

Re-examination of the volatile leaf oils of *Juniperus flaccida*, *J. martinezii*, and *J. poblana***Robert P. Adams**

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and

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Sigma 119, Durango, Dgo., 34234 Mexico**ABSTRACT**

The composition of the volatile leaf oils (chiefly terpenoids) of *Juniperus flaccida*, *J. martinezii*, *J. poblana*, *J. poblana* var. *decurrens* and affiliated *J. poblana* from Nayarit are reported. All of the taxa's oils are dominated by α -pinene (16.6 - 65.0%). However, divergence is evident in the oils of *J. martinezii* and the juniper from Nayarit as well as *J. poblana*, Oaxaca. The number of unique compounds in the oil of the aff. *J. poblana* from Nayarit support its recognition as a distinct taxon. However, DNA sequences, morphology and ecological data are needed to determine the taxonomic status of the Nayarit junipers. Published on-line www.phytologia.org *Phytologia* 99(3): 191-199 (Aug. 8, 2017). ISSN 030319430.

KEY WORDS: *Juniperus flaccida*, *J. martinezii*, *J. poblana*, *J. poblana* var. *decurrens*, Cupressaceae, Nayarit juniper, terpenes, leaf essential oil, morphology.

The flaccid foliage *Juniperus* of Mexico consist of three species: *J. flaccida* Schlecht. with large (9-12 mm diam.), multi-seeded [(4-)-6-10-(13)] cones; *J. poblana* (Martínez) R. P. Adams (formerly *J. flaccida* var. *poblana* Martínez) with very large (9-15 mm diam.), multi-seeded [(4-)-6-10-(13)] cones and *J. martinezii* Pérez de la Rosa with small seed cones (5-7 mm), 1-2 seeds per cone and foliage somewhat drooping but branchlets tips erect (Adams, 2014; Pérez de la Rosa, 1985). *Juniperus martinezii* is quite distinct in its morphology, but the other two taxa differ little in morphology, with *J. flaccida* having radial branching and seed cones tan to brownish purple, whereas *J. poblana* has distichous foliage in vertical planes like *Thuja/Platycladus*, and not very flaccid (Zanoni and Adams, 1976, 1979; Adams, 2014) with bluish-brown seed cones. Each of these taxa has leaf margins that are hyaline and nearly entire, with either a few small teeth or merely a wavy margin (Adams, 2014). However, their DNA clearly places them in the serrate leaf margined *Juniperus* species of the western hemisphere with toothed margins secondarily lost (Adams, 2014).

Juniperus flaccida, *J. martinezii* and *J. poblana* have been treated as varieties of *J. flaccida*, until DNA sequencing of nrDNA (ITS) and trnC-trnD (Adams et al., 2006) revealed that *J. flaccida* varieties are not monophyletic and they recognized *J. f.* var. *martinezii* as *J. martinezii* and *J. f.* var. *poblana* as *J. poblana*. More recently, Adams and Schwarzbach (2013) published a detailed phylogeny of the serrate junipers of the western hemisphere based on nrDNA and four cp genes. They found *J. flaccida* (var. *flaccida*) in a group with *J. standleyi* and *J. poblana* (*J. f.* var. *poblana*) in a well-supported sister group relationship. Likewise, *Juniperus martinezii* (*J. f.* var. *martinezii*) grouped with *J. durangensis* supported by high branch support. Their work appears to solidify support for the recognition of *J. martinezii* and *J. poblana*.

Recently, samples were collected from a new population of aff. *J. poblana* in Nayarit. Samples of *J. poblana* from the type locality (Amozoc) and a population of *J. flaccida* from Coahuila were also

collected. Preliminary DNA analysis revealed the Nayarit junipers grouped with *J. poblana* (authors, unpublished).

The composition of the volatile leaf oils of *J. flaccida* and *J. poblana* (as *J. f.* var. *poblana*) were first reported by Adams, Zanoni and Hogge (1984). The composition of the leaf oil of *J. martinezii* was reported by Adams, Pérez de la Rosa and Cházaro (1990). Recently, Adams and Zanoni (2015) have reported on a re-examination the leaf oils of *J. flaccida*, *J. martinezii* and *J. poblana* using modern FID-GC quantitation methods.

The purpose of this paper is to report on the volatile leaf oils of the Nayarit junipers as well as the oil of *J. poblana* from the type locality (Amozoc) and *J. flaccida* from Coahuila.

