



Research Article

The volatile phytochemicals of *Purshia tridentata* var. *tridentata* from southern Idaho

Kathy Swor¹ , Ambika Poudel² , Prabodh Satyal² and William N. Setzer^{2, 3*}

1. Independent Researcher, 1432 W. Heartland Dr, Kuna, ID 83634, USA
2. Aromatic Plant Research Center, 230 N 1200 E, Suite 100, Lehi, UT 84043, USA
3. Department of Chemistry, University of Alabama in Huntsville, Huntsville, AL 35899, USA

Article Information

Received: 13 February, 2023
Revised: 27 February, 2023
Accepted: 04 March, 2023

Academic Editor

Radoslaw Kowalski

Corresponding Author

William N. Setzer
wsetzer@chemistry.uah.edu
Tel.: +1-256-468-2862

Keywords

Bitterbrush, essential oil, chemical composition, enantiomers, chiral, gas chromatography

Abstract

Purshia tridentata is an arid lands shrub, native to western North America. The plant has been used in Native American traditional medicine and also serves as an important winter forage for mule deer. The purpose of this work was to examine the essential oil of *P. tridentata*. Aerial parts of *P. tridentata* var. *tridentata* were collected from several locations in southern Idaho. The essential oils were obtained by hydrodistillation and analyzed by gas chromatographic techniques (GC-MS, GC-FID, and chiral GC-MS). The essential oil components with the highest concentrations were heptacosane (3.1-18.7%), *trans*-calamenene (0.5%-17.1%), 2-coumaranone (0.5-11.3%), *trans*-cadinane-1,4-diene (0.2-7.0%), (3*Z*)-hexen-1-ol (0.3-8.0%), and linalool (0.5-5.7%). The (–)-enantiomers predominated in the essential oils for α -pinene, β -pinene, β -phellandrene, α -thujone, α -terpineol, bornyl acetate, (*E*)- β -caryophyllene, germacrene D, β -bisabolene, and (*E*)-nerolidol, while the (+)-enantiomers for limonene, linalool, camphor, and δ -cadinene were dominant. This is the first report on the essential oil composition and enantiomeric distribution of *P. tridentata* var. *tridentata* or any *Purshia* species. As in other members of the Rosaceae, fatty acid derivatives and sesquiterpenoids dominated the aerial parts essential oils of *P. tridentata* var. *tridentata*.

1. Introduction

Purshia tridentata (Pursh) DC. (syn. *Kunzia tridentata* Spreng., bitterbrush), Rosaceae, is an evergreen or partially deciduous shrub around 1-5 m tall with three-lobed leaves 4-15 mm long \times 3-7 mm wide (Fig. 1) [1]. Two varieties of *P. tridentata* are currently recognized, *Purshia tridentata* var. *tridentata* (antelope bitterbrush), and *Purshia tridentata* var. *glandulosa* (Curran) M.E. Jones (syn. *Purshia glandulosa* Curran, desert bitterbrush) [2]. *Purshia tridentata* var. *tridentata* normally ranges from southern British Columbia, south through eastern Washington, eastern Oregon, Idaho, Nevada, and Utah, and into northern Arizona (Fig. 2), while *P. tridentata* var. *glandulosa* is found in Nevada, Utah, south into northern Sonora, Mexico [3].

The Paiute and Shoshoni people took an infusion of the aerial parts as a cathartic/emetic, while a poultice of the leaves was used to treat skin problems [4]. The Chumash people took a tea made from *P. tridentata* to ease menstrual cramps [5]. The triterpenoids cucurbitacin D and cucurbitacin I [6] as well as the cyanogenic glycosides purshianin and menisdaurin [7] have been isolated from *P. tridentata*. Several ungulates utilize *P. tridentata* for forage [8], in particular mule deer (*Odocoileus hemionus*) rely heavily on the plant in the winter [9–11]. Domestic sheep and cattle, but not horses, have also shown a preference for *P. tridentata* [12,13].



Figure 1. *Purshia tridentata* var. *tridentata* from southern Idaho. Photograph by K. Swor.

The purpose of this present study was to collect *P. tridentata* var. *tridentata* from several locations in southern Idaho, obtain the essential oils by hydrodistillation and characterize the essential oils using gas chromatographic techniques. As far as we are aware, this is the first report on the essential oil composition of *P. tridentata*.

