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

**Robert P. Adams**
Biology Department, Baylor University, Box 97388, Waco, TX 76798, USA Robert_Adams@baylor.edu

and

**M. Socorro Gonzalez-Elizondo and Martha Gonzalez-Elizondo**
CIIDIR Unidad Durango, Instituto Politecnico Nacional,
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 teethed 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 Munoz 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, 21º 33.08' N, 101º 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 ºC until analyzed. The extracted leaves were oven dried (100 ºC, 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)-caryphyllene (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%), piperitone (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 contain 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.

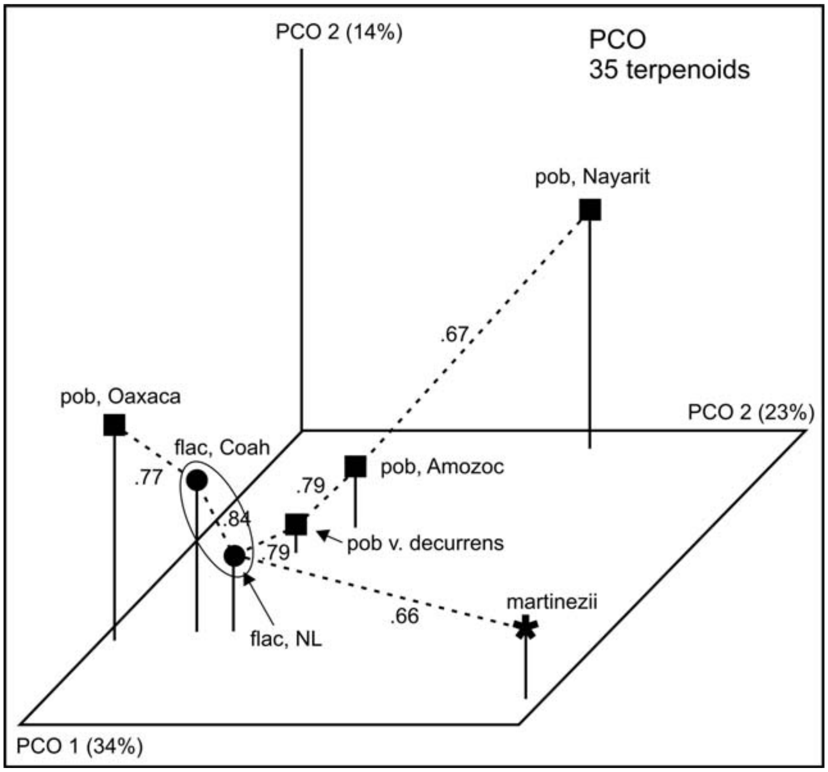


Figure 1. PCO based on 35 terpenoids. The dashed lines are the minimum spanning network. The numbers next to the dashed lines are the similarity between taxa. NL = Nuevo Leon.

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.

## ACKNOWLEDGEMENTS

Thanks to Amy Tebeest for lab assistance and to Allen Coombes, L. Caamano and Manuel Rodíguez Muñoz for kindly getting samples from Puebla and Coahuila. This research was supported in part with funds from Baylor University.

## 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. Springler- 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 | <u>96</u>, 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 |

| KI | 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-thujanly 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-muuola-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-muurol-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. *decurrens* | *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 <u>149</u>,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-muurol-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,<u>43</u>,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,<u>43</u>,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 | - |
| | | | | | | | | |