

Chemical Composition of the Essential Oil from Different Plant Parts of Two Important *Salvia* Species Cultivated in Semi Arid Environment

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Abstract

This study investigated the essential oil yield and chemical composition of different plant parts (leaf, flower and herbage) of *Salvia officinalis* L. and *Salvia triloba* cultivated under semi-arid conditions in Southeastern Türkiye. Plant material was obtained from the collection garden of Dicle University, Faculty of Agriculture. Essential oils were extracted by hydrodistillation using a Clevenger-type apparatus and analyzed by GC–mass spectrometry (GC/MS). Essential oil yield ranged between 1.00–1.68%, with the highest values recorded in flowers (1.68% in *S. officinalis* and 1.50% in *S. triloba*). Sixteen constituents (>1% GC area), representing 95.55–99.18% of the total oil, were identified. Monoterpenes were the dominant class (72.08–90.67%), while sesquiterpenes ranged between 8.51–26.74%. The main components of *S. triloba* were 1,8-cineole (up to 54.05%), camphor (17.66%) and β -pinene (14.44%), whereas *S. officinalis* were determined as the main components by α -thujone (31.98%), β -thujone (14.73%), 1,8-cineole (20.13%) and camphor (14.38%). Significant plant part–dependent variation was observed in essential oil composition. GGE biplot analysis explained 92.15% of total variation, confirming distinct clustering according to species and plant parts. It was determined that essential oil components varied depending on the species and harvested plant parts.

Research Article

Article History

Received	:22.12.2025
Revised	:20.01.2026
Accepted	:30.01.2026

Keywords

Salvia sp.
sage
essential oil
plant part

Citation: Kamçı, G., Tonçer, Ö., 2026. Chemical Composition of The Essential Oil From Different Plant Parts of Two Important *Salvia* Species Cultivated in Semi Arid Environment. *ISPEC Journal of Agricultural Sciences*, 10(2): 334-343.
DOI: <https://doi.org/10.5281/zenodo.19329079>

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1. Introduction

The genus *Salvia* is an perennial aromatic plant, belonging to Lamiaceae family, with about 1000 species in the World. This species are exist in the Turkish flora, as being represented by 115 taxa and 63 of which are endemic (Celep and Doğan, 2023). Pharmacological activities of *Salvia* essential oils have been well recognized for many years. Furthermore, *Salvia* species are a rich source of polyphenolic flavonoids and phenolic acids. Flavones, flavonols and their glycosides constitute the majority of flavonoids present (Lu and Foo, 2002). Wu et al. (2012) reported that over 730 secondary metabolites have been reported from *Salvia* species. The main secondary metabolite constituents of *Salvia* species are terpenoids and flavonoids. Of these, more than 80% are terpenoids, especially abietane and clerodane diterpenoids; relatively, sesquiterpenoids and triterpenoids are rare in the *Salvia* species, which is in agreement with the biosynthesis of terpenoids. Species of the genus *Salvia* contain different compounds in its essential oils, some of which are economically important since they have use as spices and flavouring agents in perfumery and cosmetics. The analysis of the essential oil composition of several *Salvia* species indicates that 1,8-cineole (eucalyptol), and borneol are its main constituents (Delamare et al., 2007). As mentioned by Figueiredo et al. (2008) essential oil composition for different organs in a medicinal plant can also largely depend on the plant part used: flowers, green parts (leaves and stems), bark, wood, whole fruits, pericarp only, or seeds or roots. Franz (1993), reported that variability of essential oil consist of factors such as individual genetic variability, variation among different plant parts and the different developmental stages; and modifications due to the environment. The distribution of essential oil constituents among different plant organs is a critical factor in optimizing cultivation strategies for economically important *Salvia* species, as both yield and chemical composition vary significantly according to organ type and developmental stage (Figueiredo et al., 2008; Dudai et al.,

1999). Organ-specific variation is primarily associated with differences in glandular trichome density and metabolic activity (Santos-Gomes and Fernandes-Ferreira, 2001). In addition, environmental conditions typical of semi-arid regions can influence secondary metabolite accumulation (Franz, 1993). Since the biological activity of *Salvia* essential oils depends directly on their phytochemical profile, identifying the most appropriate plant part and harvest timing is essential for maximizing both oil quality and industrial value. Thus, this study aim to describe relationships between plant's morphogenetic development and accumulation of essential oil for components in two *Salvia* sp.

