07	0.86	0.76	0.69	1.31	0.71	0.41
α-Cadinene	SH	$C_{15}H_{24}$	1561	-	-	-	-	-	-	0.07	0.84	-	0.57	0.45	0.37	0.43	-	-	0.16
α-Calacorene	OC	$C_{15}H_{20}$	1566	-	-	-	-	-	-	-	-	1.06	-	-	-	-	-	-	-
Isocaryophyllene	SH	$C_{15}H_{24}$	1586	-	-	0.06	-	-	0.65	-	0.41	-	1.15	1.65	0.05	0.83	-	-	0.04
Caryophyllene oxide	OS	$C_{15}H_{24}O$	1607	4.57	3.37	0.51	1.45	-	3.34	0.57	1.80	3.13	1.88	1.57	1.80	4.95	1.40	3.81	2.89
Curcumene	SH	$C_{15}H_{22}$	1977	-	-	-	-	-	1.15	-	-	-	-	-	0.23	-	-		
Total				100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Number of compounds				41	51	64	54	42	61	51	66	62	60	53	61	64	65	57	72
MH: Monoterpene hydrocarbon				92.36	91.95	66.07	48.67	76.17	44.65	86.36	28.72	29.02	10.83	3.49	19.82	16.79	40.00	17.33	30.43
AAI: Aromatic aldehyde				0.98	0.69	0.74	1.24	0.91	1.45	1.72	1.69	3.89	0.94	1.77	0.96	2.99	1.65	3.48	2.49
AA: Aromatic alcohol				-	0.06	0.99	0.12	1.00	0.51	1.06	0.16	0.3	0.09	0.17	0.02	0.18	0.11	0.12	0.24
OS: Oxygenated sesquiterpene				4.57	3.43	0.51	1.45	-	3.48	0.57	2.09	3.24	2.26	1.57	2.08	4.95	1.49	3.81	3.02
AH: Aromatic hydrocarbon				-	-	0.01	-	0.02	-	-	0.03	0.06	0.02	0.02	-	0.13	-	0.13	0.05
OM: Oxygenated monoterpene				0.01	0.52	0.12	1.12	0.17	2.32	0.17	0.76	2.00	0.8	0.56	0.42	0.99	1.26	0.48	0.33
OC: Other components				0.11	0.57	0.36	2.3	0.35	5.47	0.74	1.89	6.46	4.75	1.99	1.75	3.66	1.83	4.94	3.01
MA: Monoterpene aldehyde				0.99	0.81	0.02	0.16	10.64	0.28	0.03	0.17	0.15	0.58	0.08	0.07	0.29	0.04	0.31	0.46
PP: Phenylpropanoid				0.07	-	-	-	-	-	-	-	0.16	-	0.11	-	0.73	0.68	0.24	0.12
SH: Sesquiterpene hydrocarbon				0.91	1.97	31.15	43.57	10.71	41.32	9.35	64.41	54.5	78.63	90.05	74.65	69.0	52.09	68.84	59.45
H: Hydrocarbon				-	-	0.02	1.03	0.03	0.13	-	0.06	0.16	0.06	0.05	0.06	0.29	0.09	0.14	0.21
FA: Fatty acid				-	-	0.01	0.34	-	0.39	-	0.02	0.06	1.04	0.14	0.17	-	0.76	0.18	0.19

a Linear Retention Indices, as determined on a Restek Rxi-5Sil MS column using a series of the standards of C7_C30 saturated n-alkanes, -: not detected.