MATERIALS AND METHODS

Specimens examined:

- J. flaccida*, Adams 6892-6896, 23 km e of San Roberto Junction on Mex. 60, Nuevo Leon, Mexico;
J. flaccida, Reserva Ecologica Municipal de Sierra y Cañon de Jimulco, 25° 07' 38" N, 103° 16' 15" W., 2118 m, 17 Jan 2017, Torreon, Coahuila, Mexico, Coll. Manuel Rodríguez Muñoz et al. #1,2,3,4,5, Lab Acc. Adams 15203 - 15207;
J. martinezii, Adams 5950-5952, 8709, 40 km n of Lagos de Moreno on Mex. 85 to Amarillo, thence 10 km e to La Quebrada Ranch, 21° 33.08' N, 101° 32.57' W, Jalisco, Mexico;
J. poblana var. *decurrens*, R. P. Adams 11926, 11927, 11928, small trees, to 5 m tall, with strong central axis, foliage very, very, weeping, common, about 2 km s of Valle de Topia. All leaves decurrent, and prickly and are not merely juvenile leaves. 25° 14' 11" N; 106° 26' 55.7" W, 1818 m, 30 Jun 2009, Durango, Mexico;
J. poblana, Adams 6868-6870, 62 km s of Oaxaca, Mexico on Mex. 190.
J. poblana, uncommon young trees (saplings) 2 m, in oak woodland dominated by *Quercus resinosa*, Mexico, Nayarit, Mpio. El Nayar, SW of Mesa del Nayar on road to Ruiz, Km 86.8; S of bridge of arroyo del Fraile, E of El Maguey, 22° 10' 08" N, 104° 43' 51" W, 1150 m, 19 Jan. 2016, Coll. M. S. Gonzalez-Elizondo and M. Gonzalez-Elizondo 8381 with L. López, A. Torres Soto; Lab Acc. Adams 14896
J. poblana, large, single stemmed trees, foliage long and pendulous, abundant trees, up to 25 m high, on strongly rocky slope, forest of *Juniperus-Clusia* with elements of mesophytic forest (*Magnolia*) and tropical forest (*Bursera*, *Opuntia*, *Pilosocereus purpusii*) as well as *Agave attenuata* and *Yucca jaliscensis*, Mexico, Nayarit, Mpio. El Nayar, SW of Mesa del Nayar on road to Ruiz; NE of El Maguey, 22° 07' 40" N, 104° 47' 47" W, 1430 m, 19 Jan. 2016, Coll. M. S. Gonzalez-Elizondo and M. Gonzalez-Elizondo 8379a,b,c,d, with L. López, A. Torres Soto; Lab Acc. Adams 14897-14900,
J. poblana, growing in a *J. poblana* - oak forest. Amozoc de Mota, just S of town. 19° 01' N, 98° 01' W, 2300 m. Date 15 Dec 2016 Mpio. Amozoc State: Puebla, Mexico, Coll. L. Caamano A and Allen Coombes 10172, 10173, 10174, 10180, 10181, Det. Socorro Gonzalez, Lab Acc. Adams 15208 - 15212

Voucher specimens are deposited at BAYLU and CIIDIR when applicable.

Fresh, air dried leaves (50-100 g) were steam distilled for 2 h using a circulatory Clevenger-type apparatus (Adams, 1991). The oil samples were concentrated (ether trap removed) with nitrogen and the samples stored at 20 °C until analyzed. The extracted leaves were oven dried (100 °C, 48 h) for determination of oil yields.

Oils from 4-5 trees of each taxon were analyzed and average values reported. The oils were analyzed on a HP 5971 MSD mass spectrometer, scan time 1/ sec., directly coupled to a HP 5890 gas chromatograph, using a J & W DB-5, 0.26 mm x 30 m, 0.25 micron coating thickness, fused silica

capillary column (see Adams, 2007 for operating details). Identifications were made by library searches of our volatile oil library (Adams, 2007), using the HP Chemstation library search routines, coupled with retention time data of authentic reference compounds. Quantitation was by FID on an HP 5890 gas chromatograph using a J & W DB-5, 0.26 mm x 30 m, 0.25 micron coating thickness, fused silica capillary column using the HP Chemstation software. PCO (Principle Coordinates Ordination) (Veldman, 1967) was performed on the similarity matrix (Adams, 1975).