2. Materials and methods

2.1 Plant material

The aerial parts of *P. tridentata* var. *tridentata* were



Figure 2. Distribution of *Purshia tridentata* var. *tridentata* (antelope bitterbrush) in western North America. Adapted from McArthur et al. [3].

collected from several different plants (samples #1, #2, #3, #4, and #5) growing wild in southern Idaho (Table 1). The plants were identified by Daniel Murphy, Collections Curator, Idaho Botanical Garden, and verified by W.N. Setzer based on botanical descriptions [1] and by comparison with samples from the New York Botanical Garden virtual herbarium

(<https://sweetgum.nybg.org/science/vh/specimen-list/?SummaryData=Purshia%20tridentata>, accessed on June 29, 2022). A voucher specimen (WNS-Ptt-5682) has been deposited in the University of Alabama in Huntsville herbarium. The aerial parts were immediately frozen ($-20\text{ }^{\circ}\text{C}$) until distilled. Each of the plant samples was hydrodistilled using a Likens-Nickerson apparatus with continuous extraction with dichloromethane for 3 h to give the essential oils (Table 1).

2.2 Gas chromatographic analysis

The essential oils were analyzed by gas chromatography with flame ionization detection (GC-FID), gas chromatography – mass spectrometry (GC-MS) and chiral GC-MS as previously described [14]. Retention index values were determined using a homologous series of n-alkanes on a ZB-5ms column

Table 1. Collection and hydrodistillation details of *Purshia tridentata* var. *tridentata*.

Sample	Collection Date	Coordinates, elevation	Mass aerial parts (g)	Mass Essential oil (mg)
#1	6/28/2022	43°24'20"N, 115°17'34"W, 1420 m	81.24	787.3
#2	6/28/2022	43°24'20"N, 115°17'34"W, 1420 m	84.93	644.5
#3	6/28/2022	43°24'20"N, 115°17'34"W, 1420 m	86.33	297.0
#4	7/7/2022	43°43'34"N, 116°9'28"W, 1481 m	40.07	197.1
#5	7/29/2021	43°36'04"N, 116°09'35"W, 862 m	42.26	127.2

using the linear formula of van den Dool and Kratz [15]. The essential oil components were identified by comparison of the mass spectral fragmentation patterns and by comparison of retention index (RI) values available in the Adams [16], FFNSC 3 [17], NIST20 [18], and our own in-house database [19]. The identification of enantiomers was determined by comparison of retention times with authentic samples obtained from Sigma-Aldrich (Milwaukee, WI, USA).

2.3. Multivariate analyses

For the agglomerative hierarchical cluster (AHC) analyses, the essential oil compositions for the five samples were treated as operational taxonomic units (OTUs), and the percentages of the most abundant essential oil components (heptacosane, *trans*-calamenene, 2-coumaranone, (3*Z*)-hexen-1-ol, *trans*-cadin-1,4-diene, (2*E*)-hexenal, α -muurolol, α -cadinol, pentacosane, linalool, bornyl acetate, tetradecanal, (*E*)-nerolidol, dodecanal, (3*Z*)-hexenyl benzoate, germacrene D, cubenol, benzyl alcohol, nonanal, and δ -cadinene) were used to establish the chemical associations between the essential oil samples. Pearson correlation was used to measure similarity, and the unweighted pair group method with arithmetic average (UPGMA) was used for cluster definition. Principal component analysis (PCA) was performed for the visual verification of the essential

oil interrelationships of the different samples of *P. tridentata* var. *tridentata* using the major components as variables with a Pearson correlation matrix. The AHC and PCA analyses were performed using XLSTAT v. 2018.1.1.62926 (Addinsoft, Paris, France).

4. Results and discussion

3.1 Essential oil composition

Hydrodistillation of the aerial parts of *P. tridentata* var. *tridentata* gave colorless essential oils in yields ranging from 0.301% to 0.969%. The gas chromatographic analysis (GC-MS and GC-FID) results are summarized in Table 2.

Monoterpenoids made up relatively small percentages in the essential oils. Sesquiterpenoids and fatty acid derivatives, however, were relatively abundant. The components in the essential oils with the highest concentrations were heptacosane (3.1-18.7%), *trans*-calamenene (0.5%-17.1%), 2-coumaranone (0.5-11.3%), *trans*-cadin-1,4-diene (0.2-7.0%), (3*Z*)-hexen-1-ol (0.3-8.0%), and linalool (0.5-5.7%). Bornyl acetate was relatively abundant in sample #5 (8.7%), but not detected in the other samples, and (2*E*)-hexenal was relatively abundant in samples #1, #2 and #4 (5.1%, 4.0%, and 3.4%, respectively), but not observed in samples #3 or #5.

