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Morus murrayana
A new mulberry species

Romulea rosea
Adventive in Texas

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Cover Photos: *Morus murrayana* by Dayle E. Saar and *Euthamia caroliniana* by Jason Singhurst.

THE GENUS *RHYNCHOSIA* (FABACEAE) IN ALABAMA

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ABSTRACT

The genus *Rhynchosia* (Fabaceae), commonly known as snout bean, is recognized as consisting of five species and no infraspecific taxa in Alabama. The most common species are *R. tomentosa*, *R. reniformis*, and *R. difformis*. The least common species are *R. cytisoides* and *R. minima*. Dichotomous keys and descriptions were generated based on morphological features of the vegetative and reproductive structures of the more than 400 specimens studied during this project. Data for the county-level distribution maps were compiled entirely from herbaria vouchers. *Phytologia 91(1):3-17,(April, 2009*).

KEY WORDS: Fabaceae, Leguminosae, *Rhynchosia*, Alabama

Rhynchosia Loureiro, commonly known as snout bean, is a member of the legume family Fabaceae (Leguminosae), subfamily Papilionoideae, tribe Phaseoleae, subtribe Cajaninae (Lackey 1981). The genus consists of approximately 200 species and occurs in both the eastern and western hemisphere in warm temperate and tropical regions (Grear 1978). Fourteen species and two infraspecific taxa of *Rhynchosia* have been reported from the United States (NatureServe 2005). Of these, ten species and one infraspecific taxon have been reported from the southeastern United States (Isely 1990).

Vail (1899) revised the genus for the taxa occurring in the United States. She recognized 16 taxa but used the genus *Dolicholus* Medikus and listed *Rhynchosia* as a synonym. For the next 60 years, the names *Dolicholus* and *Rhynchosia* were both used in the literature. It was not until 1959 when, under the provisions of the *International Code of Botanical Nomenclature*, *Rhynchosia* was conserved against *Dolicholus* (Rickett and Stafleu 1959).

In the only comprehensive revision of the New World species of *Rhynchosia*, Grear (1978) solved many of the problems of nomenclature, taxonomy and distribution with which previous workers had dealt.

METHODS

The data for the distribution maps were gathered from more than 400 specimens deposited in the herbaria of Troy University (TROY), Auburn University (AUA), The University of Alabama (UNA), The University of South Alabama (USAM), Jacksonville State University (JSU), University of North Alabama (UNAF), Smithsonian Institution (US), and Vanderbilt University (VDB), which is located at the Botanical Institute of Texas (BRIT) in Fort Worth.

The dichotomous keys are modifications of Isely (1990) and Weakley (2007); however, all measurements are based on morphological features of the vegetative and reproductive structures of the plants analyzed during this study. Descriptions for each taxon are based on Grear (1978) and Isely (1990); however, measurements were taken from the specimens studied and incorporated into the descriptions if they differed. Illustrations of *Rhynchosia cytisoides* (Bertoloni) Wilbur and *R. minima* (Linnaeus) de Candolle are by the first author. All other illustrations are from Britton and Brown (1913). The lists of specimens examined are limited to one record from each county.

Herbarium specimens were initially divided into groups based on overall morphological similarity and the species concepts established by Isely (1990) and Weakley (2007). Morphological measurements were then made from selective specimens of each group.

RESULTS

Five species and no infraspecific taxa of *Rhynchosia* have been documented from Alabama. Based on herbarium specimens, the most common species are *R. tomentosa* (Linnaeus) Hooker & Arnott (48 counties), *R. reniformis* de Candolle (24 counties), and *R. difformis* (Elliott) de Candolle (16 counties). The least common species are *R.*

cytisoides (Bertoloni) Wilbur (8 counties) and *R. minima* (Linnaeus) de Candolle (2 counties).

TAXONOMIC TREATMENT OF *RHYNCHOSIA*

Rhynchosia Loureiro, Fl. Cochinch. 425, 460. 1790. nom. cons.
Dolicholus Medikus, Vorl. Churpf. Phys. Okon. Ges. 2: 354. 1787. nom. rejic.
Cylista Aiton, Hort. Kew. ed. 1, 3: 36, 512. 1789. nom. rejic.
Arcyphyllum Elliott, Jour. Acad. Phila. 1: 371. 1818.
Austerium Poit. ex DC., Prodr. 2: 385. 1825. nom. nudum.
Polytropia Presl, Symb. Bot. 21, t. 13. 1831.
Nomismia Wight & Arnott, Prodr. 1: 236. 1834.
Cyanospermum Wight & Arnott, Prodr. 1: 259. 1834.
Pitcheria Nuttall, Jour. Acad. Phila. 7: 93. 1834.
Hidrosia E. Meyer, Comm. Pl. Afr. Aust. 1: 89. 1836.
Orthodanum E. Meyer, Comm. Pl. Afr. Aust. 1: 131. 1836.
Copisma E. Meyer, Comm. Pl. Afr. Aust. 1: 132. 1836.
Chrysoscias E. Meyer, Comm. Pl. Afr. Aust. 1: 139. 1836.
Rynchosia J. Macfadyen, Fl. Jam. 1: 275. 1837.
Phyllomatia Benth., Ann. Wien. Mus. 2: 113. 1839.
Ptychocentrum Benth., Ann. Wien. Mus. 2: 113. 1839.
Chrysonias Benth., Ann. Wien. Mus. 2: 114. 1839.
Phaseolus subgenus *Rhynchosia* Eaton & Wright, N. Amer. Bot. 353. 1840.
Sigmodostyles Meissn., Hook. Lond. Jour. Bot. 2: 93. 1843.
Walpersia Meissn. ex Krauss, Flora 27: 357. 1844.
Rhinchosia Zoll. & Mor., Natuur-en Geneesk. Arch. Nederl. Indie 3: 78. 1846.
Stipellaria Klotz., Schomb. Faun. Fl. Brit. Gui. 3: 1203. 1848. nom. nudum.
Hydrosia A. Juss., Orbigny: Dict. Hist. Nat. 7: 270. 1849.
Leycephyllum Piper, Jour. Wash. Acad. 14: 363. 1924.
Leucopterum Small, Man. S. E. Fl. 713. 1933.

Roots perennial. Stems herbaceous, trailing, twining, or erect, simple or branched, glabrous to pubescent. Leaves unifoliate or pinnately trifoliate; petioles 1-90 mm long; leaflets entire, elliptic to rhomboid, 10-70 mm long, glabrous to pubescent, glandular punctuate with yellow, dome-shaped, resin glands. Inflorescence pseudoracemes, axillary or short terminal; peduncles 1-90 mm long. Calyx 2.5-12.0 mm long; corolla yellow, some with purple to brown veins, 4-10 mm long; stamens 10, diadelphous (9 + 1); styles glabrous; ovaries glabrous to pubescent; ovules 1-2. Fruits 10-20 mm long, dehiscent, short and broad, asymmetrically ovate to oblong to falcate-oblong, laterally compressed, short-beaked, glandular-punctate, pubescent.

KEY TO THE ALABAMA SPECIES OF *RHYNCHOSIA*

1. Leaves unifoliate, upper ones rarely trifoliate..........1. ***R. reniformis***
1. Leaves trifoliate, lower ones rarely unifoliate 2
    2. Corolla exceeding calyx...3
    2. Corolla shorter than or equal to calyx...4
3. Plants erect; flowers single (-3) in leaf axils.............2. ***R. cytisoides***
3. Plants trailing or twining; flowers in racemes..............3. ***R. minima***
    4. Plants erect; calyx 6-9 mm long; lower leaflet surface grayish tomentose...4. ***R. tomentosa***
    4. Plants trailing, twining, semi-erect; calyx 8-12 mm long; lower leaflet surface villose...................................5. ***R. difformis***

1. ***Rhynchosia reniformis*** de Candolle, Prodr. 2: 384. 1825.
[Figure 1a]

Trifolium simplicifolium Walter, Fl. Carol. 184. 1788.

Glycine tomentosa Linnaeus var. *monophylla* Michaux, Fl. Bor.-Amer. 2: 63. 1803.

Glycine reniformis Pursh, Fl. Amer. Sept. 486. 1814, nom. illegit.

Arcyphyllum simplicifolium (Walter) Elliott, J. Acad. Nat. Sci. Philadelphia 2: 115. 1818.

Glycine monophylla (Michaux) Nuttall, Gen. N. Amer. Pl. 2: 115. 1818, nom. illegit. et non Linnaeus 1767.

Glycine simplicifolia (Walter) Elliott, Sketch Bot. S. Carolina 2: 234. 1823.

Phaseolus reniformis (de Candolle) Eaton & J. Wright, Man. Bot., ed. 8. 353. 1840, nom. illegit.

Psoralea alnifolia Bertoloni, Mem. Reale Accad. Sci. Ist. Bologna 2: 274, t. 4(1). 1850.