RESULTS AND DISCUSSION

Analyses of the volatile leaf oils of *J. p.* var. *decurrens*, *J. poblana* (Amozoc, Nayarit and Oaxaca), *J. flaccida* (Coahuila and Nuevo Leon) and *J. martinezii* are given in Table 1. The oil of *J. poblana* (Amozoc, type locality) is dominated by α -pinene (41.9%) with moderate amounts of β -pinene (3.9%), myrcene (4.5%), limonene (3.5%), β -phellandrene (3.5%), (E)-nerolidol (2.7%) and manool oxide (1.8%). The leaf oil of *J. p.* var. *decurrens* is dominated by α -pinene (53.2%) with moderate amounts of β -pinene (5.3%), myrcene (5.6%), δ -2-carene (1.5%), δ -3-carene (2.5%), limonene (3.2%), β -phellandrene (3.1%), terpinolene (1.0%), (E)-caryophyllene (1.1%) and germacrene D (1.5%). Its oil is most similar to that of *J. poblana* from Amozoc.

The leaf oil of *J. poblana* from Oaxaca is dominated by α -pinene (41.3%) and δ -3-carene (10.7%), with moderate amounts of β -pinene (2.9%), myrcene (3.7%), δ -2-carene (3.5%), limonene (5.6%), β -phellandrene (3.7%), linalool (2.5%), pipéritone (1.8%) and elemol (1.8%).

The oil of aff. *J. poblana* from Nayarit is quite distinct and is dominated by α -pinene (41.9%) and germacrene D (12.1%) with moderate amounts of γ -cadinene (6.1%), β -pinene (3.4%), myrcene (3.7%), β -phellandrene (2.3%), (E)-caryophyllene (3.0%), (E)-nerolidol (3.3%), epi- α -cadinol (3.0%) and epi- α -muurolol (3.0%). The oil also contains ten (10) compounds unique to the taxa studied: β -bourbonene, α -muurolene, α -cadinene, germacrene D-4-ol, trans-muurol-5-en-4- α -ol, salvial-4(14)-en-1-one, pentadecanal, octadecane, hexadecanal and hexahydrofarnesyl acetone.

The oil of *J. flaccida* from Coahuila is dominated by α -pinene (32.4%), δ -3-carene (18.1%) and manoyl oxide (10.4%) with moderate amounts of δ -2-carene (2.3%), β -pinene (2.9%), myrcene (3.7%), limonene (2.7%), β -phellandrene (4.0%), terpinolene (2.4%) and abietatriene (1.0%).

The leaf oil of *J. flaccida* (Nuevo Leon) is similar to that from Coahuila as, it too, is dominated by α -pinene (65.0%) with moderate amounts of β -pinene (4.8%), myrcene (4.3%), limonene (3.5%), β -phellandrene (3.4%), linalool (2.9%) and manool oxide (3.0%), but it contains no δ -3-carene.

The oil of *J. martinezii* is quite distinct with major components being α -pinene (16.6%), sabinene (10.4%) and camphor (11.1%) and moderate amounts of β -pinene (1.4%), myrcene (3.6%), limonene (1.8%), β -phellandrene (5.3%), linalool (2.8%), γ -terpinene (1.8%) and terpinen-4-ol (6.1%). It also contains seven (7) unique compounds: cis-sabinene hydrate (0.6%), p-cymenene (0.7%), karahanaenone (1.3%), linalool acetate (0.4%), neo-iso-3-thujanyl acetate (0.8%), an aromatic phenol (KI 1320, 0.5%), and an unknown diterpene (KI 1978, 0.6%).

To determine the overall similarities of the oils of these taxa, 35 components (Table 2) were coded and pair-wise similarity measures computed. The resulting similarity matrix was factored and yielded six (6) eigenroots accounting for: 34.4, 23.2, 13.9, 11.4, 10.9 and 6.1% of the variance (100%). Interestingly, the eigenroots asymptote after five roots, implying there are six entities of variation among the seven taxa. From the PCO (Fig. 1) these six entities appear to be: *J. martinezii*; *J.* aff. *poblana*, Nayarit; *J. flaccida* (Coah, Nuevo Leon); *J. poblana*, Amozoc; *J. poblana* var. *decurrens*; and *J. poblana*, Oaxaca.

The first coordinate separated aff. *J. poblana*, Nayarit and *J. martinezii* from all other taxa (Fig. 1). Their oils are quite distinct, so this is not surprising. The second coordinate separated did not clearly separate taxa, but combined with coordinate three, they ordinate several groups.

