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Seasonal variation in the essential oil composition of *Salvia microphylla*

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Abstract
The leaf essential oils of *Salvia microphylla* cv. "hot lips" were obtained by hydrodistillation during the vegetative (spring), flowering (summer), and senescent (autumn) stages. The essential oils were analyzed by gas chromatography-mass spectrometry (GC-MS). The major components were guaiol (24.6-26.3%), α-eudesmol (15.6-19.9%), (*E*)-caryophyllene (5.5-11.5%), camphor (3.5-10.5%), and 1,8-cineole (1.4-6.2%). Sesquiterpene hydrocarbons, especially (*E*)-caryophyllene, were elevated in the spring; essential oil yield, monoterpene hydrocarbons, and oxygenated monoterpenoids, in particular camphor and 1,8-cineole, were elevated in the summer; and monoterpene hydrocarbons and oxygenated sesquiterpenoids were elevated in the autumn.

Keywords: Chemical composition, guaiol, α-eudesmol, (*E*)-caryophyllene, phenological stages

1. Introduction
There are around 800-900 species of *Salvia* (Lamiaceae) found throughout the world [1]. *Salvia microphylla* Kunth is an evergreen woody shrub that naturally ranges from southern Arizona, through Mexico, and south to Guatemala [2–4], but is now planted as an ornamental in gardens in warm, dry geographical locations [5]. A tea of *S. microphylla* is used traditionally to treat gastrointestinal problems such as stomachaches and diarrhea and as a treatment for insomnia [6–8]. Extracts of *S. microphylla* have shown antimutagenic [9], lipase-inhibitory, free radical-inhibitory [10], and insecticidal (*Spodoptera frugiperda*) [11,12] activities. The plant is the source of several biologically active phenolics, triterpenoids, diterpenoids, and sesquiterpenoids [7,13–15]. The essential oil compositions of cultivated samples of *S. microphylla* from Ventimiglia, Italy [16], and Lavras, Brazil [17], have been reported. In this work, the leaves of *S. microphylla* cv. "hot lips", cultivated in Grover Beach, California (Figure 1), were collected during the vegetative stage (April), flowering stage (July), and senescent stage (November), and the essential oils obtained by hydrodistillation.

Fig 1: Photograph of *Salvia microphylla* cv. "hot lips" cultivated in Grover Beach, California

2. Materials and Methods

2.1 Plant Material

Fresh leaves were collected from a single plant growing in a garden in Grover Beach, California (35° 06′ 59.64″ N, 120° 36′ 44.46″ W, 69 m elevation). The leaves were air-dried in the shade for several days, and the leaf material hydrodistilled using an all-glass Clevenger apparatus for 4 h to give the colorless essential oils (Table 1).

2.2 Gas Chromatographic-Mass Spectral Analysis

The essential oil of *S. microphylla* was analyzed by GC-MS, as described previously [18, 19], using a Shimadzu GC-MS-QP2010 Ultra fitted with a Phenomenex ZB-5ms column. Identification of the essential oil components was determined by comparison of their retention indices and their mass spectral fragmentation patters with those in the essential oil databases [20–23].

3. Results and Discussion

Essential oils of *S. microphylla* were obtained as colorless oils in 0.3% (April), 6.7% (July), and 1.1% (November) yields (Table 1). A total of 105 compounds were identified in the essential oils accounting for 98.2-99.2% of the compositions. The major components in the essential oils were guaiol (24.6-26.3%), α-eudesmol (15.6%-19.9%), (*E*)-caryophyllene (5.5-11.5%), camphor (3.5-10.6%), and 1,8-cineole (1.4-6.2%) (Table 2).

Table 1: Collection and hydrodistillation details of *Salvia microphylla*.

	April, 2020 (vegetative)	July, 2019 (flowering)	November, 2019 (senescent)
Mass of dry leaves	101.6 g	16.8 g	53.0 g
Mass of essential oil	0.31 g	1.12 g	0.56 g

Table 2: Essential oil compositions of *Salvia microphylla* from three different phenological stages.

