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Araştırma Makalesi

Determination of Minerals and Trace Elements of Some *Salvia* Species Distributed in Kırşehir

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Abstract

This study was conducted to determine the contents of some macro and micronutrients of Salvia spp. (*Salvia aethiopis* L., *S. virgata* Jacq., *S. syriaca* L., *S. absconditiflora* Montbret & Aucher ex Bentham, *S. ceratophylla* L*., S. bracteata* Banks et Sol., *S. cyanenses* Boiss et Bal.) species growing in 17 locations of Kırşehir city. Based on the findings, it was found that phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), iron (Fe), copper (Cu), manganese (Mn) and zinc (Zn) contents of the samples obtained from the soil were 3.6-43.2 mg kg^{-1}, 120-398 mg kg^{-1}, 5344-8778 mg kg^{-1}, 134-763 mg kg^{-1}, 0.01-2.43 mg kg^{-1}, 0.03-1.27 mg kg^{-1}, 1.29-8.60 mg kg^{-1} and 0.17-1.22 mg kg^{-1}, respectively. The K, Ca, Mg, Fe, Cu, Mn, and Zn contents of the plant samples were 0.002-0.17%, 1.67-5.54%, 0.26-0.90%, 243-3479 mg kg^{-1}, 4.78-7.77 mg kg^{-1}, 4.75-97.00 mg kg^{-1} and 21.50-45.05 mg kg^{-1}, respectively. The Ca and Mg were the available macronutrients with the highest concentration, Fe was the available micronutrient with the highest concentration, which was followed by Mn, Zn and Cu elements, respectively. When the elements in the plant are evaluated, Ca, K and Zn in *S. virgata* are the most; Ca and Fe in *S. absconditiflora* is at least; in *S. cyanescens*, Mg and Mn are the most, K and Zn the least; in S. syriaca, Mg is at least; in *S. ceratophylla* Cu the most, Mn least; *S. aethiopis* Cu at least; Fe was found in excess in *S. bracteata*. As a result of the soil and plant analyses, it was determined that Salvia plants received the required plant nutrient elements sufficiently although Fe, Mn and Zn nutrient elements were deficient in soil.

Key words: *Sage, Salvia,* Soil, Plant analysis, Plant nutrient elements

Kırşehir'de Yayılış Gösteren Bazı *Salvia* Türlerinin Mineral ve İz Elementleri Tayini

Öz

Bu çalışma Kırşehir ilinin 17 farklı lokasyonunda yetişen Salvia spp. (*Salvia aethiopis* L., *Salvia virgata* Jacq., *Salvia syriaca* L., *Salvia absconditiflora* Montbret & Aucher ex Bentham, *Salvia ceratophylla* L., *Salvia bracteata* Banks et Sol., *Salvia cyanenses* Boiss et Bal.) türlerinin bazı makro ve mikro besin elementi içeriklerinin belirlenmesi amacıyla yapılmıştır. Elde edilen bulgulara göre, toprak örneklerinin fosfor (P), potasyum (K), kalsiyum (Ca), magnezyum (Mg), demir (Fe), bakır (Cu), mangan (Mn) ve çinko (Zn) içerikleri sırasıyla 3.6-43.2 mg kg^{-1}, 120-398 mg kg^{-1}, 5344-8778 mg kg^{-1}, 134-763 mg kg^{-1}, 0.01-2.43 mg kg^{-1}, 0.03-1.27 mg kg^{-1}, 1.29-8.60 mg kg^{-1} ve 0.17-1.22 mg kg^{-1} arasında bulunmuştur. Bitki örneklerinin K, Ca, Mg, Na, Fe, Cu, Mn ve Zn içerikleri sırasıyla % 0.002-0.17, % 1.67-5.54, % 0.26-0.90, % 0.01-0.03, 243-3479 mg kg^{-1}, 4.78-7.77 mg kg^{-1}, 4.75-97.00 mg kg^{-1}, 21.50-45.05 mg kg^{-1} arasında olduğu belirlenmiştir. En yüksek konsantrasyonlu yarayışlı makro besin elementi Ca ve Mg, en yüksek konsantrasyonlu yarayışlı mikro besin elementi Fe bulunmuş ve bunu azalan sırayla Mn, Zn ve Cu elementleri takip etmiştir. Bitkideki elementler değerlendirildiğinde *S.virgata'* da Ca, K, Zn en fazla; *S. absconditiflora'* da Ca, Fe en az; *S. cyanescens'* te Mg, Mn en fazla, K, Zn en az; *S. syriaca'* da Mg en az; *S. ceratophylla'* da Cu en fazla, Mn en az; *S. aethiopis* Cu en az; *S. bracteata'* da Fe fazla bulunmuştur. Toprak ve bitki analizleri sonucunda, *Salvia* bitkilerinin toprakta Fe, Mn ve Zn besin elementlerinin eksik olmasına rağmen gerekli bitki besin elementlerini yeterince aldığı belirlenmiştir.

Anahtar kelimeler: Adaçayı, *Salvia*, Toprak, Bitki analizleri, Bitki besin elementleri

Introduction

Salvia is the genus including the highest number of species in *Lamiaceae* family and known with the name "Sage" (Kocabas et al., 2007). In the world, *Salvia* genus includes approximately 1000 species and Turkey hosts 96 species and 4 sub-species (Dogan et al., 2008; Ozler et al., 2013). Sage species have an important place among the plants used for medical purposes (Ozer, 2016). It has been used in the treatment of various diseases from time immemorial until today consciously or unconsciously. For this reason, sage species have been named as *Salvia*, derived from *Salveo* meaning 'to save' in Latin (Ozkan, 2001). Many names have been used for *Salvia* species due to their therapeutic characteristics and *S. aethiopis* has been named as abyssinian sage and *S. virgata* has been named as erysipelas (Ozkan, 2001).