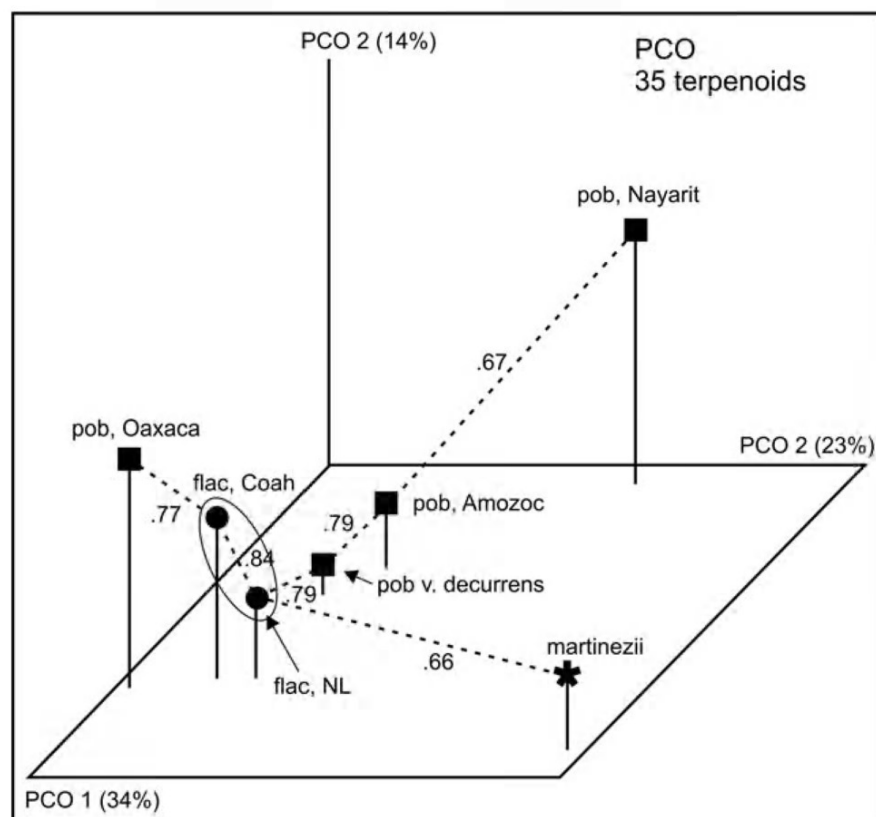


Figure 1. PCO based on 35 terpenoids. The dashed lines are the minimum spanning network. The numbers next to the dashed lines are the similarity between taxa. NL = Nuevo Leon.

It seems unusual that the oil of *J. p. var. decurrens* is equally similar to that of *J. poblana*, Amozoc and that of *J. flaccida*, NL (Nuevo Leon) (Fig. 1). It is also surprising that the oil of *J. poblana*, Oaxaca is most like that of *J. flaccida*, Coah. (Fig. 1). As far as the volatile leaf oils are concerned, the oil of *J. poblana*, Oaxaca is not typical, but considerably different from other *J. poblana* oils (Fig. 1).

In summary, the oils of these taxa are dominated by α -pinene (16.6 - 65.0%) and are generally similar. However, divergence is evident in the oils of *J. martinezii* and the juniper from Nayarit. The number of unique compounds in the oil of the putative *J. poblana* from Nayarit support its recognition as a distinct taxon. Additional DNA, morphology and ecological data are needed (in progress) to determine the taxonomic affinity of the Nayarit junipers.

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LITERATURE CITED

- Adams, R. P. 1975. Statistical character weighting and similarity stability. *Brittonia* 27:305-316.
 Adams, R. P. 1991. Cedarwood oil - Analysis and properties. pp. 159-173. in: *Modern Methods of Plant Analysis*, New Series: Oil and Waxes. H.-F. Linskens and J. F. Jackson, eds. Springer-Verlag, Berlin.