Psoralea alopecurina Bertoloni, Mem. Reale Accad. Sci. Ist. Bologna 2: 275, t. 4(2). 1850.
Rhynchosia simplicifolia (Walter) A. W. Wood, Class-Book Bot., ed. 1861. 321. 1861, non de Candolle 1825.
Rhynchosia tomentosa (Linnaeus) Hooker & Arnott var. *monophylla* (Michaux) Torrey & A. Gray, Fl. N. Amer. 1: 284. 1838.
Rhynchosia tomentosa (Linnaeus) Hooker & Arnott, var. *intermedia* Torrey & A. Gray, Fl. N. Amer. 1: 285. 1838.
Dolicholus simplicifolius (Walter) Vail, Bull. Torrey Bot. Club 26: 114. 1899.
Dolicholus intermedius (Torrey & A. Gray) Vail, Bull. Torrey Bot. Club 26: 115. 1899.
Rhynchosia intermedia (Torrey & A. Gray) Small, Man. S.E. Fl. 715. 1933.
Rhynchosia simplicifolia (Walter) A. W. Wood var. *intermedia* (Torrey & A. Gray) F. J. Hermann, J. Wash. Acad. Sci. 38: 238. 1948.

Roots perennial. Stems erect, simple or branched, villous. Leaves 4-6, unifoliate, upper one rarely trifoliate; petioles 20-45 mm long; leaflets reniform or subcordate, 25-50 mm long, strigose above, hirsute beneath, especially along the veins. Inflorescence short and subsessile; peduncles 5-20 mm long. Calyx 7-10 mm long, lobes longer than tube; corolla yellow, 6.0-9.5 mm long, subequal to calyx. Fruits shortly oblong or elliptic-oblong, 12-18 mm long, villous especially along the sutures.

Habitat and distribution in Alabama: dry woods, sandhills, fields and roadsides; throughout the southern half of the state (Figure 1b).

Specimens examined. Autauga County: *Kral 33542*, 4 October 1968 (VDB). Baldwin County: *Lelong 7868*, 15 June 1974 (USAM). Barbour County: *MacDonald 10465,* 12 May 1997 (VDB). Bullock County: *Keys 83,* 10 May 1963 (AUA). Butler County: *Diamond 17963,* 23 September 2007 (TROY). Chilton County: *Freeman 714*, 20 May 1971 (AUA). Choctaw County: *Kral 39661*, 4 June 1970 (VDB). Clarke County: *Kral 43048*, 6 June 1971 (VDB). Coffee County: *Martin 61,* 24 June 1999 (TROY). Covington County:

Diamond 14481, 7 July 2004 (AUA, TROY, UNA, VDB). Crenshaw County: *Diamond 10357,* 23 July 1996 (AUA). Dale County: *Pennington 664,* 7 May 2000 (TROY). Dallas County: *Whetstone 14080,* 9 June 1984 (JSU). Escambia County: *Brittain 131,* 5 May 1995 (TROY). Geneva County: *Moore 435-69,* 25 July 1969 (AUA). Hale County: *McKitrick 53,* 4 July 1971 (AUA). Henry County: *Kral 31959,* 24 July 1968 (VDB). Lee County: *Barnes 158*, 22 May 1969 (AUA). Macon County: *Redmond 147*, 28 May 1970 (AUA). Mobile County: *Lelong 3066,* 21 April 1967 (USAM). Monroe County: *Diamond 15899,* 8 October 2005 (AUA, TROY, VDB). Pike County: *Diamond 11059*, 28 July 1997 (AUA). Russell County: *Gil 151*, 2 May 2003 (AUA). Tuscaloosa County: *Spaulding 11842,* 11 May 2003 (JSU, TROY, UNA, VDB).

2. ***Rhynchosia cytisoides*** (Bertoloni) Wilbur, Rhodora 64: 60. 1962. [Figure 1c]

Pitcheria galactoides Nuttall, J. Acad. Nat. Sci. Philadelphia 7: 93. 1834.

Pitcheria galactoides Nuttall var. *parvifolia* Torrey & A. Gray, Fl. N. Amer. 1: 286. 1838.

Rhynchosia galactoides (Nuttall) Endlicher & Walpers, in Walpers, Repert. Bot. Syst. 1: 790. 1842, non (Kunth) de Candolle 1825.

Lespedeza cytisoides Bertoloni, Mem. Reale Accad. Sci. Ist. Bologna 2: 278. 1850.

Rhynchosia pitcheria Burkart, Darwiniana 11(2): 268. 1957.

Roots perennial. Stems erect, branched, glabrous to villous. Leaves trifoliate; petioles 1-4 mm long; leaflets ovate to elliptic, 10-20 mm long, finely strigose above, puberulent beneath. Inflorescence 1(-3) flowered; peduncles 1-3 mm long. Calyx 5-7 mm long, lobes equal or short than tube; corolla yellow with purple veins, 7-10 mm, equal or longer than calyx. Fruits oblong, 12-20 mm long, puberulent.

Habitat and distribution in Alabama: dry open woods, sandy pinehills; extreme southern part of state (Figure 1d).

Specimens examined. Baldwin County: *Diamond 16587*, 26 June 2006 (TROY). Covington County: *Kral 33652*, 5 October 1968

(VDB). Dale County: *Diamond 13177*, 12 May 2002 (TROY). Escambia County: *Diamond 13196*, 19 May 2002 (TROY). Geneva County: *Kral 35097,* 7 June 1969 (AUA, VDB). Houston County: *Kral 43148*, 9 June 1971 (AUA). Mobile County: *Kral 39618*, 3 June 1970 (JSU, VDB). Washington County: *Kral 31185*, 6 June 1968 (UNA, VDB).

3. ***Rhynchosia minima*** (Linnaeus) de Candolle, Prodr. 2: 385. 1825. [Figure 1e]

Dolichos minimus Linnaeus, Sp. Pl. 726. 1753.
Dolicholus minimus (Linnaeus) Medikus, Vorles. Churpfaelz. Phys.-Oecon. Ges. 2: 354. 1787.
Glycine minor Lagascay Segura, Elench. Pl. 8. 1816, nom. illegit.
Glycine reflexa Nuttall, Gen. N. Amer. Pl. 2: 115. 1818.
Glycine lamarckii Kunth, in Humboldt et al., Nov. Gen. Sp. 6: 424. 1824.
Rhynchosia punctata de Candolle, Prodr. 2: 385. 1825.
Rhynchosia rhombifolia (Willdenow) de Candolle var. *timoriensis* de Candolle, Prodr. 2: 386. 1825.
Rhynchosia candollei Decaisne, Nouv. Ann. Mus. Hist. Nat. 3: 473. 1834.
Rhynchosia mexicana Hooker & Arnott, Bot. Beechey Voy. 287. 1841.
Rhynchosia aureoguttata Andersson, Kongl. Vetensk. Acad. Handl. 1853: 252. 1855.
Rhynchosia exigua Andersson, Kongl. Vetensk. Acad. Handl. 1853: 252. 1855.
Rhynchosia minima (Linnaeus) de Candolle var. *lutea* Eggers, Bull. U.S. Natl. Mus. 13: 42. 1879.
Rhynchosia minima (Linnaeus) de Candolle var. *pauciflora* Kuntze, Revis. Gen. Pl. 1: 204. 1891.
Rhynchosia minima (Linnaeus) de Candolle var. *diminifolia* Walraven, Brittonia 22: 85. 1970.

Roots perennial. Stems trailing or twining, branched, glabrous to puberulent or villous. Leaves trifoliate; petioles 5-90 mm long; leaflets broadly ovate-acuminate to rhomboid, 10-35 mm long, glabrous to villous, gland dotted. Inflorescence 5-15 flowered; peduncles 10-90 mm long. Calyx 2.5-3.0 mm long, longest lobes equal or longer than tube; corolla yellow with purple or brown veins, 4-8 mm, longer than calyx. Fruits oblong-ovate to flacate, 10-20 mm long, villous.

Habitat and distribution in Alabama: disturbed pinelands; known from two historical collections in south Alabama (Figure 1f).

Specimens examined. Autauga County: *Mohr s.n.*, July 1869 (US). Mobile County: *Mohr s.n.*, July 1870 (UNA).

4. ***Rhynchosia tomentosa*** (Linnaeus) Hooker & Arnott, Companion Bot. Mag. 1: 23. 1835. [Figure 2a]

Glycine tomentosa Linnaeus, Sp. Pl. 754. 1753.
Trifolium erectum Walter, Fl. Carol. 184. 1788.
Arcyphyllum erectum (Walter) Elliott, J. Acad. Nat. Sci. Philadelphia 1: 372. 1803.
Glycine tomentosa Linnaeus var. *erecta* (Walter) Michaux, Fl. Bor.-Amer. 2: 63. 1803.
Glycine erecta (Walter) Nuttall, Gen. N. Amer. Pl. 2:114. 1818, non Thunberg 1800.
Glycine mollissima Elliott, Sketch Bot. S. Carolina 2: 235. 1823.
Rhynchosia erecta (Walter) de Candolle, Prodr. 2: 384. 1825.
Glycine caroliniana Sprengel, Syst. Veg. 3: 197. 1826.
Rhynchosia tomentosa (Linnaeus) Hooker & Arnott var. *erecta* (Walter) Torrey & A. Gray, Fl. N. Amer. 1: 285. 1838.
Dolicholus drummondii Vail, Bull. Torrey Bot. Club 26: 116. 1899.
Dolicholus erectus (Walter) Vail, Bull. Torrey Bot. Club 26: 115. 1899.
Dolicholus tomentosus (Linnaeus) Vail, Bull. Torrey Bot. Club 26: 112. 1899.
Rhynchosia drummondii (Vail) K. Schumann, Bot. Jahrb. Syst. 26: 496. 1901.

