



The impact of altitude and soil properties on the essential oil components of wild Libyan *Salvia fruticosa* Mill. from Al-Jabal Al-Akhdar area

Sohila A Mousa¹, Sabah H Lamloom^{2*}, Mariem F Al-Barghathi³

Botany Department, Science Faculty, Derna University, Libya

² Botany Department, Science Faculty, Omar Al-Mukhtar University, Libya

³ Botany Department, Science Faculty, Benghazi University, Libya

Abstract

Salvia fruticosa Mill. (Syn. *S. triloba* L.) is one of the most used medicinal plant in Al- Jabal Al-Akhdar, Libya. Plant materials were collected from three different sites (Alwasita, Sidi Khaled and Wadi Al-kuf) of Al-Jabal Al-Akhdar area during spring season of the year (2022). Essential oils (EOs) were isolated from fresh aerial parts of the plant species growing wild by hydrodistillation. The chemical composition of EOs has been carried out by Gas Chromatography and GC Mass spectrometry (GC/MS). Chemical and physical properties of soil samples from the three locations were estimated. One-way ANOVA method was conducted to analyze the obtained data using with Least Significant Difference (LSD) test. The results indicated that oil percentages obtained from the altitudes of Alwasita (360 m), Sidi Khaled (385 m) and Wadi Al-kuf (600 m) were (2.24%, 2.00%, and 1.55%, respectively), so that Alwasita area revealed the greatest quantity, and Wadi Al-kuf area represented the smallest quantity. EOs percentage and the main components of EOs from different regions were compared. As the results of the analyses 13 major components were determined, 1,8-cineole was the most abundant constituent among them. All these components differed significantly at the three different altitudes. Sand, pH, electrical conductivity, organic matter, Mg⁺⁺ and K⁺ contents were highest in lower altitude (Alwasita area). As the altitude increased, silt, clay, HCO₃⁻, Cl⁻, Ca⁺⁺ and Na⁺ showed a statistically significant increase. The range of soil pH (7.38-8.34) has a positive effect on oil yields. To improve the production of the essence of the plant species, it is recommended that this species to be cultivated in areas with alkaline soils and low altitude. In conclusion, altitude and soil properties are important factors that should be considered as they affected the yield, composition and biology of the plant extracts.

Keywords: *Salvia fruticosa*, essential oil, soil properties, region, chemical composition

Introduction

The genus *Salvia* L. is the largest in the Lamiaceae family. In the world in general, 1000 *Salvia* species are mostly found, of which 10 in Libya (Jafri and El-Gadi, 1985) [25]. These 10 species are: *S. fruticosa*, *S. aegyptiaca*, *S. lanigera*, *S. verbenaca*, *S. chudaei*, *S. spinosa*, *S. viridis*, *S. officinalis*, *S. coccinea*, *S. splendens*, (Jafri and El-Gadi, 1985) [25]. High consideration has been given to *Salvia* species because of the broad range of its biological activities (Askun *et al.*, 2010). Many studies have focused on the biological characteristics of the EOs obtained from *Salvia* species and their main compounds such as antibacterial, cytostatic (Janssen *et al.*, 1987; Stankovic, 2020) [26], antiviral (Alim *et al.*, 2009; Martins *et al.*, 2016) [3, 32] and antioxidant activities (Sarrou *et al.*, 2016) [40]. Furthermore, they are commonly used in traditional medicine to treat diarrhea, eye diseases, gonorrhea; they possess antiseptic and antispasmodic activities.

Salvia fruticosa Mill. (Syn. *S. triloba* L.) generally known as Eastern Mediterranean Sage, was used in folk medicine. Essential oils obtained from *S. fruticosa* are used in the treatment of flu (colds, cough), tonsillitis, digestive problems (stomachache, flatulence, constipation), skin disease, and wounds (Ali-Shtayah *et al.*, 2000; Carmona *et al.*, 2005; Süzgeç-Selçuk *et al.*, 2021) [5, 44, 13].