- Adams, R. P. 2007. Identification of essential oil components by gas chromatography/ mass spectrometry. 4th ed. Allured Publ., Carol Stream, IL.
- Adams, R. P. 2014. The junipers of the world: The genus *Juniperus*. 4th ed. Trafford Publ., Bloomington, IN.
- Adams, R. P., J. A. Pérez de la Rosa and M. Cházaro B. 1990. The leaf oil of *Juniperus martinezii* Pérez de la Rosa and taxonomic status. J. Essential Oils Res. 2: 99-104.
- Adams, R. P., A. E. Schwarzbach and S. Nguyen. 2006 Re-examination of the taxonomy of *Juniperus flaccida* var. *martinezii*, and var. *poblana* (Cupressaceae) Phytologia 88: 233-241.
- Adams, R. P. and A. E. Schwarzbach. 2013. Taxonomy of the serrate leaf *Juniperus* of North America: Phylogenetic analyses using nrDNA and four cpDNA regions. Phytologia 95: 172-178.
- Adams, R. P. and T. A. Zanoni. 2015. The volatile leaf oils of *Juniperus flaccida* Schltdl., *J. martinezii* Pérez de la Rosa and *J. poblana* (Mart.) R. P. Adams, re-examined. Phytologia 97: 145-151.
- Adams, R. P., T. A. Zanoni and L. Hogge. 1984. The volatile leaf oils of *Juniperus flaccida* var. *flaccida* and var. *poblana*. J. Natl. Prod. 47:1064-1065.
- Pérez de la Rosa, J. A. 1985. Una nueva especie de *Juniperus* de Mexico. Phytologia 57: 81-86.
- Veldman, D. J. 1967. Fortran programming for the behavioral sciences. Holt, Rinehart and Winston Publ., NY.
- Zanoni, T. A. and R. P. Adams. 1976. The genus *Juniperus* (Cupressaceae) in Mexico and Guatemala: Numerical and chemosystematic analysis. Biochem. Syst. Ecol. 4: 147-158.
- Zanoni, T. A., Adams, R. P. 1979. The genus *Juniperus* (Cupressaceae) in Mexico and Guatemala: Synonymy, Key, and distributions of the taxa. Bol. Soc. Bot. Mexico 39: 83-121.

Table 1. Leaf essential oil composition for aff. *J. poblana* (Nayarit, Adams 15034) compared with *J. poblana* var. *poblana* (Amozoc, Adams 15214), *J. poblana* var. *decurrens* (Adams 11932), *J. poblana* (Oaxaca, Adams 6868-6872), *J. flaccida*, Coah. (Adams 15213) *J. flaccida*, Nuevo Leon (NL, Adams 6892) and *J. martinezii* (Adams 5974) based on FID gas chromatography and GCMS identification. Those compounds that appear to distinguish the Nayarit juniper or group Nayarit with *J. poblana* and *J. p.* var. *decurrens* are in boldface. Thirty-five (35) compounds marked with an asterisk (*) were used in PCO.

