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The volatile phytochemicals of *Eriogonum heracleoides* Nutt. var. *heracleoides* (Polygonaceae)

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Abstract
The aerial parts of *Eriogonum heracleoides* var. *heracleoides* were collected from plants growing in the Owyhee Mountains of southwestern Idaho. The essential oils were obtained by hydrodistillation (1.87-2.74% yield) and analyzed by gas chromatography. The major component classes were fatty aldehydes (33.5-60.0%), *n*-alkanes (5.7-14.6%), and fatty acids (7.6-11.4%). This is the first report on the essential oil composition of *E. heracleoides*.

Keywords: *Parsnipflower* buckwheat, whorled buckwheat, essential oil, gas chromatography, mass spectrometry

1. Introduction
The genus *Eriogonum* Michx. (Polygonaceae) is comprised of around 255 taxa [1]. *Eriogonum heracleoides* Nutt. Naturally ranges in intermountain (between the Cascade Range and the Rocky Mountain range) western North America from British Columbia and Montana, south to eastern California, northern Nevada, and Utah. It is dominant in the Columbia Basin, Snake River Plain, and southeastern Oregon (Figure 1). There are two varieties, *E. heracleoides* var. *heracleoides*, which is the more widely distributed, and *E. heracleoides* var. *leucophaeum* Reveal, which is restricted to eastern Washington and northern Idaho [2]. The plant is a perennial forb, 10-40 cm tall; the flowering stems often have whorls of 2-10 leaf like bracts; the leaves are linear to oblanceolate (20-80 mm long, 2-15 mm wide); the stems and leaves are covered with dense short hairs [3]. The plant blooms from May through June, producing several clusters of white or cream-colored flowers (Figure 2) [4].
To our knowledge, there have been no reports on the essential oil or other phytochemical studies of *E. heracleoides*. The purpose of this study, therefore, is to characterize the essential oil of this plant.

2. Materials and Methods
2.1 Plant Collection and Hydrodistillation
Aerial parts of *E. heracleoides* were collected from three different plants growing in the Owyhee Mountains (43°7′7″ N, 116°43′51″ W, 1863 m elevation) on 21 July 2023. The plants were identified by W.N. Setzer based on botanical description [6] and by comparison with herbarium samples from the New York Botanical Garden [7]. A voucher specimen (WNS-Ehh-7664) was deposited with the University of Alabama in Huntsville herbarium. The plants were stored frozen (-20 °C) until processed.
The fresh-frozen aerial parts of *E. heracleoides* (82.04 g, 57.62 g, and 51.87 g) were hydro distilled for four hours using a Likens-Nickerson apparatus [8–10] with continuous extraction of the distillate with dichloromethane to give pale yellow essential oils (1.534 g, 1.581 g, and 1.327 g, respectively).

2.2 Gas Chromatographic Analysis
The essential oils from the aerial parts of *E. heracleoides* were analyzed by GC-MS and GC-FID as previously described [11]. The chemical components of the essential oils were identified by comparison of their retention indices, calculated with respect to a homologous series of *n*-alkanes on a ZB-5ms column [12], and their mass spectral fragmentation patterns with those

reported in the Adams [13], FFNSC3 [14], NIST20 [15], and Satyal [16] databases.

