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THE UPTAKE OF ESSENTIAL MINERAL ELEMENTS BY ENDEMIC SALVIA ABSCONDITIFLORA (GREUTER & BURDET) GROWING IN NATURAL HABITATS

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Abstract: This study was conducted to determine the uptake of essential mineral elements by endemic *Salvia absconditiflora* species growing in the natural habitats of Kırşehir province and its dependence on some physical and chemical properties of soil. The plant and soil samples were collected from 10 different locations. It was found that in the collected plants, K concentration was inadequate (0.344%), Fe had an excessive amount (541.853 mg kg^{-1}), while Cu, Zn, Mn, Mg and Ca concentrations were adequate (6.154 mg kg^{-1}, 32.610 mg kg^{-1}, 43.395 mg kg^{-1}, 0.507% and 3.650%). The soils had sandy clay loam texture, slight alkaline reaction (pH=7.92), an average amount of organic matter (3.06%), high amount of calcareous (35.61%) and low amount of soluble salts. It was also determined that soils had adequate K, Ca and Mg concentrations and 80% of the soil samples had inadequate level of P. Since Cu concentration was adequate in terms of microelement stock, concentrations of Zn were inadequate (0.292 mg kg^{-1}). It was found that *Salvia absconditiflora* plant had the ability to grow in the soil with inadequate Zn and Mn.

Keywords: *Salvia absconditiflora*, soil properties, plant nutritions

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1. Introduction

Turkey is famous for growing many medicinal and aromatic plants and microclimate richness. *Salvia* species is one of the important medicinal aromatic plants which are cultivated widely throughout the world and belongs to Lamiaceae family. 89 species of *Salvia* genus have been identified in Turkey and 45 of these are endemic (Yılar and Altuntaş, 2017).

Salvia absconditiflora (Greuter & Burdet) is a perennial plant spread between 700 m and 2500 m altitude in Turkey and has been found to be endemic in lime soils (Saadia et al., 2010; Dogan et al., 2017). It prefers dry habitat like the other *Salvia* species and survives in the soil even in drought and at high temperature typically. It develops well in the places, having low groundwater, in rocky slopes and sunny places. Alkaline, sandy, loamy soil with high lime rate and well drainage that warms easily is ideal for *Salvia* farming (Yılar and Altuntaş, 2017). It is known that *Salvia sclarea* L. is a plant tolerant to heavy metals and can be cultivated in polluted soils. It is classified as the accumulator of zinc and cadmium and the hyperaccumulator of lead (Angelova et al., 2016).

Kırşehir, the study area, is located in the Central Anatolian region and in Irano-Turanian Floristic Region. This area includes the arid and sub-arid regions of the Anatolian Plateau. No study was found in the literature including the nutrition elements concentration of *Salvia absconditiflora* (Greuter & Burdet) plant growing in natural ecosystems, the physical and chemical properties of the soil where it grows and examining the heavy metal amounts of soil.

This study was conducted to determine the uptake of basic nutrition elements by endemic *Salvia absconditiflora* (Greuter & Burdet) species growing in the natural habitats of Kırşehir province and its dependence on soil physical and chemical properties. It will lead the studies on developing the non-agricultural rural industries in order to support the rural development.

2. Material and Methods

The plant and soil samples of *Salvia absconditiflora* (Greuter & Burdet) growing in the natural flora were collected from 10 locations in Kırşehir province and its districts between May and July 2018. Soil sample was taken from 0-30 cm depth. The collected plant and soil samples were brought to Kirsehir Ahi Evran University Central Research and Application Laboratory.

2.1. Analysis Methods of Soil Samples

The soil samples from the studied areas were collected in accordance with the principles reported by Jackson (1962), were dried in the laboratory and they were sifted out through a sieve of 2 mm. The soil reaction was performed according to Thomas (1996), electrical conductivity was performed according to Rhoades

(1996), texture and total calcerous were analyzed according to Klute et al. (1994), the organic matter was analyzed according to Nelson and Sommers (1996), exchangeable K, Ca, Mg, and Na concentrations determination was performed according to Helmke and Sparks (1996), available phosphorus was analyzed according to Olsen and Sommers (1982). The analyses of the plant available microelement (Fe, Cu, Zn, Mn) was performed based on DTPA (diethylenetriamine penta acetic acid)+TEA (triethanolamine) (pH:7.3) method stated by Lindsay and Norvell (1978) and the concentrations of the elements were determined in Atomic Absorption Spectrophotometer. The available Fe was evaluated according to the reference range reported by Lindsay and Norvell (1978), Mn, Zn and P were evaluated according to Silanpaa (1990), K, Ca and Mg were evaluated according to Sumner and Miller (1996), Cu was evaluated according to Follet (1969).