2. Material and Methods

The experimental plants of *Salvia officinalis* and *Salvia triloba* were obtained from the collection garden of the Faculty of Agriculture, Dicle University (latitude 37°53' N, longitude 40°16' E, altitude 680 m), Türkiye. The climatic conditions of this area have continental climate features and a harsh climate prevails in the semi-arid highland climate. The summers are very hot, dry, and long, cold winters have a little irregular rain (Toncer et al., 2022). The plants were irrigated and hoewed when required during the vegetation period. To determine the essential oil content and the constituents of the various parts of the plant, the plant was harvested in the morning of May 18, 2022, when it was in full blooming. The sampling was done from a 3-year-old cultivated population, by the random collection of 3 individual samples for each plant part. After collected, plant materials were dissected into flower, leaf and herba tissues, dried at room temperature (20 ± 2 °C) and subsequently assayed for volatile constituents. Dried overground parts of the plants (about 30 g) were cut into small pieces and subjected to hydrodistillation for 3 h using a Clevenger type apparatus; and the essential oil was stored at 4 °C until GC/MS analysis (Salachna et al., 2021, Nabi et al., 2025). Gas chromatography/mass spectrometry (GC/MS) analysis conditions; Shimadzu GS MS-QP2010 ULTRA system;

Colon Rtx-Wax; (30 m x 0.25 mm Ø, 0.25 µm film thickness); Temperature Program was the following: 2 min at 40 °C // 5 °C/min increment; 4 min to 80°C //4 °C/min increment; At 240 °C; 6 min, Injector 240 °C; Carrier Gas was Helium (1.00 ml/min); Split 1:00; Mass Range m/z 40–400; It was identified by comparing the values of FFNSC1.2 and W10N14R libraries.

2.1. Statistical analysis

Data on essential oil content were subjected to ANOVA for a split plot experiment, with species as main plots and plant parts distilled

(leaf, flower, herbage) as sub plots. The differences between means were tested by 'LSD'. Statistical analyses were conducted using JMP® Pro 14. GGE- biplotanalysis was performed using GenStat 12th Edition Program.

3. Result and Discussion

No statistically significant difference was detected between the two species in terms of essential oil content in leaf, flower, and herbage samples. The results are summarized in Table 1.

Table 1. Changes in essential oil content of the leaves, flowers and herbage of experimental species

Species	Plant Part	Essential oil content(%)
<i>Salvia officinalis</i>	Leaf	1.30
	Flower	1.68
	Herbage	1.28
<i>Salvia triloba</i>	Leaf	1.00
	Flower	1.50
	Herbage	1.40
LSD (%)		ns

ns: not significant

The essential oil content obtained for leaves was 1.30%; 1.68% for flower; 1.28% for herbage of *S. officinalis*. In *S. triloba*, essential oil content ranged from 1.00% to 1.50% depending on plant part, with the lowest value recorded in leaves (1.00%), followed by herbage (1.40%) and the highest value in flowers (1.50%). Putievsky et al. (1986) reported the essential oil yield of *Salvia fruticosa* Mill. (syn. *S. triloba*) based on fresh plant material, indicating very low levels in stems (0.02%), higher values in inflorescences (0.22%), and slightly lower values in leaves (0.18%). The studies of Perry et al. (1999) showed that flowering parts of *S. officinalis* had higher oil contents (1.6 versus 1.1%) and β-pinene levels (27 versus 10%) than leaves and lower thujone levels (16 versus 31%). Veličković et al. (2003) determined that essential oil yields of the dry extracts were 3.5% (flower), 3.1% (leaf) and 1.2% (stem) in *S. officinalis*. Verma et al. (2015) stated that the essential oil yield of the individual plant parts collected during the flowering stage in spring, i.e. leaf, inflorescence and stem were found to be 0.23%, 0.60% and 0.15%,

respectively. The study of Nguyen et al. (2019) showed that the highest EO content of *S. officinalis* was obtained from flowers in floral budding (2.82 ml 100 g⁻¹) and the lowest one was also detected in flowers at after flowering stage (0.73 ml 100 g⁻¹). Flowers always contained higher levels of volatiles compared with the leaves at the same developmental stage. In aromatic plant species, essential oil biosynthesis occurs through two major metabolic pathways, namely the methylerythritol phosphate (MEP) and mevalonate (MVA) pathways, which involve complex enzymatic reactions (Rehman et al., 2016). Essential oils represent the end products of intricate biochemical processes, and their yield and composition may vary considerably depending on plant organ, genotype, soil characteristics, climatic conditions, harvest time, and geographical origin (Boelens, 1986; Salido et al., 2004; Muñoz-Bertomeu et al., 2007; Herraiz-Peñalver et al., 2013). Essential oil biosynthesis is strongly influenced by ontogenetic development, as glandular trichome density and metabolic activity differ among plant organs and phenological stages.