Salvia aethiopis L., belonging to *Salvia* genus is a biennial or perennial, herbaceous plant, with a height of 25-60 cm and grows on steppes, volcanic and limestone slopes, fallow fields and road-sides and it may be seen up to a 2100 m altitude (Ozer, 2016). Medically, it has an antioxidant effect (Tosun et al., 2009). *Salvia virgata* Jacq. is a perennial plant and it is a herbaceous species which can reach to an height of 30-100 cm and it can spread in every region of Turkey at an altitude of 0-2300 m in bushes, coppice forests, pastures, fallow fields and road-sides (Karabacak, 2009; Ozer, 2016). Medically, it has antioxidant (Sarbanha et al., 2011; Alizadeh, 2013) and antimicrobial (Alizadeh, 2013) effects. *Salvia syriaca* L. is a perennial species and it is a herbaceous plant growing approximately up to 30 cm and it is observed in steppes, calcareous watersides, cultivated lands or fallow areas at an altitude of 450-1850 m (Ozer, 2016). Medically, it has antimicrobial (Karamian et al.„ 2014), antioxidant (Karamian et al., 2014; Orhan et al., 2013) and anti-cholinesterase (Orhan et al., 2013) activity. *Salvia absconditiflora* Montbret & Aucher ex Bentham is observed in rocky and limestone slopes, dry steppes, fallow areas and road-sides at altitudes of 700-2500 m (Ozer, 2016). Medically, it has an anti-tumor (Ozer et al., 2013), antioxidant, and wound healing effect (Suntar et al., 2011). *Salvia ceratophylla* L. is a biennial, lemon-scented, growing up to 30-60 cm, steady plant with an upright stem and it grows at an altitude of 300-2250 m in volcanic, limestone, gypsum slopes and fallow areas (Ozer, 2016). Medically, it has an antioxidant effect (Gursoy et al., 2012). *Salvia bracteata* Banks et Sol. is a herbaceous growing up to 50-2000 m and it can grow in every region of Turkey and medically it has an anti-microbial characteristic (Cardilea et al., 2009; Anonymous, 2017; Yilar and Kadioglu, 2018). *Salvia cyanenses* Boiss et Bal. is a perennial plant growing up to 25-70 cm and it can grow on volcanic and limestone areas and road-sides and it can be seen at 2300 m and medically it has an antiviral and antioxidant effect (Ozcelik, 2006; Karabacak, 2009; Suntar et al., 2011; Yilar and Kadioglu, 2018).

Salvia species have been used in folk medicine since ancient times due to its medical characteristics such as antibacterial, antifungal, antiviral, antiseptic, analgesic (pain killer), antispasmodic, carminative, and antidiabetic (Yilmaz and Guvenc, 2007). They are collected from their natural environment for the treatment of various diseases and the sage species used unconsciously may have a toxic effect due to the mineral matters they contain and when they are used more than adequate these materials may be harmful for people. For example, it is observed that pregnant women and mothers in breastfeeding period use herbal therapeutic products commonly, especially herbal teas are among these products in therapeutic use (Chan, 2003; Kalny et al., 2007; Rubio et al., 2012; Meena et al., 2010; Gil et al., 2011). Mineral elements have a very important place for the survival of plants and humans. When they are abundant or are deficient, they cause many problems both in human and plant lives. Plants obtain the mineral matters they need from the mineral matters hold in dissolved form in soil solution or in the solid phase of soil (Ca, Mg, K, Na, Fe, Cu, Zn, Mn) in absorbed form (Jing et al, 2012; López-Bucio et al., 2014). It has been stated that the vital activities of living things, especially plants, are affected negatively when the levels of micronutrients in soil exceed specific rates (Benavides et al., 2005). For example, although iron rate in soil is high, the rate of iron which is beneficial for plants is low. For this reason, iron deficiency is observed frequently and commonly in plants. Many plants are sensitive against iron deficiency and the iron deficiency in plants is caused by the less amount of iron in soil or no enough iron (Kobayashi and Nishizawa, 2012). For the healthy development of plants, it is required that there is adequate amount of plant nutrients in soil. However, nutrients at toxic levels in soil and negative soil conditions such as salinity, alkalinity and acidity affect plant development negatively (Karaman et al., 2007). In other words, pH value of soil and the rates of the other elements in soil and the interaction between them are quite important (Haider et al., 2004; Sarma et al., 2011).

Turkey has a quite rich variety of *Salvia* species. It is required to introduce correctly and clearly *Salvia* species, determine the main compounds they contain, inform people about them and, therefore, know the chemical mineral content of these plants and the characteristics of soil in which they grow. In this study, *Salvia* species growing in Kırşehir were collected from their natural environments in 17 different locations and 17 plant samples and 17 soil samples in total were obtained. The mineral elements of the plants and the mineral elements of the soil they grew in as well as some chemical and physical analyses were determined. The aim of this study was to determine the level of macronutrients and micronutrients of sage species, the similarities and differences between them, the compatibility of the analysis data with the permissible values, and the physical and chemical characteristics of soil in which the plants grew. Also, the study results will form a basis for many other scientific studies on sage.

Materials and Methods

Collecting soil and plant sample: The study area included Kırsehir province and some districts, where *Salvia* species grow, located in the Central Anatolia Region. Figure 1 shows the information related to the study area. Continental climate is dominant in the area and the annual average precipitation is less than 400 mm and the annual temperature average is 11.3˚C. Plant species and soil samples (0-30 cm) were obtained in 17 locations in Kırşehir province and some of its districts in the 2019 vegetation period.