2.2. Analysis Methods of Leaf Samples

Salvia absconditiflora (Greuter & Burdet) plant samples were washed with tap water and then distilled water, placed into paper bags separately without using any metal tool and dried in circulating air drying oven at 65°C until reaching the fixed weight. The dried plant samples were pounded in porcelain mortar and were grounded with a porcelain pestle. They were kept in the locked plastic bags in a dark and cool environment. The plant samples were burnt using nitric acid and perchloric acid mixture following block digestion procedure, defined by Jones and Case (1990), and the homogeneous extractions of the samples were obtained. The elemental concentrations of the total Mg, Ca, Mn, Cu, Zn and Fe were determined in Atomic Absorption Spectrophotometer and the elemental concentrations of total K and Na were determined in flame spectrometer in the clear solutions.

2.3. Statistical Analysis

The results obtained were assessed by using analysis of variance and multiple comparison test (Duncan's test) (Genc and Soysal, 2018) of the SPSS software (version 21.0). Cluster analysis was also performed on data sets obtained through the study (Ali et al., 2019).

3. Results and Discussion

Figure 1 shows the results of the soil samples analyses obtained from each location of *Salvia absconditiflora* species. When the sand, clay and silt rates were examined, the texture of studied soils was classified as sandy clay loam (Ulgen and Yurtsever, 1995), in general. Accordingly, the habitat has suitable physical properties in terms of water holding capacity, porosity and ventilation for plant growing. Dengiz et al. (2007) reported that a great majority of the surface soil of Büyükçay basin such as 67.6% was included in sandy clay loam and clay loam texture classes.

The values of basic soil properties: pH and concentration of total salt, lime, organic matter, phosphorus and potassium were classified according to the limit values reported by Ulgen and Yurtsever (1995). The pH values of soils varied between 7.63 and 8.21, and 100% of them had slight alkaline properties. The soil organic matter concentration fell into the middle range and was found to be between 1.30% and 3.53%. The lime concentration in soils was quite changeable between 3.45% and 65.28% and the area was included in a high lime class according to the average value (Figure 1).

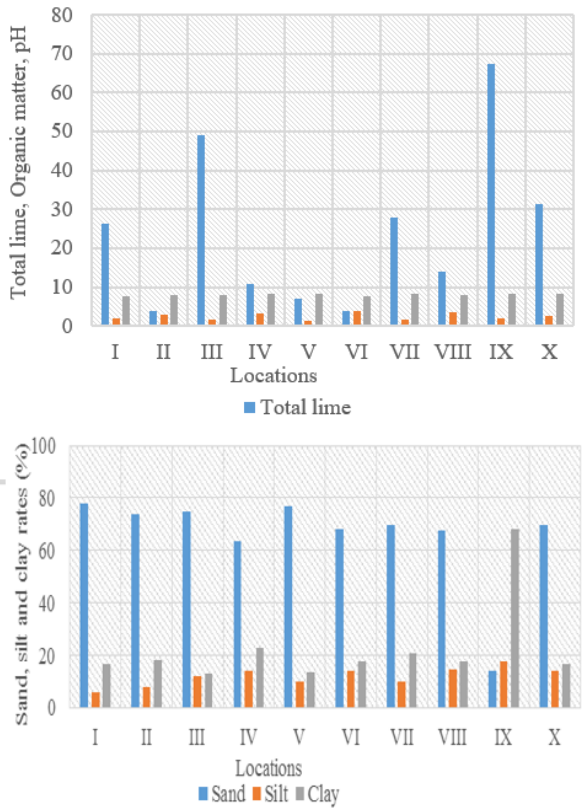

Figure 1. Analysis values of some chemical properties of soils.

