Journal of Essential Oil & Plant Composition

JEOPC, 2(1), 30-37, 2024
https://doi.org/10.58985/jeopc.2024.v02i01.41
ISSN (Print): 2958-9630

Research Article

The essential oil composition of *Picea sitchensis* growing in the Oregon Coast Range

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Article Information
Received: 18 November 2023
Revised: 01 December 2023
Accepted: 08 December 2023
Published: 10 December 2023

Academic Editor
Prof. Dr. Radosław Kowalski

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Keywords
Sitka spruce, Pinaceae, gas chromatography, enantiomeric distribution, chiral

Abstract

Picea sitchensis (Sitka spruce) is a very large tree that is locally common in the moist coastal ranges of the Pacific Northwest. The purpose of this work was to obtain and analyze the foliar essential oil of the Sitka spruce growing in the Oregon Coast Range. Foliage from three individual trees was collected and the essential oils were obtained by hydrodistillation. The essential oils were analyzed by gas chromatographic techniques (GC-MS, GC-FID, and chiral GC-MS). The major components in the essential oils were α-pinene (1.2-12.5%, > 85% (–)-α-pinene), β-pinene (1.2-7.2%, > 95% (–)-β-pinene), myrcene (15.9-22.2%), β-phellandrene (9.1-25.1%, > 99% (–)-β-phellandrene), isoamyl isovalerate (2.3-6.4%), 3-methyl-3-butenyl isovalerate (1.5-6.9%), and piperitone (2.9-18.0%, > 98% (–)-piperitone). The essential oil compositions of the Oregon samples are qualitatively similar to samples from British Columbia. However, sampling from other populations at other latitudes and at different seasons of the year would be necessary to fully describe the volatile chemistry of this species.

1. Introduction

Picea sitchensis (Bong.) Carrière, Pinaceae (Sitka spruce) is a large tree (up to 80 m tall), with drooping branches (Fig. 1A) [1]. The leaves are needles (15-25 mm long), abaxial surface (blue-green), adaxial surface (glaucous) with two dense bands of stomata (Fig. 1B). The bark is thin, scaley, and grayish-brown in color (Fig. 1C). The cones are slender and cylindrical (6-10 cm long) with thin, diamond-shaped scales (12-16 mm) (Fig. 1D). Sitka spruce ranges along a narrow strip along the northern Pacific coast from south-central Alaska south to northern California (Fig. 2) [2, 3]. The tree was introduced to western Europe (Great Britain, France, Norway, Denmark, Germany, Sweden, and Iceland) in the 19th century [4, 5]. It has also been introduced to New Zealand and Australia [6].

Picea species have been important sources of traditional medicines throughout their ranges (see, for example, [7–13]). The foliage of *P. sitchensis* has been used by Native American tribes as a cold medicine (Kwakiutl), as an antirheumatic (Gitksan), and as a gastrointestinal aid (Southern Carrier, Hanaksiala) [14]. *Picea* species, including *Picea abies* (L.) H. Karst (Norway spruce), *Picea engelmannii* Engelm. (Engelmann spruce), *Picea glauca* (Moench) Voss (white spruce), *Picea mariana* Britton, Sterns & Poggenb. (black spruce), *Picea pungens* Engelm. (blue spruce), *Picea rubens* Sarg. (red spruce), and *P. sitchensis* (Sitka spruce), are important sources of essential oils [15]. As part of our continuing

Figure 1. *Picea sitchensis* (Sitka spruce) in the Oregon Coast Range. **A:** Branches. **B:** Leaves (needles). **C:** Bark. **D:** Cones.

Figure 2. The native range of *Picea sitchensis* (Sitka spruce) along the west coast of North America [3].

investigation of essential oils of North American gymnosperms, we have obtained the foliar essential oils from three individual *P. sitchensis* trees growing in the Van Duzer Forest, Oregon Coast Range. There has been a previous report on *P. sitchensis* essential oils from coastal British Columbia [16], as well as a report on volatiles identified in *P. sitchensis* bark extracts [17].