There are some notable differences in the essential oil compositions. In order to assess the differences, an agglomerative hierarchical cluster (AHC) analysis as well as a principal cluster analysis (PCA) were carried out (Fig. 3 and 4). The AHC analysis reveals samples #1 and #2 to have 83% similarity, while samples #4 and #5 have 59% similarity. Sample #3 shows only 22% similarity to the other samples. The PCA further explains the differences. Samples #1 and #2 correlate strongly with heptacosane, 2-coumaranone, (3*Z*)-hexen-1-ol, and (2*E*)-hexenal. Samples #4 and #5 correlate very strongly with heptacosane, while #5 also correlates with bornyl acetate. Sample #3, on the other hand, shows correlation with *trans*-calamenene as well as *trans*-cadin-1,4-diene and α -muurolol.

It is not obvious what factors may be attributable to the compositional differences. Essential oil differences are often attributed to geographical, edaphic, climatic, or genetic differences. Samples #1, #2, and #3 were collected from the same location on the same day; differences in composition are likely attributable to

Table 2. Essential oil compositions (percentages) of the aerial parts of *Purshia tridentata* var. *tridentata* collected in southern Idaho.

RI _{calc}	RI _{db}	Compound	#1	#2	#3	#4	#5
800	801	Hexanal	0.8	0.7	-	1.0	0.1
850	850	(2E)-Hexenal	5.1	4.0	-	3.4	-
852	853	(3Z)-Hexen-1-ol	5.5	5.5	0.3	3.0	8.0
863	863	(2E)-Hexen-1-ol	0.5	0.4	tr	0.3	0.4
867	867	1-Hexanol	0.5	0.4	tr	0.3	0.4
902	905	Heptanal	-	0.3	-	0.3	-
934	933	α-Pinene	0.9	1.9	tr	0.2	2.7
947	942	4,4-Dimethyl-2-butenolide	0.9	1.0	0.2	0.3	-
950	953	Camphene	-	-	-	-	0.2
963	964	Benzaldehyde	0.5	0.6	0.1	0.4	0.7
972	974	Hexanoic acid	-	-	0.2	-	-
972	972	Sabinene	-	-	-	-	0.1
978	978	β-Pinene	1.0	0.3	tr	0.4	1.4
989	989	Myrcene	-	-	-	-	0.2
1005	1006	Octanal	0.5	0.6	0.1	1.4	0.3
1024	1025	p-Cymene	0.3	0.3	tr	0.1	-
1029	1030	Limonene	0.8	0.3	tr	0.3	0.6
1031	1031	β-Phellandrene	0.7	0.4	tr	2.3	0.2
1032	1032	1,8-Cineole	-	-	tr	0.2	-
1033	1033	Benzyl alcohol	3.8	1.4	0.4	0.8	0.2
1035	1034	(Z)-β-Ocimene	0.8	0.5	tr	-	1.1
1043	1045	Phenylacetaldehyde	0.5	1.2	0.1	0.7	-
1044	1044	Salicylaldehyde	0.5	0.3	-	-	0.5
1046	1046	(E)-β-Ocimene	0.4	0.2	tr	0.2	0.1
1050	1049	cis-Arbusculone	0.4	0.4	tr	0.2	-
1055	1047	Methyl 2-hydroxyhexanoate	-	-	0.1	-	-
1069	1068	trans-Arbusculone	-	-	tr	-	-
1070	1073	Allyl hexanoate	-	-	0.1	-	-
1071	1069	cis-Linalool oxide (furanoid)	-	-	-	0.4	-
1086	1086	Terpinolene	0.6	0.3	0.1	-	-
1087	1086	trans-Linalool oxide (furanoid)	-	-	tr	0.4	-
1100	1101	Linalool	1.1	0.5	0.2	5.7	1.7
1103	1102	6-Methylhepta-3,5-diene	-	-	0.1	-	-
1105	1107	Nonanal	1.1	1.6	0.3	1.6	1.5
1107	1105	α-Thujone	2.0	0.4	0.3	0.3	-
1112	1113	Phenethyl alcohol	1.8	1.5	0.6	0.7	0.2
1113	1113	(E)-4,8-Dimethylnona-1,3,7-triene	-	-	0.1	0.3	-
1126	1126	α-Campholenal	-	0.3	0.1	-	-
1145	1145	trans-Verbenol	0.3	0.7	0.1	-	-
1148	1149	Camphor	0.8	0.5	0.1	0.5	0.3
1152	1153	(2E,6Z)-Nonadienal	0.6	0.3	0.1	0.4	-
1156	1156	Camphene hydrate	-	-	-	-	0.1
1162	1162	β-Artemisyl acetate	-	0.9	-	0.4	-
1168	1169	3-Thujanol	0.4	-	0.3	-	-
1171	1171	p-Mentha-1,5-dien-8-ol	-	-	0.1	-	-
1180	1180	Terpinen-4-ol	0.3	0.5	0.1	0.3	0.3
1192	1192	Methyl salicylate	0.4	0.2	0.1	-	-
1195	1195	α-Terpineol	0.4	0.1	0.1	1.1	1.4
1196	1195	Myrtenol	-	0.4	-	-	-
1206	1206	Decanal	1.0	1.1	0.3	1.9	0.6
1232	-	2-Coumaranone	5.3	3.8	0.5	2.9	11.3
1251	1249	Geraniol	-	-	-	0.4	-
1284	1285	Bornyl acetate	-	-	-	-	8.7
1285	1286	2,4-Pentadiynylbenzene	0.7	0.3	0.1	-	-
1292	1293	2-Undecanone	-	-	-	-	0.2