Roots perennial. Stems erect, branched, densely villous. Leaves trifoliate, lower one rarely unifoliate; petioles 15-50 mm long; leaflets broadly ovate to elliptic, 35-70 mm long, densely puberulent or tomentose above, tomentose below. Inflorescence axillary, 10-30 mm long, and short terminal, 7-15 mm long; peduncles 5-15 mm long. Calyx 5-9 mm long, lobes longer than tube; corolla yellow, 5-10 mm, equal or short than calyx. Fruits ovate-oblong to broadly oblong, 15-20 mm long, hirsute and puberulent.

Habitat and distribution in Alabama: dry woodlands, sandhills, woodland borders, rich woodlands; scattered throughout the state (Figure 2b).

Specimens examined. Autauga County: *Diamond 6179*, 29 July 1989 (AUA). Baldwin County: *Moore 83,* 15 May 1955 (AUA). Barbour County: *MacDonald 11492*, 27 June 1998 (UNA). Blount County: *Keener 910*, 6 June 1998 (UNA). Bullock County: *Diamond 14165,* 18 September 2003 (AUA, JSU, TROY, UNA, VDB). Butler County: *Diamond 17964*, 23 September 2003 (TROY). Calhoun County: *Whetstone 12207*, 9 September 1982 (JSU). Cherokee County: *Kral 47626*, 12 July 1972 (VDB). Chilton County: *Diamond 15567,* 27 July 2005 (TROY, VDB). Choctaw County: *Moore 949,* 8 September 1970 (AUA). Clarke County: *Kral 41122,* 5 September 1970 (VDB). Clay County: *Rutland 460,* 23 June 1975 (AUA). Cleburne County: *Adams s.n.*, 27 June 1957 (AUA). Colbert County: *Kral 67598*, 26 July 1981 (VDB). Conecuh County: *Diamond 11983*, 13 August 2000 (TROY). Coosa County: *Rutland 1159,* 2 September 1975 (AUA). Covington County: *MacDonald 13273,* 24 July 1999 (VDB). Crenshaw County: *Diamond 16398,* 17 May 2006 (TROY). Dale County: *Rundell 260,* 1 July 1997 (TROY). DeKalb County: *Price 101*, 25 July 1970 (AUA). Elmore County: *McDaniel 7773,* 28 September 1966 (UNA). Etowah County: *Hodge & Spaulding 2716/6893*, 23 June 1994 (JSU). Fayette County: *Haynes 9593,* 20 September 1997 (UNA). Geneva County: *MacDonald 12933*, 29 May 1999 (VDB). Greene County: *Thomas 1695,* 3 June 1968 (UNA). Hale County: *Maginness 316*, 13 June 1966 (UNA). Houston County: *Kral 40011,* 16 July 1970 (UNA, VDB). Jackson County: *Whetstone 4528*, 5 August 1994 (JSU). Jefferson County: *Barber 922,* 27 July 1984 (JSU). Lamar County: *Kral 39789,* 27 June 1970 (UNA). Lauderdale County: *Kral 69506,* 20 July 1982 (VDB). Lee County: *Robertson 81*, 23 August 1924 (AUA). Lowndes County: *Diamond 14736*, 30 September 2004 (AUA, TROY). Macon County: *Moore 300,* 9 July 1970 (AUA). Marengo County: *Kral 31220,* 6 June 1968

(VDB). Marshall County: *Spaulding 2286*, 12 July 1992 (JSU). Mobile County: *Lelong 6513,* 24 May 1972 (USAM). Morgan County: *Kral 41169*, 22 September 1970 (VDB). Randolph County: *Nixon et al., 4061*, 15 July 1988 (JSU). Russell County: *Kral 62284,* 8 July 1978 (JSU, VDB). Shelby County: *Kral 51154,* 11 August 1973 (UNA). St. Clair County: *Kral 65949*, 3 July 1980 (TROY). Sumter County: *Spaulding 12036,* 24 August 2003 (AUA, JSU, TROY, UNA, VDB). Talladega County: *Rutland 1040*, 29 August 1975 (AUA). Tallapoosa County: *Kral 62150,* 25 June 1978 (JSU, VDB). Tuscaloosa County: *Burdett 72*, 26 June 1971 (AUA). Wilcox County: *Kral 82408,* 21 May 1993 (VDB).

5. ***Rhynchosia difformis*** (Elliott) de Candolle, Prodr. 2: 384. 1825. [Figure 2c]

    Glycine tomentosa Linnaeus var. *volubilis* Michaux, Fl. Bor.-Amer. 2: 63. 1803.
    Arcyphyllum difforme Elliott, J. Acad. Nat. Sci. Philadelphia 1: 372. 1818.
    Rhynchosia tomentosa (Linnaeus) Hooker & Arnott var. *volubilis* (Michaux) Torrey & A. Gray, Fl. N. Amer. 1: 284. 1838.
    Rhynchosia volubilis A. W. Wood, Class-Book Bot., ed. 1861. 321. 1861, non Loureiro 1790.
    Dolicholus lewtonii Vail, Bull. Torrey Bot. Club 26: 113. 1899.
    Dolicholus tomentosus (Linnaeus) Vail var. *undulatus* Vail, Bull. Torrey Bot. Club 26: 113. 1899.
    Rhynchosia lewtonii (Vail) Small, Man. S.E. Fl. 714. 1933.

Roots perennial. Stems trailing, twining, rarely semi-erect, simple or branched, strigose or hirsute. Leaves trifoliate, lower one rarely unifoliate; petioles 20-50 mm long; leaflets suborbicular to elliptic, 25-50 mm long, glabrous to strigose above, villose below. Inflorescence axillary, 10-20 mm long; peduncles 5-15 mm long. Calyx 8-12 mm long, lobes longer than tube; corolla yellow, 8-10 mm, equal or short than calyx. Fruits ovate-accuminate to broadly oblong, 12-20 mm long, puberulent and villous.

Habitat and distribution in Alabama: mixed and deciduous woodlands, sandhills, old fields and roadsides; throughout southeast Alabama and widely scattered in the northern one-half of the state. (Figure 2d).

Specimens examined. Autauga County: *Gunn 708*, 14 June 1982 (AUA, UNA). Barbour County: *Moore 441,* 29 July 1970 (AUA). Butler County: *Diamond 12123*, 9 September 2000 (TROY). Coffee County: *Martin 873b*, 10 August 2000 (TROY). Crenshaw County: *Diamond 11435,* 11 October 1998 (AUA). Dale County: *Rundell 408,* 29 August 1997 (TROY). Dallas County: *Kral 32774*, 21 August 1968 (VDB). Fayette County: *Moore 2977*, 14 September 1954 (AUA). Henry County: *Kral 79307*, 30 June 1991 (VDB). Houston County: *Kral 35747,* 25 July 1969 (VDB). Jackson County: *Henderson 472,* 25 July 1981 (AUA). Macon County: *Botts 189,* 2 July 1976 (AUA). Montgomery County: *Diamond 12474*, 3 July 2001 (TROY). Pike County: *Hall 138,* 21 September 2000 (TROY). Russell County: *Kral 62065b*, 19 June 1978 (VDB). Talladega County: *Mohr 407*, June 1892 (UNA).

DISCUSSION

In Alabama, *Rhynchosia,* is a common genus of open, dry woodlands, savannahs, prairie openings, fields and roadsides. The taxa can normally be recognized by a combination of conspicuously glandular foliage, yellow corolla, and 1-2 seeded pods.

Both Alabama collections of *Rhynchosia minima* (Linnaeus) de Candolle are historical. Charles Mohr made the Autauga County collection in July 1869 and the Mobile County collection in July 1870. It is possible that this species has been extirpated from the state. However, a collection by James Burkhalter in September 1987 from Escambia County, Florida, documents the continued presence of the species immediately adjacent to Alabama.

Of the 146 herbarium specimens of *Rhynchosia tomentosa* (Linnaeus) Hooker & Arnott that were studied during this project, all were the typical variety. The second variety, *R. tomentosa* var. *mollissima* (Elliott) Torrey & Gray is known from Florida, Georgia and

South Carolina. In Florida, it has been reported from Leon County, which is approximately 100 km southeast of Houston County, Alabama. Because of the proximity of the Florida collection to Alabama, this taxon possibly occurs in the southeastern section of the state. The typical variety has persistent stipules, several axillary inflorescences, 1-3 cm long and an occasional short terminal raceme. Variety *mollissima* differs from the typical variety by having caducous stipules and a single, strongly exerted, terminal inflorescence 5-20 cm long.

Rhynchosia michauxii Vail is another taxon that possibly occurs in the southern tier of Alabama counties. Although this taxon has not been reported from state, it does occur in Okaloosa County, Florida, which is immediately south of Covington and Escambia Counties.