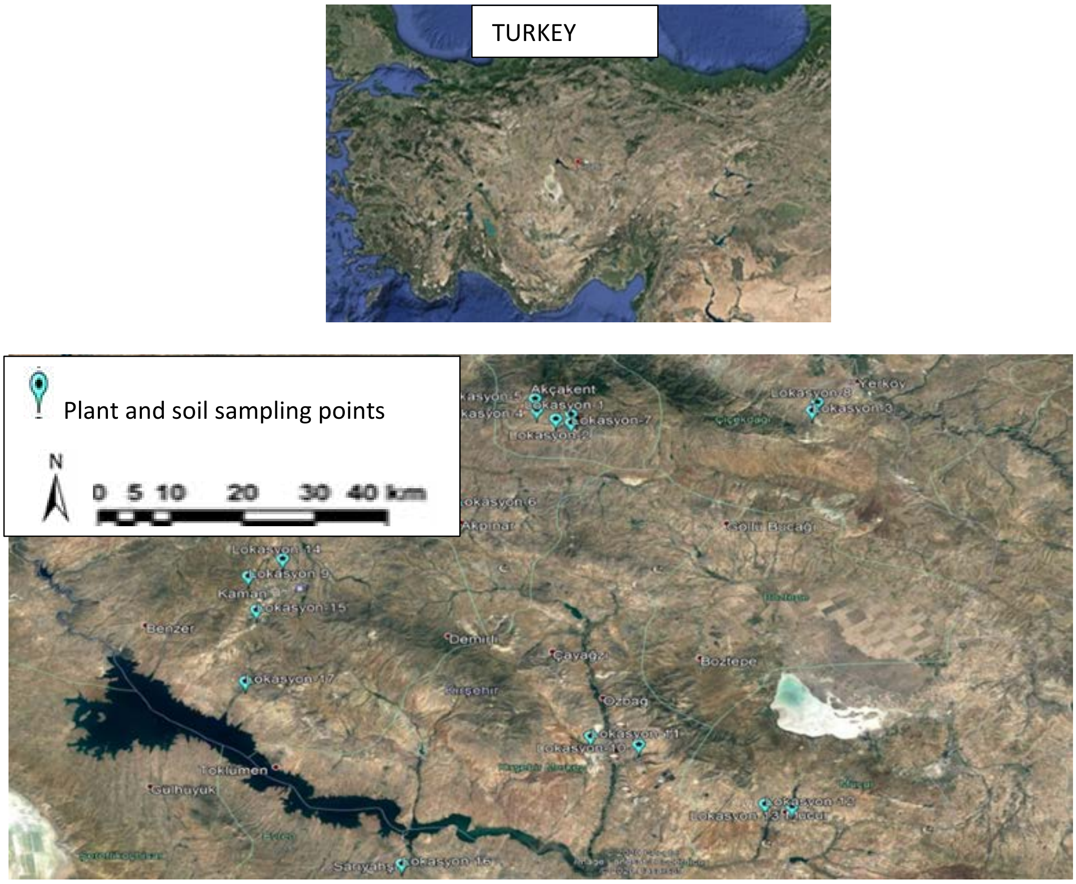

Figure 1. Plant and soil sampling site locations.

Analyzing soil samples: The soil samples were dried in the laboratory; they were passed throught with a 2-mm sieve and made ready for analysis (Jackson, 1962). The soil analyses were performed in 2 repetitions. Saturation percentage was analyzed by saturating colloid surface areas with water (Demiralay, 1993); pH and electrical conductivity determinations were analyzed in saturation paste (Black, 1965; Tuzuner,1990); organic matter was analyzed by using modified Walkey-Black method (Nelson and Sommers, 1996); total lime was analyzed by using Scheibler calcimeter (Gulcur, 1974); and texture was analyzed by using Bouyoucos hydrometer method (Bouyoucos, 1951). Available phosphorus was determined by extracting the soil samples with sodium bicarbonate (pH:8.5, 0.5 N $NaHCO_3$) (Olsen et al, 1954); macro elements (K, Mg, Ca) were determined by extracting with ammonium acetate (pH:7, 1 N NH_4OAc) (Helmke and Sparks, 1996); micro elements (Fe, Cu, Zn, Mn) and the elements going through solution by being extracted by DTPA+TEA (pH 7.5) extraction method were determined by AAS (Atomic Absorption Spectrometer) device (Lindsay and Norvell, 1978).

Analyzing plant samples: The plants were washed, rinsed with blotting paper and put into separate paper bags and dried in drying oven at 65˚C for 48 hours and then ground using a porcelain mortar. Block-fragmentation procedure was performed and homogeneous filtrates were obtained using HNO_3 and $HClO_4$ chemical substances defined by Jones and Case (1990) in 2 repetitions. The macro and micro element concentration was determined in the obtained filtrates in AAS. In the study, the limit values for interpreting some physical and chemical properties and nutrient content of soils are given in Table 1, and the standard values used in the interpretation of plant analysis results are given in Table 2.

Table 1. Limit values for interpreting some physical and chemical properties and nutrient content of Soils.

Nutrient elements	Qualification Class					References
	Very little	Little	Sufficient	Much	Too much	
Available P (mg kg^{-1})	<2.5	2.5-8	8-25	25-80	80<	Silanpää, 1990
Receivable K (mg kg^{-1})	<50	50-140	140-370	370-1000	>1000	Sumner and Miller, 1996
Receivable Ca (mg kg^{-1})	<380	380-1150	1150-3500	3500-10000	>10000	Sumner and Miller, 1996
Receivable Mg (mg kg^{-1})	<50	50-160	160-480	480-1500	>1500	Sumner and Miller, 1996
Receivable Mn (mg kg^{-1})	<4	4-14	14-50	50-170	170<	Silanpää, 1990
Receivable Zn (mg kg^{-1})	<0.2	0.2-0.7	0.7-2.4	2.4-8.0	8.0<	Silanpää, 1990
Receivable Fe (mg kg^{-1})	Little <2.5	Medium 2.5-4.5	Much >4.5			Lindsay and Norwell, 1978
Receivable Cu (mg kg^{-1})	Insufficient <0.2	Sufficient 0.2<				Follet, 1969
Total lime (g kg^{-1})	Very little lime <10	Less lime 10-50	Medium lime 50-150	Much lime 150-250	Too much lime 250<	Ulgen and Yurtsever, 1974
Organic matter (g kg^{-1})	Very little <10	Little 10-20	Medium 20-30	Fine 30-40	High 40<	Ulgen and Yurtsever, 1974
EC (dS m^{-1})	Unsalted 0-4	Slightly salty 4-8	Medium salt 8-15	Salty 15<		Maas, 1986
pH	Medium acid 4.5-5.5	Mild acid 5.5-6.5	Neutral 6.5-7.5	slightly alkaline 7.5-8.5	Strongly alkaline 8.5<	Richards, 1954

Table 2. Limit values for interpreting nutrient content of plants.

Nutrient elements	Qualification Class			References
	Deficient	Sufficient	Much	
Available P (%)	<0.15	0.15-0.50	>0.50	Jones and Case, 1991
Receivable K (%)	1.00-1.29	1.30-1.40	>1.40	Jones and Case, 1991
Receivable Ca (%)	1.50-1.99	2.00-2.50	>2.50	Jones and Case, 1991
Receivable Mg (%)	<0.30	0.30-1.50	>1.50	Jones and Case, 1991
Receivable Mn (mg kg^{-1})	<30	30-150	>150	Jones and Case, 1991
Receivable Fe (mg kg^{-1})	<40	40-300	>300	Jones and Case, 1991
Receivable Cu (mg kg^{-1})	3-4	5-50	>50	Jones and Case, 1991
Receivable Zn (mg kg^{-1})	18-24	25-100	>100	Jones and Case, 1991

Statistical Assessment of the Data: The data of the study were assessed in SPSS (IBM SPSS Advanced Statistics version 21.0.0) by using Analysis of Variance (ANOVA) and Clustering analysis was performed for the examined plant and soil data sets.