Table 2 (Continued).

RI _{calc}	RI _{db}	Compound	#1	#2	#3	#4	#5
1300	1300	Tridecane	0.3	0.4	0.1	0.6	0.2
1309	1309	Undecanal	0.6	0.5	0.3	1.9	1.3
1310	1309	4-Vinylguaiaicol	0.5	0.4	-	-	-
1349	1349	α -Cubebene	0.7	0.9	2.4	0.4	-
1350	1356	Eugenol	-	-	-	-	0.2
1376	1375	α -Copaene	0.4	0.3	0.5	0.2	-
1383	1382	β -Bourbonene	0.4	0.3	1.4	0.2	-
1385	1385	α -Bourbonene	-	-	0.1	-	-
1386	1387	β -Cubebene	-	-	0.3	-	-
1389	1390	<i>trans</i> - β -Elemene	-	-	-	1.6	-
1389	1387	(6 <i>E</i>)-6-Methyl-5-(1-methylethylidene)-6,8-nonadien-2-one	2.1	1.3	0.4	1.1	0.5
1400	1403	Methyl eugenol	0.4	0.3	-	-	-
1405	1406	α -Gurjunene	-	-	0.4	-	-
1409	1409	Dodecanal	2.2	2.1	0.3	2.3	0.7
1419	1418	(<i>E</i>)- β -Caryophyllene	1.4	1.1	0.7	1.0	tr
1428	1430	β -Copaene	-	-	0.2	-	-
1433	1432	<i>trans</i> - α -Bergamotene	-	0.3	0.6	-	-
1443	1444	Guaia-6,9-diene	1.6	-	-	-	-
1451	1453	<i>trans</i> -Muurola-3,5-diene	0.6	0.5	1.5	-	-
1453	1454	α -Humulene	-	-	0.4	-	-
1463	1463	γ -Decalactone	-	-	-	-	0.6
1471	1472	<i>trans</i> -Cadina-1(6),4-diene	-	-	1.0	-	-
1478	1479	α -Amorphene	-	-	-	0.5	-
1480	1480	Germacrene D	2.6	1.6	2.0	1.1	-
1484	1483	Davana ether 1	0.3	0.5	-	0.2	-
1490	1490	γ -Amorphene	-	-	3.2	0.4	tr
1494	1496	<i>trans</i> -Muurola-4(14),5-diene	0.9	1.0	-	-	-
1496	1598	Viridiflorol	-	-	0.9	-	-
1497	1497	<i>epi</i> -Cubebol	0.5	0.6	0.5	-	1.9
1498	1497	Bicyclogermacrene	-	-	0.5	-	-
1499	1497	Capillene	0.9	0.7	-	-	-
1499	1500	α -Muurolene	-	-	0.5	-	0.6
1500	1500	Pentadecane	0.3	0.6	-	-	0.2
1502	1502	Davana ether 2	1.5	1.8	-	0.9	-
1503	1503	(<i>Z</i>)- α -Bisabolene	-	-	0.6	-	-
1504	1504	Davana ether 3	0.5	0.5	0.1	0.2	-
1510	1510	β -Bisabolene	-	-	0.4	-	0.4
1511	1510	Tridecanal	-	-	-	0.2	tr
1511	1511	(<i>Z</i>)- γ -Bisabolene	0.4	0.8	0.9	0.1	-
1513	1512	γ -Cadinene	-	-	-	-	0.3
1516	1515	Cubebol	0.6	0.5	1.2	0.2	0.8
1518	1518	δ -Cadinene	0.6	0.6	1.3	0.5	3.0
1523	1527	<i>trans</i> -Calamenene	5.3	7.9	17.1	4.2	0.5
1526	1526	Zonarene	-	-	1.3	-	-
1535	1533	<i>trans</i> -Cadina-1,4-diene	1.7	2.6	7.0	1.2	0.2
1543	1544	α -Calacorene	0.8	0.8	2.0	0.8	-
1546	1550	5-Ethyl-1-tetralone	0.8	1.0	2.1	0.7	-
1549	1549	α -Elemol	-	-	-	0.4	1.7
1562	1562	(<i>E</i>)-Nerolidol	2.5	2.6	-	3.0	0.2
1564	1564	β -Calacorene	-	-	1.3	-	-
1572	1571	(3 <i>Z</i>)-Hexenyl benzoate	1.3	2.4	0.9	1.7	1.2
1573	1567	Palustrol	-	-	0.8	-	-
1578	1576	Spathulenol	0.3	-	0.4	-	tr
1579	1577	Davanone	-	1.0	-	0.6	-
1580	1578	Furopolargone B	1.6	-	-	-	-
1584	1587	Caryophyllene oxide	0.9	1.0	2.3	0.9	tr