Table 2.Total phenolic content and antioxidant activity

Grown in			Species	N	Mean Rank	X	SE
wild conditions	**Total phenolic content (mg GAE/g dry sample)**	TPC	*S. condensata*	3	8.16 EF	12.83	0.16
			S. congesta	3	15.16 DE	13.26	0.12
			S. libanotica subsp. libanotica	3	13.83 E	13.20	0.11
			S. erythrantha	3	2.00 F	11.56	0.17
			S. stricta	3	16.00 DE	13.50	0.45
			S. leptoclada	3	9.16 E	12.86	0.20
			S. libanotica subsp. *linearis*	3	22.83 CD	14.06	0.12
			S. hispita	3	15.33 DE	13.30	0.60
			S. perfoliata	3	38.83 A	16.23	0.23
			S. dichotoma	3	29.5B C	14.86	0.39
			S. phrygia	3	35.83 AB	15.83	0.59
			S. pisidica	3	35.16 AB	15.73	0.34
			S. syriaca	3	27.16 BC	14.70	0.45
			S. cilicica	3	32 AB	15.20	0.00
			Total	42			
	Antioxidant analyses	DPPH **(mmol TE/g dry sample)**	*S. condensata*	3	33 B	0.00	0.00
			S. congesta	3	17 C	0.00	0.00
			S. libanotica subsp. libanotica	3	17 C	0.00	0.00
			S. erythrantha	3	33 B	0.00	0.00
			S. stricta	3	5.83 D	0.00	0.00
			S. leptoclada	3	33 B	0.00	0.00
			S. libanotica subsp. *linearis*	3	17 C	0.00	0.00
			S. hispita	3	36 A	0.00	0.00
			S. perfoliata	3	17 C	0.00	0.00
			S. dichotoma	3	33 B	0.00	0.00
			S. phrygia	3	17 C	0.00	0.00
			S. pisidica	3	2.16 E	0.00	0.00
			S. syriaca	3	7 D	0.00	0.00
			S. cilicica	3	33 B	0.00	0.00
			Total	42			
		CUPRAC **(mmol TE/g dry sample)**	*S. condensata*	3	12.83D	0.10	0.00
			S. congesta	3	29.33 AB	0.11	0.00
			S. libanotica subsp. libanotica	3	12.66 CD	0.10	0.00
			S. erythrantha	3	5 DE	0.10	0.00
			S. stricta	3	22.5 BC	0.11	0.00
			S. leptoclada	3	18.83 C	0.11	0.00
			S. libanotica subsp. *linearis*	3	2 E	0.07	0.00
			S. hispita	3	12.83 CD	0.10	0.00
			S. perfoliata	3	38 A	0.11	0.00
			S. dichotoma	3	32 AB	0.11	0.00
			S. phrygia	3	29.83 AB	0.11	0.00
			S. pisidica	3	36.16 A	0.12	0.00
			S. syriaca	3	29.83 AB	0.11	0.00
			S. cilicica	3	19.16 C	0.11	0.00
			Total	42			
cultivated	**Total phenolic content (mg GAE/g dry sample)**	TPC	*S. condensata*	3	15.33 BC	13.46	0.03
			S. congesta	3	7.33 DE	11.83	0.26
			S. libanotica subsp. libanotica	3	16.16 B	13.50	0.05
			S. stricta	3	7.66 CDE	12.03	0.18
			S. leptoclada	3	3 E	10.60	0.20
			S. libanotica subsp. *linearis*	3	12.5 BCD	12.56	0.29
			S. hispita	3	19.83 AB	14.66	0.65
			S. perfoliata	3	25.83 A	16.13	0.31
			S. syriaca	3	18.33 AB	14.43	0.59
			Total	27			

Antioxidant analyses	DPPH **(mmol TE/g dry sample)**	*S. condensata*	3	20 B	0.00	0.00
		S. congesta	3	13 C	0.00	0.00
		S. libanotica subsp. libanotica	3	13 C	0.00	0.00
		S. stricta	3	2.5 D	0.00	0.00
		S. leptoclada	3	23.5 A	0.00	0.00
		S. libanotica subsp. *linearis*	3	13 C	0.00	0.00
		S. hispita	3	23.5 A	0.00	0.00
		S. perfoliata	3	13 C	0.00	0.00
		S. syriaca	3	4.5 D	0.00	0.00
		Total	27			
	CUPRAC **(mmol TE/g dry sample)**	*S. condensata*	3	15 BC	0.11	0.00
		S. congesta	3	18.16 AB	0.11	0.00
		S. libanotica subsp. libanotica	3	18.66 AB	0.11	0.00
		S. stricta	3	26 A	0.12	0.00
		S. leptoclada	3	8.66 CD	0.11	0.00
		S. libanotica subsp. *linearis*	3	2 D	0.07	0.00
		S. hispita	3	13.33 BC	0.11	0.00
		S. perfoliata	3	9.83 BCD	0.11	0.00
		S. syriaca	3	14.33 BC	0.11	0.00
		Total	27			

N: number of observations, X: average, SE: standard error

(*S. syriaca* subsp. *nusairiensis*- wild conditions) to form a cluster. Then, species 14 (*S. stricta*- cultivated) and 2 (*S. condensata*- cultivated) showed 90.60% similarity, and species 14 joined the previously linked species 2 (*S. condensata*- cultivated) and 12 (*S. libanotica* subsp. *libanotica*- cultivated) to form a cluster.