Results and Discussion

Table 3 shows the results of the analyses of some physical and chemical characteristics of the soil samples obtained from the places of the populations collected from nature in *Salvia* species. When the obtained results were observed, it was determined that saturation of the soil samples was between 44-74% and they had a loamy-clayey structure. It was determined that there was no salt in the content of the soil samples (0.19-0.45 ds m^{-1}), and the pH levels varied from mildly alkaline (7.8) to moderately alkali (8.4). It was observed that *Salvia* species was not affected and especially *Salvia absconditiflora* was not affected from the soils with variable pH range. Quite interesting results were obtained in the lime content of the soil samples. It was observed that some soil samples were calcerous (38.66 g kg^{-1}) and some samples were too much calcerous (670.35 g kg^{-1}). These results revealed that *Salvia* plant was not affected from the calcerous content in soil. *Salvia aethiopis* has a natural spread especially in the areas with limestone rocks in the nature. For this reason, excessive amount of calcerous in soil is not a negative factor for the growth of the plant. It was determined as a result of the analyses that the soil samples had a quite different content in terms of organic matter and these values varied between low (14.2 g kg^{-1}) and high (47.2 g kg^{-1}) based on samples. As a result, it may be asserted that especially *Salvia absconditiflora* and the other species were not affected from the organic matter amount in soil in terms of growth. It is reported by Yilar et al. (2020a) that S. *absconditiflora* species can grow in alkaline (pH 7.58-8.30), high $CaCO_3$ (3.78-67.45%), medium organic matter (1.39-3.71%) and clay loam soils. In another study, Yilar et al. (2020b) for salvia species water saturation 58.3%, pH 8.09, total salinity 0.008%, total calcerous ratio 14.074%, organic matter 3.501%, K_2O 98.766 kg da^{-1} and P_2O_5 3.914 kg da^{-1} have obtained data.

Table 3. Some soil analysis results of *Salvia* species samples collected from natural flora.

Plant type	Location	Depth	$CaCO_3$	OM	pH	Sat.	EC
		cm	g kg^{-1}	g kg^{-1}		%	ds m^{-1}
S. syriaca	I	0-30	101.4	34.9	8.0	55.0	0.25
S. ceratophylla	II	0-30	271.9	16.1	8.3	62.0	0.25
S. aethiopis	III	0-30	670.3	19.0	8.3	73.0	0.32
S. absconditiflora	IV	0-30	136.3	35.4	8.1	59.0	0.21
S. bracteata	V	0-30	192.5	15.8	8.3	65.0	0.45
S. syriaca	VI	0-30	253.7	25.5	8.2	61.0	0.26
S. cyanescens	VII	0-30	108.6	31.7	8.2	63.0	0.22
S. virgata	VIII	0-30	482.9	47.2	8.2	64.0	0.19
S. syriaca	IX	0-30	310.6	39.6	8.1	72.0	0.26
S. syriaca	X	0-30	294.7	20.4	8.1	61.0	0.36
S. aethiopis	XI	0-30	214.0	23.7	8.2	55.0	0.22
S. ceratophylla	XII	0-30	484.5	15.1	8.1	50.0	0.37
S. absconditiflora	XIII	0-30	223.0	16.4	8.3	60.0	0.39
S. absconditiflora	XIV	0-30	41.9	36.6	7.8	55.0	0.25
S. ceratophylla	XV	0-30	441.8	20.4	8.3	62.0	0.28
S. absconditiflora	XVI	0-30	63.8	14.2	8.2	44.0	0.25
S. bracteata	XVII	0-30	38.7	26.8	7.9	64.0	0.29

$CaCO_3$=total lime, OM=organic matter, pH=soil reaction, Sat.=saturation percentage, EC=electrical conductivity

When examining Table 4, it was determined that the soil samples included the values between low (3.6±0.976 mg kg^{-1}) and high (43.2±0.326 mg kg^{-1}) in terms of available P and between low (120±2.836 mg kg^{-1}) and high (398±5.672 mg kg^{-1}) in terms of changeable K. It was observed that *Salvia ceratophylla, S. bracteata, S. absconditiflora* and *S. aethiopis* species can grow in soil with a low level of phosphorus. The fact that K element was present in soil with varying ranges did not prevent the growth of *S. absconditiflora* especially at Location XIV. It was observed that the soil samples had much variable Ca (5344±282.847-8778±235.706 mg kg^{-1}) and it had the values between low (134±0.099 mg kg^{-1}) and high (763±0.707 mg kg^{-1}) in terms of variable Mg. It was determined that *S. virgata* species can grow in soil with low level of magnesium, especially in Location VIII.

It was found that the available Fe content of the study area soil samples was between 0.01±0.009 and 2.43±0.006 mg kg^{-1} and Fe level of the soil samples were low. Generally the lime level of the soil samples with the lowest Fe level and the soil samples with high Fe content had low level of lime. This was caused due to the fact that the soil samples generally had alkaline pH and the study results were compatible with the previous studies (Koca et al., 2019; Gunes et al., 1996).

The soil samples had a significant difference between insufficient (0.03±0.008 mg kg^{-1}) and sufficient (1.27±0.004 mg kg^{-1}) in terms of available Cu. Especially the lowest Cu level was determined in the soil in which *S. ceratophylla* species grew in Location XIII and the highest Cu level was detected in the soil sample in which *S. syriaca* species grew in Location IX. The obtained values were similar to the study conducted by Koca et al. (2019).

The available Mn content of the soils varied between 1.29±0.006 mg kg^{-1} and 8.60±0.141 mg kg^{-1}. The Mn content of the soil samples in the Locations II, III, V, X, XI, XII, XIII, XV, and XVI was very little and the Mn content of the soil samples in the other locations were low. The findings on the Mn level of the soil samples were similar to the study conducted by Eyupoglu et al. (1996). In general, the fact that the Mn levels of all the soil samples were very low did not prevent the growth of *Salvia* species.