2. Materials and methods

2.1. Plant Material

Foliage (leaves and twigs) of *P. sitchensis* were collected using plant pruning shears from the ends of branches from several different positions on three individual trees (samples #1, #2, #3) located in the Van Duzer Forest, Oregon Coast Range on 14 April 2023. The trees were identified by W.N. Setzer based on botanical descriptions [18] and comparison with herbarium samples from the New York Botanical Garden [19]. A voucher specimen (WNS-Ps-6893) has been deposited in the University of Alabama in Huntsville herbarium. The fresh foliage from each tree was combined and the samples were stored under refrigeration (–20 °C). The fresh/frozen samples were hydrodistilled using a Likens-Nickerson apparatus with continuous extraction of the distillate with dichloromethane for four hours to give pale-yellow essential oils (Table 1).

2.2. Gas Chromatographic Analysis

The *P. sitchensis* foliar essential oils were analyzed by GC-MS, GC-FID, and chiral GC-MS as previously described [20]. The essential oil compositions were determined by comparing both MS fragmentation and RI values with those reported in the Adams [21], FFNSC3 [22], NIST20 [23], and Satyal [24] databases. The percent compositions were determined from raw peak areas (GC-FID) without standardization. Enantiomeric distributions were determined by comparison of RI values with authentic samples (Sigma-Aldrich, Milwaukee, WI, USA), which are compiled in our own in-house database.

3. Results and discussion

Hydrodistillation of the leaves (needles) and twigs of *P. sitchensis* gave pale-yellow essential oils in yields of 1.302-2.101%. The gas chromatographic analysis allowed for the identification of 140 chemical components, which accounted for 99.3-99.6% of the compositions (Table 2).

The foliar essential oil compositions of *P. sitchensis* from Oregon are qualitatively similar to those from British Columbia [16]. That is, the major components in both collections were α-pinene, β-pinene, myrcene, β-phellandrene, isoamyl isovalerate, 3-methyl-3-

Table 1. Collection and hydrodistillation details of *Picea sitchensis* from the Oregon Coast Range.

Samples	Location	Mass foliage	Mass essential oil	Yield (%)
#1	45°2′16″ N, 123°48′29″ W, 116 m asl	99.77 g	1.2731 g	1.302%
#2	45°2′16″ N, 123°48′32″ W, 116 m asl	116.25 g	2.4420 g	2.101%
#3	45°2′16″ N, 123°48′34″ W, 115 m asl	93.27 g	1.2648 g	1.356%

Table 2. Chemical compositions (%) of *Picea sitchensis* foliar essential oils from the Oregon Coast Range.