Furthermore, environmental factors such as temperature, solar radiation, water availability, and soil properties significantly effect secondary metabolite accumulation. Under semi-arid conditions, high light intensity and elevated temperatures may stimulate monoterpene biosynthesis as part of plant adaptive responses to abiotic stress. In the present study, the relatively stable and

comparable essential oil yields obtained under semi-arid conditions indicate that these ecological factors did not negatively affect oil production. The main constituents (>1%) of the essential oils of *S. officinalis* and *S. triloba* cultivated in Diyarbakir, Türkiye and used in the experiments are presented in Table 2.

Table 2. Changes in essential oil composition¹ of *Salvia triloba* and *Salvia officinalis* due to different plant parts

Compounds	<i>Salvia triloba</i>				<i>Salvia officinalis</i>		
	RT	Leaf	Flower	Herbage	Leaf	Flower	Herbage
β-pinene	11.46	7.10	14.44	7.93	2.99	15.19	7.37
Myrcene	11.65	6.99	2.4	4.29	4.17	1.65	2.28
Limonene	12.14	2.74	1.51	2.06	1.91	1.52	1.64
α-pinene	12.40	-	-	-	0.24	0.22	0.17
γ-Terpinene	12.67	1.08	1.69	1.06	1.04	1.02	0.91
1,8-Cineole	13.22	38.27	52.25	54.05	17.76	17.94	20.13
p-Cymene	13.60	-	-	2.63	0.93	0.47	0.59
trans-4-Thujanol	16.58	0.42	0.52	0.38	0.28	0.36	0.34
β-thujone	17.52	0.52	1.23	1.22	6.14	8.70	14.73
α-Thujone	17.74	1.12	0.82	0.80	31.98	4.02	11.26
β-Caryophyllene	17.87	11.31	8.73	6.51	-	7.74	10.44
Bornyl acetate	18.55	2.46	0.85	1.5	2.65	2.48	2.0
α-humulene	18.91	3.93	2.07	1.41	6.46	5.18	3.76
Camphor	19.52	17.66	8.92	13.53	11.16	14.38	11.82
Borneol	20.12	1.69	1.32	1.22	1.82	4.13	4.65
Valencene	24.08	0.26	1.65	0.59	7.97	13.82	6.47
Total monoterpenes (%)		80.05	85.95	90.67	83.07	72.08	77.89
Total sesquiterpenes (%)		15.50	12.45	8.51	14.43	26.74	20.67
Total identified percentage		95.55	98.40	99.18	97.50	98.82	98.56

¹Components reaching 0.5% of GC area are listed

In this study conducted with two sage species, the ratio of monoterpenes and sesquiterpenes in the essential oil varied between 72.08-90.67% and 8.51-26.74%, respectively. In total, sixteen constituents which were higher than 1% of the GC area were identified, representing 95.55-99.18% of the total area. 1,8-Cineol, camphor and β-pinene were identified as major components in *S. triloba* and thujone, 1,8-cineol and camphor were identified as major components in *S. officinalis* in the study investigating essential oil changes due to morphogenetic variability in two different sage species. Significant differences in major constituents were found in different plant parts for both species. The highest values for β-pinene in both species were found in the flower. On the contrary,

myrcene was found to be lowest in the flower. While in *S. triloba* species 1,8-cineol, which is an important component for sage species, was high in both flowers and herbage, it reached the highest value (54.05%) in the herbage. In *S. officinalis* species, the same component showed similar values in different plant parts. α-Thujone is the main component in *S. officinalis* and the highest value (31.98%) was obtained from the leaf. β-thujone, which is one of the main components in *Salvia* species, was found in the highest amount (14.73%) in the herb, while lower values (6.14%) were obtained from the leaf. While β-caryophyllene was high in the leaves of *S. triloba* (11.31%), it was not found at all in the leaves of *S. officinalis* and was high in the herbage (10.44%). Camphor, one of the main