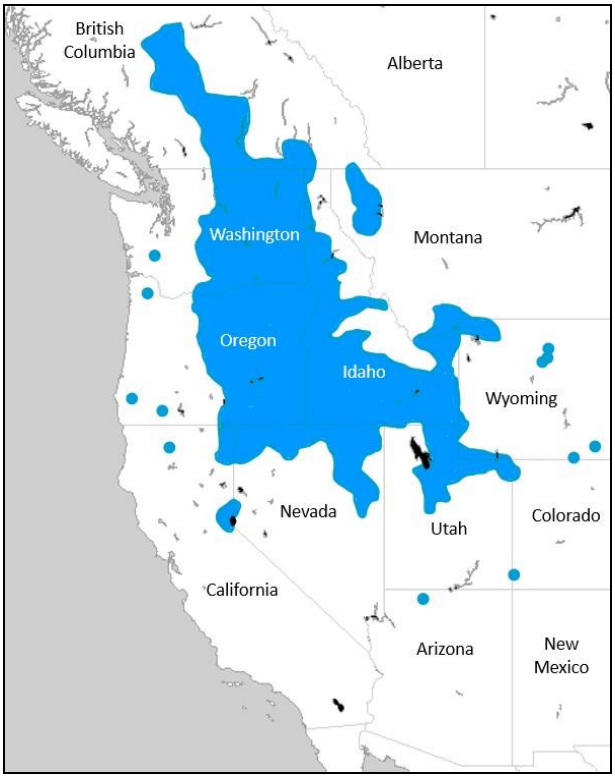

Fig 1: Range of *Eriogonum heracleoides*, based on [5]

Fig 2: *Eriogonum heracleoides* var. heracleoides. A: Photograph by K. Swor at the time of collection. B: Scan of the pressed plant

3. Results and Discussion

Pale yellow essential oils of *E. heracleoides* were obtained in yields of 1.87-2.74%. Gas chromatographic analysis led to identification of 106 components, which accounted for 97.9-99.6% of the compositions (Table 1). Fatty acid derivatives, fatty aldehydes in particular, dominated the essential oils. The major fatty aldehyde components were hexanal (2.3-3.8%), (2*E*)-hexenal (4.9-14.2%), nonanal (4.7-6.4%), dodecanal (2.8-7.4%), tridecanal (4.1-6.4%), and tetradecanal (2.5-4.7%). Interestingly, sample #2 was also rich in diterpenoids (16.4% serratol, 4.8% incensole). Other important constituents were *iso*-valeric acid (2.5-8.3%), and 4-vinylguaiacol (3.8-5.0%).

Table 1: Volatile components (percent of total) from *Eriogonum heracleoides* var. *heracleoides* collected from the Owyhee Mountains, Idaho

RI_{calc}	RI_{db}	Compounds	#1	#2	#3
798	797	(3*Z*)-Hexenal	1.1	-	2.3
799	801	Hexanal	3.8	2.3	3.1
800	800	Octane	-	1.4	-
826	830	*iso*-Valeric acid	3.3	8.3	2.5
827	825	Furfural	1.7	3.6	1.5
840	840	2-Methylbutanoic acid	1.1	1.7	0.5
847	849	(2*E*)-Hexenal	14.2	4.9	12.2
852	853	(3*Z*)-Hexenol	0.3	-	1.3
880	878	3-Methyl-2-butenoic acid	1.4	0.7	-
891	891	Styrene	-	0.3	-
900	900	Nonane	0.2	0.3	0.5
903	902	Santolina triene	0.8	-	0.1
903	901	Heptanal	0.8	0.9	0.4
933	933	α-Pinene	-	0.4	0.3
947	944	4-Methyl-2-pentenolide	0.6	-	-
956	956	(2*E*)-Heptenal	0.8	0.4	0.8
962	959	Benzaldehyde	0.3	0.2	0.2
972	971	Artemiseole	1.3	0.2	0.1
972	974	Hexanoic acid	-	0.3	0.3
978	978	β-Pinene	-	-	0.2
984	982	6-Methyl-5-hepten-2-one	0.4	0.2	0.2
990	989	2-Pentylfuran	0.6	0.2	0.3
998	999	(2*E*,4*E*)-Heptadienal	0.3	-	-
1000	1000	Decane	0.5	0.6	0.6
1004	1004	Octanal	0.8	0.6	1.2
1005	1005	(3*Z*)-Hexenyl acetate	0.5	0.1	-
1030	1030	Limonene	-	-	0.2
1032	1032	1,8-Cineole	0.5	-	0.1
1044	1043	Phenylacetaldehyde	0.8	0.6	0.7
1050	1049	*cis*-Arbusculone	0.3	-	-
1058	1059	(2*E*)-Octenal	0.4	0.3	0.2
1069	1068	*trans*-Arbusculone	0.3	-	-
1100	1100	Undecane	-	-	1.0
1100	1101	Linalool	2.5	0.7	0.3