Next, species 18 (*S. syriaca* subsp. *nusairiensis*- cultivated) and 10 (*S. congesta*- cultivated) showed 90.57% similarity, and species 18 joined the previously linked species 15 (*S. leptoclada*- wild conditions), 17 (*S. syriaca* subsp. *nusairiensis*- wild conditions), and 10 (*S. congesta*- cultivated) to form a cluster. Species 6 (*S. hispita*- cultivated) and 8 (*S. libanotica* subsp. *linearis*- cultivated) showed 87.02% similarity and were included in the same cluster. Species 3 (*S. perfoliata*- wild conditions) and 4 (*S. perfoliata*- cultivated) showed 86.41% similarity and were included in the same cluster. Species 5 (*S. hispita*- wild conditions) and 7 (*S. libanotica* subsp. *linearis*- wild conditions) showed 86.34% similarity and were included in the same cluster. In the next step, species 13 (*S. stricta*- wild conditions) and 2 (*S. condensata*- cultivated) showed 83.20% similarity, and species 13 joined the previously linked species 14 (*S. stricta*- cultivated), 12 (*S. libanotica* subsp. *libanotica*- cultivated), and 2 (*S. condensata*- cultivated) to form a cluster.

Species 16 (*S. leptoclada*- cultivated) showed 79.93% similarity to the cluster previously named cluster 10 with 4 species, and it was included in the cluster. Afterward, species 5 (*S. hispita*- wild conditions) and 9 (*S. congesta*- wild conditions) showed 72.51% similarity, and species 9 joined the previously linked species 5 (*S. hispita*- wild conditions) and 7 (*S. libanotica* subsp. *linearis*- wild conditions) to form a cluster. Species 11 (*S. libanotica* subsp. *libanotica*- wild conditions) showed 69.10% similarity to the cluster previously named cluster 10 with 5 species, and it was included in the cluster. Additionally, species 1 (*S. condensata*- wild conditions) showed 68.29% similarity to the cluster previously named cluster 2 with 4 species, and it was included in the cluster. Species 6 (*S. hispita*- cultivated) showed 64.10% similarity to the cluster previously named cluster 10 with 7 species, and it was included in the cluster. With a similarity rate of 45.05%, the cluster previously named cluster 6 with 8 species and the cluster previously named 5 with 3 species were combined to form a new cluster. Again, with a similarity rate of 22.46%, the cluster previously named cluster 5 with 11 species and the cluster previously named cluster 1 with 5 species were combined to form a new cluster. Species 3 (*S. perfoliata*- wild conditions) did not show similarity to any of the other species that were linked to form a single cluster until the 16th step, and it was added to the other species in the last step as a requirement of the analysis. The steps of the process that continued until a single cluster consisting of all included species was reached are presented in Table 3. The names of the species given with numbers in the dendrogram were as follows: 1-*S. condensata*- wild conditions, 2-*S. condensata*- cultivated, 3-*S. perfoliata*- wild conditions, 4-*S. perfoliata*- cultivated, 5-*S. hispita*- wild conditions, 6-*S. hispita*- cultivated, 7-*S. libanotica* subsp. *linearis*- wild conditions, 8-*S. libanotica* subsp. *linearis*- cultivated, 9-*S. congesta*- wild conditions, 10-*S. congesta*- cultivated, 11-*S. libanotica* subsp. *libanotica*- wild conditions, 12-*S. libanotica* subsp. *libanotica*- cultivated, 13-*S. stricta*- wild conditions, 14-*S. stricta*- cultivated, 15-*S. leptoclada*- wild conditions, 16-*S. leptoclada*- cultivated, 17-*S. syriaca* subsp. *nusairiensis*- wild conditions, 18-*S.*

syriaca subsp. *nusairiensis*- cultivated. These species were linked to create clusters.