The elemental concentration distribution of the soils obtained from each natural location of *S. absconditiflora* species was compared using Duncan's test by performing one-way analysis of variance (Table 1). It was found that the K concentration varied between 175.9 and 415.1 mg kg^{-1}, the available Mg between 165.410 and 761.600 mg kg^{-1}, Ca from 6525 to 10045 mg kg^{-1}, Na from 251.0 to 285.98 mg kg^{-1}, and available P varied between 2.701 and 21.215 mg kg^{-1}. It was determined that there was no problem related to K and Mg availability throughout the studied area and these nutrients were in an adequate level and the Ca had an excessive concentration.

In the studied area, the existence of the P inadequacy was determined as a result of the analyses. It was observed that *Salvia absconditiflora* plants could grow in soils with P deficit. It was observed that soils of VII, IX and X among the study locations had high pH and calcerous values and, on the contrary, the plant available P concentration was inadequate. It has also been reported in the studies by Zhou and Li (2001) that the available P concentration is low due to high amount of clay and inadequate humidity in addition to high pH and calcerous concentration.

Table 1. Duncan test results of plant nutrient concentrations of soils taken from each location belonging to *Salvia absconditiflora* species

Location number	Macro nutrient concentrations				Micro nutrient concentrations				
	K	Mg	Ca	P	Fe	Cu	Mn	Zn	Na
	mg kg^{-1}								
I	379.12±4.24^{b}	190.0±7.071^{i}	6525±63.639^{e}	3.914±0.067^{e}	0.100±0.007^{e}	0.373±0.032^{d}	3.499±0.019^{e}	0.345±0.028^{b}	251.0±0.414^{h}
II	301.10±1.41^{e}	281.4±0.099^{e}	9555±148.49^{b}	2.716±0.325^{e}	0.107±0.004^{e}	0.495±0.001^{c}	4.789±0.001^{d}	0.165±0.00^{g}	270.69±0.198^{fg}
III	238.52±0.71^{g}	223.7±0.099^{h}	7385±49.497^{d}	11.745±0.00^{b}	0.043±0.001^{f}	0.027±0.004^{g}	2.311±0.001^{g}	0.285±0.00^{de}	285.98±0.049^{a}
IV	331.50±0.71^{c}	261.3±0.198^{f}	9520±98.995^{b}	7.387±0.325^{c}	0.692±0.003^{c}	0.253±0.004^{e}	5.327±0.004^{b}	0.265±0.00^{ef}	277.27±0.098^{c}
V	290.09±1.41^{f}	165.4±0.099^{i}	6755±148.492^{e}	3.786±0.325^{e}	0.487±0.004^{d}	0.387±0.004^{d}	1.274±0.006^{i}	0.260±0.00^{f}	271.32±0.098^{f}
VI	182.51±3.53^{h}	534.3±0.149^{b}	6650±296.985^{e}	20.258±0.975^{a}	2.413±0.004^{a}	0.266±0.006^{e}	8.470±0.042^{a}	0.541±0.00^{a}	272.58±0.098^{e}
VII	242.02±1.41^{g}	410.6±0.099^{c}	9555±148.492^{b}	3.274±0.975^{e}	0.052±0.003^{f}	0.215±0.001^{f}	3.467±0.004^{ef}	0.269±0.00^{ef}	269.92±0.098^{g}
VIII	326.55±2.12^{d}	236.4±0.198^{g}	8225±49.497^{c}	6.956±0.325^{cd}	1.619±0.004^{b}	0.747±0.004^{a}	4.902±0.002^{c}	0.299±0.00^{cd}	244.09±1.198^{i}
IX	375.25±0.70^{b}	761.6±0.282^{a}	8500±141.421^{c}	5.784±0.651^{d}	0.108±0.003^{e}	0.246±0.006^{e}	1.811±0.001^{h}	0.317±0.00^{c}	278.50±1.141^{b}
X	415.11±0.00^{a}	388.8±0.099^{d}	10045±49.497^{a}	7.154±0.650^{c}	0.027±0.004^{g}	0.685±0.007^{b}	3.451±0.001^{f}	0.177±0.00^{g}	278.50±0.198^{d}

The average values indicated by the same symbol in the same column are not statistically different from each other at $P \leq 0.05$ level according to Duncan test.