It is believed that along with the influence of altitude variations on the essential oil amounts and component proportions of the plants, soil differences also have

significant impact on these (Intrigliolo *et al.*, 1999; Kazemi *et al.*, 2017). Consequently, it is of pronounced importance for its cultivation and trade sustainability to determine the growing area where the amount of essential oil of the *S. fruticosa* plant and the amounts of the main constituents forming the essential oil are high, and to evaluate the essential oil components of this plant in relation to soil properties, since it is collected from the wild and its export has profitable significance.

In this study, an investigation was done on the effects of altitude and soil properties on the amount of essential oil and the essential oil components of wild *Salvia fruticosa* Mill. from Al-Jabal Al-Akhdar area which is part of the natural flora of the Libya.

Materials and methods

Study areas

Table (1) show compilation of *S. fruticosa* from three different sites (Alwasita, Sidi Khaled and Wadi Al-kuf) of Al- Jabal Al-Akhdar. The sites divided according to different elevation using (GPS reading).

Table 1: The GPS data for the three different locations.

Sites	Elevation (m/amsl)	Latitude	Longitude
Alwasita	360	32 47'360"N	21 39' 479"E
Sidi Khaled	385	32 44' 815"N	22 28' 072"E
Wadi Al-kuf	600	32 41' 435"N	21 38' 764"E

Soil analyses

Spring soil sample gives a more accurate picture of what will be available to the plant that year (Murdock Lloyd and Dottie Call, 2006) [35]. Therefore, three soil samples during spring season of 2022 from each site were collected from soil surface layer (30 cm) and transferred to the laboratory to determine the mechanical and chemical soil properties for the different locations. All soil samples were analyzed at the Central Laboratory (Omar Al-Mukhtar University, Al-Bayda, Libya). The soil samples were air dried, crushed and sieved through 2mm sieve and stored in polythene bags for analysis. Soil pH and electrical conductivity were determined using pH meter type (Jenway, model 3310) and (ELE, model 470) device. Soil texture (50 g soil) was determined by using hydrometer method as mentioned in (Black *et al.*, 1965) [11]. Organic matter was determined by the wet oxidation method (Walkley-Black procedure) using a potassium dichromate ($K_2Cr_2O_7$) solution in 1g of soil sample (Black, 1965) [11]. The concentration of sodium and potassium ions in the aqueous extract of the sample was estimated using a flame photometer (Jenway clinical PFP7). The determination of these calcium and magnesium by classical procedures (i.e. by non-instrumental procedures). The concentration of chlorine was estimated according to Mohr's method as mentioned in (Black *et al.*, 1965) [11]. Carbonates and Bicarbonates was measured according to the method described in (Reitemier, 1943) [39]. The soil analysis was performed in three replications.

Plant material

Plant samples collected during spring season of the year (2022) from the studied sites. New aerial parts from one plant collected from three regions. The identification of specimens was carried out by *Sylphum Herbarium* of the Botany Department, Sciences Faculty, Omar AL-Mukhtar University, El-Bayda, Libya.

Essential oils extraction of *S. fruticosa*

The essential oil was obtained by hydrodistillation of 100 g of air-dried aerial parts of *S. fruticosa* using a Clevenger-type apparatus for 2 h according to the British Pharmacopoeia specifications (Pharmacopoeia, B 1980) [37]. The oil was stored in dark glass vials at 4°C of *S. fruticosa*. The production of oils (v/w) was calculated on a fresh weight basis.

Gas Chromatography/Mass Spectrometry (GC/MS)

At the National Research Center (NRC), Cairo – Egypt, quantitative analyses of the oils were performed using GC-MS. The GC-MS analysis was carried out by a HP G 1800C Series II GCD system equipped with HP-5MS column (30 m x 0.25 mm, 0.25 μ m film thickness) was used. The transfer line was heated at 260°C. Mass spectra were acquired in EI mode (70 eV) in an m/z range of 40-700. Identification of the individual oil components was accomplished by comparison of the retention times with standard substances and by matching mass spectral data with those held in the Wiley 275 library of mass spectra. Confirmation was performed using AMDIS software and literature (Adams, 2007) [1]. For the purpose of quantitative analysis, area percents obtained by FID were used as a base. Quantities of the essential oils were determined according to the European Pharmacopoeia 4th Ed (Council of Europe, 2002) [15].