The species were categorized into five distinct clusters based on characteristics (Table 3). The first cluster comprised species numbered 1 (*S. condensata*- wild conditions), 2 (*S. condensata*- cultivated), 12 (*S. libanotica* subsp. *libanotica*- cultivated), 14 (*S. stricta*- cultivated), and 13 (*S. stricta*- wild conditions). The second cluster included species 5 (*S. hispita*- wild conditions), 7 (*S. libanotica* subsp. *linearis*- wild conditions), and 9 (*S. congesta*- wild conditions). The third cluster consisted of species 6 (*S. hispita*- cultivated) and 8 (*S. libanotica* subsp. *linearis*- cultivated). The fourth cluster encompassed species 10 (*S. congesta*-cultivated), 15 (*S. leptoclada*- wild conditions), 17 (*S. syriaca* subsp. *nusairiensis*- wild conditions), 18 (*S. syriaca* subsp. *nusairiensis*- cultivated), 16 (*S. leptoclada*- cultivated), and 11 (*S. libanotica* subsp. *libanotica*-wild conditions). Lastly, the fifth cluster grouped species 3 (*S. perfoliata*- wild conditions) and 4 (*S. perfoliata*- cultivated). These groupings were determined based on the analysis results of their volatile compound profiles.

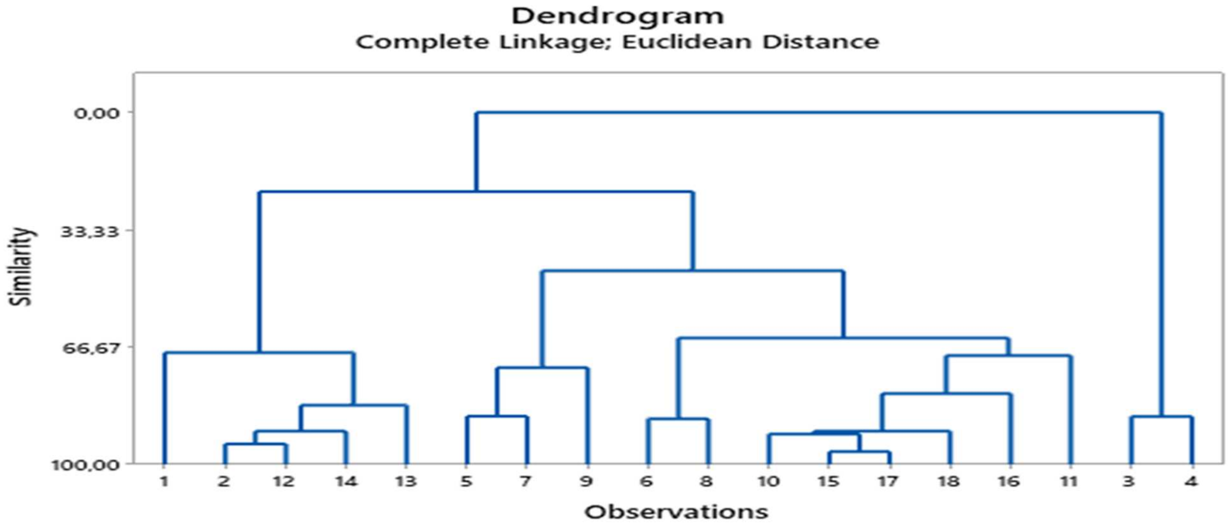

Figure 2-Cluster analysis

Table 3-Cluster analysis results

Step	Clusters	Similarity (%)	Distance	First added	Second added	New cluster name	Number of observations in cluster
1	17	96.33	2.3223	15	17	15	2
2	16	94.24	3.6490	2	12	2	2
3	15	91.39	5.4524	10	15	10	3
4	14	90.60	5.9520	2	14	2	3
5	13	90.57	5.9699	10	18	10	4
6	12	87.02	8.2204	6	8	6	2
7	11	86.41	8.6068	3	4	3	2
8	10	86.34	8.6517	5	7	5	2
9	9	83.20	10.6404	2	13	2	4
10	8	79.93	12.7063	10	16	10	5
11	7	72.51	17.4108	5	9	5	3
12	6	69.10	19.5679	10	11	10	6
13	5	68.29	20.0842	1	2	1	5
14	4	64.10	22.7366	6	10	6	8
15	3	45.05	34.8031	5	6	5	11
16	2	22.46	49.1083	1	5	1	16
17	1	0.00	63.3373	1	3	1	18

The Kruskal-Wallis test results indicate that there is no statistically significant difference in the mean ranks of the following components among the *Sideritis* spp. species: Tricyclene, *α*-Thujene,1-Phenyl-2-Propanol, *α*-Pinene, Camphene, Verbenene, (E) 2 Heptenal, Phenylmethanal, Benzaldehyde, Sabinene, *β*-Pinene, 1-