Table 2. Duncan test results of macro and micro nutrient concentration of *Salvia absconditiflora* plant

Location number	K	Ca	Mg	Na	Fe	Cu	Zn	Mn
	%				mg kg^{-1}			
I	0.3905±0.0007^{a}	2.500±0.000^{e}	0.389±0.0035^{f}	0.017±0.00^{f}	639.500±0.000^{c}	6.405±0.007^{d}	24.240±1.400^{f}	28.250±0.35^{f}
II	0.3255±0.0007^{f}	5.750±0.353^{a}	0.865±0.0007^{s}	0.016±0.00^{i}	1357.525±0.035^{a}	5.860±0.0141^{f}	31.838±0.1768^{d}	93.250±0.35^{a}
III	0.3305±0.0007^{e}	3.750±0.353^{c}	0.511±0.0070^{d}	0.022±0.00^{a}	305.450±0.0707^{i}	6.160±0.0141^{e}	31.188±0.0035^{d}	7.250±0.35^{i}
IV	0.2955±0.0007^{h}	5.250±0.353^{a}	0.755±0.0028^{b}	0.017±0.00^{g}	345.725±0.0353^{h}	6.850±0.0707^{b}	28.468±0.0035^{e}	27.250±0.35^{g}
V	0.3750±0.0000^{c}	2.750±0.353^{de}	0.260±0.0014^{h}	0.017±0.00^{e}	518.450±0.0707^{e}	4.600±0.1414^{h}	39.640±0.0141^{b}	18.250±0.35^{h}
VI	0.2955±0.0007^{h}	3.000±0.000^{de}	0.494±0.0007^{d}	0.019±0.00^{c}	744.450±0.0707^{b}	5.260±0.0141^{g}	37.700±0.0141^{c}	18.250±0.35^{h}
VII	0.3155±0.0007^{g}	4.500±0.000^{b}	0.425±0.0353^{e}	0.016±0.00^{h}	250.050±0.0707^{i}	6.735±0.0212^{c}	20.760±0.0141^{g}	38.450±0.07^{e}
VIII	0.3905±0.0007^{a}	2.500±0.000^{e}	0.346±0.0028^{g}	0.019±0.00^{b}	369.075±0.0353^{f}	6.460±0.0141^{d}	31.773±0.0106^{d}	74.250±0.35^{b}
IX	0.3790±0.0014^{b}	3.250±0.353^{cd}	0.346±0.0035^{g}	0.012±0.00^{i}	364.750±0.0707^{g}	7.260±0.0141^{a}	37.338±0.0177^{c}	67.250±0.35^{c}
X	0.3455±0.0007^{d}	3.250±0.353^{cd}	0.681±0.0212^{c}	0.018±0.00^{d}	523.550±0.0707^{d}	5.945±0.0070^{f}	43.160±0.0141^{a}	61.500±0.00^{d}

Table 1 indicated that according to microelement levels of the soil samples, the plant available Fe concentration varied between 0.027 and 2.413 mg kg^{-1}, Mn between 1.274 and 8.470 mg kg^{-1}, Zn 0.165 and 0.541 mg kg^{-1}, and Cu varied between 0.027 and 0.747 mg kg^{-1}. Accordingly, it was found that in all of the soil samples, there was inadequacy of Mn, Fe adequacy limit, while Zn and Cu were inadequate in 10% of the soil samples and adequate in 90% of the soil samples.