The available Zn level in the soil samples obtained for the study varied between 0.17±0.001 mg kg^{-1} and 1.22±0.002 mg kg^{-1}. If the zinc value in soil samples is below 0.5 mg kg-1, the zinc amount in the soil is considered insufficient (FAO/WHO, 1984). Accordingly, the study area soil except for Locations I, VI, VIII, XI, and XIV had a Zn content under the critical value.

When examining eight mineral element data of the plants specified in Table 4 in terms of the limit values determined by Jones et al. (1991), all the plants in the study were found to be deficient in variable K (0.002±0.000-0.17±0.009 %). Er (2012) stated in the study conducted on the *Salvia* species growing in Konya that the K content of the plants varied between 1.45% and 2.41%, Ozcan (2005) mentioned that *Salvia aucheri* species had K of 1.36%, and he indicated that *Salvia fruticosa* species had K of 1.16%.

The plants varied between deficient (1.67±0.000%) and excessive (5.54±0.322%) rates in terms of variable Ca. It was found that the *S. absconditiflora* species in Location IV and *S. syriaca* species in Location X were poor in calcium and *S. bracteata* in Location XVII and *S. virgata* species in Location VIII. were excessive in terms of Ca concentration. In the study conducted by Basgel and Erdemoglu (2006) on medicinal plants, they stated that Ca element had the highest concentration with the rate of 2.36%. In the same study, they found that Ca element was low in rosehip (17.59 mg kg^{-1}) and high in linden (22.76 mg kg^{-1}), senna tea (26.05 mg kg^{-1}) and nettle (30.48 mg kg^{-1}). In the studies by Fernandez et al. (2002), on black and green tea plants and Lozak et al. (2002), on mint leaves, they reported that Ca (15.331 mg kg^{-1}) element had a higher rate compared to the other macro elements. Er (2012) stated that *Salvia* species had a Ca content of 1.55%, Ozcan (2005) reported that *Salvia* species had Ca of 1.11%.

The plants varied between deficient (0.26±0.001%) and sufficient (0.90±0.000%) in terms of variable Mg. It was determined that *S. absconditiflora* in Location XVI and *S. syriaca* species in Location IX were deficient in terms of Mg and *S. bracteata* species in Location XVII and the species in the other location were excessive in terms of Mg concentration. Er (2012) has reported that the Mg content of *Salvia* species is between 0.21% and 0.29%, Basgel and Erdemoglu (2006) stated that *Salvia* species had Mg of 0.21%, Ozcan (2005) reported that *Salvia* species had Mg of 0.15%, and Ozcan (2004) reported in another study that *Salvia* species had Mg of 0.42%.

As seen in Figure 2, Ca was found to be the available macronutrient with the highest concentration, which was followed by Mg and K elements, respectively (Figure 2a)

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Table 4. Soil and plant analysis results of *Salvia* species samples collected from natural flora.

	Soil analysis results								Plant analysis results						
Plant type	**P**	**K**	**Ca**	**Mg**	**Fe**	**Cu**	**Mn**	**Zn**	**K**	**Ca**	**Mg**	**Fe**	**Cu**	**Mn**	**Zn**
	mg kg^{-1}	**mg kg^{-1}**	**mg kg^{-1}**	**mg kg^{-1}**	**mg kg^{-1}**	**mg kg^{-1}**	**mg kg^{-1}**	**mg kg^{-1}**	**%**	**%**	**%**	**mg kg^{-1}**	**mg kg^{-1}**	**mg kg^{-1}**	**mg kg^{-1}**
S. syriaca	19.5±0.65	217±1.13	8778±235.7	270±3.5	0.41±0.02	0.73±0.01	5.52±0.00	0.71±0.00	0.12±0.006	2.35±0.321	0.33±0.026	366±2.12	7.30±0.07	68.75±2.47	37.52±0.27
S. cerat.	3.6±0.97	167±1.13	7878±188.5	411±0.09	0.06±0.00	0.22±0.00	3.48±0.00	0.27±0.00	0.07±0.002	3.49±0.000	0.41±0.016	253±4.38	6.78±0.04	40.25±2.47	21.50±1.06
S. aet.	7.3±0.32	275±0.56	6444±336.7	763±0.70	0.11±0.00	0.26±0.00	1.83±0.00	0.32±0.00	0.09±0.012	2.35±0.321	0.67±0.007	525±2.51	6.01±0.08	67.00±7.78	41.94±1.71
S. abs.	8.2±0.32	235±1.70	6578±141.4	237±0.64	1.64±0.00	0.75±0.00	4.91±0.03	0.30±0.00	0.13±0.012	1.67±0.000	0.35±0.003	366±4.49	6.50±0.07	75.50±2.12	32.19±0.59
S. brac.	7.3±0.97	357±1.13	7778±47.1	369±2.0	0.15±0.00	0.86±0.01	3.17±0.00	0.23±0.00	0.11±0.003	3.26±0.321	0.56±0.014	787±18.3	5.34±0.19	40.00±2.83	31.99±1.03
S. syriaca	15.4±1.30	342±0.56	6558±452.5	338±5.7	0.20±0.00	0.53±0.08	5.04±0.01	1.22±0.00	0.08±0.002	4.63±0.321	0.86±0.005	1357±0.28	5.95±0.14	97.00±4.95	31.55±0.39
S. cyan.	8.2±0.32	239±0.56	7911±141.4	263±2.4	0.71±0.00	0.25±0.00	5.33±0.00	0.27±0.00	0.02±0.009	4.93±0.749	0.86±0.010	626±3.14	6.89±0.16	77.00±2.83	28.07±1.20
S. virgata	43.2±0.32	389±0.56	5644±47.1	134±0.09	0.31±0.00	1.25±0.00	4.39±0.00	0.85±0.00	0.17±0.009	5.08±0.322	0.60±0.004	670±11.3	6.24±0.04	43.75±4.59	38.90±1.38
S. syriaca	8.2±0.32	344±1.13	8011±282.8	397±0.34	0.47±0.01	1.27±0.00	4.17±0.00	0.34±0.01	0.12±0.014	1.90±0.322	0.27±0.001	243±0.781	7.77±0.23	4.75±0.35	28.65±0.79
S. syriaca	13.3±1.62	287±1.13	6744±188.5	536±0.19	0.04±0.00	0.34±0.01	3.21±0.00	0.26±0.00	0.13±0.012	1.67±0.000	0.38±0.002	641±2.26	6.59±0.26	29.25±1.77	25.35±0.17
S. aet.	6.2±0.00	291±0.56	6644±47.1	255±3.0	0.01±0.00	0.50±0.00	3.46±0.02	0.63±0.01	0.17±0.021	3.49±0.000	0.84±0.029	687±13.4	5.60±0.21	19.50±1.41	31.64±0.18
S. cerat.	11.2±0.65	165±0.56	5744±282.8	225±0.59	0.05±0.00	0.03±0.00	2.31±0.00	0.29±0.00	0.08±0.012	2.81±0.322	0.51±0.009	317±15.5	6.38±0.32	8.25±1.77	30.99±0.28
S. abs.	7.1±1.30	398±5.67	5744±188.5	386±0.14	0.07±0.00	0.22±0.01	3.31±0.00	0.23±0.00	0.05±0.002	4.17±0.322	0.76±0.002	347±2.27	6.99±0.12	29.75±3.89	28.69±0.32
S. abs.	20.2±0.32	120±2.83	5578±47.1	535±0.14	2.43±0.00	0.27±0.00	8.60±0.14	0.56±0.00	0.04±0.015	2.13±0.000	0.49±0.000	729±22.5	5.51±0.36	18.75±1.06	37.98±0.41
S. cerat.	7.1±0.65	202±1.13	7178±47.1	316±0.79	0.48±0.03	0.55±0.00	3.01±0.00	0.42±0.00	0.01±0.000	3.80±0.643	0.72±0.001	1149±7.14	7.67±3.06	50.05±1.48	45.05±0.23
S. abs.	4.5±0.32	207±1.13	5344±282.8	166±0.34	0.48±0.02	0.39±0.00	1.29±0.00	0.26±0.00	0.12±0.002	1.90±0.322	0.26±0.000	524±7.56	4.78±0.38	19.30±1.84	39.78±0.20
S. brac.	3.6±0.32	215±1.1	7778±47.1	282±0.1	0.10±0.	0.49±0.00	4.79±0.00	0.17±0.00	0.002±0.00	5.54±0.322	0.90±0.000	3479±18.7	7.46±0.65	61.60±1.55	28.39±0.44