RI_{calc}[a]	RI_{db}[b]	Compound	Spring (vegetative)	Summer (flowering)	Autumn (senescent)
922	923	Tricyclene	---	0.1	tr[c]
925	927	α-Thujene	0.1	0.7	0.3
932	933	α-Pinene	0.1	2.3	1.6
949	950	Camphene	0.3	2.4	1.8
952	953	Thuja-2,4(10)-diene	---	tr	tr
972	972	Sabinene	0.1	0.2	0.3
977	978	β-Pinene	0.2	0.9	1.0
1006	1006	α-Phellandrene	tr	tr	tr
1017	1018	α-Terpinene	0.2	0.3	0.3
1024	1025	*p*-Cymene	0.5	0.8	1.3
1028	1030	Limonene	0.7	0.8	1.3
1031	1031	β-Phellandrene	0.1	tr	0.1
1031	1032	1,8-Cineole	1.4	6.2	2.4
1045	1046	(*E*)-β-Ocimene	tr	---	tr
1057	1057	γ-Terpinene	1.7	1.2	1.3
1069	1069	*cis*-Sabinene hydrate	0.2	0.4	0.2
1085	1086	Terpinolene	0.1	0.1	0.1
1086	1086	*trans*-Linalool oxide (furanoid)	---	tr	---
1100	1101	Linalool	tr	0.1	tr
1101	1099	*trans*-Sabinene hydrate	0.1	0.4	0.2
1124	1124	*cis*-*p*-Menth-2-en-1-ol	---	tr	tr
1126	1126	α-Campholenal	tr	0.1	0.1
1145	1145	*trans*-Verbenol	tr	tr	0.1
1146	1145	Camphor	3.5	10.5	5.5
1160	1160	*trans*-Pinocamphone	tr	---	---
1162	1164	Pinocarvone	tr	tr	tr
1170	1170	δ-Terpineol	tr	0.1	tr
1171	1170	Borneol	0.3	0.7	0.5
1180	1180	Terpinen-4-ol	0.2	0.5	0.3
1195	1195	α-Terpineol	0.1	0.2	0.1
1198	1201	Safranal	tr	---	---
1218	1219	β-Cyclocitral	tr	---	---
1279	1278	Pregeijerene B	0.1	---	---
1280	1281	Thymol	0.1	tr	0.1
1283	1285	Bornyl acetate	4.6	0.9	2.1
1297	1300	Carvacrol	tr	tr	0.1
1347	1348	α-Cubebene	0.4	0.2	0.3
1369	1371	α-Ylangene	0.5	0.3	0.4
1375	1375	α-Copaene	3.6	1.8	2.8
1383	1382	β-Bourbonene	0.3	0.4	0.4
1387	1387	β-Cubebene	0.3	0.1	0.2
1402	1403	α-Funebrene	tr	tr	tr
1404	1405	(*Z*)-Caryophyllene	0.1	0.1	0.2
1406	1406	α-Gurjunene	0.1	0.1	0.1
1413	1416	*cis*-α-Bergamotene	0.1	tr	tr
1419	1417	(*E*)-Caryophyllene	11.5	5.5	7.3