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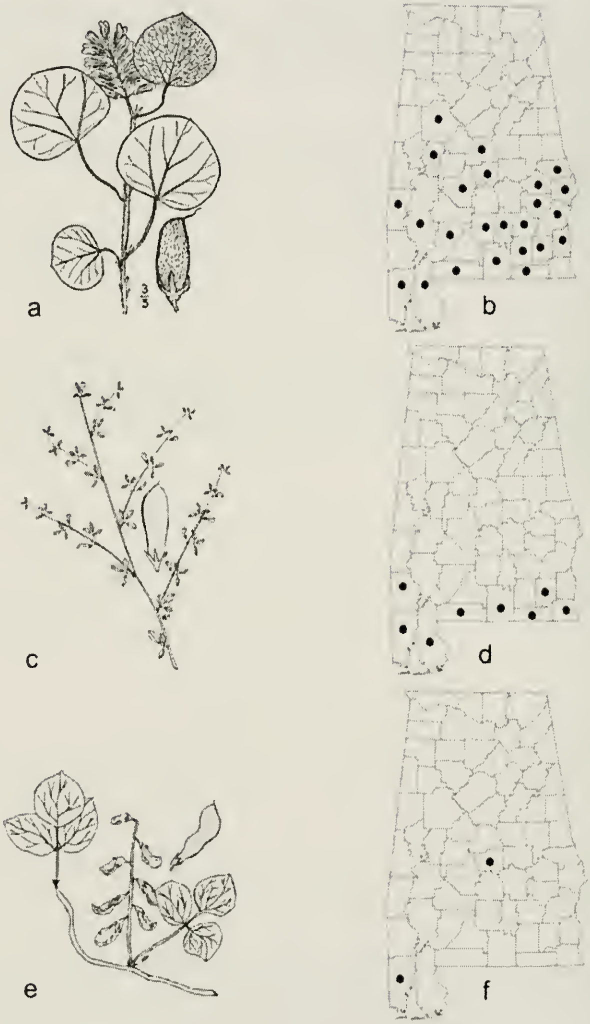

Figure 1. a) illustration of *Rhynchosia reniformis*, b) distribution of *R. reniformis*, c) illustration of *R. cytisoides*, d) distribution of *R. cytisoides*, e) illustration of *R. minima*, f) distribution of *R. minima*

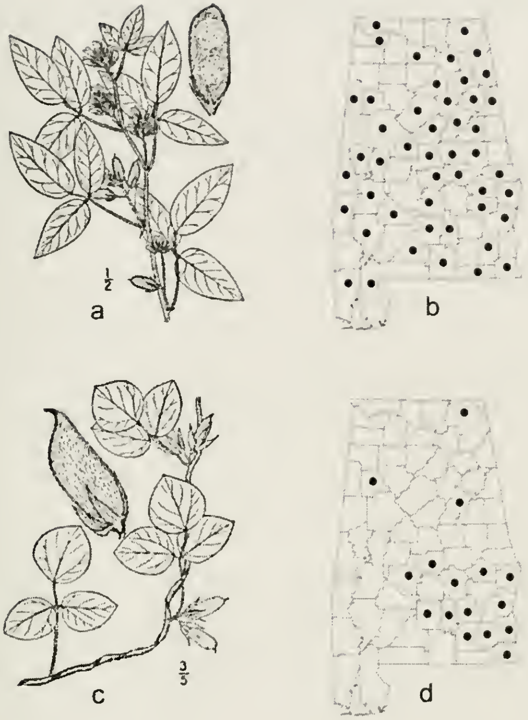

Figure 2. a) illustration of *Rhynchosia tomentosa*, b) distribution of *R. tomentosa*, c) illustration of *R. difformis*, d) distribution of *R. difformis*.

KEYS TO THE FLORA OF FLORIDA: 21, *CRATAEGUS* (ROSACEAE)

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ABSTRACT

Crataegus (Rosaceae) is represented in Florida by 11 species. The name *Crataegus michauxii* is reaffirmed for the Summer Haw; the species is treated as consisting of 2 varieties, with var. ***lacrimata*** newly ranked. *Crataegus phaenopyrum* is rated as endangered. An amplified key is given to the Florida taxa. *Phytologia 91(1):18-25, (April, 2009)*.

KEY WORDS: *Crataegus*, Rosaceae, Florida flora.

> "No wonder you ponder my application of names to the Hawthorns. But with so many children of my imagination, and the free use by others in naming their offspring, names with sympathetic tolerance and interpretation with their subjects are much in demand." Chauncey D. Beadle, 2 September 1940, letter to William A. Murrill, in response to Murrill's complaint that species of *Crataegus* had become so numerous that all suitable epithets had already been used.

Crataegus (Rosaceae), the hawthorns, has received its full share of attention from several prolific authors. Their energies have generated impressive , even unmanageable, numbers of specific names. Few perhaps now remember that in J. K. Small's early *Flora of the Southeastern United States* (1903), C. D. Beadle described and named 185 species of *Crataegus*, and that fully 47 of them were from Florida. Some relief was felt when, in Small's revised *Manual of the Southeastern Flora* (1933), Ivar Tidestrom reduced this number of total southeastern species to 33 and the Florida species to 11. Even better -- from the standpoint of persons with finite retentive powers -- R. K.

Godfrey, in his *Trees, Shrubs and Woody Vines* (1988), saw fit to recognize only 9 species in the three-state Southeast, all to be found in Florida.

Even as some writers were winnowing the published names of *Crataegus*, other investigators were adding to the list. T. G. Harbison and W. W. Ashe, operating from the Biltmore Herbarium, North Carolina; E. J. Palmer and C. S. Sargent, with the Arnold Arboretum, Massachusetts; and W. A. Murrill, University of Florida, Gainesville, all found variations in southeastern and Florida hawthorns that they believed merited naming.

But with the passage of years a new champion of the hawthorns had arisen, whose reports again serve to push the number of recognized species ever upward. J. B. Phipps, based at the University of Western Ontario, began to search the continent, to study and collect *Crataegus*, and has now excellently documented, described, mapped and beautifully illustrated most series within the genus. He has skillfully addressed: *C. aestivalis*, *C. opaca*, and *C. rufula* (J. Arnold Arbor. 69: 401-431. 1988); *C. marshallii*, *C. phaenopyrum*, and *C. spathulata* (Ann. Missouri Bot. Gard. 85: 475-491. 1998); and *C. uniflora* (with Dvorsky, Sida 22: 423-445. 2006). He determined Aiton's widely used *C. flava* is not the familiar Summer Haw (Taxon 37: 108-113. 1988). Though he made no reassignment himself, the characteristics and specimens he cited point to it being the Smooth Haw, *C. pulcherrima*, a name of later date. In turn -- though Phipps (below) argues to the contrary -- the Summer Haw *s.l.* now must become *C. michauxii* Persoon. (This name has independently been accepted by R. P. Wunderlin, *Guide to the Vascular Plants of Florida*. 1998.)

The present treatment, however, must take issue with two recent studies by J. B. Phipps & K. A. Dvorsky (J. Bot. Res. Inst. Texas 1: 171-202. 2007; ibid. 2: 1101-1162. 2008). In the first of these papers (2007), 13 species described by C. D. Beadle (1902, 1903) and E. J. Palmer (1932) are redescribed, mapped, illustrated, and given new life as species recognized by someone other than their original author.

Eight are reported to occur in Florida (*C. annosa* Beadle, *C. aprica* Beadle, *C. egregia* Beadle, *C. galbana* Beadle, *C. leonensis* Palmer, *C. mira* Beadle, *C. segnis* Beadle, *C. visenda* Beadle). In the second of these papers (2008) a further 26 species are described, fully 20 of them to be found in Florida (*C. alabamensis* Beadle, *C. attrita* Beadle, *C. condigna* Beadle, *C. crocea* Beadle, *C. dispar* Beadle, *C. egens* Beadle, *C. florens* Beadle, *C. floridana* Sarg., *C. furtiva* Beadle, *C. integra* (Nash) Beadle, *C. lacrimata* Small, *C. lanata* Beadle, *C. lancei* J. B. Phipps, *C. lassa* Beadle, *C. lepida* Beadle, *C. meridiana* Beadle, *C. munda* Beadle, *C. quaesita* Beadle, *C. senta* Beadle, *C. vicana* Beadle). [Of these entities, only *C. lacrimata* is recognized here.] Nearly all of these reported species are infrequent to rare, many with very restricted locations or with disjunct ranges extending over wide areas. Though the species are carefully keyed, the distinctions are slight. Phipps & Dvorsky maintain these plants to be different from *C. michauxii* (the Summer Haw, as treated here), the first eight not even in the same series. Though one wishes to acknowledge Phipps' judgments, as merited by the value of his previous studies (above), one cannot but view these "species" as apomictic populations, unworthy of being placed alongside the taxa that elsewhere constitute the genus *Crataegus*. They exactly parallel the many discrete but too finely distinguished agamospermic populations also encountered in *Rubus* (Phytologia 87: 29-39. 2005).

As noted (above), the reassignment of *Crataegus flava* to the hawthorn formerly known as *C. pulcherrima* has left *C. michauxii* Pers. the prior name for the Summer Haw. However Phipps & Dvorsky now reject that name. Their argument (2008: 1102-1103) is based on the claim that Michaux' type (at P) is "simply a piece from a vigorously growing extension shoot of an unidentifiable species." Although Michaux' original name, *C. glandulosa* (1803) was a later homonym (of *C. glandulosa* Georgi, 1776), Persoon (1806) based his *C. michauxii* on the Michaux description and specimen. That specimen (P, fiche 65, image 9) is one of 9 images of *Crataegus*, all collected by Michaux during his decade-long (1785-1796) exploration of eastern North America. It consists of a single slightly zigzag stem bearing 4 long spines and 8 leaves, each with nearly orbicular blades and well-defined petioles. Numerous glands and minute teeth can be discerned on the lower blade margins. The only label data are the words "*glandulosa*" and "(*varietas?*)," in Michaux' hand. Far from being "unidentifiable," its image very nearly matches the illustration of *C. condigna* Beadle, as shown by Phipps & Dvorsky (2008: 1125). It is certainly a Summer Haw, as commonly understood. The name *Crataegus michauxii* Pers. (1806) remains well-based and prior.