Statistical analysis

Data obtained for three replicates from plant samples from each region, was statistically analyzed by one – way analysis of variance (ANOVA) using Minitab Statistical Package (Minitab Inc., State College, PA, USA. 2010) [33]. Mean comparisons was done by Least Significant Difference (LSD) test at 5% level of significance ($p \leq 0.05$).

Results

Essential oil amount and essential oil major components

One-way ANOVA test proved that the region of study largely affected ($p \leq 0.05$) the studied components. EO percentages varied significantly among regions. They were highest in the Alwasita area and lowest in Wadi AL-Kuf area. Our findings are in consistent with previous studies, which showed that with increasing altitude, a decrease was determined in the amounts of EO in the plants (Delazar *et al.*, 2011; Mohamadi and Rajaei, 2016) [17, 34], this decrease was found to be statistically significant.

In the current research, between 43 and 50 different EO components were identified in *S. fruticosa* plants. Thirteen 13 major chemical constituents 1,8-cineole, camphor, α -pinene, caryophyllene, β -pinene, camphene, α -thujene, myrcene, α -terpinene, limonene, linalool, bornyl acetate, borneol were detected. 1,8-cineole was the highest component (Table 3).

Table 2: Effect of different locations on essential oil percentage of *Salvia fruticosa* during the spring season.

Area	Essential Oil %
Alwasita	2.24 ^a
Sidi Khaled	2.00 ^b
Wadi AL-Kuf	1.55 ^c
p -Value = 0.000	
Season	Essential Oil %
Spring	1.82
p -Value = 0.000	

Table 3: 1, 8-Cineole percentage of *S. fruticosa* at the three different locations during spring season.

Area	1,8 -Cineole
Alwasita	27.18 ^a
Sidi Khaled	24.38 ^b
Wadi AL-Kuf	26.67 ^a
p -Value = 0.027	
Season	1,8 -Cineole
Spring	23.65
p -Value = 0.000	

It can be concluded that thirteen (13) major chemical constituents of *S. fruticosa* at the three different locations were detected. The highest amounts in Alwasita area (i.e. the lowest altitude) were two components only (1, 8-cineole, caryophyllene). Similarly, the highest amounts in Sidi Khaled area were two components (camphor, α -pinene). In comparison, the highest amounts in Wadi Al-kuf area (i.e. the highest altitude) were six components (β -pinene, camphene, α -thujene, myrcene, α -terpinene, borneol). There were no significant differences among regions in the remaining three components (bornyl acetate, linalool, limonene).

In studies on the EO components of *S. fruticosa*, the most important EO component is stated to be 1, 8-cineole (Bayrak and Akgul, 1987; Leontaritou *et al.*, 2020) [9, 29]. The 1, 8 cineol content of EOs was found to vary from country to country (Skoula *et al.*, 2000; Delamare *et al.*,

20007; Giweli *et al.*, 2013; Karik *et al.*, 2018; Kocabaş and Kaplan, 2023) [18, 42, 23, 28]. These changes in EOs compositions may vary under the influence of the environment (climatic, seasonal, geographical) (Bellomaria *et al.*, 1992) [10], genetic factors (Perry *et al.*, 1999) [36] and agricultural practices (Sorrou *et al.*, 2016) and growth stages of the plant (Zigheb *et al.*, 2019).

Table 5: The chemical analysis of the soil at the experimental sites.