KI	Compound	aff. pob Nayarit	poblana Amozoc	pob. var. decurrens	poblana Oaxaca	flaccida Coah.	flaccida NL	mart.
921	tricyclene	t	t	t	t	t	0.2	0.6
924	α -thujene	t	t	t	t	t	t	0.6
932*	α-pinene	26.3	41.8	53.2	41.3	32.4	65.0	16.6
945	α -fenchene	-	t	0.1	0.5	-	t	-
946	camphene	0.3	0.5	0.5	0.5	0.6	0.6	0.7
953	thuja-2,4-diene	t	0.1	t	t	0.3	t	0.1
961*	verbenene	0.3	0.5	0.1	1.9	1.3	1.3	0.2
969*	sabinene	0.1	t	-	t	0.2	0.2	10.4
974	1-octen-3-ol	t	t	0.1	t	-	-	-
974*	β -pinene	3.4	3.9	5.3	3.2	2.9	4.8	1.4
988*	myrcene	3.7	4.5	5.6	4.3	3.7	4.3	3.6
1001*	δ-2-carene	0.9	1.5	1.2	3.5	2.3	-	-
1002	α -phellandrene	0.2	0.2	0.1	0.2	t	0.1	1.0
1008*	δ-3-carene	0.9	0.7	2.5	10.7	18.1	-	-
1014	α -terpinene	t	t	t	0.3	t	t	1.0
1020	p-cymene	0.1	0.2	t	0.2	t	0.1	1.8
1024*	limonene	1.6	3.5	3.2	5.6	2.7	3.5	1.8
1025*	β -phellandrene	2.3	3.5	3.1	3.7	4.0	3.4	5.3
1032	(Z)- β -ocimene	t	t	0.1	t	t	t	t
1044	(E)- β -ocimene	1.0	1.3	1.8	0.8	0.7	1.5	0.4
1054	γ -terpinene	t	t	0.1	0.1	t	0.2	1.8
1065	cis-sabinene hydrate	-	-	-	-	-	-	0.6
1067	cis-linalool oxide (furanoid)	-	-	-	-	t	0.1	-
1086	terpinolene	0.6	0.9	1.0	1.9	2.4	0.5	0.8
1089*	p-cymenene	-	-	-	-	-	-	0.7
1094	96, 109, 43, 152, C10-OH	0.1	0.2	-	0.9	0.5	1.0	1.8
1095	linalool	0.5	1.1	0.7	2.5	1.1	2.9	2.8
1111	6-camphenol	-	-	-	-	0.3	-	-
1112	3-m-3-buten-me-butanoate	-	-	-	-	-	0.2	-
1114	endo-fenchol	t	0.2	0.1	t	t	-	-
1118	cis-p-menth-2-en-1-ol	0.2	0.2	0.1	0.4	0.3	0.1	0.5
1122	α -campholenal	0.3	1.2	0.1	0.3	0.4	0.3	0.4
1135	trans-pinocarveol	0.4	1.1	-	0.4	0.4	0.3	0.8
1136	trans-p-menth-2-en-1-ol	-	-	0.2	0.4	-	-	-
1141	camphor	0.3	1.8	0.3	0.4	0.6	0.5	11.1
1141	trans-verbenol	-	-	-	-	-	-	-
1145	camphene hydrate	0.2	0.6	0.2	0.4	0.2	0.4	1.3
1148	citronellal	-	-	-	t	0.7	0.2	-
1154*	karahanaenone	-	-	-	-	-	-	1.3
1153	myrtenyl, methyl ether	-	0.2	-	-	-	-	-
1155	iso-isopulegol	0.2	0.5	-	0.5	0.2	0.1	-
1155	isomer - p-mentha-1,5-dien-8-ol	-	-	-	-	0.5	-	-
1160	p-mentha-1,5-dien-8-ol	-	1.2	-	0.6	0.7	-	1.0
1165	borneol	0.4	-	0.7	t	t	0.7	-
1172	cis-pinocamphone	t	0.3	0.1	t	0.2	0.2	0.3
1174	terpinen-4-ol	0.2	0.2	0.2	0.3	0.5	0.3	6.1
1178	naphthalene	t	-	0.4	-	-	-	t
1179	p-cymen-8-ol	t	0.2	t	t	0.2	t	0.5