RI_{calc}	RI_{db}	Compounds	#1	#2	#3
780	780	(2*Z*)-Pentenol	0.1	0.2	0.2
782	782	3-Methyl-2-buten-1-ol (= Prenol)	tr	0.5	0.2
800	797	(3*Z*)-Hexenal	tr	0.1	0.2
801	801	Hexanal	tr	0.2	0.3
849	849	(2*E*)-Hexenal	0.9	2.1	2.9
850	853	(3Z)-Hexen-1-ol	0.1	0.4	0.4
864	864	1-Hexanol	-	-	tr
872	873	Isoamyl acetate	-	-	tr
880	880	Santene	-	0.1	tr
902	901	Heptanal	-	-	0.2
922	923	Tricyclene	tr	tr	0.1
925	925	α-Thujene	tr	0.1	0.3
932	933	α-Pinene	1.2	12.5	5.9
949	950	Camphene	0.6	0.6	1.8
961	959	Benzaldehyde	0.1	tr	tr
967	967	Isoamyl propionate	tr	-	tr
972	971	Sabinene	0.2	0.3	0.7
977	978	β-Pinene	1.2	7.2	4.4
989	989	Myrcene	22.2	15.9	18.2
1007	1006	α-Phellandrene	0.5	0.4	0.5
1009	1008	δ-3-Carene	1.7	0.4	2.9
1017	1017	α-Terpinene	0.2	0.2	0.3
1024	1025	*p*-Cymene	0.6	0.4	0.4
1029	1030	Limonene	0.8	1.1	0.7
1031	1031	β-Phellandrene	9.1	25.1	17.5
1032	1032	1,8-Cineole	1.8	0.9	1.8
1034	1034	(*Z*)-β-Ocimene	tr	0.1	tr
1043	1043	Phenylacetaldehyde	tr	tr	tr
1045	1045	(*E*)-β-Ocimene	tr	tr	0.1
1054	1056	Isoamyl butyrate	0.5	0.1	0.2
1057	1057	γ-Terpinene	0.2	0.3	0.5
1063	1064	3-Methyl-2-butenyl butyrate	0.2	-	tr
1070	1069	*cis*-Sabinene hydrate	tr	0.1	0.1
1085	1086	Terpinolene	0.5	0.7	1.0
1088	1090	Fenchone	-	-	0.1
1090	1090	6,7-Epoxymyrcene	0.1	0.1	0.1
1098	1098	Perillene	0.1	tr	tr
1099	1101	Linalool	0.4	0.3	0.3
1101	1101	*trans*-Sabinene hydrate	tr	tr	0.1
1104	1104	Nonanal	tr	0.2	0.2
1106	1109	Isoamyl isovalerate (= Solusterol)	6.4	2.3	3.2
1107	1109	2-Methylbutyl isovalerate	-	tr	-
1116	1114	3-Methyl-3-butenyl isovalerate	6.9	1.5	1.9
1120	1120	*endo*-Fenchol	tr	tr	0.8

Table 2. *(Continued)*

RI_{calc}	RI_{db}	Compounds	#1	#2	#3
1125	1124	*cis-p*-Menth-2-en-1-ol	1.3	0.4	0.8
1140	1141	*trans*-Pinocarveol	-	tr	-
1142	1142	*trans-p*-Menth-2-en-1-ol	1.0	0.3	0.6
1147	1145	Camphor	4.4	0.9	3.1
1155	1156	Camphene hydrate	0.3	0.1	0.8
1163	1162	*iso*-Borneol	-	-	tr
1169	1169	Umbellulone	-	-	tr
1172	1170	Borneol	3.4	0.4	3.9
1176	1176	*cis*-Pinocamphone	-	tr	0.1
1178	1179	2-Isopropenyl-5-methyl-4-hexenal	tr	tr	0.1
1180	1180	Terpinen-4-ol	0.4	0.4	0.8
1183	1184	Cyclopentyl 3-methyl-2-butenoate	0.1	tr	tr
1187	1185	Cryptone	0.1	0.2	0.1
1187	1186	*p*-Cymen-8-ol	0.1	tr	0.1
1191	1192	Methyl salicylate	-	tr	-
1191	1190	2-Methyl-2-butenyl angelate	0.2	-	-
1195	1195	α-Terpineol	1.0	0.9	1.6
1197	1196	*cis*-Piperitol	0.3	0.1	0.2
1207	1208	Verbenone	-	0.1	-
1209	1208	*trans*-Piperitol	0.6	0.1	0.3
1227	1227	Citronellol	0.1	-	tr
1228	1229	Thymyl methyl ether	0.1	0.1	0.1
1237	1238	Neral	0.1	-	tr
1249	1252	Isoamyl hexanoate	0.2	0.1	0.1
1250	1249	Geraniol	0.1	-	-
1254	1254	Piperitone	18.0	2.9	5.8
1258	1272	4-Pentenyl hexanoate[a]	0.1	0.1	0.1
1268	1268	Geranial	0.1	-	tr
1278	1277	Phellandral	0.1	0.1	0.1
1284	1282	Bornyl acetate	0.2	0.1	0.8
1292	1293	2-Undecanone	-	-	tr
1294	1294	Methyl myrtenate	-	0.1	-
1306	1304	(*E*)-Cinnamyl alcohol	0.2	0.1	-
1309	1309	4-Vinylguaiacol	0.1	-	-
1323	1322	Methyl decanoate	0.1	-	-
1335	1335	*cis*-Piperitol acetate	0.1	0.1	0.1
1346	1346	α-Cubebene	-	0.1	tr
1364	1365	(2*E*)-Undecenal	-	-	tr
1375	1375	α-Copaene	0.1	0.2	0.2
1377	1378	Geranyl acetate	tr	tr	0.1
1387	1387	β-Cubebene	-	tr	tr
1434	1433	*cis*-Thujopsene	-	0.1	-
1437	1439	Isoamyl benzoate	0.1	tr	0.1
1444	1443	3-Methyl-2-buten-1-yl benzoate	-	-	0.1
1444	1446	*cis*-Muurola-3,5-diene	-	0.1	-
1448	1450	*trans*-Muurola-3,5-diene	-	0.1	tr
1451	1452	(*E*)-β-Farnesene	-	0.1	tr

