DETERMINATION OF MORPHOLOGICAL CHARACTERISTICS AND ADAPTATION CAPABILITIES OF TWO *TEUCRIUM* TAXA

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Abstract. In this study, it is aimed to determine the possibilities of cultivation of 2 taxa (*Teucrium chamaedrys* subsp. *chamaedrys, Teucrium polium*) belonging to the Lamiaceae family. The plants were collected from an area where plants grow naturally and cultivated in "Randomized Complete Block Design". Phenological observations, morphological measurements and plant elemental analysis were carried out in the natural and in the cultivated areas. 72 (96%) of *Teucrium chamaedrys* subsp. *chamaedrys* and 54 (72%) of *Teucrium polium* survived of the plants transferred to the cultivation area. Cultivated *Teucrium chamaedrys* subsp. *chamaedrys* showed higher growth compared to those in terms of plant width and number of spikes. Data on the morphological parameters of cultivated plants of *T. polium* was higher than that of. The highest N content for T. *chamaedrys* and *T. polium* was determined as (2.75, 2.09%) in the 2nd year cultivated plants. No statistical difference was observed in terms of other macro and micro elements in both plants of origin.
Keywords: *Lamiaceae, Teucrium sp., cultivation, xeriscape, medicinal and aromatic plants*

Introduction

Many of the first urban areas in arid climates developed near reliable sources of fresh river water. In the modern era, urban and suburban population growth has considerably changed the balance between consumed water demand and available supply (Hilaire et al., 2008). Total amount of water in the world is 1.4 billion km^3, however, only 2.5% is fresh water that is usable for various purposes (Gupta and Gupta, 2020). Landscaping which is one of the primary features of cities, which is thought to be the most significant area that uses of a lot of water. This needs to be decreased while maintaining the aesthetic appeal of cities (AlHalim, 2020). There are numerous ideas that can be implemented to ensure the sustainability of landscape design while saving water (Devitt, 2005; Bayramoğlu et al., 2013; Çakmak and Gökalp, 2011). The most well-known idea is xeriscape, which can be implemented by following its basic guidelines to conserve water, particularly in arid areas. Xeriscape concept aims to protect water resources by using plants that need less water (Küçükyumuk et al., 2013; Çakır and Dönmez, 2018; AlHalim, 2020; Liu and Nijhuis, 2020; Zohny and Moaawad, 2021; Saher et al., 2022). Selecting plants which are suitable for natural climatic conditions is an important factor for sustainable design. Recently, studies have been focused on to cultivate and develop natural species in order to carry out xeriscape designs (Altuntaş, 2020; Abd El-Salam, 2021; Erken, 2022).

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Two natural plant species from Lamiaceae family, *Teucrium chamaedrys* subsp. *chamaedrys* and *Teucrium polium*, can be classified as xeriscape, ornamental and medicinal-aromatic plants and it is distributed in arid areas (Coll and Tandron, 2008; Guo et al., 2011; Wesolowska and Jadczak, 2019; Michel et al., 2020; Casella, 2023). Lamiaceae is seen with 400 genus and 3200 species worldwide, with 45 genus and over 550 species found in Türkiye (Kahraman et al., 2009; Alsaraf et al., 2021).

Teucrium sp. (germander) having 300 species, can be seen naturally in the temperate zones of Asia, Europe, and North Africa (Bukhari et al., 2015; Crespo et al., 2018; Navarro, 2020; Sadeghi et al., 2022). *Teucrium chamaedrys* subsp. *chamaedrys*, a rhizomatous perennial herb, is seen in forest clearings, steep cliffs, slopes and barren pastures from sea level to 1800 m. in Anatolia (Özcan, 2020). The taxa can grow up to 20 cm. height. Its leaves have a rectangle aspect of 1.4×1.8 cm, and the spike flowers are 12-20 cm long with pink color (Tekin, 2007; Küçük et al., 2006; Giuliani et al., 2021; Dönmez and Önal, 2023) (*Figs. 1* and *2*). *Teucrium polium*, a perennial aromatic plant, is found throughout South-Western Asia, Europe (the Mediterranean region), and North Africa (Djabou et al., 2012; Rahmouni et al., 2021). It can grow to a height of 20 to 50 cm and its sessile, oblong or linear leaves are about 3 cm. Its small, white flowers in clusters are fragrant (Bahramikia and Yazdanparast, 2012; Elmasri et al., 2016) (*Figs. 3* and *4*). Studies conducted on these species generally show that the isolated chemical compounds exhibit significant effects such as antibacterial, antifungal, anti-tumor and insect protection (Stankovic et al., 2012; Belmakki et al., 2013; Raei et al., 2013; Asghari et al., 2020; Catinella et al., 2021; Dönmez, 2022; Al-Shaebi et al., 2023; Tafrihi et al., 2023). Cultivation of the plants are of great importance for the protection and sustainability of plants and providing the necessary material for their use in different industries. These plants having medicinal and aromatic importance are not commonly cultivated and are usually gathered directly from the wild (Kostas et al., 2022). Moreover, there are no studies related with the cultivation of these plants.