Table 2 (Continued).

RI _{calc}	RI _{db}	Compound	#1	#2	#3	#4	#5
1594	1593	Salvial-4(14)-en-1-one			0.5		
1595	1594	Viridiflorol	0.6	0.6	-	-	0.8
1598	-	Unidentified	-	-	1.2	1.5	-
1600	1600	Hexadecane	-	-	-	-	0.1
1603	1607	β -Oplopenone	-	-	-	-	0.4
1606	1605	Ledol	-	-	0.5	-	-
1611	1611	Humulene epoxide II	-	-	1.3	-	-
1616	1614	Tetradecanal	1.9	2.2	0.5	2.6	1.3
1630	1631	1- <i>epi</i> -Cubenol	-	0.5	1.2	0.5	1.3
1631	1629	<i>iso</i> -Spathulenol	1.3	-	-	-	-
1632	1632	γ -Eudesmol	-	-	-	-	0.4
1644	1644	τ -Muurolol	-	-	-	-	2.6
1645	1646	Cubenol	0.9	1.6	2.6	0.8	1.1
1649	1651	α -Muurolol (= δ -Cadinol)	1.3	2.6	4.8	1.4	1.6
1655	1655	α -Cadinol	2.2	2.1	-	0.7	6.0
1656	1656	β -Eudesmol	-	-	-	1.9	-
1657	-	Unidentified	-	-	1.9	-	0.3
1660	1660	Selin-11-en-4 α -ol	-	-	-	0.8	-
1665	1665	Intermedeol	-	-	-	-	3.4
1666	1670	<i>trans</i> -Calamenen-10-ol	-	-	0.4	-	-
1674	1674	β -Bisabolol	-	0.6	-	-	-
1676	1677	Cadalene	0.9	0.8	2.6	1.0	tr
1687	1688	α -Bisabolol	-	1.0	0.8	0.4	0.6
1692	1690	Germacra-4(15),5,10(14)-trien-1 β -ol	-	-	0.4	-	-
1699	-	Unidentified	-	-	1.0	-	-
1700	1700	Heptadecane	-	-	-	-	0.2
1716	1715	5-Hydroxy- <i>cis</i> -calamenene			0.6		
1728	-	Unidentified	-	0.5	1.3	0.5	-
1742	1742	(6 <i>S</i> ,7 <i>R</i>)-Bisabolone	-	-	-	-	0.4
1766	1769	Benzyl benzoate	0.6	1.1	-	0.8	tr
1818	1817	Hexadecanal	1.0	1.1	0.4	1.2	0.7
1842	1841	Phytone	0.4	0.3	0.2	0.7	0.3
1876	-	Unidentified	1.3	0.3	0.2	-	-
1900	1900	Nonadecane	-	-	0.2	-	-
1937	-	Unidentified	-	-	-	1.0	-
1961	1958	Palmitic acid	-	-	0.4	-	-
1975	-	Unidentified	-	-	-	1.2	-
1998	-	Unidentified	-	-	-	1.3	-
2000	2000	Eicosane	-	-	0.1	-	-
2100	2100	Heneicosane	0.3	0.7	0.2	0.3	-
2111	2109	Phytol	1.6	0.6	0.2	2.0	-
2194	2193	Ethyl stearate	-	-	0.2	-	-
2200	2200	Docosane	-	-	0.1	-	-
2245	2243	9-Hexylheptadecane	-	-	-	3.5	-
2300	2300	Tricosane	1.4	1.9	1.1	1.1	0.3
2394	2394	Ethyl eicosanoate	-	-	0.5	-	-
2400	2400	Tetracosane	-	-	0.1	-	-
2500	2500	Pentacosane	2.2	2.4	1.0	2.7	1.5
2600	2600	Hexacosane	-	-	0.1	-	-
2700	2700	Heptacosane	5.2	7.0	3.1	12.0	18.7
		Essential oil compound classes					
		Monoterpene hydrocarbons	5.5	4.1	0.1	3.5	6.7
		Oxygenated monoterpenoids	5.3	4.4	1.4	9.7	12.5
		Sesquiterpene hydrocarbons	18.2	19.7	50.2	13.1	4.7
		Oxygenated sesquiterpenoids	15.1	17.6	19.3	12.7	23.2
		Diterpenoids	1.6	0.6	0.2	2.0	0.0

Table 2 (Continued).