Table 2. *(Continued)*

RI_{calc}	RI_{db}	Compounds	#1	#2	#3
1461	1463	*cis*-Muurola-4(14),5-diene	tr	0.2	tr
1468	1467	9-*epi*-(*E*)-Caryophyllene	-	0.1	tr
1471	1472	Cadina-1(6),4-diene	-	0.1	tr
1474	1475	γ-Muurolene	-	0.2	0.1
1480	1480	Germacrene D	-	0.1	tr
1488	1487	β-Selinene	-	0.1	tr
1491	1490	γ-Amorphene	-	0.2	0.1
1495	1497	α-Selinene	0.1	0.4	0.1
1497	1500	α-Muurolene	tr	0.4	0.2
1502	1503	(*E*,*E*)-α-Farnesene	-	0.1	-
1511	1512	γ-Cadinene	0.1	1.2	0.4
1514	1515	Cubebol	-	0.1	0.1
1517	1518	δ-Cadinene	0.3	2.4	0.9
1521	1521	Zonarene	-	0.1	-
1531	1533	*trans*-Cadina-1,4-diene	-	0.1	tr
1535	1538	α-Cadinene	-	0.1	tr
1539	1540	(*E*)-α-Bisabolene	-	0.1	0.1
1559	1560	(*E*)-Nerolidol	0.1	-	-
1575	1576	Germacra-1(10),5-dien-4β-ol	-	0.1	0.1
1602	1600	α-Oplopenone	-	0.2	0.1
1602	1593	Isoamyl 3-phenylpropionate	0.3	-	-
1608	1610	Cedrol	-	0.1	-
1613	1614	1,10-di-*epi*-Cubenol	0.1	0.1	tr
1627	1628	1-*epi*-Cubenol	-	0.1	0.1
1641	1640	τ-Cadinol	0.1	0.3	0.1
1643	1641	τ-Muurolol	0.1	0.3	0.1
1646	1646	Himachal-2-en-7β-ol	0.1	-	-
1654	1655	α-Cadinol	0.2	0.7	0.2
1662	1664	*ar*-Turmerone	tr	0.1	tr
1667	1668	α-Turmerone	0.1	0.4	0.1
1871	1875	Oplopanonyl acetate	1.7	0.5	0.2
1922	1929	Cembrene	0.5	1.3	1.6
1935	1931	Beyerene	0.6	0.5	0.3