Locations	pH	E.C. (mS/cm)	O.M. (%)	Soluble Anions(meq/l) CO ₃ ⁻ HCO ₃ ⁻ Cl ⁻			Soluble Cations(meq/l) Ca ⁺⁺ Mg ⁺⁺ Na ⁺ K ⁺			
Alwasita	8.34	0.19	4.16	0.02	0.34	0.15	0.06	0.11	0.92	0.18
Sidi Khaled	7.38	0.21	4.58	NP	0.50	0.16	0.04	0.04	2.34	0.08
Wadi Al-kuf	7.44	0.16	3.13	NP	1.77	0.98	0.20	0.03	1.20	0.13

Based on the previous tables, it can be concluded that sand, pH, E.C, O.M, Mg⁺⁺ and K⁺ contents were highest in lower altitude (ALwasita area). As the altitude increased, silt, clay, HCO₃⁻, Cl⁻, Ca⁺⁺ and Na⁺ showed a statistically significant increase (i.e. they were highest in higher altitude, Wadi Al-kuf area). It was found that the sand content of the soils increased and the silt content decreased in a similar way the increase in altitude in the studied areas from which plants were collected. This change in soil texture was statistically significant at a 5% level. This can be elucidated by the slow maturation in the soils of high-altitude areas and the appearance of a large number of sand, gravel and stone formations (Charan *et al.*, 2013) [14]. The altitude did cause significant changes in silt and clay contents of the soils. Their contents increased with increasing altitude. The amount of organic matter in the soil samples decreased with increasing altitude (p<0.05). Erosion, that generates the transport of fine organic particles from high altitude regions to low altitude regions, is considered the cause for the lower organic matter content of soils in the higher altitude area (Wadi Al-Kuf). The effect of soil pH (7.38-8.34) on (major components) EO content showed that the mean percentage of EO increases by increasing soil pH.

One-way ANOVA test demonstrated that the region of harvest largely affected (p<0.05) the studied components and permitted to conclude that 10 components (1, 8-cineole (p<0.027), caryophyllene (p<0.001), camphor (p<0.000), α -pinene (p<0.000), β -pinene (p<0.000), camphene (p<0.000), α -thujene (p<0.000), myrcene (p<0.014), α -terpinene (p<0.007) and borneol (p<0.000) varied significantly among the regions. Three components (bornyl acetate (p<0.590), linalool (p<0.244), and limonene (p<0.339) did not vary among regions. This conclusion verifies the result of (Giweli, *et al.*, 2013) [23] ratifying that *S. fruticosa* EO chemical composition differs in line with different geographical locations. Chemical polymorphism produced by the region is connected to geographical and environmental factors, such as altitude, climate, humidity, photoperiod, temperature, soil composition or genetic factors and botanical diversity (Topçu *et al.*, 2013). In comparison, Cvetkovikj *et al.* (2015) [16] concluded that EO composition of Greek sage was not influenced by the geographical locations, which is in contrast with our findings.

Discussion

EO percentage was found to be higher in Alwasita area and this can be attributed to higher pH levels which explained by the increased activity of soil biological factors such as microorganisms and earthworms. This activity by the soil

Table 4: The mechanical analysis of the soil at the experimental sites.

Locations	Sand (%)	Silt (%)	Clay (%)	Soil texture
Alwasita	47.93	33.00	18.02	Silt
Sidi Khaled	24.91	39.06	34.96	silt clay
Wadi Al-kuf	17.18	40.18	42.17	celtic clay

minerals and nutrients are melted and accelerates the active components production in plant. Based on our findings from measurement of chemical and physical properties of soil samples, it is obvious that soil texture, soil pH, electrical conductivity (E.C), organic matter (OM), and chemical elements of the soil altogether influenced EO contents and compositions significantly. According to our study, it is recommended to investigate the environmental conditions of the location which aromatic plants will be cultivated.

These results indicated that environmental factors could have an effect on the quality of the oil, which corresponds with the results of previous work on this genus (Aziz *et al.*, 2008; El-Wahab *et al.*, 2015; Zigheb *et al.*, 2019; Kocabaş and Kaplan, 2023) [7, 22, 28]. Based on the results of this study, it was found that EO of *S. fruticosa* changes under the influence of environmental factors. The range of soil pH (7.38-8.34) has a positive effect on oil yields. To improve the production of the essence of the plant species, it is recommended that this species to be cultivated in areas with alkaline soils and low altitude.