Kl	Compound	aff. pob Nayarit	poblana Amozoc	pob. var. decurrens	poblana Oaxaca	flaccida Coah.	flaccida NL	mart.
1186	α -terpineol	0.6	0.5	0.9	0.8	0.6	0.4	0.7
1195	myrtenol	t	-	-	t	t	0.1	t
1195	myrtenal	t	1.0	-	0.4	-	-	0.1
1195*	methyl chavicol	0.7	t	0.8	t	t	-	-
1200	terpene alcohol, 95,121,139,154	-	0.9	-	0.4	-	-	-
1200	trans-dehydrocarvone	-	-	-	-	0.2	-	0.6
1204	verbenone	0.2	0.6	t	0.4	0.3	t	0.5
1215	trans-carveol	0.1	0.8	-	0.2	0.2	0.1	-
1218	endo-fenchyl acetate	-	t	0.1	-	-	-	-
1223	citronellol	t	t	-	t	0.3	0.1	-
1232	thymol, methyl ether	t	-	0.1	-	-	-	-
1235	trans-chrysanthenyl acetate	t	-	-	-	0.1	-	0.5
1239	carvone	-	0.2	-	t	t	-	-
1249*	piperitone	0.1	0.9	0.1	1.8	0.8	0.2	0.9
1254	linalool acetate	-	-	-	-	-	-	0.4
1255	4Z-decenol	-	-	-	-	0.3	0.2	-
1284	bornyl acetate	0.6	1.2	0.8	0.2	0.1	0.4	1.8
1289	trans-sabinyl acetate	-	-	-	-	-	-	0.1
1289*	neo-iso-3-thujanlyl acetate	-	-	-	-	-	-	0.8
1289	thymol	-	-	-	-	0.1	-	-
1291	trans-verbenyl acetate	-	0.1	-	t	-	-	-
1292	(2E,4Z)-decadienal	0.1	-	-	-	-	0.1	-
1298	trans-pinocarvyl acetate	-	0.1	-	-	-	-	-
1315	(2E,4E)-decadienal	-	-	-	-	t	0.1	-
1320*	aromatic phenol 149,91,77,164	-	-	-	-	-	-	0.6
1324	myrtenyl acetate	0.1	0.5	-	-	-	-	-
1345	α -terpinyl acetate	t	-	-	-	t	-	0.2
1345	α -cubebene	t	t	-	-	t	0.1	0.3
1374	α-copaene	0.2	t	-	-	-	-	-
1387	β-bourbonene	0.2	-	-	-	-	-	-
1389	β-elemene	0.1	t	-	-	-	-	-
1396	duvalene acetate	0.1	0.1	0.3	-	t	-	-
1403	methyl eugenol	t	0.3	0.3	-	t	0.1	-
1417*	(E)-caryophyllene	3.0	1.3	1.1	0.5	0.3	0.2	0.1
1448	cis-muurola-3,5-diene	0.1	-	0.2	-	-	-	-
1451	trans-muurola-3,5-diene	0.2	-	-	-	-	-	0.2
1452*	α-humulene	0.6	0.1	-	-	-	-	-
1465	cis-muurola-4(14),5-diene	-	0.1	-	-	-	-	-
1475	trans-cadina-1(6),4-diene	0.2	-	0.1	-	-	-	0.3
1484*	germacrene D	12.1	1.8	1.5	0.4	0.5	0.1	-
1493	trans-muurola-4(14),5-diene	0.7	-	0.1	-	-	-	0.7
1493	epi-cubebol	0.6	-	-	-	-	-	0.5
1500	α -muurolene	0.5	-	-	-	t	-	-
1513*	γ-cadinene	6.1	0.1	0.2	t	t	-	-
1514	cubebol	-	-	0.4	-	-	-	1.1
1521	trans-calamenene	-	-	-	-	-	-	0.5
1522	δ -cadinene	1.7	0.2	0.4	t	t	-	0.4
1528	zonarene	-	-	0.1	-	-	-	0.1
1533	trans-cadina-1,4-diene	-	-	-	-	-	-	t
1537	α -cadinene	0.2	-	-	-	-	-	-
1548*	elemol	0.5	0.7	-	1.8	0.2	0.1	1.0
1555*	elemicin	t	0.8	0.4	t	t	-	-
1561*	(E)-nerolidol	3.3	2.7	0.9	0.4	t	-	-
1574	germacrene D-4-ol	0.4	-	-	-	-	-	-
1582	caryophyllene oxide	1.0	0.8	0.8	0.3	0.3	0.2	0.3
1587*	trans-murol-5-en-4-α-ol	0.5	-	-	-	-	-	-
1594	salvial-4(14)-en-1-one	0.2	-	-	-	-	-	-

KI	Compound	aff. pob Nayarit	poblana Amozoc	pob. var. decurrens	poblana Oaxaca	flaccida Coah.	flaccida NL	mart.
1627	1-epi-cubenol	0.9	-	0.7	-	-	-	1.0
1630*	γ-eudesmol	-	-	-	0.5	t	-	t
1638*	epi-α-cadinol	3.0	0.1	0.8	t	t	-	-
1638	epi- α -muurolol	3.0	0.1	0.8	t	t	-	-
1644	α -muurolol	0.3	-	-	t	-	-	-
1649*	β-eudesmol	-	0.3	-	0.5	t	-	0.3
1652	α -eudesmol	-	0.4	-	0.5	t	-	0.3
1652*	α-cadinol	1.7	0.5	0.8	t	t	-	-
1685*	germacra-4(15),5,10-trien-1-al	1.0	0.6	0.8	0.2	t	-	-
1688	shyobunol	-	-	-	-	t	-	-
1759	benzyl benzoate	-	-	t	-	0.2	-	-
1712	pentadecanal	0.2	-	-	-	-	-	-
1800	octadecane	0.1	-	-	-	-	-	-
1814	hexadecanal	0.1	-	-	-	-	-	-
1840	hexahydrofarnesyl acetone	0.1	-	-	-	-	-	-
1933	cyclohexadecanolide	0.3	0.1	t	-	t	t	-
1958*	iso-pimara-8(14),15-diene	-	-	-	-	t	0.1	1.0
1959*	hexadecanoic acid	1.8	1.1	0.3	-	-	-	-
1978*	diterpene,43,81,147,243	-	-	-	-	-	-	0.6
1987*	manoyl oxide	1.6	1.8	0.6	0.3	10.4	3.0	1.0
2009	epi-13-manool oxide	-	-	-	-	t	t	-
2055*	abietatriene	0.9	1.2	0.1	0.2	1.0	0.3	0.8
2056	manool	t	-	0.1	-	-	t	-
2087	abietadiene	-	-	-	-	-	-	2.3
2105	iso-abienol	0.3	0.6	t	t	0.1	t	-
2107	phytol, isomer	t	0.6	t	-	-	-	-
2184	sandaracopimarinal	-	-	-	-	0.2	t	-
2256	methyl sandaracopimarate	-	-	-	-	0.1	t	-
2264*	diterpene,43,55,271,286	0.3	0.5	0.8	0.4	t	-	-
2314	trans-totarol	t	t	-	-	0.3	t	t
2331*	trans-ferruginol	0.6	1.1	0.2	0.1	0.4	t	-