P=available phosphorus, K=exchangeable potassium, Ca= exchangeable calcium, Mg= exchangeable magnesium, Fe= available iron, Cu=available copper, Mn=available manganese, Zn= available zinc

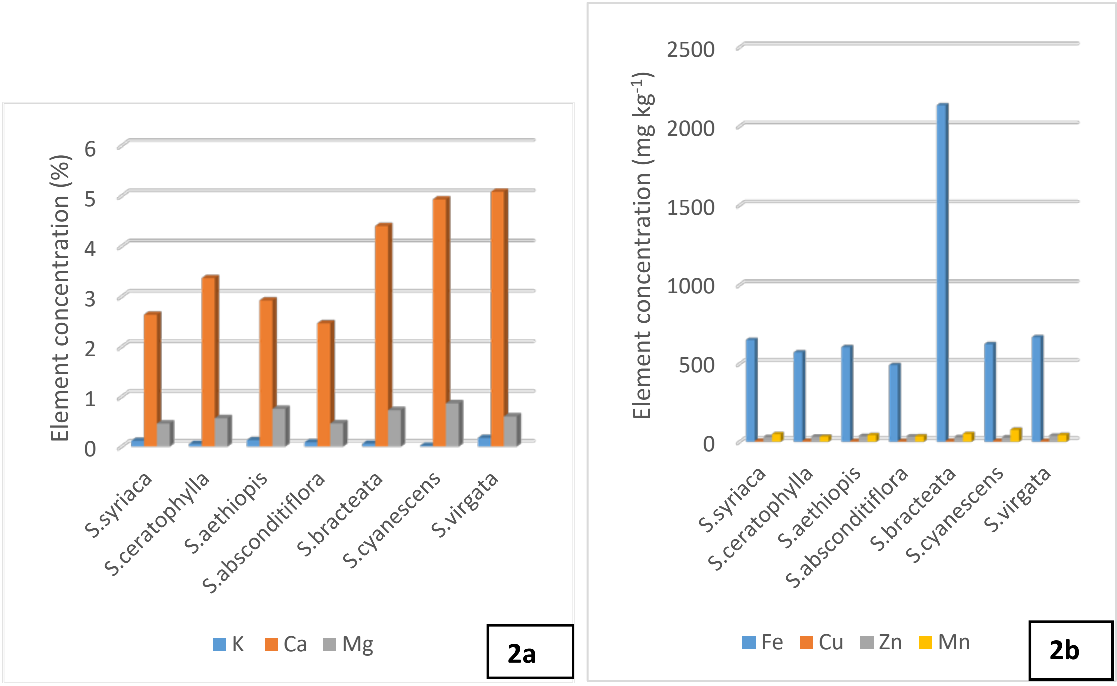

Figure 2. Macronutrient (2a) and micronutrient (2b) element concentration of *Salvia* plant samples collected from different areas.

In terms of species, Ca was determined in *S. virgata* at the highest level and in *S. absconditiflora* at the lowest level, Mg was determined in *S. cyanescens* at the highest level and in S. *syriaca* at the lowest level, K was determined in *S. virgata* at the highest level and in *S. cyanescens* at the lowest level. Ozcan (2005) reported that K was the highest macro element of *Salvia* (*Salvia aucheri*) species, which was followed by Mg and Ca elements, respectively and it was reported in another study of Ozcan (2004) on sage (*Salvia fruticosa*) that K was the highest element, which was followed by Ca and Mg elements, respectively. Er (2012) reported in the study on *Salvia* species that K had the highest macro element concentration, which was followed by Ca and Mg elements. Basgel and Erdemoglu (2006) reported that Ca had the highest macro element concentration in *Salvia* and Mg element followed it.