constituents, reached the highest value (17.66%) in the leaf of *S. triloba*, while its content decreased in the flower. While in *S. officinalis* species it showed similar values, it increased in flowers. The valencene component was found to be significantly high in *S. officinalis* species, with the highest value (13.82%) found in the flower. The essential oil of *Salvia officinalis* L. in five selected clones of different origins (France, Hungary, Portugal, Romania, Czech Republic) was studied by Chalchat et al. (1998) yields of oils from dried leaves were excellent (2–3%), and higher than those previously reported. The α - β -thujone ratio varied according to origin. Overall, some of the oils were of high quality in terms of their α - and β -thujone and camphor contents. The essential oil of three-lobed sage normally has low β - and α -thujone levels (less than 5%), and the main components are 1,8-cineole (40-50%), camphor, (10%), and β - and α -pinene (10-20%)¹⁴. Karik et al. (2018) in their study examining the essential oil composition of some sage (*Salvia* spp.) species. They reported that the main component was 1,8-cineole (57.18%) in the *Salvia fruticosa* Mill. Species (syn *S. triloba*) and β -thujone (34.59%) in the *Salvia officinalis* L. species. Celik et al. (2018) determined the main components of the *S. officinalis* species grown in different locations as camphor, α -thujone and 1.8 cineole, although their ratios varied. *S. officinalis* samples collected from a wild region in China, the percentage of β -thujone was higher in leaves (14.86%) than in the flower oil (6.05%) while the ratio of α -thujone was three times higher in the flowers than in the leaf oil. Li et al. (2015) reported in their study that the essential oil composition of four *Salvia* species differed. Researchers have emphasized that the polymorphism of the chemical composition of the oils obtained from the leaves and flowers of these *Salvia* species is tissue and organ specific, and this may be due to the genetic diversity of these *Salvia* species. Nguyen et al.

(2019) determined that leaf oils and flower oils showed different profiles. α -thujone (16.7-24.7%) is the major component of leaves while it is found only in lower concentrations in the flower oils where viridiflorol was detected as the main component (20.9-28.6%). β -thujone was present both in leaves and flowers and varied from 2.9% (in flowers) to 8.6% (in leaves). Perry et al. (1999) also stated lower thujone levels in flowers (16%) compared with leaves (31%). Santos-Gomes and Fernandes-Ferreira (2001) reported that the alpha-thujone content of *S. officinalis* stem, leaf and flower oil in Portugal was 55, 30 and 18% of total oil respectively. We observed similar results in terms of thujone content in our study. The major constituents identified in this study, including 1,8-cineole, camphor, α - and β -thujone, and β -pinene, are widely recognized as key bioactive compounds in *Salvia* essential oils. Their desirability, however, depends on the intended industrial application. In the pharmaceutical and medicinal sectors, 1,8-cineole is particularly valued due to its antimicrobial, anti-inflammatory, and penetration-enhancing properties (Bernotienė et al., 2007). Similarly, valencene has demonstrated anti-inflammatory activity in preclinical studies (Dantas et al., 2022). Camphor is commonly used in topical formulations for its analgesic and antimicrobial effects (Russo et al., 2013; Gali-Muhtasib, 2006). In the food and flavoring industry, thujones contribute to the characteristic aroma of sage; however, their concentration is strictly regulated due to potential neurotoxicity. Therefore, while moderate thujone levels are desirable for aroma quality, excessively high concentrations may limit internal applications. Since biological and commercial value depends strongly on phytochemical composition, selecting genotypes and plant parts with optimized constituent profiles is essential for sector-specific utilization (Sharifi-Rad et al., 2018).