1429	1430	β-Copaene	0.5	0.3	0.3
1433	1433	*trans*-α-Bergamotene	0.1	0.1	0.1
1435	1436	α-Guaiene	0.2	0.1	0.2
1438	1438	Aromadendrene	tr	tr	tr
1440	1439	(*Z*)-β-Farnesene	tr	tr	tr
1445	1446	*cis*-Muurola-3,5-diene	tr	tr	tr
1449	1453	*trans*-Muurola-3,5-diene	0.1	tr	tr
1452	1452	(*E*)-β-Farnesene	0.1	0.1	0.1
1455	1454	α-Humulene	0.7	0.4	0.6
1459	1457	*allo*-Aromadendrene	0.1	tr	0.1
1462	1463	*cis*-Cadina-1(6),4-diene	0.1	tr	tr
1472	1472	*trans*-Cadina-1(6),4-diene	0.1	0.1	tr
1474	1478	γ-Muurolene	1.4	0.8	1.2
1477	1482	γ-Curcumene	0.1	tr	tr
1479	1479	α-Amorphene	0.1	tr	0.1
1480	1480	*ar*-Curcumene	---	0.2	0.3
1480	1480	Germacrene D	0.4	---	---
1487	1489	δ-Selinene	tr	---	---
1488	1489	β-Selinene	0.1	0.1	0.1
1491	1490	γ-Amorphene	0.4	0.2	0.2
1494	1494	α-Zingiberene	0.9	0.3	0.2
1495	1501	α-Selinene	---	0.2	0.2
1498	1500	α-Muurolene	0.4	0.2	0.3
1501	1505	α-Bulnesene	tr	---	---
1502	1506	δ-Amorphene	0.1	---	---
1503	1504	(*E*,*E*)-α-Farnesene	0.2	0.1	---
1507	1508	β-Bisabolene	tr	tr	tr
1509	1509	β-Curcumene	0.1	0.1	0.1
1512	1512	γ-Cadinene	1.0	0.5	0.7
1515	1515	Cubebol	0.3	0.2	0.2
1518	1518	δ-Cadinene	4.5	2.2	2.9
1521	1521	*cis*-Calamenene	0.1	0.3	0.4
1523	1523	β-Sesquiphellandrene	0.2	0.2	0.2
1530	1531	10-*epi*-Cubebol	0.1	---	---
1532	1533	*trans*-Cadina-1,4-diene	0.1	0.1	0.1
1536	1538	α-Cadinene	0.1	0.1	0.1
1541	1544	α-Calacorene	0.1	0.1	0.2
1543	1544	*cis*-Sesquisabinene hydrate	0.1	0.1	0.1
1554	1555	7-*epi*-*cis*-Sesquisabinene hydrate	0.1	0.1	0.1
1581	1587	Caryophyllene oxide	0.8	0.7	1.6
1594	1594	Viridiflorol	0.5	0.2	0.2
1597	1603	Guaiol	25.0	24.6	26.3
1609	1613	Humulene epoxide II	---	tr	0.1
1612	1609	Rosifoliol	0.1	0.1	---
1625	1632	Muurola-4,10(14)-dien-1β-ol	---	tr	0.2
1630	1631	Eremoligenol	2.5	2.3	1.8
1632	1633	γ-Eudesmol	2.4	2.4	2.3
1633	---	Unidentified [d]	0.7	0.6	1.2
1639	1645	Hinesol	0.8	0.7	0.6
1642	1643	τ-Cadinol	0.2	0.1	---
1644	1644	τ-Muurolol	0.1	0.1	---
1656	1652	α-Eudesmol	15.6	18.0	19.9
1665	1673	Bulnesol	2.8	2.7	2.2
1673	1672	Jatamansone	2.6	1.0	1.5
1777	1792	8α-Acetoxyelemol	0.7	0.8	0.4
1816	1816	Cryptomeridiol	---	0.1	---
1840	1841	Phytone	tr	---	0.1
1947	1947	Geranyl-α-terpinene	0.1	0.1	tr
2052	2049	Abietatriene	tr	tr	0.1
2318	2315	*trans*-Totarol	tr	0.1	---
		Monoterpene hydrocarbons	4.0	9.8	9.4
		Oxygenated monoterpenoids	10.5	20.1	11.7
		Sesquiterpene hydrocarbons	29.4	14.9	20.2
		Oxygenated sesquiterpenoids	54.7	54.2	57.1
		Diterpenoids	0.1	0.2	0.1
		Total identified	98.7	99.2	98.4

[a] RI_{calc} = Retention indices calculated with respect to a homologous series of *n*-alkanes on a ZB-5ms column. [b] RI_{db} = Retention indices from the databases [20–23]. [c] tr = trace (< 0.05%). [d] MS(EI): 204(18%), 189(19%), 161(48%), 147(25%), 133(15%), 119(13%), 105(100%), 93(17%), 91(23%), 59(31%), 43(22%), 41(13%).