The available Fe content of the plants varied between sufficient (243±0.781 mg kg^{-1}) and excessive (3479±18.774 mg kg^{-1}). Fe concentration was found to be at higher amounts in the plant species compared to the other elements. All the plants except for the *S. ceratophylla* plant at Location II had excessive Fe content and Fe was found in *S. bracteata* at the highest level. Okut (2019) determined in the study conducted on the medicinal plants (*Salvia, Hypericum, Achillea, Alcea, Urtica, thymus, Frangula, Matricaria, Rheum)* in Van province that Fe concentration of the plants was 0.33-18.05 mg kg^{-1} and Kohzadi et al. (2018), found in their study conducted with different medicinal plant types that Fe content was 1.224-0.750 mg kg^{-1}. Rajan et al. (2014), determined in their study conducted on *Mimosa pudica* that Fe rates varied between 33.70 mg kg^{-1} and 308.47 mg kg^{-1} and found the highest element concentration in medicinal plants to be Fe, Mn and Zn, respectively. Er (2012) reported that in *Salvia* species the micro element with the highest rate was Fe and the plants had Fe content between 179 and 782 mg kg^{-1}. Zengin et al., (2004) reported that *Salvia* contained Fe of 981.1 mg kg^{-1}. Er (2012) reported that Fe content of the plants of *Salvia* species was 481 mg kg^{-1}, Ozcan (2004) stated that Fe content in *Salvia fruticosa* species was 565 mg kg^{-1}, Basgel and Erdemoglu (2006) reported that Fe content in *Salvia officinalis* species was 297.4 mg kg^{-1}. The results of the study are supported by many literature studies.

It was determined that *Salvia* species were deficient (4.78±0.389 mg kg^{-1}) and sufficient (7.77±0.237 mg kg^{-1}) in terms of available Cu. *S. absconditiflora* species in Location XVI was deficient in terms of Cu element and the highest Cu value was determined in *S. syriaca* in Location IX and *S. ceratophylla* species in Location XV. Rajan et al. (2014), determined in their study conducted with *Mimosa pudica* that Cu rates varied between 7.93 mg kg^{-1} and 18.21 mg kg^{-1}. Er (2012) found that Cu content of the plants included in *Salvia* species was 5.62 mg kg $^{-1}$, Ozcan (2004) reported Cu of 4.67 mg kg^{-1} in sage, and Maiga et al. (2005), found that Cu was 2.4-7.1 mg kg^{-1} in their study conducted with some medicinal and edible plants in Mali. The values obtained for Cu were compatible with the range of the data obtained in the study conducted with *Salvia* species.

The available Mn content of the plants varied between deficient (4.75±0.354 mg kg^{-1}) and sufficient (97.00±4.950 mg kg^{-1}). The lowest Mn was found in *S. syriaca* in Location IX, which was followed by *S. ceratophylla* species in Location XII. The highest Mn was found in *S. syrciaca* species in Location VI. Er (2012) determined that Mn content of the plants of *Salvia* species was 29.07 mg kg^{-1}, Ozcan (2004) found that Mn content in *Salvia aucheri* was 12.36 mg kg^{-1}, Ozcan (2004) determined that Mn content in *Salvia fruticosa* was 38.8 mg kg^{-1} and Basgel and Erdemoglu (2006) found that Mn content in *Salvia officinalis* was 32.6 mg kg^{-1}. Kirmani et al. (2011), stated in their study on eight different plant species that Mn concentration varied between 6.86-57.30 µg g^{-1} and while *Brassica rapa* had the lowest Mn concentration, *Syzygium aromaticum* had the highest Mn concentration. Lozak et al., (2002) reported that Mn content was 188 mg kg^{-1} in mint leaves.

Salvia species varied between deficient (21.50±1.061 mg kg^{-1}) and sufficient (45.05±0.233 mg kg^{-1}) in terms of available Zn. The highest Zn concentration was found in *S. ceratophylla* in Location XV and *S. aethiopis* species in Location III. Er (2012) reported that the plants of *Salvia* species had 26.35 mg kg^{-1} Zn, Ozcan (2004) stated that sage (*Salvia aucheri* var. canescens) had 33.27 mg kg^{-1} Zn and Ozcan (2004) mentioned that sage (*Salvia fruticosa*) had 28.7 mg kg^{-1} Zn, and Basgel and Erdemoglu (2006) had (*Salvia officinalis*) 48.4 mg kg^{-1} Zn. Zn was reported to have a high concentration in *Trachyspermum ammi* (53.74 µg g^{-1}) and *Foenicumlum vulgare* (53.69 µg g^{-1}) plant species (Kirmani et al. 2011).

The Fe was found to be the available micronutrient with the highest concentration in this study conducted with *Salvia* plants, seen in Figure 2b, which was followed by Mn, Zn and Cu elements, respectively. Among species, Fe was found in *S. bracteata* at the highest level and in *S. absconditiflora* at the lowest level, Mn was found in *S. cyanescens* at the highest level and in *S. ceratophylla* at the lowest level, Zn was found in *S. virgata* at the highest level and in *S. cyanescens* at the lowest level and Cu was found in *S. ceratophylla* at the highest level and in *S. aethiopis* species at the lowest level (Figure 2b). Rajan et al., (2014) reported in the study on medicinal plants, Ozcan (2004) reported in the study on *Salvia* (*Salvia fruticosa*) and Er (2012) stated in the study on *Salvia* species that Fe had the highest micro element concentration, which was followed by Mn, Zn and Cu elements, respectively. Basgel and Erdemoglu (2006) reported that Fe was the highest micro element concentration in *Salvia,* which was followed by Zn, Cu, and Mn elements, respectively. Some element content ranges in the results of the present study had similarities with the literature and some of them were different from the literature studies. This was probably caused by plant genetic structure, nutrition type, geographic characteristics of the environment they grew, species difference and analytic factors.

Hierarchical clustering analysis was applied to categorize the physical and chemical characteristics included in the soil set examined in the study based on their similarities more easily. Figure 3 shows the dendrogram resulting as a result of the hierarchical clustering analysis performed in order to categorize the similarities of 17 different locations based on the soil analysis results (Figure 3a). According to the dendrogram, it was observed that the soil samples were classified in two main groups. It was determined that in the first group, Locations 1-2-5-7-9 and 17 were perceived as similar to each other and there were other locations in the second group and they were perceived to be similar.

Hierarchical clustering analysis was applied to categorize the macronutrient and micronutrient characteristics included in the plant data set examined in the study based on their similarities more easily and the dendrogram was presented in Figure 3b. When the dendrogram demonstrating the cluster analysis results was examined, it was observed that the plants were categorized in two main groups. According to the classification in dendrogram, *S. bracteata* species in Location 17 was separated from the other species and it formed a single group. The other second group was composed of *S. ceratophylla, S. aethiopis, S. absconditiflora, S. syriaca, S. cyanescens* and *S. virgata* species and they were perceived to be similar to each other.