It was aimed in the study that to determine the cultivation possibilities of *Teucrium chamaedrys* subsp. *chamaedrys* and *Teucrium polium*, which have the potential to be used in arid landscape design and as medicinal and aromatic plants, to enable their use in different industries.

Materials and methods

Plant materials and establishment of field experiment

It was determined that Burdur province of Türkiye had the areas where plants grow naturally. Burdur province has a transition zone between the Mediterranean and the continental climate, and semi-arid characteristics.

For both plant species (*Teucrium chamaedrys* subsp. *chamaedrys* and *Teucrium polium*), 75 plants were collected with roots in July 2015 during the flowering period (because of the plants are in semi-shrub (suffrutescens) structure, this period is preferred.) and planted in Isparta Süleyman Demirel University (SDU) Botanical Garden, named as cultivation area. In the areas where the plants were taken, 10 plants were marked so that measurements in the natural environment could be made. Environmental characteristics and locations of the natural area where the plants taken and the cultivation area can be seen in *Table 1*. Experimental plots in the cultivation area were established in accordance with the "Randomized Complete Block Design"

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with 3 replications and 25 plants for each replication at a depth of 30 cm with a distance of 20 cm between plants. Plant measurements and analyzes were carried out for two years in 2016 and 2017. The plants were irrigated every other day between June and August. Irrigation was made by drip irrigation system. No pest or disease control was required, but weed removal was done manually.

Table 1. *Details and environmental characteristics of sampling and cultivation areas*

	Cultivation area	**Natural habitat**	
		T. chamaedrys* subsp. *chamaedrys	***T. polium***
Locality	Isparta	Burdur	Burdur
Longitude (E)	30°31’ 39	30° 15’ 25”	30° 14’ 31”
Latitude (N)	37°50’ 46”	37° 25’ 30”	37° 24’ 40”
Altitude (m)	1025	1600	1200
Relative humidity (%)	61	55	
Minimum temp. (°C)	-21	-15	
Maximum temp. (°C)	38	41	
Average ann. temp. (°C)	12.3	13.3	
Average ann. rainfall (mm)	508.3	429	

Figure 1. *Teucrium chamaedrys subsp. chamaedrys (experimental sites)*

Figure 2. *Teucrium chamaedrys subsp. chamaedrys (in habitats)*

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Figure 3. *Teucrium polium (the experimental sites)*

Figure 4. *Teucrium polium (in habitats)*

Soil analysis

Soil analyses were done on the soil samples taken both from cultivation and natural areas. Samples were taken from 0-30 cm depth in accordance with the principles reported by Jackson (1967) and dried in the laboratory until air-dry condition. Analyzes were carried out after the coarse stones were removed, the clods were hammered and the samples were screened by a 2 mm sieve. Texture was determined according to the hydrometer method as reported by Bouyoucos (1951), pH was determined according to Jackson's method (1967), $CaCO_3$ was determined by using Scheibler calcimeter. Organic matter was determined according to the Walkey-Black method, total N was determined according to the Kjeldahl method as reported by Bremner (1996), plant available P was measured according to the vanadomolybdophosphoric blue color method and exchangeable K, Ca, Mg was determined by Atomic absorption spectrophotometer (Thermo Scientific, ICE 3000 Series, UK) (Jackson, 1967). Soil available Fe, Zn, Mn, Cu was determined by atomic absorption spectrophotometer (Thermo Scientific, ICE 3000 Series, UK) as stated by Lindsay and Norvell (1978), after the soil samples were extracted with DTPA.

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Phenological observations and plant measurements

Phenological observations that number of living plants, vegetation and flowering times (the number of the days within the each year) were carried out in both natural area and cultivated plants. Plant measurements and analyzes were carried out at the end of the flowering period. Plant height and width, spike flower length were measured with a ruler, while electronic caliper was used to measure of leaf width and length. Spike length and number of flower per spike in plants were counted. SPAD-502 (Minolta Ltd., Osaka, Japan) chlorophyll meter was used to determine leaf chlorophyll content of all plants by measuring three leaves from each plant. SPAD value is the value obtained as a result of measurements between 940 and 650 nm (Monostori et al., 2016).