1103	1104	Hotrienol	0.2	0.1	0.3
1104	1102	6-Methyl-3,5-Heptadien-2-one	0.2	-	-
1105	1107	Nonanal	6.4	6.2	4.7
1147	1145	Camphor	0.6	0.1	0.1
1160	1163	(2*E*)-Nonenal	0.5	0.2	0.3
1169	1171	Octanoic acid	0.4	0.1	0.2
1181	1180	Terpinen-4-ol	0.2	0.1	-
1192	1192	Methyl salicylate	0.2	tr	-
1196	1195	α-Terpineol	0.2	0.1	-
1200	1200	Dodecane	0.8	0.8	1.2
1206	1206	Decanal	2.0	1.4	2.8
1211	1210	(2*E*)-Octenyl acetate	0.2	-	-
1216	1217	Coumaran	0.4	0.2	-
1219	1211	β-Cyclocitral	0.5	0.2	0.3
1255	1253	*p*-Anisaldehyde	0.2	-	-
1262	1263	(2*E*)-Decenal	1.7	1.2	2.2
1266	1272	Nonanoic acid	0.6	0.3	-
1271	1269	(2*E*)-Decen-1-ol	0.4	0.2	0.2
1284	1282	Bornyl acetate	0.4	0.1	0.2
1300	1300	Tridecane	1.2	0.7	1.3
1308	1309	Undecanal	3.6	2.0	2.2
1309	1309	4-Vinylguaiacol	3.8	4.8	5.0
1319	1318	(2*E*,4*E*)-Decadienal	0.5	0.2	0.3
1324	1327	Methyl decanoate	-	-	0.5
1363	1367	Decanoic acid	0.4	-	0.5
1365	1365	(2*E*)-Undecenal	2.0	0.7	0.8
1400	1400	Tetradecane	0.5	0.4	1.0
1409	1409	Dodecanal	7.4	2.8	2.9
1426	1425	Florhydral	0.3	-	0.4
1447	1447	Geranyl acetone	0.3	0.2	0.2
1474	1470	(2*E*)-Dodecen-1-ol	0.4	0.2	-
1500	1500	Pentadecane	0.1	0.1	0.2
1511	1510	Tridecanal	4.2	4.1	6.4
1518	1518	δ-Cadinene	-	0.3	0.4
1527	1524	Dihydroactinidiolide	0.3	-	-
1561	1560	(*E*)-Nerolidol	0.8	0.2	-
1562	1560	Dodecanoic acid	0.4	-	1.6
1571	1571	(3Z)-Hexenyl benzoate	-	0.2	0.3
1576	1574	(2*E*)-Tridecen-1-ol	0.3	-	-
1594	1594	Viridiflorol	-	3.2	-
1596	1596	Fokienol	0.5	-	-
1600	1600	Hexadecane	-	-	0.4
1614	1614	Tetradecanal	4.7	2.5	4.5
1641	1640	τ-Cadinol	-	0.6	0.3
1647	1647	Methyl jasmonate	-	0.3	0.3
1657	1655	α-Cadinol	0.5	0.4	0.4
1672	1673	(2*E*)-Tetradecenal	0.9	0.2	0.3
1678	1680	1-Tetradecanol	0.5	0.1	0.2
1715	1717	Pentadecanal	3.5	2.2	3.8
1758	1758	Myristic acid	-	-	0.8
1769	1769	Benzyl benzoate	-	-	0.2
1800	1800	Octadecane	-	-	0.6
1816	1817	Hexadecanal	0.5	0.2	0.4
1840	1841	Phytone	2.6	1.2	0.9
1871	1869	Benzyl salicylate	-	-	0.5
1933	1931	Beyerene	0.3	-	0.5
1951	1951	(3*E*)-Cembrene A	-	0.9	-
1958	1958	Palmitic acid	-	-	3.3
2000	2000	Eicosane	-	-	1.0
2009	2012	Verticilla 4(20),7,11-triene	-	0.6	-
2098	2098	γ-Stearolactone	-	0.3	0.2
2132	2134	Linolenic acid	-	-	1.4
2133	2138	Cembrenol	-	2.6	-
2146	2143	Serratol	-	16.4	3.2
2157	2159	Incensole	-	4.8	-
2200	2200	Docosane	-	-	1.3
2300	2300	Tricosane	0.3	0.3	0.4
2400	2400	Tetracosane	-	3.7	1.2
2430	2429	Docosanal	-	-	0.4