Octen-3-ol, 6-Methyl-5-Hepten-2-One, 3-Octanone, *β*-Myrcene, (E,E)-2,4-Heptadienal, Pseudolimonene, Octanal, n-Octanal, l-Phellandrene, *δ*-3-Carene, 2,4-Heptadienal, *α*-Terpinene, p-Cymene, Limonene, dl-Limonene, Eucalyptol, 1,8-Cineole, *cis*-Ocimene, Benzeneacetaldehyde, Trans-*β*-Ocimene, *β*-Ocimene Y, *γ*-Terpinene, Cyclohexadiene (1-methyl-4-(1-methylethyl)), Alloocimene, (E,E)-3,5-Octadien-2-one, Trans-Sabinenehydrate, p-Mentha-1,5, 8-triene, *α*-Terpinolene, 1-Methyl-4isopropenylbenzene, Linalool, n-Nonanal, *α*-Campholene aldehyde, *α*-Campholenal, Neoalloocimene, Trans-Pinocarveol, Carveol, Buten-1-ol (3-methyl-, acetate), Prenyl acetate, 2-Nonenal (E), Pinocarvone, 4-Terpineol, *cis*-3-Hexenyl iso-butyrate, Hex-3(Z)-Enyl Butyrate, Methyl salicylate, Myrtenal, Dodecane, *α*-Campholene Aldehyde, Capraldehyde, Decanal, Z-3-hexenyl 2-methylbutanoate, Hexyl 2-methylbutyrate, Benzyl isobutyrate, Tridecane, Carvacrol, 3(Z)-Hexenyl-tiglate, Nonan, 4-Methylen-2,8,8-Trimethyl-2-Vinyl-(Isocaryoph), Bicycloelemene, *α*-Cubebene, Citronellyl acetate, Eugenol, Cyclosativene, Ylangene, *α*-Copaene, *β*-Bourbonene, Epi-bicyclosesquiphellandrene, *β*-Elemene, Benzyl pentanoate, Phenyl ether, Tetradecane, and *α*-Gurjunene.

DISCUSSION

Volatile Compounds of Samples Collected from Wild Conditions and Cultivated Environments: The main compounds of *S. perfoliata* in wild conditions and cultivated were identified as *α*-pinene, *β*-pinene, and limonene. Sarıkaya and Canıs (2019) reported the main compounds of leaf and flower samples of *S. perfoliata* collected from three different sampling areas as *α*-pinene, *β*-pinene, limonene, and caryophyllene. The main compounds of *S. hispita* in wild conditions and cultivated were identified as *α*-pinene, *β*-pinene, and caryophyllene. Sarıkaya and Canıs (2019) reported the main compounds of the leaf and flower samples of *S. hispita* collected from three different sampling areas as (E)-2-hexenal, *β*-myrcene, caryophyllene, and p-cymene. The main compounds of *S. libanotica* subsp. *linearis* in wild conditions and cultivated were identified as *α*-pinene, *β*-pinene, and *β*-myrcene. Erbaş and Fakir (2012) stated that the main compounds of *S. libanotica* subsp. *linearis* were α-bisabolol, β-phellandrene, and germacrene-D. Erbaş and Fakir (2012) determined *α*-bisabolol, *β*-phellandren and germacrene-D as the main components according to the analysis results of *S. libanotica* subsp *linearis*. Sarıkaya and Canıs (2019) reported the main compounds of the leaf and flower samples of *S. libanotica* subsp. *linearis* collected from three different sampling areas as (E)-2-hexenal, 3-octanol, limonene, and caryophyllene. In their studies, Sarıkaya and Canıs (2019) determined (E)-2-hexenal, 3-octanol, limonene and caryophyllene as the main components according to the analysis results of *S. libanotica* subsp. *linearis*. In our study, *α*-pinene, *β*-pinene and *β*-myrcene were determined as the main components according to the analysis results of *S. libanotica* subsp. *linearis*.