The Florida variability found within *Crataegus michauxii* justifies inclusion under that name of nine synonyms (see the key), all typified by Florida plants -- by Beadle, Palmer, Sargent, and Small. Within this complex the Weeping Haw, *C. lacrimata*, of the Florida panhandle sandhills stands out, both as to substantial but discrete range and adequately distinct morphology (pendent branches, narrowly spatulate leaves). It is at times recognized at specific rank (Small, 1933; Kurz & Godfrey, 1962; Little, 1979).

But there is also a case to be made for leaving *Crataegus lacrimata* submerged within the greater apomictic *C. michauxii* complex. Even in the heart of its Florida panhandle range one can readily find plants -- or more commonly, branchlets within plants -- that are intermediate or seemingly of the second taxon. This phenomenon is not discussed by Phipps, though he twice illustrates it: a specimen labeled *C. lacrimata* (2008: 1113), and a specimen labeled *C. lassa* (2008: 1137). In each, lower leaves are narrow, appropriate to *C. lacrimata*, while the more terminal leaves are broad, readily identifiable as *C. michauxii*. Varietal status, as given here, is an approximate way of acknowledging this curious intermediacy. A new combination is required.

> ***Crataegus michauxii*** Persoon var. ***lacrimata*** (Small) D. B. Ward, comb. et stat. nov. Basionym: *Crataegus lacrimata* J. K. Small, Torreya 1:97. 1901. TYPE: Holotype: United States, Florida, Okaloosa Co., Crestview. C. D. Beadle, Biltmore Herbarium B-17 and B-969, 8 April 1899 (NY). Isotype (cited as lectotype by Phipps & Dvorsky 2008: 1112): C. D. Beadle 17, 8 April 1899 (US).

CRATAEGUS L. Hawthorns *

1.Flowers and fruits solitary, on short (1-3 mm.) pedicels; sepals prominent, persistent in fruit, broad at base, with coarsely serrate margins; leaves glossy green above, elliptic to obovate, with regular crenate teeth on apical half, the lower margins entire; fruits dull brown, 10 mm. dia.; thorns ±3 cm. long, slender and gray. Shrub or rarely small tree. Understory in moist woodlands. North Florida (s. to Marion County); frequent. Spring. [*Crataegus croomiana* Sarg.]
ONE-FLOWERED HAW. **Crataegus uniflora** Muench.

1.Flowers and fruits in corymbs of several (or if solitary, on long (10-15 mm.) pedicels); sepals not prominent, entire or weakly serrate, often withering in fruit; leaves various.
  2.Leaves red-maplelike, with 2 (or 4) sharply pointed lateral lobes; fruits red, 4-5 mm. dia.; thorns 1-2 cm. long. Small tree. Low woodlands. Mid-panhandle (Washington; Wakulla counties: Ochlockonee R.); rare. Spring. ENDANGERED (State listing). [*Crataegus youngii* Sarg.]
  WASHINGTON HAW. **Crataegus phaenopyrum** (L.f.) Medic.

  2.Leaves not maplelike, unlobed or with irregularly rounded lateral lobes (the apex rounded or acute).
    3.All leaves deeply and symmetrically divided, with some sinuses nearly reaching the midrib, the lobes sharply incised; fruits small (5-6 mm. dia.), bright red, solitary or in corymbs of several; thorns nearly lacking. Small tree. Wet floodplain forests, moist wooded slopes. Panhandle and north Florida (s. to Marion County; excl. n.e. Fla.), disjunct to mid-peninsula (Hillsborough County); infrequent and local. Early spring.
    PARSLEY HAW. **Crataegus marshallii** Egglest.

    3.All leaves either unlobed or with irregular shallow lobes.
      4.Fruits very small (3-4 mm. dia.), in several-flowered glabrous corymbs; leaves glabrous when mature, spatulate with long-cuneate bases and rounded crenately toothed apices, sometimes with three apical lobes; veins largely (except the lower midrib) immersed in leaf tissue, without sunken axil pockets; thorns nearly lacking. Spindly shrub or small tree. Moist calcareous

wooded slopes, mostly near the Apalachicola R. bluffs (Gadsden, Jackson, Liberty counties); infrequent and local. Spring.
RED HAW. **Crataegus spathulata** Michx.

4.Fruits larger (>4 mm. dia.), or if small, with sharply serrate leaves; leaves and inflorescences usually with some hairs; lateral veins protruding above lower leaf surface.

5.Leaves, or at least some, with acute apices; blades elliptic, unlobed or with 2-4 lateral lobes.

6.Fruits medium (4-7 mm. dia.), usually in several-flowered corymbs; lower surface of leaves with small sunken pockets in axils of major veins; thorns few. Small to mid-sized tree. Floodplains, riverbottom forests, swamps. Panhandle and north Florida, south to north peninsula (Marion County); frequent. Early spring. [*Crataegus paludosa* Sarg.]
GREEN HAW. **Crataegus viridis** L.

6.Fruits large (6-15 mm. dia.), solitary or usually so (if several together, usually not of the same corymb).

7.Lower surface of leaves with pockets lacking in vein axils; petioles distinct, the blade cuneate at base but not extended downward; leaves usually with 2-4 shallow sharply-serrate lobes; thorns few. Small to mid-size tree. Open woodlands, moist hammocks and slopes. Panhandle, locally eastward (to Alachua, Columbia, Levy counties); frequent. Spring. [*Crataegus opima* Beadle; *Crataegus pulcherrima* Ashe; *Crataegus rober* Beadle]
SMOOTH HAW. **Crataegus flava** Ait.

7.Lower surface of leaves with prominent hair-filled sunken pockets in axils of major lateral veins (domatia); leaves unlobed or deeply but irregularly cut or lobed; petioles indistinct, changing gradually into cuneate-based blade.

8.Leaves 3-5 cm. long, serrate or crenate toward apex, glossy above, nearly glabrous below; thorns few. Shrub or small tree. Pond margins, creek banks. Mid-panhandle (Gadsden County), east to northeast Florida (Nassau County), south along east coast (to Volusia County); frequent. Early spring. [*Crataegus luculenta* Sarg.; *Crataegus maloides* Sarg.]

MAY HAW. **Crataegus aestivalis** (Walt.) Torr. & Gray

8.Leaves 5-7 cm. long, entire or finely serrate-crenate toward apex, dull green above, densely rufous-tomentose below when young, persisting along veins when full-grown.

9.Leaves elliptic to broad-elliptic; lateral veins 5-9; pedicels glabrous; fruits 12-15 mm. dia. Small tree. Stream and river banks. Western panhandle (n.e. Escambia County: Century); rare. Spring. APPLE HAW. **Crataegus opaca** Hook. & Arn.

9.Leaves broad-elliptic to obovate; lateral veins 3-5; pedicels rufous-tomentose; fruits 10-12 mm. dia. Small tree. River bottoms. Central panhandle (Jackson, Gadsden counties); rare. [*Crataegus aestivalis*, misapplied]
RUFOUS MAY HAW. **Crataegus rufula** Sarg.

5.Leaves with rounded apices, or a few acute; blades oblanceolate to spatulate, without lobes (or some leaves irregularly lobed on vigorous shoots of *C. michauxii*); fruits large (6-12 mm. dia.).

10.Leaves glossy green above, without glands on petioles or margins, without pockets (domatia) in vein axils; thorns usually very prominent (3-4 cm. long). Small tree. Floodplain forests, moist hammocks. North Florida (excl. w. panhandle), south into north peninsula (to Clay, Levy counties); frequent. Spring. [*Crataegus pyracanthoides* Beadle]
COCKSPUR HAW. **Crataegus crus-galli** L.

10.Leaves uniformly light green above and below; petioles and margins with dark button-like glands; lower leaf surface with proximal vein axils sunken and hairy, forming small pockets (domatia); thorns numerous but small (1-2 cm. long). Spring. An apomictic complex, of many named forms, only two of which are here given recognition. SUMMER HAW, YELLOW HAW.
Crataegus michauxii Pers.

a.Leaves broadly spatulate to obovate; branches variously spreading, not weeping. Shrub or small to mid-sized

tree. Dry to moist woodlands, fencerows, open pastures. North Florida, south to mid-peninsula (Highlands County); common. [*Crataegus audens* Beadle; *Crataegus egregia* Beadle; *Crataegus flava*, misapplied; *Crataegus floridana* Sarg.; *Crataegus galbana* Beadle; *Crataegus leonensis* Palmer; *Crataegus lepida* Beadle; *Crataegus ravenelii* Sarg.; *Crataegus visenda* Beadle]
SUMMER HAW (typical). var. **michauxii**

a. Leaves narrowly spatulate (except on vigorous shoots, when sometimes broader); branches and branchlets prominently weeping (pendent). Small tree. Dry sandhills. Western half of panhandle (Escambia to Calhoun counties); infrequent and local. [*Crataegus lacrimata* Small]
WEEPING HAW. var. **lacrimata** (Small) D. B. Ward

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*This paper is a continuation of a series begun in 1977. The "amplified key" format employed here is designed to present in compact form the basic morphological framework of a conventional dichotomous key, as well as data on habitat, range, and frequency. Amplified keys are being prepared for all genera of the Florida vascular flora; the present series is restricted to genera where a new combination is required or a special situation merits extended discussion.