The results of the analyses performed to determine some of the macro and micro nutrition elements of *Salvia absconditiflora* plant were assessed via Duncan's test by performing one-way analysis of variance and were presented in Table 2. The concentration of K in plants varied between 0.30% and 0.39%, Ca from 2.50% to 5.75%, Mg 0.26%-0.87% and Na 0.01%-0.02%. When the micro nutrition elements of the plant samples were examined, it was found that Fe was between 250.050 and 1357.525 mg kg^{-1}, Cu was between 4.600 and 7.260 mg kg^{-1}, Zn was between 20.760 and 43.160 mg kg^{-1} and Mn was between 7.250 and 93.250 mg kg^{-1}. It was observed that K was inadequate in all of the collected plant samples and these plants had high concentration of Ca and adequate level of Mg. In all of the study soil samples, K was at an adequate level and all the plants had inadequate K due to the antagonistic effect of Ca on K. The Mn inadequacy was determined mostly in the plants in III location, Zn inadequacy was determined in the plants in VII location, and Cu inadequacy was determined in the plants in V location. In general, the micro element levels of the plants were found to be adequate based on their average values.

Sardans et al. (2004) have stated that there is a low rate of extractable P concentration in the calcareous, alkaline soils with high pH. It has been reported in a study examining the growth of *Pinus halepensis*, *Rosmarinus officinalis* and *Cistus albidus* in calcareous and siliceous soils in PACA region of Southeastern France that there was higher yield from the calcerous-rich soils and based on the chemical analysis compound of calcerous soils, the available P was 44.67 mg kg^{-1}, Ca was 9.33 mg kg^{-1}, K was 590.20 mg kg^{-1}, Mg was 106.02 mg kg^{-1} and the Ca levels of the soils with high pH were high. When Ca is high in the soils of arid regions, it has an antagonistic effect on absorption of some nutrition macro and micro elements. Many studies have revealed that high concentration of Ca ion reduces the effectiveness of P in soil and K, Fe and other elements are converted into forms that plants cannot benefit. It has been reported that the presence of high concentration of K in soil does not make a harmful effect on plants contrary to excessive nitrogen and P or excessive amount of K that negatively affects the intake of Fe and Zn by plants (Bosgelmez et al., 2001). It has been revealed that the reasons of the inadequate plant available concentration of Zn in soil include high pH, clay percentage, calcerous concentration, low organic matter and moisture concentration and it was assessed as an expected result that the plant available Zn is low in the soils with high pH and calcerous concentration (Abu-Darwish et al., 2011). It was recorded that Zn was at least 95.81 mg kg^{-1} and Fe was 935.40 mg kg^{-1} in *Salvia officinalis* species in Ash-Shoubak University research farm and Cu concentration was between 7.02 and 13.07 mg kg^{-1} (Abu-Darwish et al., 2011).

The calcarous and alkaline soils of the arid and semi-arid regions with low organic matter lead the amount of plant available Fe to be inadequate by decreasing the solubility of Fe. The pH value of many soils containing calcium carbonate varies between 7.3-8.5 and the Fe solubility within these limits was at the lowest levels. In addition, the events such as soil compaction, flood, long-term precipitation or excessive irrigation cause iron inadequacy. In addition, high amount of Cu causes Fe inadequacy. Upon organic matter is bonding Cu very strongly, high amount of available Cu may be observed in the soils poor in organic matter. It has been reported that *Salvia* can grow in the soils polluted by heavy metals such as Cu and Zn in Southern Europe and it has tolerance to these metals (Bolat and Kara, 2017). It is reported by Yılar et al. (2020a) that *S. absconditiflora* species can grow in alkaline soils, high $CaCO_3$ levels, medium organic matter levels and clay loam soils. In another study, Yılar 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.

Hierarchical clustering analysis was applied to categorize the physical and chemical properties included in the plant and soil data set examined in the study based on their similarities more easily. Figure 2 shows the dendrogram obtained as a result of the hierarchical clustering analysis performed in order to categorize the similarities of 10 different locations. When the dendrogram demonstrating the cluster analysis results was examined, it was observed that the soils were categorized in two main groups. According to the classifications in dendrogram, II, IV, VII, VIII, IX, and X locations were perceived to be similar with each other in the first group and I, III, V and VI locations were perceived to be similar in the second group.