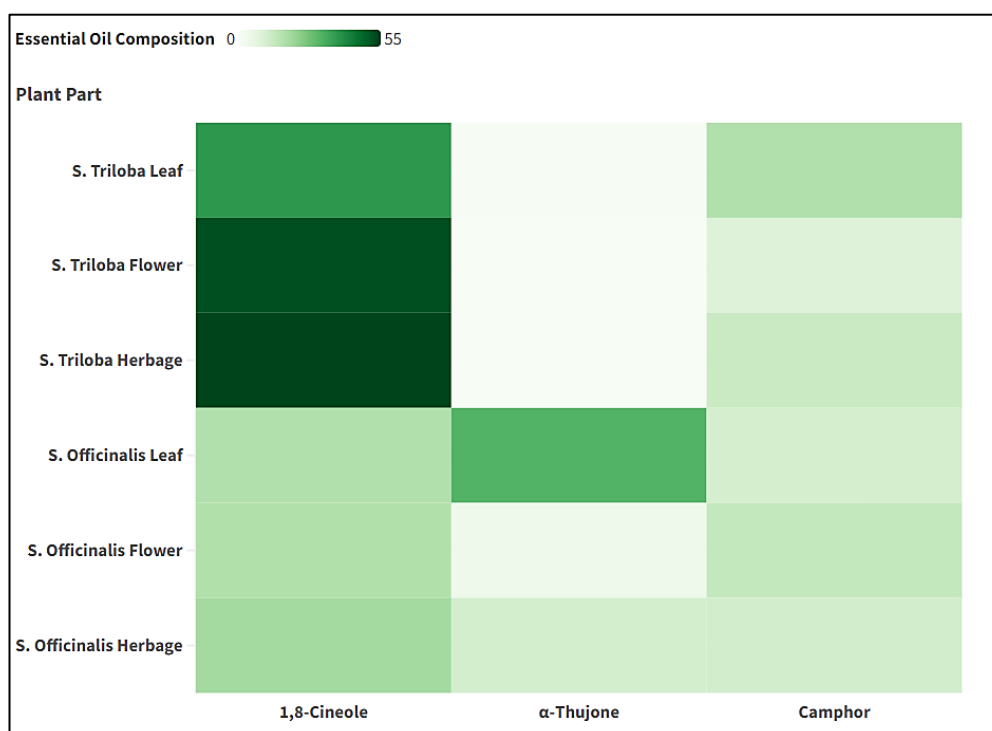


Figure 1. Heatmap based on Changes in essential oil composition of *Salvia triloba* and *Salvia officinalis* due to different plant parts. (Value = %) (Intensegreen indicates strong positive correlations)

Changes in essential oil composition were visualized using a heat map. In Figure 1, essential oil compounds were visualized according to the leaves, flowers and herbs of two different species of sage. The differences between 1,8-cineole *S. triloba* and *S. officinalis* leaves, flowers and herbs can be clearly observed. While the rate of camphor in the *S. triloba* leaf was the highest, the rate of α -Thujone in the *S. officinalis* leaf was the highest. In the study, a GGE Biplot (Figure: 2-3) was created to determine the multivariate relationships between plant's morphogenetic development and accumulation of essential oil for components in two *Salvia* sp. In the study, the PC1 value, which forms the GGE Biplot graph, is 75.51% and the PC2 value is 17.64%, and these two components constituted 92.15% of the total variation. The GGE biplot in Figure 2 shows the relative ranking of the essential oil and ideal *Salvia* genus. According to Yang et

al. (2009) an ideal environment should have high PC1 and zero PC2 scores. An ideal genotype should have high performance and stability against environmental factors. The highest-essential oil *Salvia* genus were identified for each sector. *S. triloba* leaf and *S. triloba* flower, which have high essential oil content compared to morphological plant parts, were detected. In contrast, *S. officinalis* leaf was found to be lower in essential oil components than the others. When Figure 3 is examined, the GGE biplot analysis clustered 16 different essential oil in 4 mega-environments. In the GGE biplot (Figure 3), the vectors from the biplot center divided the graph into four sectors. There was a negative relationship between α -Thujone and Valencene, β -thujone, a positive relationship between β -pinene, β -Caryophyllene, and a positive relationship between Camphor, Myrcene, and Borneol.

4. Conclusion

This study demonstrated that essential oil yield and chemical composition in *Salvia officinalis* and *Salvia triloba* are significantly influenced by plant part under semi-arid cultivation conditions. Although total essential oil yield showed limited variation between species, clear qualitative and quantitative differences were observed among leaves, flowers, and herbage. Flowers generally produced higher oil yields, while species-specific chemotypic patterns were evident. *S. triloba* was characterized by high 1,8-cineole and camphor contents, whereas *S. officinalis* exhibited elevated α - and β -thujone levels. Multivariate analysis further confirmed organ-dependent clustering of essential oil constituents. The relatively stable oil yields obtained under semi-arid conditions suggest that this ecological environment does not adversely affect essential oil production. Moreover, the accumulation of key bioactive compounds under these conditions may provide a potential advantage for cultivation and industrial applications in semi-arid regions.