Table 2. *(Continued)*

RI_{calc}	RI_{db}	Compounds	#1	#2	#3
1936	1934	(3*Z*)-Cembrene A	0.1	0.4	0.6
1946	1946	*m*-Camphorene	0.1	-	tr
1953	1951	(3*E*)-Cembrene A	-	0.1	0.1
1965	1968	Sandaracopimara-8(14),15-diene	-	0.1	Tr
1993	1994	Manoyl oxide	0.1	0.1	0.1
1997	2000	Isopimara-7,15-diene	-	0.2	0.1
2004	1998	Luxuriadiene	0.2	0.1	-
2041	2038	Thunbergol A	0.3	0.5	0.9
2053	2053	Manool	4.3	1.8	2.7
2085	2086	Abietadiene	0.2	0.5	0.4
2222	2224[b]	Isopimarinal	-	-	0.1
2230	2245[c]	Palustral	0.5	1.4	0.9
2234	2265[c]	Levopimarinal	0.1	0.3	0.1
2262	2266	Dehydroabietal	0.1	0.1	0.1
2307	2312	Abietal	0.1	0.3	0.1
2366	2366	Neoabietic acid	0.1	0.2	0.1
Compound Classes					
Monoterpene hydrocarbons			38.8	65.4	55.3
Oxygenated monoterpenoids			33.9	8.4	22.6
Sesquiterpene hydrocarbons			0.6	6.4	2.0
Oxygenated sesquiterpenoids			2.3	3.1	1.0
Diterpenoids			7.2	8.0	8.2
Benzenoid aromatics			0.4	0.1	0.2
Others			16.0	8.1	10.2
Total identified			**99.3**	**99.4**	**99.6**

RI_{calc} = Retention index calculated with respect to a homologous series of *n*-alkanes on a ZB-5ms column. RI_{db} = Retention index from the available databases [21–24] unless otherwise indicated. tr = trace (< 0.05%). [a] The identification is only tentative; although there is a good MS match, the RI values are very different. [b] RI value from Shpatov et al., 2017 [38]. [c] The identification is only tentative; although there is a good MS match, the RI values are very different; however, the compound was identified in the bark of *P. sitchensis* [17].

butenyl isovalerate, and piperitone. Furthermore, the major monoterpenoids, α-pinene, β-pinene, δ-3-carene, myrcene, and β-phellandrene, were also observed to be major components in the bark extracts from Vancouver Island, British Columbia [17]. A comparison of the main foliar essential oil components is summarized in Table 3. α-Pinene is a relatively abundant constituent in the foliar essential oils of *Picea* species [25–27]. On the other hand, β-pinene, myrcene, β-phellandrene, isoamyl isovalerate, 3-methyl-3-butenyl isovalerate, and piperitone were not present in one or more *Picea* species [25, 28, 29]. Bornyl acetate is often an abundant constituent of *Picea* essential oils [25, 26], but was not observed in *P. engelmannii* from northern Arizona [28]. Similarly, camphor is often found in *Picea* essential oils, but was not detected in samples of *P. glauca* [25] or *P. sitchensis* [16] from Canada.

Although the essential oils are qualitatively similar, there are some notable quantitative differences. Monoterpene hydrocarbons were generally higher in the British Columbia samples compared to those from Oregon, while oxygenated monoterpenoid and sesquiterpenoid concentrations were higher in the Oregon samples. It is not clear what factors affect the compositional differences. Previous workers have reported large variations in monoterpene concentrations in essential oils of *Picea* species both within and between populations [27, 30] as well as seasonal variations in individual monoterpenoid concentrations [31–33]. Furthermore, the monoterpenoid concentrations vary widely between young leaves and older leaves in *P. sitchensis*; myrcene was found in high concentrations in immature foliage (95%), but decreased with age with concomitant increase in piperitone concentration [34]. The volatile

Table 3. Comparison of the percentages of the main components in the essential oils of *Picea sitchensis* from Oregon, British Columbia, and a commercial sample from New Zealand.