Plant elemental analysis

In order to determine if cultivated plants adapt to new ecological conditions, their biochemical structure as well as phenological characteristics must be determined. Plant elemental analysis were performed in the samples taken from natural environment plants and cultivated plants in flowering period when plant growth is completed. Randomly collected three plants from each plot, were dried in an oven at 65°C until constant weight was obtained. Total N content was determined as percentage by Kjeldahl method (Trikilidou et al., 2022). Atomic absorption spectrometry (Thermo Scientific, ICE 3000 Series, UK) was used to determine the mineral content (K, Ca, Mg, Fe, Cu, Mn, Zn) of plant materials (Tariq et al., 2017; Mahood, 2021). The amount of P was defined with the modifications of spectrophotometric method developed by Olsen (1954).

Statistical analysis

SPSS (ver. 22.0, SPSS Inc., USA) program was used for statistical analyses. The mean values and standard deviation values of the data were given. For comparison of measurements and analysis performed on natural and cultivated plants, significant difference was determined by independent sample T test (confidence level of 95%).

Results and discussion

The availability of metals in a soil-plant system depends on a number of factors which include pH of the soil, soil organic matter content, cationic exchange capacity as well as plant species, stage of development, and others (Kassim and Rahim, 2014). The soil of the cultivation area had a clay, the area where *Teucrium chamaedrys* subsp. *chamaedrys* naturally spreads had a clay loam and *Teucrium polium* had a sandy loam texture and were slightly alkaline (Richards, 1954). In addition, it was calcareous with high content of $CaCO_3$ and organic matter and low EC (Charman and Roper, 2000). Moreover, the soil had low content of available N and sufficient concentrations of available P and K (Bruce and Rayment, 1982; Ülgen and Yurtsever, 1995) (*Table 2*). Similar results were observed in studies conducted on the natural environment soils of these species (Obratov-Petković et al., 2008; Pavlova and Karadjova, 2012; Hilooğlu et al., 2017).

The plants transferred to the cultivation area, 72 (96%) of *Teucrium chamaedrys* subsp. *chamaedrys* and 54 (72%) of *Teucrium polium* survived. It was seen that vegetation time extended by approximately 2 months in the cultivation area, compared to the natural area. It is thought that irrigation is effective in extended this period.

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Table 2. *Physical and elemental analysis of the soil of cultivated and natural areas*

Analysis	Cultivation area	Natural area	
		Teucrium chamaedrys **subsp.** ***chamaedrys***	***Teucrium polium***
Soil type	Clay	Clay loam	Sand loam
Sand (%)	31.60	40.60	55.60
Silt (%)	28.00	24.00	24.00
Clay (%)	40.40	35.40	20.40
EC (dS/m)	2.92	1.61	1.10
Ph	7.79	7.60	7.75
$CaCO_3$(%)	18.52	7.47	20.89
Organic Mat. (%)	1.84	3.74	1.97
N (ppm)	1155	994	1249
P (ppm)	14.00	2.50	3.50
K (ppm)	1874.92	170.28	92.00
Ca (ppm)	13843.90	17065.10	15061.40
Mg (ppm)	446.83	376.53	210.06
Fe (ppm)	2.86	5.32	6.42
Cu (ppm)	2.48	0.87	0.41
Mn (ppm)	12.24	10.12	4.62
Zn (ppm)	0.92	0.33	0.31

Cultivated *Teucrium chamaedrys* subsp. *chamaedrys* plants showed statistically higher growth ($p < 0.001$) in terms of plant width and number of spikes at the second year compared to natural plants. While the plant width was 25.04 cm. in the first year and 37.45 cm. at the second year in natural plants, the width in cultivated plants increased from 27.56 cm. to 48.63 cm. The increasement of width also affected the number of spike in cultivated plants, which was 24.93 cm. in the first year, and it was 57.59 cm. in the second year. However, no statistical change was observed in plant height, leaf characteristics and flower size (*Table 3*).

Teucrium polium had statistically higher growth in cultivated plants than natural plants, by taking into account of two year under cultivation, which influenced almost all the measured parameters except for number of flower per spike. There was a significant difference in plant height and width (17.74 cm., 48.49 cm. respectively) in cultivated plants compared to naturally grown, at the second year. While the number and the length of spikes was found as 160.20 cm. and 9.40 cm., respectively, in natural plants, it was determined 192.40 cm. and 11.99 cm. in cultivated plants. Moreover, the development of spikes in cultivated plants is higher than in natural environment plants (*Table 4*). In the study done by Djebau et al. (2012) the length of spikes of *T. polium* were found 10-25 cm.