2500	2500	Pentacosane	0.8	0.6	0.8
2600	2600	Hexacosane	-	-	1.2
2700	2700	Heptacosane	1.2	0.8	2.1
		Alkanes	5.7	9.7	14.6
		Fatty acids	7.6	11.4	11.1
		Fatty alcohols	1.9	0.5	1.7
		Fatty aldehydes	60.0	33.5	52.2
		Fatty esters	0.8	0.1	0.5
		Monoterpenoids	7.0	2.0	2.1
		Sesquiterpenoids	1.3	4.7	1.1
		Diterpenoids	0.3	25.3	3.7
		Benzenoid aromatics	6.0	6.4	7.3
		Others	7.6	6.0	3.7
		Total identified	98.4	99.6	97.9

RT = Retention Time in minutes. RI_{calc} = Retention Index calculated with respect to a homologous series of *n*-alkanes on a ZB-5ms column. RI_{db} = Reference Retention Index from the databases [13-16]. tr = trace (< 0.05%). [a] Although there was a good MS match (90% similarity), a reference RI was not available.

The Polygonaceae is not regarded as an essential oil-producing family, and there have been no previous reports on essential oil compositions of *Eriogonum*. Nevertheless, essential oils of *Polygonum* species have been reported. Demirpolat has investigated seven *Polygonum* species from Türkiye (*Polygonum aviculare* L., *Polygonum persicaria* L. (syn. *Persicaria maculosa* Gray), *Polygonum lapathifolium* L. (syn. *Persicaria lapathifolia* (L.) Delarbre), *Polygonum arenarium* Waldst. & Kit., *Polygonum bellardii* All., *Polygonum arenastrum* Boreau, and *Polygonum cognatum* Meisn.) [17]. The essential oils from the aerial parts of these plants were all rich in dodecanal (14.0% to 25.7%) as well as smaller concentrations of undecanal (up to 7.4%) and decanal (up to 3.3%). Similarly, *Polygonum minus* Huds. (syn. *Persicaria minor* Opiz) was dominated by decanal (18.7%) and dodecanal (54.3%) [18]. Decanal (27.7%) and dodecanal (44.1%) were also major components in *Polygonum odoratum* Lour. (syn. *Persicaria odorata* (Lour.) Soják) essential oil [19,20]. The essential oil of *Polygonum equisetiforme* Sm., on the other hand, showed hexadecanal (0.33%) as the only aldehyde, but did have several long-chain alkanes (14.4%) [21].

4. Conclusions

This is the first report of the essential oil from *Eriogonum heracleoides*, and the first report of any member of the genus. The essential oil was dominated by fatty acid derivatives, particularly fatty aldehydes as well as fatty acids and long-chain alkanes. These constituents may be common in the Polygonaceae. Additional research is needed to confirm these observations.

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7. Conflicts of Interest

The authors declare no conflicts of interest.

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