Essential oil compound classes	#1	#2	#3	#4	#5
Benzenoid aromatics	17.2	14.1	2.7	8.0	14.3
Fatty acid derivatives	30.8	33.6	10.1	42.0	37.5
Others	4.6	4.0	3.1	3.2	0.8
Total identified	98.2	98.0	87.1	94.2	99.7

RI_{calc}=Retention index determined using a homologous series of *n*-alkanes on a ZB-5ms column [15]. RI_{db}=Reference retention index from the databases [16–19]. tr = trace (< 0.5%). #1-#5 refer to sample numbers of the collected plants.

variation within the species. Samples #4 and #5 were collected on different dates from different locations, so compositional differences may be attributed to seasonal (although all samples were collected in mid-summer), edaphic, geographical (although the locations are relatively close to one another), or elevation (sample #5 was collected at much lower elevation than the others).

Outside of floral essential oils, the Rosaceae is not considered to be an essential oil-bearing plant family [20]. Fatty acid derivatives and sesquiterpenoids generally dominate the essential oils of aerial parts of members of the Rosaceae.

For example, the aerial parts essential oils of *Rosa* spp. were dominated by long-chain *n*-alkanes [21,22]. Long-chain *n*-alkanes as well as other fatty acid derivatives were abundant in the essential oil of *Filipendula hexapetala* [23], while *Sibiraea laevigata* was a rich source of fatty acid esters [24]. Thus, the essential oil compositions of *P. tridentata* var. *tridentata* are consistent with those observed in other members of the Rosaceae.

3.2 Enantiomeric distributions

The *P. tridentata* var. *tridentata* essential oils were analyzed using chiral GC-MS. The enantiomeric distributions of chiral terpenoid components are listed in Table 3.

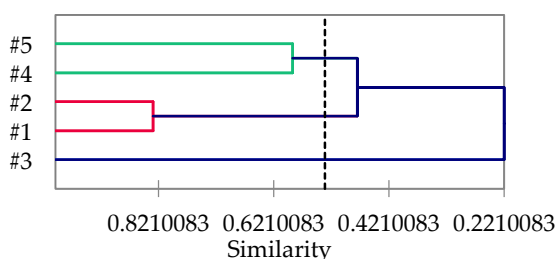


Figure 3. Dendrogram based on hierarchical cluster analysis of *Purshia tridentata* var. *tridentata* essential oil compositions.

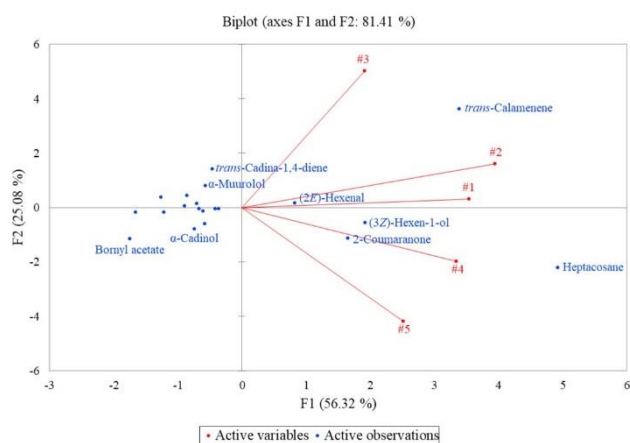


Figure 4. Biplot based on principal component analysis of *Purshia tridentata* var. *tridentata* chemical compositions.

The (-)-enantiomers predominated in the essential oils for α -pinene, β -pinene, β -phellandrene, α -thujone, α -terpineol, bornyl acetate, (*E*)- β -caryophyllene, germacrene D, β -bisabolene, and (*E*)-nerolidol, while the (+)-enantiomers for limonene, linalool, camphor, and δ -cadinene were dominant. The floral essential oil of *Rosa damascena* Mill., in comparison, showed (+)- α -pinene, (+)- β -pinene, and (+)- α -terpineol to be the dominant enantiomers, while (-)-linalool predominated over (+)-linalool, and the enantiomeric distribution of limonene depended on the geographical location (Bulgaria or Türkiye) [25]. Thus, the enantiomeric distributions of chiral terpenoids in *P. tridentata* var. *tridentata* are consistent throughout the samples. However, the enantiomeric distributions of monoterpenoids are different between *P. tridentata* and *R. damascena*.