The main compounds of *S. stricta* in wild conditions and cultivated were identified as germacrene-D, caryophyllene, and *β*-elemene. For the same species, the main compounds identified by Dülgeroğlu (2013) were, caryophyllene, *β*-pinene, δ-cadinene, abietatriene, *α*-pinene, and cadina-1,4-diene. Bilginoğlu (2019) identified *β*-pinene as a main compound. In the current study, the main compounds of *S. stricta* were determined as germacrene-D, caryophyllene and *β*-elemen. In the study of Bilginoğlu (2019), according to the analysis results, the main compound of *S. stricta* was determined as *β*-pinene. In both studies, the main compound of *S. stricta* was determined differently. The main compounds of *S. leptoclada* in wild conditions and cultivated were identified as trans-caryophyllene, *α*-pinene, and *β*-pinene in our study. Semiz and Özel (2017) reported *β*-pinene, trans-*β*-caryophyllene, *α*-pinene, and caryophyllene oxide as the main compounds of the species. According to the analysis results of *S.leptoclada*, the main compounds were determined as trans-caryophyllene, *α*-pinene and *β*-pinene. In the studies of Semiz and Özel (2017), according to the analysis results of *S.leptoclada*, the main compounds were determined as *β*-pinene, trans-*β*-caryophyllene, *α*-pinene and caryophyllene oxide. The main compounds identified by Usluer (2005) in this species were germacrene-D, *β*-caryophyllene, caryophyllene oxide, *β*-pinene, *α*-pinene, and verbenone. The main compounds of *S. leptoclada* were determined as trans-caryophyllene, *α*-pinene and *β*-pinene. In the study of Usluer (2005), the main compounds of *S. leptoclada* were determined as germacrene-D, *β*-caryophyllene, caryophyllene oxide, *β*-pinene, *α*-pinene and verbenone. In our study, the main compounds of *S. syriaca* subsp. *nusairiensis* in wild conditions and cultivated were identified as caryophyllene, germacrene-D, and bicyclogermacrene.

The main compounds of *S. congesta* in wild conditions and cultivated were identified as *β*-pinene, limonene, and trans-caryophyllene. Bilginoğlu (2019) also found *β*-pinene to be among the main compounds of *S. congesta.* While Bilginoğlu (2019) also revealed that *β*-pinene was among the main compounds of *S. congesta* in his study, *β*-pinene was also found among the main compounds of *S. congesta* in our study. The common constituents among the taxa were determined as *β*-pinene in *S. condensata*, *S. perfoliata*, *S. hispita,* and *S. libanotica* subsp. *linearis*, *trans*-caryophyllene in *S. condensata*, *S. libanotica* subsp. *libanotica*, *S. stricta*, *S. leptoclada*, *S. syriaca* subsp. *nusairiensis*, *S. hispita,* and *S. congesta*, germacrene D in *S. condensata*, *S. libanotica* subsp. *libanotica*, *S. stricta*, and *S. syriaca* subsp. *nusairiensis*, and *α*-pinene in *S. condensata*, *S. perfoliata*, *S. hispita*, *S. libanotica* subsp. *linearis*, *S. leptoclada*, and *S. congesta*. A few different compounds identified between the wild conditions and the cultivated environment were attributed to differences in altitude, soil, and ecological characteristics of the locations where the samples were collected.

Total Phenolic Contents and Antioxidant Activities: In this study, the TPC (mg GAE/g dry sample) values of *S. libanotica* subsp. *linearis* were 14.06 mg/g GAE in wild conditions and 12.56 mg/g GAE in cultivated conditions. The antioxidant activity levels of *S. libanotica* subsp. *linearis* were 0.07 mmol TE/g in wild conditions and 0.07 mmol TE/g in cultivated conditions. The TPC of the species was higher in its wild conditions than in cultivated conditions. It had similar antioxidant activity in both settings. Şahin (2010), *S. libanotica* subsp. *linearis* had a TPC of 179±13 µg GAE. It was determined that the high TPC values in the methanolic extract of *S. libanotica* subsp. *linearis* resulted in high levels of antioxidant activity. In our study, the TPC values of *S. congesta* were 13.26 mg/g GAE in wild conditions and 11.83 mg/g GAE in cultivated conditions. The antioxidant activity levels of *S. congesta* were 0.11 mmol TE/g in wild conditions and 0.11 mmol TE/g in cultivated conditions. The TPC of the species was higher in its wild conditions than in cultivated conditions. *S. congesta* showed high levels of antioxidant activity. It had similar antioxidant activity in both settings. Yılmaz (2013) also found that *S. congesta* displayed high antioxidant activity. Their result was similar to ours. İnciman (2020) reported the TPC of *S. congesta* as 199.64±3.66 mg GAE/g. The TPC values of *S. condensata* were found to be 12.83 mg/g GAE in wild conditions and 13.46 mg/g GAE in the cultivated conditions of our study. The antioxidant activity levels of the species were 0.10 mmol TE/g in wild conditions and 0.11 mmol TE/g in cultivated conditions. The TPC of the species was higher in cultivation conditions than in wild conditions. *S. condensata* showed higher levels of antioxidant activity in cultivated conditions. The TPC value of *S. condensata* was reported by İnciman (2020) as 387.83±8.25 mg GAE/g.