Compounds	Oregon (this work)		British Columbia [16]		New Zealand
	Average	Range	Average	Range	Commercial[a]
α-Pinene	6.5	1.2-12.5	7.4	2.9-11.5	5.1
Camphene	1.0	0.6-1.8	1.0	0.0-1.6	3.0
β-Pinene	4.3	1.2-7.2	5.6	2.9-9.8	3.3
Myrcene	18.8	15.9-22.2	23.1	12.1-33.3	20.7
δ-3-Carene	1.7	0.4-2.9	2.9	0.0-5.9	2.0
Limonene	0.8	0.7-1.1	4.5	1.3-9.9	10.8
β-Phellandrene	17.2	9.1-25.1	21.1	15.5-35.6	9.9
1,8-Cineole	1.5	0.9-1.8	1.3	1.2-1.8	1.7
Terpinolene	0.7	0.5-1.0	0.9	0.0-1.7	0.9
Isoamyl isovalerate (= Solusterol)	4.0	2.3-6.4	3.4	0.8-6.4	3.8
3-Methyl-3-butenyl isovalerate	3.5	1.5-6.9	2.3	0.0-5.3	1.4
Camphor	2.8	0.9-4.4	2.2	0.0-3.5	23.8
Borneol	2.6	0.4-3.9	0.7	0.0-1.8	2.2
α-Terpineol	1.2	0.9-1.6	0.6	0.0-1.0	0.7
Piperitone	8.9	2.9-18.0	7.0	0.5-12.5	2.2
δ-Cadinene	1.2	0.3-2.4	1.3	0.3-4.2	0.1
Manool	3.0	1.8-4.3	1.7	0.3-3.3	0.2
Monoterpene hydrocarbons	53.2	38.8-65.4	77.1	68.5-90.4	58.2
Oxygenated monoterpenoids	21.6	8.4-33.9	9.9	4.5-14.6	35.1
Sesquiterpenoids	5.2	2.9-9.5	2.8	1.3-3.6	0.3

[a] Unpublished data from the Aromatic Plant Research Center, Lehi, Utah, USA.

components of *Picea* species play an important role in avoidance of insects and browsing by herbivores. In *P. sitchensis*, both myrcene and piperitone affect the feeding behavior of spruce aphids (*Cinara costata*, *Cinara pilicornis*, *Cinara pruinosa*, and *Elatobium abietinum*) depending on their tolerance to myrcene or piperitone [30]. Total monoterpene concentration was shown to negatively influence browsing of *P. sitchensis* by red deer (*Cervus elaphus*) [35]. Genetic, edaphic, climatic, and geographic factors are often cited as affecting the essential oil profiles [36, 37]. Latitudinal differences, including climatic differences, may be responsible for the lower monoterpene hydrocarbon concentrations and higher oxygenated monoterpenoid concentrations in the Oregon samples compared to the British Columbia samples. A commercial sample of *P. sitchensis* essential oil from New Zealand (unpublished data from the Aromatic Plant Research Center, Lehi, Utah, USA) has also been included in Table 3 for comparison. The concentration of limonene in the New Zealand sample was notably higher, with concomitant lower β-phellandrene, than in the North American samples. The concentration of camphor was also very high in the New Zealand sample, while the total sesquiterpenoids was very low.

The Oregon *P. sitchensis* foliar essential oils were also analyzed by chiral GC-MS in order to determine the enantiomeric distributions of the terpenoid components (Table 4). The levorotatory enantiomers were dominant for α-pinene, β-pinene, limonene, β-phellandrene, borneol, and piperitone, while (+)-camphor, (+)-δ-3-carene, and (+)-δ-cadinene were dominant. Camphene, linalool, terpinen-4-ol, and α-terpineol were virtually racemic. Robert [17] also found (–)-α-pinene, (–)-β-pinene, (+)-δ-3-carene, and (–)-β-phellandrene to dominate the bark extract of *P. sitchensis*. However, (+)-limonene rather than (–)-limonene was identified in the bark extract. Consistent with the distributions in *P. sitchensis*, (–)-α-pinene, (–)-β-pinene, (–)-limonene, and (–)-β-phellandrene were the predominant enantiomers in *P. pungens* [26] and *P. engelmannii* [27].

4. Conclusions

This work presents the first report on the foliar essential oil of *Picea sitchensis* from the Oregon Coast Range and includes the enantiomeric distributions of chiral terpenoid components. The essential oils of *P. sichensis* were rich in (–)-α-pinene, (–)-β-pinene, myrcene, (–)-β-phellandrene, isoamyl isovalerate, 3-methyl-3-butenyl isovalerate, and (–)-piperitone.