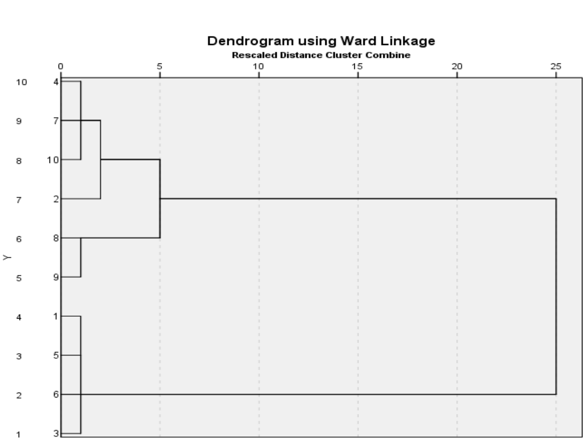

Figure 2. Dendrogram obtained by Cluster analysis of *Salvia absconditiflora* species.

4. Conclusion

In all of soil samples taken from Kırşehir province and its districts, potassium was adequate but all of the plants had inadequate K and this may be associated with the antagonistic effect of Ca on K. It was observed that K concentration in most of the plant sample is included in these limit values. According to the results, Ca concentrations in the soil and plant samples were parallel to each other and this was supported by the previous studies, as well. It was found that Zn, Mn and Cu had a high concentration in the plant samples of some areas included in the study.

Studied soils belongs to the class of alkaline soils with high pH and high calcerous concentration and these conditions negatively affected mainly Mn intake. It was determined that the studied soils with average amount of organic matter had inadequate P concentration for plant growth, but 70% of them were adequate in terms of K and 80% of them were adequate in terms of Mg and all of them were adequate in terms of Ca availability for plants. According to the plant analysis results, 100% of the plant samples had inadequate K concentration, an excessive concentration of Fe and adequate levels of Ca, Mg, Mn, Cu and Zn. As a result of the analysis performed with *Salvia absconditiflora* plant and soil, it was determined that although Mn nutrition elements were inadequate in the soil, the plants absorb these nutrition elements adequately. It also could be conclude that soils in III, VII, IX and X locations had the most suitable properties for cultivation of *Salvia absconditiflora*.

Author Contributions

All tasks made by the single author of the manuscript; A.A.A.B. (100%). The author reviewed and approved final version of the manuscript.

Conflict of Interest

The author declared that there is no conflict of interest.

Ethical Consideration

Ethics committee approval was not required for this study because of there was no study on animals or humans.

References

Abu-Darwish M, Al-Fraihat A, Dalain S, Afifi F, Al-Tabbal J. 2011. Determination of essential oils and heavy metals accumulation in Salvia officinalis cultivated in three intra-raw spacing in ash-shoubak, Jordan. Int J Agri Biol, 13: 981-985.

Ali Y, Gashaw A, Abate A. 2019. Genetic divergence and clustering of Ethiopian fenugreek (trigonella foenum-graecum L.) genotypes in South Wollo zone of Amhara region, Ethiopia. BSJ Agri, 2(4): 203-211.

Angelova VR, Ivanova RV, Todorov GM, Ivanov KI. 2016. Potential of Salvia sclarea L. for phytoremediation of soils contaminated with heavy metals. Int Schol Sci Res Innov, 10(12): 780-790.

Bolat I, Kara O. 2017. Plant nutrients: Sources, functions, deficiencies and excesses. J Bartin Fac of Forest, 19(1): 218-228.

Bosgelmez A, Bosgelmez I, Savasci S, Paslı N. 2001. Ecology-II (Soil), Başkent Cliche Printing, Ankara, Türkiye.

Dengiz O, Gol C, Baskan O. 2007. Buyukcay basin (Çankırı) soil characteristics and mapping. J Artvin Coruh Univ Fac Forest, 8(1): 46-58.

Dogan G, Hayta Ş, Demirpolat A, Bağcı E. 2017. Composition of the essential oil of endemic Salvia cryptantha (Lamiaceae) Montbret & Aucher ex bentham from. Hacettepe J Biol Chem, 45(3): 315-320.

Follet RH. 1969. Zn, Fe, Mn and Cu in Colorado Soils. Ph. D. Dissertation. Colorado State University, Colorado, US.

Genç S, Soysal Mİ. 2018. Parametric and nonparametric post hoc tests. BSJ Eng Sci, 1(1): 18-27.