KI = Kovats Index (linear) on DB-5 column. Compositional values less than 0.1% are denoted as traces (t). Unidentified components less than 0.5% are not reported.

Table 2. Thirty-five compounds used for PCO analysis. Note the patterns of the divergence of the Nayarit aff. *J. poblana* and *J. martinezii* in their oil components.

KI	Compound	aff. pob Nayarit	poblana Amozoc	pob. var. decurren.	poblana Oaxaca	flaccida Coah.	flaccida NL	martinezii
932*	α -pinene	26.3	41.8	53.2	41.3	32.4	65.0	16.6
961*	verbenene	0.3	0.5	0.1	1.9	1.3	1.3	0.2
969*	sabinene	0.1	t	-	t	0.2	0.2	10.4
974*	β -pinene	3.4	3.9	5.3	3.2	2.9	4.8	1.4
988*	myrcene	3.7	4.5	5.6	4.3	3.7	4.3	3.6
1001*	δ -2-carene	0.9	1.5	1.2	3.5	2.3	-	-
1008*	δ -3-carene	0.9	0.7	2.5	10.7	18.1	-	-
1024*	limonene	1.6	3.5	3.2	5.6	2.7	3.5	1.8
1025*	β -phellandrene	2.3	3.5	3.1	3.7	4.0	3.4	5.3
1195*	methyl chavicol	0.7	t	0.8	t	t	-	-
1089*	p-cymenene	-	-	-	-	-	-	0.7
1154*	karahanaenone	-	-	-	-	-	-	1.3
1249	piperitone	0.1	0.9	0.1	1.8	0.8	0.2	0.9
1289*	neo-iso-3-thujanly acetate	-	-	-	-	-	-	0.8
1320*	aromatic phenol 149,91,77,164	-	-	-	-	-	-	0.6
1417*	(E)-caryophyllene	3.0	1.3	1.1	0.5	0.3	0.2	0.1
1452*	α -humulene	0.6	0.1	-	-	-	-	-
1484*	germacrene D	12.1	1.8	1.5	0.4	0.5	0.1	-
1513*	γ -cadinene	6.1	0.1	0.2	t	t	-	-
1548*	elemol	0.5	0.7	-	1.8	0.2	0.1	1.0
1555*	elemicin	t	0.8	0.4	t	t	-	-
1561*	(E)-nerolidol	3.3	2.7	0.9	0.4	t	-	-
1587*	trans-muuro-5-en-4- α -ol	0.5	-	-	-	-	-	-
1630*	γ -eudesmol	-	-	-	0.5	t	-	t
1638*	epi- α -cadinol	3.0	0.1	0.8	t	t	-	-
1649*	β -eudesmol	-	0.3	-	0.5	t	-	0.3
1652*	α -cadinol	1.7	0.5	0.8	t	t	-	-
1685*	germacra-4(15),5,10-trien-1-al	1.0	0.6	0.8	0.2	t	-	-
1958*	iso-pimara-8(14),15-diene	-	-	-	-	t	0.1	1.0
1959*	hexadecanoic acid	1.8	1.1	0.3	-	-	-	-
1978*	diterpene,43,81,147,243	-	-	-	-	-	-	0.6
1987*	manoyl oxide	1.6	1.8	0.6	0.3	10.4	3.0	1.0
2055*	abietatriene	0.9	1.2	0.1	0.2	1.0	0.3	0.8
2264*	diterpene,43,55,271,286	0.3	0.5	0.8	0.4	t	-	-
2331*	trans-ferruginol	0.6	1.1	0.2	0.1	0.4	t	-



Adams, Robert P., González Elizondo, M. Socorro, and Gonzalez Elizondo, Martha. 2017. "Re-examination of the volatile leaf oils of *Juniperus flaccida*, *J. martinezii*, and *J. poblana*." *Phytologia* 99(3), 191–199.

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