Declaration of Author Contributions

The authors declare that they have contributed equally to the article. All authors declare that they have seen/read and approved the final version of the article ready for publication.

Declaration of Conflicts of Interest

All authors declare that there is no conflict of interest related to this article.

Funding

This study received no financial support.

Ethical Committee Approval

This study did not involve human or animal subjects; therefore, ethical approval was not required.

References

- Bernotienė, G., Nivinskienė, O., Butkienė, R., Mockutė, D., 2007. Essential oil

composition variability in sage (*Salvia officinalis* L.). *Chemija*, 18(4): 38-43.

- Boelens, M.H., 1986. The essential oil of spike *Lavender lavandula latifolia* Vill. (*L. spica* DC). *perfum. Flavorist*, 11: 43–63.

- Celep, F., Doğan, M., 2023. The genus *Salvia* in Turkey: morphology, ecology, phytogeography, endemism and threat categories. In *Medicinal and Aromatic Plants of Turkey* (pp. 107-120). Cham: Springer International Publishing.

- Celik, S.A., Ayran, İ., Asuman, K., Yüksel, K., 2018. Essential oil yield and compositions of sage (*Salvia officinalis* L.) cultivated in different province of Turkey. *International Journal of Agriculture Environment and Food Sciences*, 2(Special 1): 193-195.

- Chalchat, J.C., Michet, A., Pasquier, B., 1998. Study of clones of *Salvia officinalis* L. yields and chemical composition of essential oil. *Flavour and Fragrance Journal*, 13(1): 68-70.

- Dantas, L.B., Alcântara, I.S., Júnior, C.P.S., De Oliveira, M.R.C., Martins, A.O., Dantas, T.M., De Menezes, I.R.A., 2022. In vivo and in silico anti-inflammatory properties of the sesquiterpene valencene. *Biomedicine and Pharmacotherapy*, 153: 113478.

- Delamare, A.P.L., Moschen-Pistorello, I.T., Artico, L., Atti-Serafini, L., Echeverrigaray, S., 2007. Antibacterial activity of the essential oils of *Salvia officinalis* L. and *Salvia triloba* L. cultivated in South Brazil. *Food Chemistry*, 100(2): 603-608.

- Dudai, N., Lewinsohn, E., Larkov, O., Katzir, I., Ravid, U., Chaimovitch, D., Putievsky, E., 1999. Dynamics of yield components and essential oil production in a commercial hybrid sage (*Salvia officinalis* × *Salvia fruticosa* cv. Newe Ya'ar No. 4). *Journal of Agricultural and Food Chemistry*, 47(10): 4341-4345.