The TPC values of *S. stricta* in our study were 13.50 mg/g GAE in wild conditions and 12.03 mg/g GAE in cultivated conditions. The antioxidant activity levels of *S. stricta* were 0.11 mmol TE/g in wild conditions and 0.12 mmol TE/g in cultivated conditions. The TPC of the species was higher in its wild than in cultivated conditions. *S. stricta* showed higher levels of antioxidant activity in cultivated conditions. In the study conducted by İnciman (2020), the TPC of *S. stricta* was calculated as 96.104±2.42. The results of this study revealed the TPC values of *S. perfoliata* as 16.23 mg/g GAE in wild conditions and 16.13 mg/g GAE in cultivated conditions. The antioxidant activity levels of *S. perfoliata* were found to be 0.11 mmol TE/g in wild conditions and 0.11 mmol TE/g in cultivated conditions. The TPC of the species was higher in its wild conditions than in cultivated conditions. It had similar antioxidant activity in both settings. Bağlama (2018) showed high levels of antioxidant activity in *S. perfoliata*.

The TPC values of *S. leptoclada* in our study were identified as 12.86 mg/g GAE in wild conditions and 10.60 mg/g GAE in cultivated conditions. The antioxidant activity values of *S. leptoclada* were 0.11 mmol TE/g in wild conditions and 0.11 mmol TE/g in cultivated conditions. The TPC of the species was higher in its wild conditions than in cultivated conditions. *S. leptoclada* showed high levels of antioxidant activity. It had similar antioxidant activity in both settings.

In this study, the TPC values of *S. libanotica* subsp. *libanotica* were identified as 13.20 mg/g GAE in wild conditions and 13.50 mg/g GAE in cultivated conditions. The antioxidant activity levels of *S. libanotica* subsp. *libanotica* were 0.10 mmol TE/g in wild conditions and 0.11 mmol TE/g in cultivated conditions. The TPC of the species was high in the cultivated environment in comparison to its wild conditions. *S. libanotica* subsp. *libanotica* showed high levels of antioxidant activity. The antioxidant activity of the species was found to be greater in the cultivated than in wild conditions. The TPC values of *S. hispita* were found as 13.30 mg/g GAE in wild conditions and 14.66 mg/g GAE in cultivated conditions. Its antioxidant activity levels were 0.10 mmol TE/g in wild conditions and 0.11 mmol TE/g in cultivated conditions. The TPC of the species was higher in its cultivated than in its wild conditions. *S. hispita* showed high levels of antioxidant activity. The antioxidant activity of the species was higher in the cultivated than in wild conditions.

In this study, the TPC values of *S. syriaca* were 14.70 mg/g GAE in wild conditions and 14.43 mg/g GAE in cultivated conditions. The antioxidant activity levels of *S. syriaca* were 0.11 mmol TE/g in wild conditions and 0.11 mmol TE/g in cultivated conditions. The TPC of the species was higher in its wild conditions than in cultivated conditions. *S. syriaca* showed high levels of antioxidant activity. It had similar antioxidant activity in both settings.

The TPC value of *S. erythrantha* was 11.56 mg/g GAE in wild conditions, while its antioxidant activity level was 0.10 mmol TE/g in wild conditions. *S. erythrantha* showed high levels of antioxidant activity. The TPC value of *S. dichotoma* in wild conditions was 14.86 mg/g GAE, while its antioxidant activity level in wild conditions was 0.11 mmol TE/g. *S. dichotoma* showed high levels of antioxidant activity.

The TPC value of *S. phrygia* in wild conditions was 15.83 mg/g GAE, while its antioxidant activity level in wild conditions was 0.11 mmol TE/g. *S. phrygia* showed high levels of antioxidant activity.

The TPC value of *S. pisidica* in wild conditions was 15.73 mg/g GAE, while its antioxidant activity level in wild conditions was 0.12 mmol TE/g. *S. pisidica* showed high levels of antioxidant activity.