NEW COMBINATIONS IN THE GENUS *SENEGALIA* (FABACEAE: MIMOSOIDEAE)

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ABSTRACT

Morphological and genetic differences separating the subgenera of *Acacia s.l.* and molecular evidence that the genus *Acacia* s.l. is polyphyletic necessitate transfer of the following taxa from *Acacia* subgenus *Aculeiferum* Vassal to *Senegalia*, resulting in 10 new combinations in the genus *Senegalia*: *S. grandisiliqua* (Benth.) Seigler & Ebinger, *S. guarensis* (L. Cárdenas & F. García) Seigler & Ebinger, *S. laeta* (R. Br. ex Benth.) Seigler & Ebinger, *S. lowei* (L. Rico) Seigler & Ebinger, *S. polyacantha* (Willd.) Seigler & Ebinger, *S. riograndensis* (Atahuachi & L. Rico) Seigler & Ebinger, and *S. skleroxyla* (Tussac) Seigler & Ebinger. Two new combination and new status changes are necessary: *S. latifoliola* (Kuntze) Seigler & Ebinger, **comb. et stat. nov.** and *S. rhytidocarpa* (L. Rico) Seigler & Ebinger, **comb. et stat. nov**. A lectotypification is made for *Acacia grandisiliqua* Benth. One new name was required: *S. stenocarpa* Seigler & Ebinger, **nom. nov.** *Phytologia 91(1): 26-30,(April, 2009).*

KEY WORDS: *Acacia sensu lato*, Fabaceae, Mimosoideae, *Senegalia.*

Morphological and genetic differences separating the subgenera of *Acacia s.l.* and molecular evidence that the genus *Acacia* s.l. is polyphyletic necessitate recognition of segregate genera and transfer of many *Acacia* species to these genera. A large number of species of *Acacia* subgenus *Aculeiferum* Vassal must be referred to *Senegalia* Rafinesque.

Taxonomic Changes

For the following 10 taxa, this results in new combinations, changes in status and a new name in the genus *Senegalia*:

1. **SENEGALIA GRANDISILIQUA** (Benth.) Seigler & Ebinger, **comb. nov.** Basionym: *Acacia grandisiliqua* Benth. London J. Bot. 1: 518. 1842. Bentham equated this taxon with *Mimosa grandisiliqua* Vell., Fl. flumin. 11: (t. 37). 1790 [1831]. nom. nud. and made a nom. nov. based on the type specimens below. – TYPE: BRAZIL. BAHIA: *C. F. P. von Martius 1098* [lectotype, designated here: K (photo F)]; [paratypes: *Lushnath 145* (K, MO); *C. F. P. von Martius 1104* (K?)].

2. **SENEGALIA GUARENSIS** (L. Cárdenas & F. García) Seigler & Ebinger, **comb. nov.** Basionym: *Acacia guarensis* L. Cárdenas & F. García, Ernstia 10: 146. 2000. – TYPE: VENEZUELA: Territorio Federal Amazonas. Cuenca del Río Manapiare, selva alta, a media hora de camino desde el poblado de Guara en dirección SE, en la pica hacia el Caño Garrafón, alt. 140 m, 5° 15' N, 66° 03' W, 28 Jan 1977, *O. Huber 429/3435* (holotype: VEN 307571).

3. **SENEGALIA LAETA** (R. Br. ex Benth.) Seigler & Ebinger, **comb. nov.** Basionym: *Acacia laeta* R. Br. ex Benth., London J. Bot. 1: 508. 1842. – TYPE: ETHIOPIA: prope montes Tarnta, *H. Salt 82* (holotype: BM; isotypes: MO, NY).

4. **SENEGALIA LATIFOLIOLA** (Kuntze) Seigler & Ebinger, **comb. et stat. nov.** Basionym: *Acacia riparia* Kunth var. *latifoliola* Kuntze, Revis. gen. pl. 3(2): 47. 1898. – TYPE: BRAZIL. MATO GROSSO: *O. Kuntze s.n.* (holotype: NY).\

5. **SENEGALIA LOWEI** (L. Rico) Seigler & Ebinger, **comb. nov.** Basionym: ***Acacia lowei*** L. Rico, Amer. Sp. *Acacia* 114. 2007. – TYPE: Probably from Brazil, but based on a specimen cultivated in Madeira; [lectotype, Rico-Arce (2007): original drawing for plate 3366 (M. Young, K-library)].

6. **SENEGALIA POLYACANTHA** (Willd.) Seigler & Ebinger, **comb. nov.** Basionym: *Acacia polyacantha* Willd., Sp. pl. 4: 1079. 1806. – TYPE: No type cited, habitat in India orientali, *Roxburgh s.n.* [holotype: B-Willd.; isotype: (fragment K)].

7. **SENEGALIA RHYTIDOCARPA** (L. Rico) Seigler & Ebinger **comb. et stat. nov.** Basionym: *Acacia polyphylla* DC. var. *rhytidocarpa* L. Rico, Anales Jard. Bot. Madrid 63: 28. fig. 1. 2006. – TYPE: BOLIVIA. BENI: Provincia Ballivian, km 35 carretera Yucumo-Rurrenabaque, Colegio Técnico Agropecuario, río Colorado, 67° 05' W, 14° 50' S, *D. N. Smith et al. 13586* (holotype: LPB; isotypes: G, K, MO).

8. **SENEGALIA RIOGRANDENSIS** (Atahuachi & L. Rico) Seigler & Ebinger, **comb. nov.** Basionym: *Acacia riograndensis* Atahuachi & L. Rico. Kew Bull. 62: 605. 2007. – TYPE: BOLIVIA. COCHABAMBA: Provincia Campero, Pasorapa, en la bajada de Buena Vista hacia el Río Grande, 27 Dec 2004, *J. R. I. Wood, M. Atahuachi & M. Mercado 21251* (holotype: BOLV; isotypes: K, LPB).

9. **SENEGALIA SKLEROXYLA** (Tussac) Seigler & Ebinger, **comb. nov.** Basionym: *Acacia skleroxyla* Tussac, Fl. Antill. 1: 146. (pl. 21). 1808 [1808-1813]. – TYPE: Antilles. Santo Domingo [holotype: pl. 21 from Tussac (1808); isotype: K (Rico-Arce 2007)].

10. **SENEGALIA STENOCARPA** Seigler & Ebinger, **nom. nov.** Basionym: *Acacia stenocarpa* Malme, Ark. Bot. 23A(13): 46. 1931. nom. illeg. non Richard (1847). – TYPE: BRAZIL. MATO GROSSO: Corumbá, in silva satis clara regionis calcariae, 19 Dec 1902, *G. O. A. Malme 2731* [lectotype, Seigler et al. (2006): S) [paratype: *Malme 2731a* (S)].

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THE LEAF ESSENTIAL OIL OF *JUNIPERUS MARITIMA* R. P. ADAMS COMPARED WITH *J. HORIZONTALIS*, *J. SCOPULORUM* AND *J. VIRGINIANA* OILS

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ABSTRACT

This is first report on the composition of the leaf essential oil of *J. maritima* R. P. Adams, a new juniper species from the Pacific northwest USA. The volatile leaf oil of *J. maritima* is dominated by elemicin (20.2%), sabinene (20.0%), limonene (11.7%) and 8-α-acetoxyelemol (6.1%) with moderate amounts of safrole (3.8%), pregeijerene B (3.1%) and terpinen-4-ol (1.8%). The leaf oils of *J. horizontalis*, *J. scopulorum* and *J. virginiana* var. *virginiana* were re-analyzed and compared with the oil of *J. maritima*. Each of the four species has a distinct oil composition reflecting their specific status.
Phytologia 91(1):31-39, (April, 2009).

KEY WORDS: *Juniperus maritima, J. horizontalis, J. scopulorum, J. virginiana var. virginiana,* Cupressaceae, essential oil composition, elemicin, sabinene, limonene, 8-α-acetoxyelemol.

Adams (1983) examined geographic variation in leaf terpenoids throughout the range of *Juniperus scopulorum* Sarg. and found that plants from the Puget Sound area of northwestern North America showed considerable differences in their leaf terpenoids compared with typical *J. scopulorum* plants in the Rocky Mountains. Recent DNA sequencing (Schwarzbach et al, in prep.) found that the Puget Sound plants were more related to *J. virginiana* L. than *J. scopulorum*. As part of a continuing study of the genus *Juniperus* (Adams, 2004), additional plants were collected from the Puget Sound area and SNPs (Single Nucleotide Polymorphisms) were examined (Adams, 2007). That study (Adams, 2007) revealed (Fig. 1) that the junipers in the Puget Sound area also differed in their nrDNA SNPs. Based on a combination of SNPs, terpenoids, morphology and ecology, Adams (2007) recognized the junipers of Puget Sound as a new species, *J. maritima* R. P. Adams, the seaside juniper.

Although Adams (1983) reported on multivariate differences in the oils from Puget Sound plants (now *J. maritima*), no information was published on the oil composition. Because *J. maritima* is closely related to *J. horizontalis*, *J. scopulorum* and *J. virginiana*, these leaf oil compositions are included in this report. The leaf oil compositions of *J. horizontalis*, *J. scopulorum* and *J. virginiana* have been recently published (Adams, 2000).