4. Conclusions

This is the first report on the essential oil composition and enantiomeric distribution of *P. tridentata* var. *tridentata*. As in other members of the Rosaceae, fatty acid derivatives and sesquiterpenoids dominated the aerial parts essential oils *P. tridentata* var. *tridentata*.

Table 3. Enantiomeric distribution, %(+), %(-), for *Purshia tridentata* var. *tridentata* aerial parts essential oils from southern Idaho.

Compounds	#1		#2		#3		#4		#5	
	%(+)	%(-)	%(+)	%(-)	%(+)	%(-)	%(+)	%(-)	%(+)	%(-)
α -Pinene	0.0	100.0	0.0	100.0	0.0	100.0	nd		22.0	78.0
β -Pinene	0.0	100.0	0.0	100.0	0.0	100.0	0.0	100.0	0.0	100.0
Limonene	80.7	19.3	71.6	28.4	nd		nd		62.5	37.5
β -Phellandrene	26.9	73.1	20.7	79.3	nd		0.0	100.0	nd	
α -Thujone	0.0	100.0	0.0	100.0	nd		0.0	100.0	nd	
Linalool	54.3	45.7	nd		62.3	37.7	61.7	38.3	55.9	44.1
Camphor	100.0	0.0	100.0	0.0	100.0	0.0	100.0	0.0	nd	
Bornyl acetate	nd		nd		nd		nd		0.0	100.0
α -Terpineol	nd		nd		nd		38.4	61.6	31.2	78.8
(E)- β -Caryophyllene	0.0	100.0	0.0	100.0	0.0	100.0	0.0	100.0	nd	
Germacrene D	0.0	100.0	0.0	100.0	0.0	100.0	0.0	100.0	nd	
β -Bisabolene	nd		nd		0.0	100.0	nd		nd	
δ -Cadinene	100.0	0.0	100.0	0.0	100.0	0.0	100.0	0.0	100.0	0.0
(E)-Nerolidol	0.0	100.0	0.0	100.0	0.0	100.0	0.0	100.0	nd	

nd = not detected.

Additional research is needed to adequately describe the volatile phytochemistry of *Purshia* species, particularly *P. tridentata* var. *glandulosa* as well as *Purshia plicata* (D. Don) Henrickson, *Purshia mexicana* (D. Don) Henrickson, *Purshia stansburiana* (Torr.) Henrard, and *Purshia ericifolia* (Torr. ex A. Gray) Henrickson. The low yields and variable chemical compositions likely preclude any industrial exploitation of *P. tridentata* essential oil.

Authors' contributions

Conceptualization, W.N.S.; Methodology, P.S. and W.N.S.; Software, P.S.; Validation, W.N.S., Formal Analysis, A.P., P.S., and W.N.S.; Investigation, K.S., A.P., P.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, K.S., P.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/>).

Funding

This research received no specific grant from any funding agency.

Conflicts of interest

The authors declare no conflict of interest.

References

1. Flora of North America, Editorial Committee. *Purshia tridentata*. Available online: http://www.efloras.org/florataxon.aspx?flora_id=1&taxon_id=220011274 (accessed on Feb 2, 2022).
2. World Flora Online, W.F.O. *Purshia tridentata* (Pursh) DC. Available online: <http://www.worldfloraonline.org/taxon/wfo-0001014259> (accessed on Feb 10, 2023).
3. McArthur, E.D.; Stutz, H.C.; Sanderson, S.C. Taxonomy, distribution, and cytogenetics of *Purshia*, *Cowania*, and *Fallugia* (Rosioideae, Rosaceae). In Proceedings of the Symposium on Research and Management of Bitterbrush and Cliffrose in Western North America; Tiedemann, A.R., Johnson, K.L., Eds.; U.S. Department of Agriculture Forest Service: Ogden, Utah, USA, 1983; pp. 4–24.
4. Moerman, D.E. Native American Ethnobotany; Timber Press, Inc.: Portland, OR, 1998; ISBN 978-0-88192-453-4.
5. Adams, J.D.; Garcia, C. Women's health among the Chumash. Evidence-based Complement. Altern. Med. 2006, 3, 125–131, doi:10.1093/ecam/nek021.
6. Dreyer, D.L.; Trousdale, E.K. Cucurbitacins in *Purshia tridentata*. Phytochemistry 1978, 17, 325–326, doi:[https://doi.org/10.1016/S0031-9422\(00\)94181-5](https://doi.org/10.1016/S0031-9422(00)94181-5).
7. Nakanishi, T.; Nishi, M.; Somekawa, M.; Murata, H.; Mizuno, M.; Iinuma, M.; Tanaka, T.; Murata, J.; Lang, F.A.; Inada, A. Structures of new and known cyanoglucosides from a North American plant, *Purshia tridentata* DC. Chem. Pharm. Bull. 1994, 42, 2251–2255.
8. Ngugi, K.R.; Powell, J.; Hinds, F.C.; Olson, R.A. Range animal diet composition in southcentral Wyoming. J.