One of the primary indicators of a leaf's capacity for photosynthetic activity and the health of the plant is its chlorophyll concentration, the most crucial pigment needed for photosynthesis. At the second year, the SPAD values in *T. chamaedrys* were found to be 47.54 to 51.58 in the natural and cultivation areas, respectively, and *T. polium* 42.53 to 45.87. In the seed production study done on the same species by

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Dönmez and Önal (2023) the SPAD value was 52.70 and 53.60 for *T. chamaedrys*, natural and cultivated plants, respectively, it was found as 49.90 in natural and 52.53 in cultivated *T. polium*. SPAD value was also determined as 49.80 in *Teucrium* species (Manetas et al., 1998).

Quality is as important as yield in medicinal and aromatic plants. Macro and micro nutrient elements were play an important role in plant growth and quality (Şahin, 2013). Nitrogen (N) is one of the most crucial elements for plant growth. The highest N content for *T. chamaedrys* and *T. polium* was determined as (2.75, 2.09%) in the second year cultivated plants. In the study conducted by Tunçtürk et al. (2019), the nitrogen content was determined as 0.77% in *T. chamaedrys* and 1.76% in *T. polium*. P (0.16%), K (2.33%), Ca (1.58%), Mg (0.42%), Fe (149.02), Cu (17.90 ppm) and Mn (163.03 ppm), Zn (33.65 ppm) were detected at the highest rates in cultivated plants for *T. chamaedrys* subsp. *chamaedrys*. Calcium concentrations found in tissues of *Teucrium chamaedrys* were between 2369 and 6345 mg/kg in Bulgaria (Pavlova and Karadjova, 2012) and between 324 and 4872.2 mg/kg in Serbia (Zlatić et al., 2017; Pavlova et al., 2020).

At the second vegetation period, while P (0.74%) was found as the highest amount in natural plants, K (1.56%), Ca (1.74%), Mg (0.33%), Fe (145.24 ppm), Cu (26.88 ppm), Mn (98.61 ppm), and Zn (32.53 ppm) were determined at the highest rate in cultivated plants of *T. polium*. The amount of P was reported 0.66% (Yücel et al. 2011) and 4.44 g/kg (Tunçtürk et al., 2019) in *T. polium*.

Table 3. *Plant measurements and element analysis of Teucrium chamaedrys subsp. chamaedrys*

	1st year			**2nd year**		
	Natural	**Cultivated**	***p value***	**Natural**	**Cultivated**	***p value***
Vegetation time (day)	145 ± 2.0	243 ± 6.0	<0.001	144 ± 3.5	220 ± 2.6	<0.001
Flowering time (day)	60 ± 4.1	73 ± 3.7	0.005	62 ± 2.5	77 ± 1.9	0.003
Plant height (cm)	13.22 ± 2.2	15.46 ± 3.3	0.113	14.30 ± 2.4	16.90 ± 3.8	0.041
Plant width (cm)	25.04 ± 4.3	27.56 ± 6.1	0.124	37.45 ± 6.8	48.63 ± 6.6	<0.001
Leaf length (cm)	1.52 ± 0.2	1.69 ± 0.3	0.101	1.64 ± 0.3	1.70 ± 0.3	0.103
Leaf width (cm)	1.11 ± 0.1	1.05 ± 0.1	0.265	1.13 ± 0.1	1.07 ± 0.1	0.324
Number of spike	24 ± 3.2	24.93 ± 4.6	0.508	43.10 ± 3.9	57.59 ± 9.2	<0.001
Spike length (cm)	14.78 ± 2.1	15.78 ± 3.5	0.983	14.80 ± 1.9	15.56 ± 3.4	0.494
Number of flower per spike	22.44 ± 4.9	32.25 ± 9.5	<0.001	23.20 ± 4.5	35.31 ± 9.2	0.094
SPAD value	47.70 ± 5.2	50.23 ± 5.9	0.213	47.54 ± 3.8	51.58 ± 5.5	0.028
N (%)	1.27 ± 0.0	2.45 ± 0.2	<0.001	1.37 ± 0.2	2.75 ± 0.2	<0.001
P (%)	0.10 ± 0.0	0.16 ± 0.0	0.016	0.12 ± 0.1	0.15 ± 0.0	0.590
K (%)	1.50 ± 0.1	2.33 ± 0.2	0.007	1.53 ± 0.1	2.03 ± 0.1	0.283
Ca (%)	1.49 ± 0.1	1.24 ± 0.1	0.004	1.48 ± 0.2	1.58 ± 0.2	0.730
Mg (%)	0.29 ± 0.0	0.42 ± 0.1	0.003	0.31 ± 0.1	0.34 ± 0.0	0.687
Fe (ppm)	119 ± 9.4	149.02 ± 10.1	0.012	110.45 ± 3.8	120.28 ± 4.7	0.068
Cu (ppm)	14.27 ± 0.4	17.53 ± 2.5	0.135	15.25 ± 1.9	17.90 ± 1.7	0.214
Mn (ppm)	102.25 ± 9.8	134.45 ± 6.5	0.002	120.42 ± 5.9	163.03 ± 7.4	0.002
Zn (ppm)	27.47 ± 0.6	19.25 ± 0.4	0.002	28.24 ± 2.4	33.65 ± 3.2	0.076