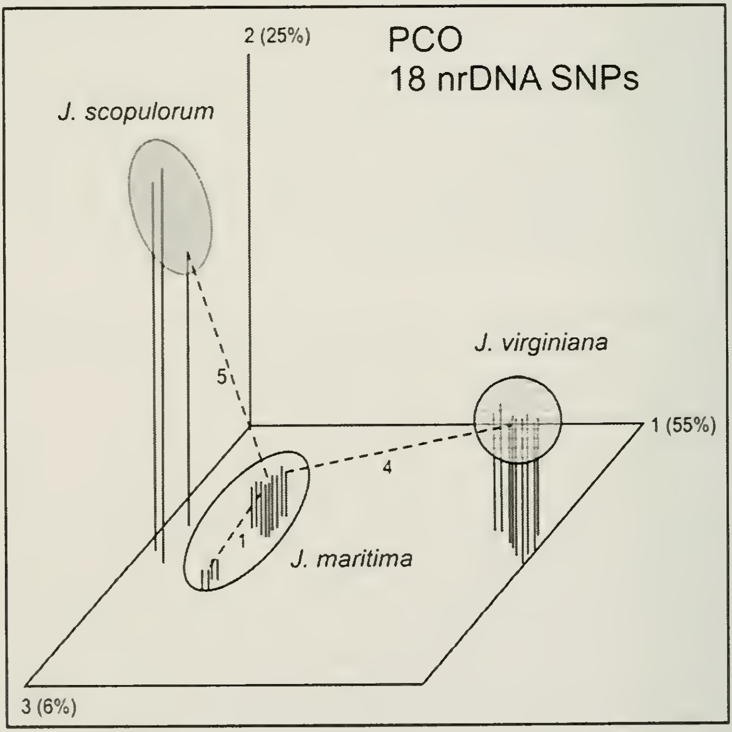

Figure 1. Principal coordinate Ordination (PCO) based on 18 SNPs. Note that *J. maritima* is genetically differentiated from *J. scopulorum* and *J. virginiana*. Modified from Adams (2007).

The purpose of this report is to present analysis of the leaf essential oil of *J. maritima* and compare the oil with the leaf oils of the most closely species: *J. horizontalis*, *J. scopulorum*, and *J. virginiana*.

MATERIAL AND METHODS

Plant material - Specimens used in this study : *J. maritima*: Brentwood Bay, Vancouver Isl., BC, *Adams 11056-58*, Cowichan Bay, Vancouver Isl., BC, Adams *11061-63*, Yellow Point, Vancouver Isl., BC, Adams *11064*, Lesqueti Isl., BC, Adams *11065-66*, Friday Harbor, San Juan Isl., WA, Adams *11067-68*, Whidbey Isl., Cranberry L., WA, Adams *11075*, Fidalgo Isl., Washington State Park, WA, Adams *11076*, Skagit Isl., WA, Adams *11077-78*; *J. horizontalis*: Saskatchewan River bank, Saskatoon, Saskatchewan, *Adams 1651-1660*; *J. scopulorum*: w bank of Animas River, Durango, CO, *Adams 2010-2024*; and *J. virginiana*, 16 km e of Dulles Airport, Washington, DC, *Adams 2409-2423*. Voucher specimens are deposited at the Herbarium, Baylor University (BAYLU).

Isolation of Oils - Fresh leaves (200 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.

Chemical Analyses - Oils from 10-15 trees of each of the taxa were analyzed and average values are reported. The oils were analyzed on a HP5971 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 5 for operating details). Identifications were made by library searches of our volatile oil library (Adams, 2006), 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.

Data Analysis - Terpenoids (as per cent total oil) were coded and compared among the species by the Gower metric (1971). Principal coordinate analysis was performed by factoring the associational matrix using the formulation of Gower (1966) and Veldman (1967).

RESULTS AND DISCUSSION

The volatile leaf oil of *J. maritima* is dominated (table 1) by elemicin (20.2%), sabinene (20.0%), limonene (11.7%) and 8-α-acetoxyelemol (6.1%) with moderate amounts of safrole (3.8%), pregeijerene B (3.1%) and terpinen-4-ol (1.8%). Several components are found only in *J. maritima*: isoamyl isovalerate (t), naphthalene (0.5), (2E,4Z)-decadienal (t), α-cubebene (t), α-humulene (t), β-bisabolene (0.3), zonarene (t), $C_{15}OH$ (AI 1586) (0.5) and cedrol (0.1). Most of these unique components are in trace amounts (less than 0.05%), and might be present in the other three juniper species in this study. It is interesting that cedrol is present as it is rare in the leaf oils of *Juniperus* in the western hemisphere (Adams, 2004). It is unusual that the leaf oil of *J. maritima* contains such large quantities of non-terpenoid (phenolic) compounds (elemicin, safrole).

The overall pattern of variation was determined by computing similarity measures among the taxa and subjecting the associational matrix to principal coordinates analysis (PCO). Figure 2 shows the PCO ordination based on the terpenoids. Each of the sticks represents 10-15 individuals: *J. horizontalis* (10); *J. maritima* (15); *J. scopulorum* (15) and *J. virginiana* (15). From this analysis, each oil appears distinct. However, the oil of *J. maritima* appears most similar to the oil of *J. virginiana*. It is interesting that *J. maritima* is separated by 4 SNPs from *J. virginiana* and 5 SNPs from *J. scopulorum* (Fig. 1) similar to the pattern of leaf oils (Fig. 2).

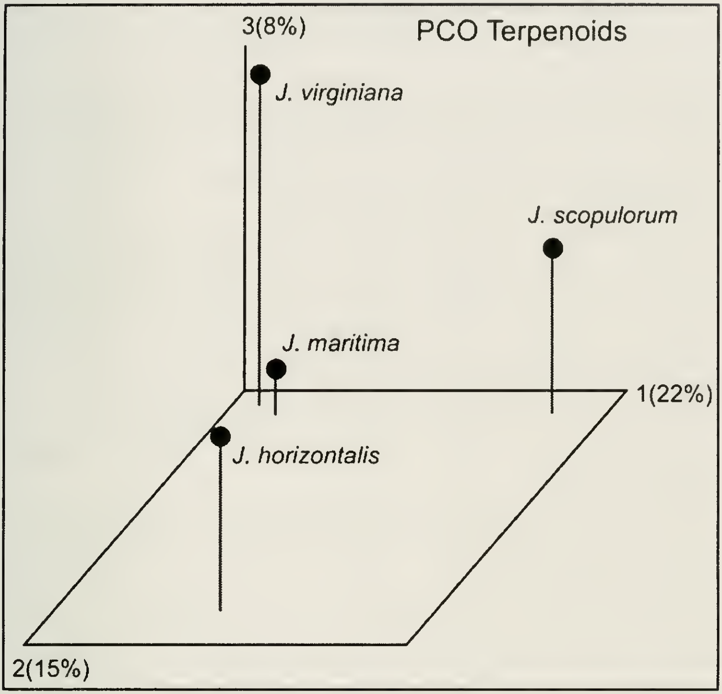

Figure 2. Principal coordinate ordination (PCO) utilizing terpenoids.

ACKNOWLEDGMENTS

Thanks for field assistance from: Steve Erickson, Whidbey and Skagit Island, WA; Eugene Kozloff, San Juan Island; Peter Dederich, NPS, English Camp, San Juan Island, WA; Ted Smith, Deception Pass State Park, Whidbey Island, WA; Richard Hebda, Adolf Ceska, and John Pinder-Moss, Royal British Columbia Museum (V); Lance Goldy, Yellow Point Resort, BC; and Drew Chapman and Wade Calder, Lesqueti Island Ecological Reserve, BC. Thanks to Tonya Yanke for lab assistance.

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Table I. Compositions of the leaf oils of *J. maritima*, (marit), *J. virginiana* (virg), *J. scopulorum* (scop) and *J. horizontalis* (horiz).

AI	Compound	marit	virg	scop	horiz
921	tricyclene	-	t	t	-
924	α-thujene	0.6	0.2	1.1	0.6
932	**α-pinene**	**0.6**	**1.4**	**4.7**	**1.7**
945	α-fenchene	-	-	t	t
946	camphene	-	0.1	0.1	t
969	**sabinene**	**20.0**	**6.7**	**46.3**	**37.2**
974	β-pinene	t	t	0.2	0.4
988	myrcene	0.9	0.7	1.3	2.8
1001	δ-2-carene	-	t	-	0.1
1002	α -phellandrene	-	-	0.1	t
1008	δ-3-carene	-	0.1	0.1	0.4
1014	α -terpinene	0.7	0.3	1.1	0.6
1020	p-cymene	t	0.1	0.5	0.4
1024	**limonene**	**11.7**	**19.5**	**5.4**	**3.5**
1025	**β-phellandrene**	**-**	**-**	**1.0**	**t**
1044	(E)-β-ocimene	-	t	0.1	0.2
1054	γ-terpinene	1.3	0.4	1.9	1.2
1065	cis-sabinene hydrate	0.5	0.3	1.4	1.3
1086	terpinolene	0.7	0.5	0.8	0.7
1187	2-nonanone	-	-	0.2	-
1095	linalool	0.1	4.0	0.3	0.3
1098	trans-sabinene hydrate	0.2	-	1.0	0.5
1100	n-nonanal	0.1	0.2	-	t
1102	isoamyl-isovalerate	t	-	-	-
1112	trans-thujone (= β-thujone)	-	-	0.1	0.1
1118	cis-p-menth-2-en-1-ol	0.3	0.4	0.4	0.4
1136	trans-p-menth-2-en-1-ol	t	-	0.2	0.2
1141	**camphor**	**-**	**4.0**	**0.2**	**0.2**
1145	**camphene hydrate**	**-**	**0.2**	**0.1**	**-**
1148	citronellal	-	t	-	-
1165	borneol	0.1	0.7	-	-
1167	umbellulone	-	-	-	t
1066	**coahuilensol**	**-**	**0.6**	**-**	**-**
1174	terpinen-4-ol	1.8	1.4	5.8	3.9