Helmke PA, Sparks DL. 1996. Lithium, sodium, potassium, rubidium, and cesium, in Sparks, D.L., (Eds). Methods of Soil Analysis, Part 3, Chemical Methods, SSSA Book Series Number 5, SSSA., Madison, WI, US, pp: 551-574.

Jackson ML. 1962. Soil chemical analysis. Advanced course. 2nd ed. University of Wisconsin, Madison, US.

Jones JR, Case VW. 1990. Sampling, handling, and analyzing plant tissue samples, chapter 15. In R.L. Westerman (ed) Soil Testing and Plant Analysis, Third Edition, SSSA, Madison, Wisconsin, US, pp: 390-420.

Klute A, Weaver RW, Mickelson SH, Sparks DL, Bartels JM, Dane JH, Topp G. 1994. Methods of soil analysis: Part 3-Chemical Methods. Soil Science Society of America Book Series, Madison, Wisconsin, US.

Lindsay WL, Norvel WA. 1978. Development of DTPA soil test for Zn, Fe, Mn and Cu. Soil Sci Soc Amer J, 42(3): 421-428.

Nelson DW, Sommers LE. 1996. Total carbon, organic carbon and organic matter. In: Sparks, D.L. (Ed). Methods of Soil Analysis. Part 3, Chemical Methods, ASA and SSSA, SSSA Book Series No: 5, Madison, WI, US, pp: 961-1010.

Olsen SR, Sommers LE. 1982. Phosphorus availability indices. Phosphorus soluble in sodium bicarbonate. Methods of soils analysis. Part II. Chemical and microbiological properties. Editors: A.L. Page, R.H. Miller, D.R. Keeney, pp: 404-430.

Rhoades JD. 1996. Salinity: Electrical conductivity and total dissolved gasses. In Sparks, D.L. (ed) Method of Soil Analysis: Chemical Methods. Part 3. SSSA, Madison, WI, US, pp: 417-437.

Saadia Z, Ozcan M, Bagci Y, Unver A, Arslan D, Durak G, Er F, Saglam C. 2010. Chemical composition of the essential oil of Salvia cryptantha. JEOBP, 13: 200-204.

Sardans J, Roda F, Penuelas J. 2004. Phosphorus limitation and competitive capacities of Pinus halepensis and Quercus ilex subsp rotundifolia on different soils. Plant Ecol, 174: 305-317.

Silanpää M. 1990. Micronutrient assessment at country level: An international study. In: FAO Soils Bulletin. N.63. Rome, Italy.

Sumner ME, Miller WP. 1996. Cation exchange capacity and exchange coefficients. In D.L. Sparks (ed.) Methods of soil analysis, Part 3. Chemical methods. Soil Science Society of America, Book series no. 5, US.

Thomas GW. 1996. Soil pH and Acidity. In D.L. Sparks (ed) Method of Soil Analysis: Chemical Methods. Part 3. SSSA, Madison, WI, US, pp: 475-491.

Ulgen N, Yurtsever N. 1995. Fertilizer and manure Turkey directory, general directorate of rural services. Soil and Fertilizer Research Institute Publication, Publication No: 209, Technical Publications No: 66-4. Printing, Ankara, Türkiye.

Yılar M, Altuntaş E. 2017. Determination of some physical properties of perennial and perennial sage seeds (Salvia viridis L., Salvia cryptantha Montbret et Aucher). Mediterr Agri Sci, 30(2): 137-141.

Yılar M, Bayar Y, Abacı Bayar AA, Genç N. 2020b. Chemical composition of the essential oil of Salvia bracteata Banks and the biological activity of its extracts: antioxidant, total phenolic, total flavonoid, antifungal and allelopathic effects. Botanica serbica. 44(1): 71-79.

Yılar M, Bayar Y, Abacı Bayar AA. 2020a. Allelopathic and Antifungal potentials of endemic Salvia absconditiflora Greuter & Burdet collected from different locations in Turkey. Allelopathy J, 49(2): 243-256. DOI: 10.26651/allelo.j/2020-49-2-1268.

Zhou M, Li Y. 2001. Phosphorus-Sorption characteristic of calcareous soils and limestone from the Southern Everglades and Adjacent Farmlands. Soil Sci Soc America J, 65: 1404-1412.