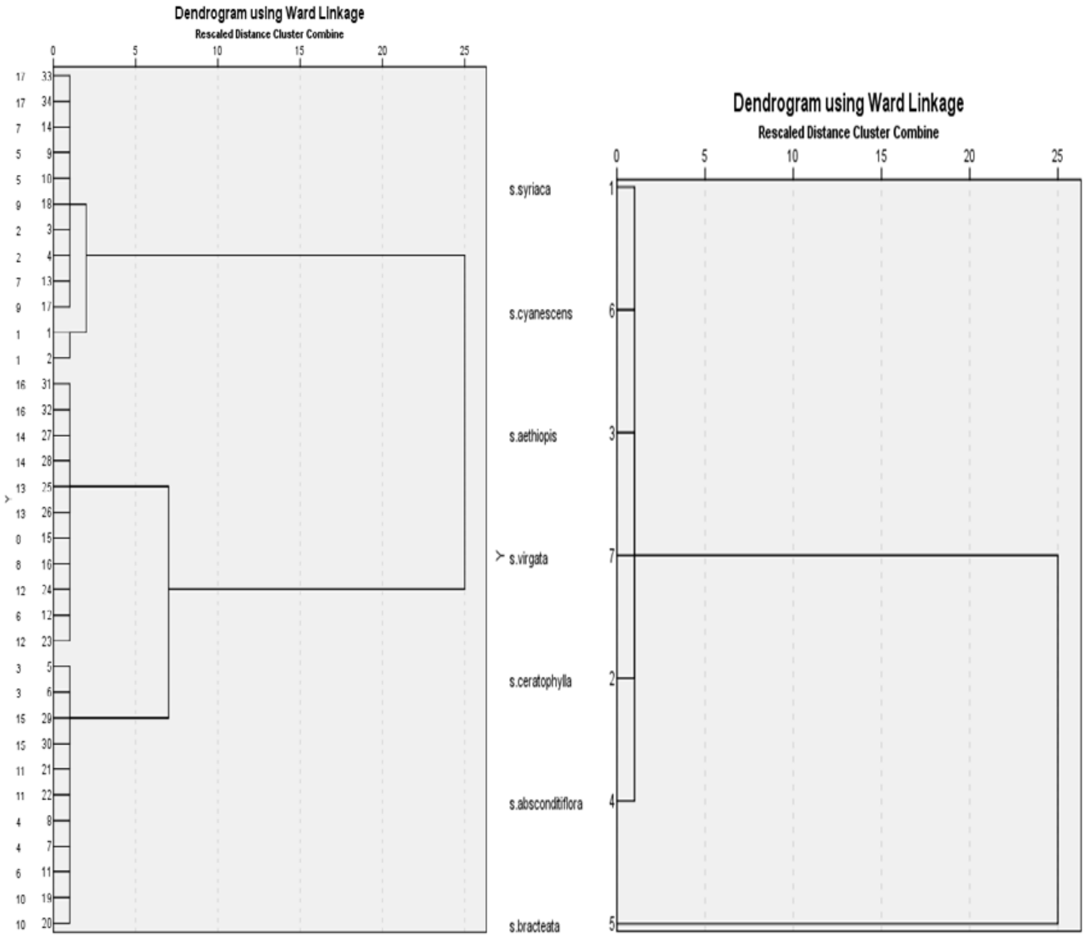

Figure 3. Dendrogram obtained by the Cluster analysis of the soil in which *Salvia* species grew.

Conclusions

The fact that the soil samples of the study area had high level of pH and lime and their organic matter amount was variable did not prevent the growth of *Salvia* species. Especially *S. ceratophylla*, *S. aethiopis*, *S. bracteata*, and *S. absconditiflora* species grew in the soil with low organic matter. It was observed that *S. aethiopis, S.virgata, S. syriaca, and S. ceratophylla* species can grow in very calcareous soil types and *S. absconditiflora and S. bracteata* can grow in the soil with variable lime content. The fact that Fe level of the soil samples was low and their Mn levels were very low and their Zn levels were insufficient did not prevent the growth of *Salvia* species. In soil samples, P, K, Mg and Cu were sufficient and Ca was excessive. Since $CaCO_3$ content of the soil samples and their pH levels were high, some mineral elements might have been at low levels. It was also observed that *S. ceratophylla, S. bracteata, S. absconditiflora* and *S. aethiopis* species can grow in the soil with low level of phosphorus, *S. ceratophylla* species can grow in the soil with low level of copper and *S. virgata* species can grow in the soil with low level of magnesium. When examined based on the limit values of the soil analyses, it was determined that especially *S. absconditiflora* species and *S. aethiopis,S. ceratophylla, S. bracteata* species were adapted to the soil types with very variable physical and chemical characteristics in flora. Ca was found to be the available macronutrient with the highest concentration in the plants used in the study, which was followed by Mg and K respectively. In terms of species, Ca was determined in *S. virgata* at the highest level and in *S. absconditiflora* at the lowest level, Mg was determined in *S. cyanescens* at the highest level and in S. *syriaca* at the lowest level, K was determined in *S. virgata* at the highest level and in *S. cyanescens* at the lowest level. K was deficient in *Salvia* plant samples, Mg, Cu, Mn and Zn were sufficient, Ca and Fe were excessive. Fe was the available micronutrient element with the highest concentration in Salvia *plants,* which was followed by Mn, Zn and Cu elements*, respectively.* Among species, Fe was found in *S. bracteata* at the highest level and in Salvia *S. absconditiflora* at the lowest level, Mn was found in *S. cyanescens* at the highest level and in *S. ceratophylla* at the lowest level, Zn was found in *S. virgata* a the highest level and in *S. cyanescens* at the lowest level and Cu was found in

S. ceratophylla at the highest level and in *S. aethiopis* species at the lowest level. Based on the soil structure, it is possible to say that there was no difference among the species in terms of mineral element.

Conflict of Interest Statement: Manuscript authors declare that there is no conflict of interest between them.

Contribution Rate Statement Summary: The authors declare that they have contributed equally to the manuscript.

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