This is likely that the detected chemical variations are due to the various climatological and geographical circumstances especially altitude related (slope side, slope percent, altitude itself, soil characteristics) factors. Also, the forces of different plant growing stages on these alterations are unavoidable. In addition to above-mentioned causes, effects of different plant genetic, biochemical and physiological capacity at different growing stages and wild growing habitats on the compartmentalization of diverse biochemical ways is commendable of great attention (Kocabaş and Kaplan, 2023) [28]. Findings from the present study that explored the effect of altitude and soil properties on the percentage of important compositions revealed that the altitude effect on the percentage of composition is statistically significant at the 0.05 level, so that as the altitude increased and the sunlight intensity dropped, the percentage of camphor and linalool were also reduced. Therefore, if *S. fruticosa* plant production is planned based on the quantities of EO components, the altitude and soil properties where the said component amounts are the highest should be taken into consideration.

References

- Adams R. Identifi cation of essential oil components by gas chgromatography/mass spectrometry, 4th ed, Allured Publishing Corp., Carol Stream, IL, USA, 2007.
- Alimpić A, Kotur N, Stanković B, Marin PD, Matevski V, Al Sheef NB, *et al.* The *in vitro* antioxidative and

- cytotoxic effects of selected *Salvia* species water extracts. *Journal of Applied Botany and Food Quality*,2015;88:115-119.
3. Alim A, Goze I, Goze HM, Tepe B, Serkedjieva J. *In vitro* antimicrobial and antiviral activities of the essential oil and various extracts of *Salvia cedronella* Boiss. *Journal of Medicinal Plants Research*,2009;3(5):413-419.
 4. Almajdoub RA, Abogmaza AF, Alaib MA. Economic importance of multi-purpose plants in al-jabal al-akhdar, Libya, 2019.
 5. Ali-Shtayeh MS, Yaniv Z, Mahajna J. Ethnobotanical survey in the Palestinian area: a classification of the healing potential of medicinal plants. *Journal of Ethnopharmacology*,2000;73(1-2):221-232.
 6. Aşkun T, BAŞER K, Tümen G, Kürkçüoğlu M. Characterization of essential oils of some *Salvia* species and their antimycobacterial activities. *Turkish Journal of Biology*,2010;34(1):89-95.
 7. Aziz RA, Hamed FK, Abdulah NA. Determination of the main components of the essential oil extracted from *Salvia fruticosa* by sing GC and GC-MS DAMASCUS. *J. AGR. SCI*,2008;24:223-236.
 8. Bahadırli NP. Economically Important Sage Species from Turkey: *Salvia fruticosa* Mill. And *S. aramiensis* Rech fil. *Current Perspectives on Medicinal and Aromatic Plants (CUPMAP)*,2020;3(1):31-42.
 9. Bayrak A, Akgül A. Composition of essential oils from Turkish *Salvia* species. *Phytochemistry*,1987;26(3):846-847.
 10. Bellomaria B, Arnold N, Valentini G, Arnold HJ. Contribution to the study of the essential oils from three species of *Salvia* growing wild in the eastern Mediterranean region. *Journal of Essential Oil Research*,1992;4(6):607-614.
 11. Black CA, *et.al.* *Methods of soil analysis*, Agronomy No 9, Part (2). The American Society of Agronomy, Inc. Publisher. Madison, Wisconsin USA, 1965.
 12. Boukhary R, Aboul-Ela M, Al-Hanbali O, El-Lakany A. Chemical Constituents from *Salvia fruticosa libanotica*. *Pharmacognosy Journal*, 2018, 10(1).
 13. Carmona MD, Llorach R, Obon C, Rivera D. “Zahraa”, a Unani multi component herbal tea widely consumed in Syria: components of drug mixtures and alleged medicinal properties. *J. Ethnopharmacol*,2005;102:344-50.