The TPC value of *S. cilicica* in wild conditions was 15.20 mg/g GAE, while its antioxidant activity level in wild conditions was 0.11 mmol TE/g. *S. cilicica* showed high levels of antioxidant activity. It was determined that endemic *Sideritis* taxa, which have significant TPC values and antioxidant activities, can be utilized as valuable resources. The high phenolic content and antioxidant activity of *Sideritis* species significantly enhance their potential for use in medical applications and as functional foods. Phenolic compounds help prevent cellular damage by reducing oxidative stress caused by free radicals in the body, which is crucial for maintaining overall health. Additionally, plants with high antioxidant activity may strengthen the immune system and reduce inflammation. This makes *Sideritis* species valuable in wild conditions as antioxidant sources for phytotherapy (plant-based treatment) applications. In the context of functional foods, *Sideritis* species can be processed into tea, capsules, extracts, or additives, enabling the development of products with both high nutritional value and health benefits. These results were compared with the analysis results obtained in our study with other species.

Cultivation: In the study, the *S. perfoliata*, *S. hispita*, *S. libanotica* subsp. *linearis*, *S. libanotica* subsp. *libanotica, S. condensata, S. cilicica, S. congesta*, *S. stricta*, *S. leptoclada*, *S. syriaca* subsp. *nusairiensis*, *S. pisidica*, *S. phrygia*, *S. dichotoma*, and *S. erythrantha* var. *erythrantha* taxa were included in cultivation trials. Among these, there were nine species whose cultivation was successful, namely *S. condensata*, *S. perfoliata*, *S. hispita*, *S. libanotica* subsp. *linearis*, *S. libanotica* subsp. *libanotica*, *S. stricta*, *S. leptoclada*, *S. syriaca* subsp. *nusairiensis*, and *S. congesta*. The reason why some compounds appear in higher concentrations in cultivated compared to wild conditions is that regular irrigation is applied in the cultivated, whereas in the wild conditions, irrigation is not regular and varies depending on seasonal drought or moisture. These results are compared with the essential oil component analysis findings of *Sideritis* spp collected from different regions.

S. stricta was successfully transferred from its wild conditions to the cultivated environment in this study. Positive results were obtained not only by producing *S. stricta* using cuttings but also via the germination of its seeds. The seeds of *S. stricta* were also successfully germinated by Dülgeroğlu (2013). In our study, the *S. congesta* and *S. stricta* taxa were transferred to the cultivated environment, separately for each species, using cuttings and seeds. Bilginoğlu (2019) also achieved the successful transfer of *S. congesta* and *S. stricta* to the cultivated environment without encountering any germination problems.

The cultivation of *S. perfoliata, S. hispita*, *S. libanotica* subsp. *linearis*, *S. libanotica* subsp. *libanotica, S. condensata, S. congesta, S. stricta*, *S. leptoclada*, and *S. syriaca* subsp. *nusairiensis* using cuttings was successful. On the other hand, it was concluded that the remaining species were not suitable for cultivation in the cultivated by production involving cuttings. Moreover, the cultivation of *S. perfoliata*, *S. libanotica* subsp. *libanotica, S. condensata, S. congesta*, and *S. stricta* via the germination of their seeds was successful. However, it was concluded that the remaining species were not suitable for cultivation in the cultivated via seed germination. Germination problems were observed in the species *S. hispita*, *S. libanotica* subsp. *linearis, S. cilicica, S. leptoclada*, *S. syriaca* subsp. *nusairiensis*, *S. phrygia*, *S. dichotoma*, and *S. erythrantha* var. *erythrantha*, and the GA_3 treatments were unsuccessful. Based on these results, it is important to continue the agricultural efficiency and quality studies of species that show successful outcomes in cultivation studies throughout the lifecycles of these plants, and profitable agricultural production potential should be evaluated based on feasibility analyses. In the cultivation results, there are nine species that were successful in the clusters. Based on the clustering results, cultivation studies can be carried out on the successful species, and by transferring them from their wild conditions to the cultivated environment, both the species' disappearance and destruction in wild conditions can be prevented, and at the same time, they can be protected and traded profitably.

Conclusions: This study successfully transferred *Sideritis* spp. from wild habitats to cultivated environments, supporting sustainable use and rural development. Cultivation enables standardized commercial production, reduces overharvesting, and prevents habitat loss. *Sideritis* spp. possess valuable medicinal and aromatic properties, including high phenolic content, antioxidant, anti-inflammatory, antiviral, and immune-boosting effects. These characteristics make them promising candidates for use in medicines, cosmetics, aromatherapy, and functional foods. The study's findings contribute to biodiversity conservation and provide economic benefits by creating sustainable income for local communities. Controlled cultivation enhances product quality and supports the sustainable management of *Sideritis* spp in Turkey .

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