Table 4. Enantiomeric distribution (%) of terpenoid components in *Picea sitchensis* from the Oregon Coast Range.

Compounds	RI_{db}	RI_{calc}	#1	#2	#3
(+)-α-Thujene	950	-	-	-	0.0
(−)-α-Thujene	951	951	-	-	100.0
(−)-α-Pinene	976	975	86.1	95.2	92.0
(+)-α-Pinene	982	982	13.9	4.8	8.0
(−)-Camphene	998	1000	54.7	60.0	66.8
(+)-Camphene	1005	1004	45.3	40.0	33.2
(+)-Sabinene	1021	1021	-	-	14.2
(−)-Sabinene	1030	1029	-	-	85.8
(+)-β-Pinene	1027	1027	5.0	3.3	3.1
(−)-β-Pinene	1031	1031	95.0	96.7	96.9
(+)-δ-3-Carene	1052	1052	100.0	100.0	100.0
(−)-δ-3-Carene	na	-	0.0	0.0	0.0
(−)-Limonene	1073	1079	77.8	76.7	70.2
(+)-Limonene	1081	1082	22.2	23.3	29.8
(−)-β-Phellandrene	1083	1083	99.7	99.6	99.6
(+)-β-Phellandrene	1089	1087	0.3	0.4	0.4
(−)-Linalool	1228	1216	43.5	48.9	60.0
(+)-Linalool	1231	1220	56.5	51.1	40.0
(−)-Camphor	1253	1253	2.1	0.0	4.6
(+)-Camphor	1259	1255	97.9	100.0	95.4
(+)-Terpinen-4-ol	1297	1298	58.3	56.6	42.0
(−)-Terpinen-4-ol	1300	1301	41.5	43.4	58.0
(−)-Borneol	1335	1338	70.0	56.9	74.5
(+)-Borneol	1340	1348	30.0	43.1	25.5
(−)-α-Terpineol	1347	1350	36.7	55.5	40.4
(+)-α-Terpineol	1356	1358	63.3	44.5	59.6
(−)-Piperitone	1380	1385	99.2	98.3	99.1
(+)-Piperitone	1385	1391	0.8	1.7	0.9
(−)-δ-Cadinene	1563	-	0.0	0.0	0.0
(+)-δ-Cadinene	1576	1567	100.0	100.0	100.0

RI_{db} = Retention index from our in-house database developed using commercially available samples on a Restek B-Dex 325 column. RI_{calc} = Retention index determined with respect to a homologous series of *n*-alkanes on a Restek B-Dex 325 column. na = reference compound not available. - = compound not observed.

While the compositions are qualitatively similar to those from British Columbia, it would be interesting to compare the Oregon and British Columbia essential oil profiles with populations from Washington state and northern California as well as western Europe in order to more fully appreciate the quantitative differences based on geographical location. Since *P. sichensis* is commercially important and cultivated for lumber, the foliage recovered represents a value-added commodity, which may be commercially exploited in the essential oil industry.

Authors' contributions

Conceptualization, W.N.S.; Methodology, P.S. and W.N.S.; Software, P.S.; Validation, W.N.S., Formal Analysis, P.S., A.P., and W.N.S.; Investigation, P.S., A.P., K.S., and W.N.S.; Resources, P.S. and W.N.S.; Data Curation, W.N.S.; Writing – Original Draft Preparation, W.N.S.; Writing – Review & Editing, P.S., A.P., K.S., and W.N.S.; Project Administration, W.N.S.

Acknowledgements

This work was carried out as part of the activities of the Aromatic Plant Research Center (APRC, https://aromaticplant.org/). We are grateful to Elizabeth and Dewey Ankney for their assistance in plant collection.

Funding

This research received no specific grant from any funding agency.

Availability of data and materials

All data will be made available on request according to the journal policy.

Conflicts of interest

The authors declare no conflict of interest.

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