 14. Charan G, Bharti VK, Jadhav SE, Kumar S, Acharya S, Kumar P, Srivastava RB. Altitudinal variations in soil physico-chemical properties at cold desert high altitude. *Journal of soil science and plant nutrition*,2013;13(2):267-277.
 15. Council of Europe. *European Pharmacopeia*. (4th Ed.), Strasbourg Cedex, France, 2002, 183–184).
 16. Cvetkovikj IG, Stefkov M Karapandzovam, Kulevanova S. Essential oil composition of *Salvia fruticosa* Mill. populations from Balkan Peninsula. *Macedonian Pharmaceutical Bulletin*,2015;61(1):19-26.
 17. Delazar A, Bahmani M, Shoar HH, Tabatabaei-Raisi A, Asnaashari S, Nahar L, *et al.* Effect of altitude, temperature and soil on essential oil production in *Thymus fedtschenkoi* flowers in Osko and surrounding areas in Iran. *Journal of Essential Oil-Bearing Plants*,2011;14(1):23-29.
 18. Delamare APL, Moschen-Pistorello IT, Artico L, Atti-Serafini L, Echeverrigaray S. Antibacterial activity of the essential oils of *Salvia officinalis* L. and *Salvia triloba* L. cultivated in South Brazil. *Food chemistry*,2007;100(2):603-608.
 19. El-Barasi YMM, Saaed MWB, Threats to plant diversity in the north eastern part of Libya (El-Jabal El-Akhdar and Marmarica Plateau). *Journal of Environmental Science and Engineering A*,2013;2:41-58.
 20. El-Darier SM, El-Mogaspri FM. Ethnobotany and Relative Importance of Some Endemic Plant Species at El-Jabal El-Akhdar Region (Libya). *World Journal of Agricultural Sciences*,2009;5(3):353-360.
 21. El-Mokasabi FM, Al-Sanosi MF, El-Mabrouk RM. Taxonomy and Ethnobotany of Medicinal Plants in Eastern Region of Libya. *IOSR Journal of Environmental Science, Toxicology and Food Technology (IOSR-JESTFT)*,2018;12(8):14-23.
 22. El-Wahab A, Mohamed A, Toaima WI, Hamed ES. Effect of different planting locations in Egypt on *Salvia fruticosa* mill. *Plants. Egyptian Journal of Desert Research*,2015;65(2):291-307.
 23. Giweli AA, Džami AM, Soković M, Ristić MS, Janačković P, Marin PD. The chemical composition, antimicrobial and antioxidant activities of the essential oil of *Salvia fruticosa* growing wild in Libya. *Archives of Biological Sciences*,2013;65(1):321-329.
 24. İpek A, Gürbüz B, Bingöl MÜ, Geven F, Akgül G, Rezaeieh KAP, Coşge B. Comparison of essential oil components of wild and field grown *Salvia cryptantha* Montbert & Aucher ex Benth, in Turkey. *Turkish Journal of Agriculture and Forestry*,2012;36(6):668-672.
 25. Jafri SMH, EL-Gadi A. *Flora of Libya*. Al Faateh University, Tripoli, 1985.
 26. Janssen AM, Scheffer JJC, Baerheim Svendsen A. Antimicrobial activity of essential oils: a 1976–86 literature review. *Aspects of the test methods. Planta Medica*,1987;53:395–398.
 27. Karik U, Çınar O, Tunçtürk M, Sekeroglu N, Gezici S. Essential oil composition of some sage (*Salvia* spp.) species cultivated in İzmir (Turkey) ecological conditions. *Indian Journal of Pharmaceutical Education and Research*,2018;52(4):102-107.
 28. Kocabaş Oğuz I, Kaplan M. The effect of altitude and soil properties on the essential oil components of Turkish sage (*Salvia fruticosa* Mill.). *Boletín Latinoamericano y del Caribe de Plantas Medicinales y Aromáticas*, 2023, 22(2).
 29. Leontaritou P, Lamari FN, Papatotiroopoulos V, Iatrou G. Morphological, genetic and essential oil variation of Greek sage (*Salvia fruticosa* Mill.) populations from Greece. *Industrial crops and products*,2020;150:112346.
 30. Louhaichi M, Salkini AK, Estita HE, Belkhir S. Initial assessment of medicinal plants across the Libyan Mediterranean coast. *Advances in Environmental Biology*,2011;5:359-370.
 31. Lu Y, Foo LY. Polyphenolics of *Salvia*—a review. *Phytochemistry*,2002;59(2):117-140.
 32. Martins F, Oliveira I, Barros A, Amaral C, Afonso S, Ferreira H, *et al.* Leaf age, seasonal and annual variations in *Salvia officinalis* L. var. *purpurascens*