The chemical compositions of several cultivated *Salvia* essential oils, including *S. microphylla*, from Ventimiglia, Italy, have been determined [16]. The essential oil of the Italian sample of *S. microphylla* was rich in (*E*)-caryophyllene (10.8%), bornyl acetate (9.1%), 1, 8-cineole (8.4%), α-eudesmol (6.4%), α-pinene (5.9%), camphene (5.3%), and β-eudesmol (5.3%). Lima and co-workers have examined the leaf essential oil of *S. microphylla* from a cultivated plant growing in Lavras, Brazil [17]. The major components in the Brazilian *S. microphylla* essential oil were (*E*)-caryophyllene (15.4%), α-eudesmol (14.1%), β-eudesmol (8.7%), γ-eudesmol (7.6%), and bicyclogermacrene (6.2%) Thus, although there are several common major components between the Italian, Brazilian, and the Californian samples, there are also some striking differences. Neither bicyclogermacrene nor β-eudesmol were detected in the sample from California. Conversely, guaiol was not reported in either the sample from Italy or the sample from Brazil. Interestingly, *S. mexicana* from Italy was rich in guaiol [16]. There are four recognized varieties [24] and several cultivars of *S. microphylla* [25] and the plant is known to readily hybridize with related *Salvia* species [26], which may account for the different chemotypes of this plant.

Compared to the averages, the overall essential oil yield and the concentrations of both monoterpene hydrocarbons and oxygenated monoterpenoids were higher in the summer. In particular, the concentrations of camphor (10.5%) and 1,8-cineole (6.2%) were higher in the summer. Monoterpene hydrocarbons were also elevated in the autumn. Sesquiterpene hydrocarbon concentrations were higher in the spring, especially (*E*)-caryophyllene (11.5%), but lower in the summer, while oxygenated sesquiterpenoids were slightly elevated in the autumn with guaiol (26.3%) and α-eudesmol (19.9%) as notable examples.

4. Conclusions

Salvia microphylla cv. "hot lips" is an easily grown and maintained plant with an interesting sesquiterpenoid-rich essential oil. The ease of cultivation coupled with the relatively high yield and chemical profile of the essential oil make this plant worthy of consideration for commercial essential oil exploitation.

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6. Conflicts of Interest

The authors declare no conflicts of interest.