p value: Significance level of the differences between natural and cultivated plant calculated by independent sample T test

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Table 4. *Plant measurements and element analysis of Teucrium polium*

	1st year			**2nd year**		
	Natural	**Cultivated**	***p value***	**Natural**	**Cultivated**	***p value***
Vegetation time (day)	166 ± 7.0	194 ± 8.5	0.015	157 ± 4.04	201 ± 4.5	<0.001
Flowering time (day)	101 ± 2.8	121 ± 4.6	0.002	103 ± 3.0	124 ± 3.1	0.003
Plant height (cm)	7.90 ± 1.4	11.39 ± 2.9	>0.001	9.80 ± 1.2	17.74 ± 3.1	<0.001
Plant width (cm)	26.40 ± 3.7	32.87 ± 6.5	0.004	29.30 ± 4.9	48.89 ± 9.2	<0.001
Leaf length (cm)	0.75 ± 0.1	1.23 ± 0.7	0.002	0.89 ± 0.1	1.40 ± 0.5	0.002
Leaf width (cm)	0.14 ± 0.0	0.31 ± 0.1	0.003	0.15 ± 0.1	0.32 ± 0.2	0.002
Number of spike	140.80 ± 10.9	159.76 ± 16.1	>0.001	160.20 ± 14.2	192.40 ± 20.4	<0.001
Spike length (cm)	6.56 ± 1.0	8.01 ± 1.6	0.001	9.40 ± 1.8	11.99 ± 2.0	<0.001
Number of flower per spike	35.31 ± 5.4	41.20 ± 4.7	0.002	41.16 ± 5.5	43.60 ± 5.8	0.211
SPAD value	35.20 ± 3.2	44.57 ± 6.6	0.137	42.53 ± 3.0	45.87 ± 6.3	0.015
N (%)	1.43 ± 0.1	1.96 ± 0.1	0.002	1.55 ± 0.1	2.09 ± 0.1	<0.001
P (%)	0.70 ± 0.1	0.50 ± 0.0	0.023	0.74 ± 0.1	0.44 ± 0.0	0.034
K (%)	1.57 ± 0.2	1.60 ± 0.2	0.880	1.45 ± 0.1	1.56 ± 0.1	0.192
Ca (%)	1.17 ± 0.1	1.42 ± 0.1	0.050	1.24 ± 0.1	1.74 ± 0.1	0.002
Mg (%)	030 ± 0.0	0.33 ± 0.0	0.882	0.31 ± 0.0	0.33 ± 0.0	0.213
Fe (ppm)	197.89 ± 13.1	296.23 ± 19.0	0.002	114.25 ± 3.7	145.24 ± 8.4	0.004
Cu (ppm)	22.62 ± 3.17	29.28 ± 3.8	0.105	20.45 ± 1.2	26.88 ± 2.7	0.023
Mn (ppm)	73.68 ± 3.6	119.92 ± 7.2	0.287	72.24 ± 2.8	98.61 ± 5.9	0.002
Zn (ppm)	26.12 ± 2.9	22.44 ± 2.7	0.102	22.41 ± 1.5	32.53 ± 2.9	0.004

p value: Significance level of the differences between natural and cultivated plant calculated by independent sample T test

Conclusion

Determining the cultivation capabilities of *Teucrium chamaedrys subsp. chamaedrys* and *Teucrium polium* grown in arid climate regions is very important both for their use in xeriscape designs and for their industrial use as medicinal and aromatic plant. As a result of the study surviving plant percentage was 96% in *Teucrium chamaedrys subsp. chamaedrys* and 72% in *Teucrium polium*. It was concluded that the cultivated plants were compatible with natural plants in terms of growth, morphological structure and nutritional content. Moreover, positive improvements were achieved in cultivated plants by taking into consideration of plant diameter and number of flowers for *Teucrium chamaedrys subsp. chamaedrys*, and plant, flower and leaf sizes for *Teucrium polium*, compared to natural plants. Further studies should be conducted to increase plant productivity and expand the industrial use of these plants.

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