- biochemical characteristics. *Journal of Applied Botany and Food Quality*, 2016, 89.
33. Minitab I. Minitab 17 statistical software: Minitab Inc. State College, Pennsylvania, 2010.
 34. Mohamadi N, Rajaei P. Effects of different ecological condition on the quality and quantity of essential oils of *Artemisia persica* Boiss. Populations from Kerman, Iran. *Journal of Essential Oil-Bearing Plants*, 2010;19(1):200-207.
 35. Murdock Lloyd, Dotti Call. Managing Seasonal Fluctuations of Soil Tests". AGR-189. Cooperative Extension Service, 2006. University of Kentucky. www.ca.uky.edu.
 36. Perry RJ, Hodges JR. Attention and executive deficits in Alzheimer's disease: A critical review. *Brain*, 1999;122(3):383-404.
 37. Pharmacopoeia B. London: her majesty's stationary office. Appendix, 1980;16:186-190.
 38. Pitarokili D, Tzakou O, Loukis A, Harvala C. Volatile metabolites from *Salvia fruticosa* as antifungal agents in soil borne pathogens. *Journal of Agricultural and Food Chemistry*, 2003;51:3294-3301.
 39. Reitemeier R. Semimicroanalysis of saline soil solutions. *Industrial & Engineering Chemistry Analytical Edition*, 1943;15(6):393-402.
 40. Sarrou E, Martens S, Chatzopoulou P. Metabolite profiling and antioxidative activity of Sage (*Salvia fruticosa* Mill.) under the influence of genotype and harvesting period. *Industrial Crops and Products*, 2016;94:240-250.
 41. Shehu M, Zekaj Z. Interspecific Variation of Micromorphology of Glandular Trichomes between two *Salvia* Species in South Albania. *Journal of Life Sciences*, 2018;12:125-128.
 42. Skoula M, Abbes JE, Johnson CB. Genetic variation of volatiles and rosmarinic acid in populations of *Salvia fruticosa* mill growing in Crete. *Biochemical systematics and ecology*, 2000;28(6):551-561.
 43. Stanković M, Stević Ž, Das, Subotić DK M, Pamučar D. A new fuzzy MARCOS method for road traffic risk analysis. *Mathematics*, 2020;8(3):457.
 44. Süzgeç-Selçuk S, Özek T, Özek G, Yur S, Göger F, Gürdal MB, *et al*, The leaf and the gall volatiles of *Salvia fruticosa* Miller from Turkey: Chemical composition and biological activities. *Rec. Nat. Prod*, 2021;15:10-24.
 45. Topcu GÜLAÇTI, Öztürk M, KUŞMAN T, DEMİRKOZ AAB, Kolak U, Ulubelen A. Terpenoids, essential oil composition, fatty acid profile, and biological activities of Anatolian *Salvia fruticosa* Mill. *Turkish Journal of Chemistry*, 2013;37(4):619632.
 46. Zgheib R, Yassine C, Azzi-Achkhouty S, Beyrouthy ME. Investigation of essential oil chemical polymorphism of *Salvia fruticosa* naturally growing in Lebanon. *Journal of Essential Oil Bearing Plants*, 2019;22(2):408-430.