7. References

1. Mabberley DJ. Mabberley's Plant-Book, 3rd ed. Cambridge University Press, Cambridge, UK, 2008, ISBN 978-0-521-87071-4.
2. Starr G. New World salvias for cultivation in southern Arizona. Desert Plants. 1985; 7(5):167-207, http://hdl.handle.net/10150/609082.
3. Martínez-Gordillo M, Bedolla-García B, Cornejotenorio G, Fragoso-Martínez I, García-Peña MDR, González-Gallegos JG *et al*. Bot. Sci. 2017; 95(4):780-806, DOI: 10.17129/botsci.1871.
4. Missouri Botanical Garden, Tropicos.org, www.tropicos.org, accessed on May 14, 2020.
5. Karabacak E, Uysal I, Doğan M. Cultivated *Salvia* species in Turkey. Biol. Divers. Conserv. 2009; 2(1):71-77.
6. Morton JF. Atlas of Medicinal Plants of Middle America, Volume II. Charles C. Thomas, Springfield, Illinois, USA, 1981, ISBN 0-398-04036-2.
7. Jenks AA, Kim SC. Medicinal plant complexes of *Salvia* subgenus *Calosphace*: An ethnobotanical study of new world sages. J Ethnopharmacol., 2013; 146:214-224, http://dx.doi.org/10.1016/j.jep.2012.12.035.
8. Pérez-Nicolás M, Vibrans H, Romero-Manzanares A. Can the use of medicinal plants motivate forest conservation in the humid mountains of northern Oaxaca, Mexico? Bot. Sci. 2018; 96(2):267-285, DOI: 10.17129/botsci.1862.
9. Mathew J, Thoppil JE. Investigation of the antimutagenic activity of three *Salvia* extracts. Int. J. Pharm. Pharm. Sci. 2012; 4(3):225-230.
10. Villa-Ruano N, Zurita-Vásquez GG, Pacheco-Hernández Y, Betancourt-Jiménez MG, Cruz-Durán R, Duque-Bautista H. Anti-lipase and antioxidant properties of 30 medicinal plants used in Oaxaca, México. Biol. Res., 2013; 46(2):153-160.
11. Zavala-Sánchez MA, Pérez Gutiérrez S, Romo-Asunción D, Cárdenas-Ortega NC, Ramos-López MA. Activity of four *Salvia* species against *Spodoptera frugiperda* (J.E. Smith) (Lepidoptera: Noctuidae). Southwest. Entomol. 2013; 38(1):67-73, DOI: http://dx.doi.org/10.3958/059.038.0107.
12. Romo-Asunción D, Ávila-Calderón MA, Ramos-López MA, Barranco-Florido JE, Rodríguez-Navarro S, Romero-Gomez S, Aldeco-Pérez EJ, Pacheco-Aguilar JR *et al* Rico-Rodríguez MA. Juvenomimetic and insecticidal activities of *Senecio salignus* (Asteraceae) and *Salvia microphylla* (Lamiaceae) on *Spodoptera frugiperda* (Lepidoptera: Noctuidae). Florida Entomol., 2016; 99(3):345–351, https://doi.org/10.1653/024.099.0301.
13. Aydoğmuş Z, Yeşilyurt V, Topcu G. Constituents of *Salvia microphylla*. Nat. Prod. Res. 2006; 20(8):775-781, https://doi.org/10.1080/14786410500462843.
14. Bautista E, Toscano RA, Ortega A. Microphyllandiolide, a new diterpene with an unprecedented skeleton from *Salvia microphylla*. Org. Lett., 2013; 15(13):3210-3213, https://doi.org/10.1021/ol401022c.
15. Bautista E, Toscano RA, Ortega A. 5, 10-*seco*-*neo*-Clerodanes and *neo*-clerodanes from *Salvia microphylla*. J. Nat. Prod. 2014; 77(4):1088-1092, https://doi.org/10.1021/np4009893.
16. Chialva F, Monguzzi F, Manitto P. Composition of the essential oils of five *Salvia* species. J. Essent. Oil Res., 1992; 4(5):447-455, https://doi.org/10.1080/10412905.1992.9698108.
17. Lima RK, Cardoso M das G, Andrade MA, Guimarães PL, Batista LR, Nelson DL. Bactericidal and antioxidant activity of essential oils from *Myristica fragrans* Houtt and *Salvia microphylla* H.B.K. J Am. Oil Chem. Soc., 2012; 89(3): 523–528, DOI 10.1007/s11746-011-1938-1.
18. DeCarlo A, Johnson S, Okeke-Agulu KI, Dosoky NS, Wax SJ, Owolabi MS, Setzer WN. Compositional analysis of the essential oil of *Boswellia dalzielii* frankincense from West Africa reveals two major chemotypes. Phytochemistry. 2019; 164:24-32, https://doi.org/10.1016/j.phytochem.2019.04.015.
19. Vargas Suarez A, Satyal P, Setzer WN. The wood

essential oil composition of *Swietenia macrophylla* from Guanacaste, Costa Rica. Am. J Essent. Oils Nat. Prod., 2019; 7(1):14-16.
20. Adams RP. Identification of Essential Oil Components by Gas Chromatography/Mass Spectrometry, 4th ed. Allured Publishing, Carol Stream, IL, USA, 2007, ISBN 978-1-932633-21-4.
21. NIST17. National Institute of Standards and Technology, Gaithersburg, Maryland, USA, 2017.
22. Mondello L. FFNSC 3. Shimadzu Scientific Instruments, Columbia, Maryland, USA, 2016.
23. Satyal P. Development of GC-MS Database of Essential Oil Components by the Analysis of Natural Essential Oils and Synthetic Compounds and Discovery of Biologically Active Novel Chemotypes in Essential Oils, Ph.D. dissertation, University of Alabama in Huntsville, 2015.
24. Royal Botanic Gardens, Kew. The Plant List. http://www.theplantlist.org/tpl1.1/search?q=Salvia+microphylla, accessed on May 15, 2020.
25. Clebsch B. The New Book of Salvias: Sages for Every Garden, 2nd Ed. Timber Press, Portland, Oregon, USA, 2003, ISBN 978-1-60469-510-6.
26. Nosrati H, Nosrati A. A survey on the genus *Salvia* as the largest genus of plants. Agric. Sci. Dev. 2013; 2(1):1-3.