- Figueiredo, A.C., Barroso, J.G., Pedro, L.G., Scheffer, J.J., 2008. Factors affecting secondary metabolite production in plants: volatile components and essential oils. *Flavour and Fragrance Journal*, 23(4): 213-226.
- Franz, C., 1993. Genetics. In R. K. M. Hay, P. G. Waterman (Eds.), *Volatile Oil Crops: Their Biology, Biochemistry and Production* (pp. 93–166). Harlow, UK: Longman.
- Gali-Muhtasib, H., 2006. Anticancer and medicinal properties of essential oil and extracts of East Mediterranean sage (*Salvia triloba*). *Advances in Phytomedicine*, 2: 169-180.
- Herraiz-Peñalver, D., Cases, M.Á., Varela, F., Navarrete, P., Sánchez-Vioque, R., Usano-Alemany, J., 2013. Chemical characterization of *Lavandula latifolia* Medik. essential oil from Spanish wild populations. *Biochemical Systematics and Ecology*, 46: 59–68.
- Karik, U., Çinar, O., Tuncturk, M., Sekeroglu, N., Gezici, S., 2018. Essential oil composition of some sage (*Salvia* spp.) species cultivated in İzmir (Turkey) ecological conditions. *Indian Journal of Pharmaceutical Education and Research*, 52(4): 102-107.
- Li, B., Zhang, C., Peng, L., Liang, Z., Yan, X., Zhu, Y., Liu, Y., 2015. Comparison of essential oil composition and phenolic acid content of selected *Salvia* species measured by GC-MS and HPLC methods. *Industrial Crops and Products*, 69: 329-334.
- Lu, Y., Foo, L.Y., 2002. Polyphenolics of *Salvia*-a review. *Phytochemistry*, 59(2): 117-140.
- Muñoz-Bertomeu, J., Arrillaga, I., Segura, J., 2007. Essential oil variation within and among natural populations of *Lavandula latifolia* and its relation to their ecological areas. *Biochemical Systematics and Ecology*, 35: 479–488.
- Nabi, M.H.B., Ahmed, M.M., Mia, M.S., Islam, S., Zzaman, W., 2025. Essential oils: advances in extraction techniques, chemical composition, bioactivities, and emerging applications. *Food Chemistry Advances*, 8:101048.
- Nguyen, H.T., Radácsi, P., Rajhárt, P., Németh, É.Z., 2019. Variability of thujone content in essential oil due to plant development and organs from *Artemisia absinthium* L. and *Salvia officinalis* L. *Journal of Applied Botany and Food Quality*, 92: 100-105.
- Perry, N.B., Anderson, R.E., Brennan, N.J., Douglas, M.H., Heaney, A.J., McGimpsey, J.A., Smallfield, B.M., 1999. Essential oils from Dalmatian sage (*Salvia officinalis* L.): variations among individuals, plant parts, seasons and sites. *Journal of Agricultural and Food Chemistry*, 47(5): 2048-2054.
- Putievsky, E., Ravid, U., Dudai, N. 1986. The essential oil and yield components from various plant parts of *Salvia fruticosa*. *Journal of Natural Products*, 49(6): 1015-1017.
- Rehman, R., Hanif, M.A., Mushtaq, Z., Al-Sadi, A.M., 2016. Biosynthesis of essential oils in aromatic plants: A review. *Food Reviews International*, 32(2): 117-160.
- Russo, A., Formisano, C., Rigano, D., Senatore, F., Delfino, S., Cardile, V., Bruno, M., 2013. Chemical composition and anticancer activity of essential oils of Mediterranean sage (*Salvia officinalis* L.) grown in different environmental conditions. *Food Chemistry, Toxicol*, 55: 42-47.
- Salachna, P., Wesołowska, A., Meller, E., Piechocki, R., 2021. Mushroom waste biomass alters the yield, total phenolic content, antioxidant activity and essential oil composition of *Tagetes patula* L. *Industrial Crops and Products*, 171: 113961.

- Salido, S., Altarejos, J., Nogueras, M., Sánchez, A., 2004. Chemical composition and seasonal variations of spike lavender oil from southern Spain. *Journal of Essential Oil Research*, 16: 206–210.
- Santos-Gomes, P.C., Fernandes-Ferreira, M., 2001. Organ-and season-dependent variation in the essential oil composition of *Salvia officinalis* L. cultivated at two different sites. *Journal of Agricultural and Food Chemistry*, 49(6): 2908-2916.
- Sharifi-Rad, M., Ozcelik, B., Altın, G., Daşkaya-Dikmen, C., Martorell, M., Ramírez-Alarcón, K., Sharifi-Rad, J., 2018. *Salvia* spp. plants from farm to food applications and phytopharmacotherapy. *Trends in Food Science and Technology*, 80: 242-263.
- Tonçer, O., Karaman, S., Kamci, G., Erdem, E., 2022. Yield and essential oil composition of *Lippia citriodora* HBK leaves and flowers in semi-arid conditions. *Journal of Essential Oil Bearing Plants*, 25(1): 9-19.
- Veličković, D.T., Randelović, N.V., Ristić, M.S., Veličković, A.S., Šmelcerović, A.A., 2003. Chemical constituents and antimicrobial activity of the ethanol extracts obtained from the flower, leaf and stem of *Salvia officinalis* L. *Journal of the Serbian Chemical Society*, 68(1): 17-24.
- Verma, R.S., Padalia, R.C., Chauhan, A., 2015. Harvesting season and plant part dependent variations in the essential oil composition of *Salvia officinalis* L. grown in northern India. *Journal of Herbal Medicine*, 5(3): 165-171.
- Wu, Y.B., Ni, Z.Y., Shi, Q.W., Dong, M., Kiyota, H., Gu, Y.C., Cong, B., 2012. Constituents from *Salvia* species and their biological activities. *Journal of Chemical Reviews*, 112(11): 5967-6026.
- Yang, R., Crossa, J., Cornelius, P.L., Burgueno, J., 2009. Biplot analysis of GEI effect. *Crop Science*, 49: 1564-1576.