- Range Manag. 1992, 45, 542–545, doi:10.2307/4002568.
9. Ferguson, R.B. Survival and growth of young bitterbrush browsed by deer. *J. Wildl. Manage.* 1968, 32, 769–772, doi:https://doi.org/10.2307/3799552.
 10. Anderson, A.E.; Medin, D.E.; Bowden, D.C. Mule deer fecal group counts related to site factors on winter range. *J. Range Manag.* 1972, 25, 66–68, doi:10.2307/3896669.
 11. Burrell, G.C. Winter diets of mule deer in relation to bitterbrush abundance. *J. Range Manag.* 1982, 35, 508–510, doi:10.2307/3898618.
 12. Jensen, C.H.; Smith, A.D.; Scotter, G.W. Guidelines for grazing sheep on rangelands used by big game in winter. *J. Range Manag.* 1972, 25, 346–352, doi:10.2307/3896543.
 13. Krannitz, P.G.; Hicks, S.L. Browsing of antelope bitterbrush (*Purshia tridentata*: Rosaceae) in the South Okanagan Valley, British Columbia: Age preferences and seasonal differences. *Am. Midl. Nat.* 2000, 144, 109–122.
 14. Swor, K.; Satyal, P.; Timsina, S.; Setzer, W.N. Chemical composition and terpenoid enantiomeric distribution of the essential oil of *Artemisia tridentata* subsp. *tridentata* from southwestern Idaho. *Nat. Prod. Commun.* 2022, 17, 1934578X2211174, doi:10.1177/1934578x221117417.
 15. van den Dool, H.; Kratz, P.D. A generalization of the retention index system including linear temperature programmed gas-liquid partition chromatography. *J. Chromatogr. A* 1963, 11, 463–471, doi:10.1016/S0021-9673(01)80947-X.
 16. Adams, R.P. 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.
 17. Mondello, L. FFNSC 3; Shimadzu Scientific Instruments: Columbia, Maryland, USA, 2016.
 18. NIST20; National Institute of Standards and Technology: Gaithersburg, Maryland, USA, 2020.
 19. 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, Huntsville, AL, USA, 2015.
 20. Başer, K.H.C.; Buchbauer, G. Handbook of Essential Oils: Science, Technology, and Applications; CRC Press: Boca Raton, Florida, USA, 2010; ISBN 978-1-4200-6315-8.
 21. Moein, M.; Karami, F.; Tavallali, H.; Ghasemi, Y. Composition of the essential oil of *Rosa damascena* Mill. from south of Iran. *Iran. J. Pharm. Sci.* 2010, 6, 59–62.
 22. Elhawary, E.A.; Mostafa, N.M.; Labib, R.M.; Singab, A.N. Metabolomic profiles of essential oils from selected *Rosa* varieties and their antimicrobial activities. *Plants* 2021, 10, 1721, doi:10.3390/plants10081721.
 23. Pavlovic, M.; Petrovic, S.; Ristic, M.; Maksimovic, Z.; Kovacevic, N. Essential oil of *Filipendula hexapetala*. *Chem. Nat. Compd.* 2007, 43, 228–229, doi:10.1007/s10600-007-0088-z.
 24. Lai, P.-X.; Zhang, X.-M.; Tian, Z.-H.; Liu, X. Composition and antioxidant activity of the essential oil from aerial parts of *Sibiraea laevigata*. *Chem. Nat. Compd.* 2016, 52, 525–526, doi:10.1007/s10600-016-1698-0.
 25. Krupčík, J.; Gorovenko, R.; Špánik, I.; Sandra, P.; Armstrong, D.W. Enantioselective comprehensive two-dimensional gas chromatography. A route to elucidate the authenticity and origin of *Rosa damascena* Miller essential oils. *J. Sep. Sci.* 2015, 38, 3397–3403, doi:10.1002/jssc.201500744.