1178	naphthalene	0.5	-	-	-
1189	p-cymen-8-ol	-	-	t	-
1186	α-terpineol	0.1	0.2	0.2	0.2
1195	**methyl chavicol**	**0.4**	**t**	-	-
1195	cis-piperitol	-	-	0.1	t
1207	trans-piperitol	-	t	0.1	0.1
1219	**coahuilensol, methyl ether**	-	**0.4**	-	-
1223	citronellol	0.5	2.4	0.5	-
1249	piperitone	-	0.3	-	-
1253	trans-sabinyl hydrate acetate	-	-	t	-
1255	(4Z)-decenol	t	0.3	0.1	0.2
1257	methyl citronellate	0.2	0.1	t	-
1274	pregeijerene B	3.1	5.7	6.0	-
1285	**safrole**	**3.8**	**10.0**	**t**	**t**
1287	**bornyl acetate**	**t**	**4.0**	**0.7**	**0.5**
1292	(2E,4Z)-decadienal	t	-	-	-
1314	decadienol isomer*	0.1	-	0.1	-
1315	(2E,4E)-decadienal	t	0.2	-	-
1322	methyl geranate	t	t	-	-
1345	α-cubebene	t	-	-	-
1350	citronellyl acetate	-	0.1	-	-
1356	eugenol	-	t	-	-
1379	geranyl acetate	-	t	-	-
1387	β-cubebene	t	-	-	-
1403	**methyl eugenol**	-	**3.2**	**0.1**	-
1417	(E)-caryophyllene	0.5	t	0.1	-
1442	6,9-guaiadiene	-	-	0.2	0.2
1448	cis-muurola-3,5-diene	-	-	-	0.1
1452	α-humulene	t	-	-	-
1461	cis-cadina-1(6),4-diene	-	-	-	0.1
1468	**pinchotene acetate**	-	**0.1**	-	-
1475	trans-cadina-1(6),4-diene	0.5	-	-	t
1478	γ-muurolene	-	-	0.1	0.3
1480	germacrene D	-	t	-	0.1
1493	**trans-muurola-4(14), 5-diene**	**1.0**	-	-	**0.2**
1493	epi-cubebol	0.5	-	0.1	0.8
1500	α-muurolene	0.4	0.1	0.1	1.0
1505	**β-bisabolene**	**0.3**	-	-	-

1513	γ-cadinene	0.8	0.2	0.2	2.2
1513	cubebol	0.8	0.1	-	-
1522	δ-cadinene	1.0	0.7	0.3	4.1
1528	zonarene	t	-	-	-
1537	α-cadinene	-	-	t	0.4
1549	**elemol**	**1.0**	**8.7**	**4.3**	**t**
1555	**elemicin**	**20.2**	**1.6**	-	-
1559	germacrene B	-	-	0.2	-
1574	germacrene D-4-ol	0.9	1.2	0.8	17.7
1586	$C_{15}OH$, 43,207,161,222	0.5	-	-	-
1600	**cedrol**	**0.1**	-	-	-
1607	β-oplopenone	0.1	0.2	0.2	2.4
1627	**1-epi-cubenol**	**0.8**	-	-	**0.2**
1630	γ-eudesmol	0.1	1.2	0.2	-
1638	epi-α-cadinol	0.6	0.7	0.2	2.0
1638	epi-α-muurolol	0.6	0.7	0.1	1.9
1644	α-muurolol	0.2	t	t	0.5
1649	β-eudesmol	0.2	1.5	0.9	-
1652	α-eudesmol	0.7	2.3	0.6	-
1653	α-cadinol	0.7	1.2	0.5	5.8
1670	bulnesol	0.2	0.8	0.3	-
1685	germacra-4(15),5,10(14)-trien-1-al	-	-	-	0.1
1739	**oplopanone**	-	-	-	**0.2**
1792	**8-α-acetoxyelemol**	**6.1**	**3.6**	**5.9**	**t**
1887	**oplopanonyl acetate**	-	-	-	**0.5**
2055	abietatriene	t	-	-	t
2056	manool	-	t	t	-
2298	4-epi-abietal	0.3	t	t	0.4

AI = Arithmetic Index on DB-5 column. Values less than 0.05% are denoted as traces (t). Unidentified components less than 0.5% are not reported. Those compounds that appear to distinguish taxa are in boldface.

GEOGRAPHIC VARIATION AND SYSTEMATICS OF *JUNIPERUS PHOENICEA* L. FROM MADEIRA AND THE CANARY ISLANDS: ANALYSES OF LEAF VOLATILE OILS

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ABSTRACT

All of the oils of *J. phoenicea* from the Canary Islands and Madeira were very similar. The volatile leaf oils were dominated by α-pinene (57.3 - 76%) as was the oil from Morocco (65.4%). This is higher than in *J. p.* var. *phoenicea*, Spain (41.2%) or var. *turbinata*, Spain, (25.8%). The Madeira and Canary Island oils had moderate amounts of β-phellandrene (0.5 - 8.0%), myrcene (2.3 - 3.3%), α-terpinyl acetate (trace - 5.0%), (E)-caryophyllene (0.4 - 1.4%), and trans-totarol (0.1 - 2.1%). There is some differentiation in the oils from Madeira and the Canary Islands from populations in Spain and Morocco, but not enough to justify the recognition of *J. p.* subsp. *canariensis* at this time. *Phytologia 91(1):40-53 (April, 2009)*.

KEY WORDS: *Juniperus phoenicea,* Cupressaceae, Madeira Island, Canary Islands, leaf essential oils, α-pinene, myrcene, β-phellandrene.

Juniperus phoenicea L. of the Mediterranean has red seed cones (berries) and is the only serrate leaf margined juniper in section Sabina in the eastern hemisphere (Adams, 2008). Gaussen (1968) discussed several other infraspecific taxa: var. *canariensis* (Guyot & Mathou) Rivas-Martinez et al., of the Canary Islands, var. *lycia* (L.) Gaussen, France littoral zone, var. *mollis* M & W, Morocco, and var. *megalocarpa* Maire, dunes near Mogador, Morocco. Adams et al. (1996) examined leaf terpenoids of *J. phoenicea* var. *phoenicea*, Greece and Spain, *J. p.* var. *turbinata* (Guss.) Parl. (=var. *oophora* Kunze), Tarifa Sand Dunes, Spain and *J. p.* subsp. *eu-mediterranea*, west of Setubal, Portugal. Adams et al. (1996) concluded that *J. p.* var. *turbinata* is conspecific with *J. p.* subsp. *eu-mediterranea*. There are a number of older literature reports on analyses of the leaf volatile oil of *J. phoenicea* and these are reviewed in Adams et al. (1996). The Adams et al. (1996) study was followed up using RAPDs (Adams et al., 2002). Figure 1 shows the PCO based on 119 RAPD bands. Note that *eu-mediterranea* and v. *turbinata* form a cluster (lower left). However, the plants from Tenerife, Canary Islands (cf. v. *canariensis*, fig. 1) cluster closely with plants from Nea Epidavios, Greece! This study confirmed the previous terpene analyses (Adams, et al., 1996) that subsp. *eu-mediterranea* and v. *turbinata* are conspecific. The plants from Corsica Island and Delphi Greece formed a separate group.

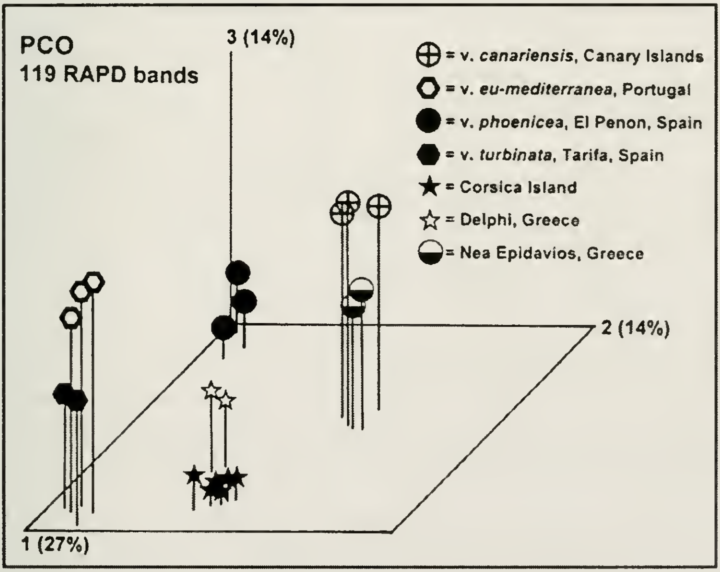

Figure 1. PCO based on 119 RAPD bands ordinating various taxa of *J. phoenicea*.

Most recently, Adams et al. (2006) analyzed RAPDs from *J. phoenicea* from sand and rock areas in Morocco and compared these populations with plants from Tenerife, Canary Islands and var. *turbinata*, Tarifa sand dunes, Spain. PCO ordination (fig. 2) shows that 41% of the variance in the RAPDs was due to the differences between var. *phoenicea* (Spain) and the Morocco, Tenerife and var. *turbinata* populations.

The Tenerife population accounted for about 14% of the variance (fig. 2). Although, the Canary Island plants are loosely associated with var. *turbinata*, they generally have large, round berries (seed cones), not turbinate shaped.

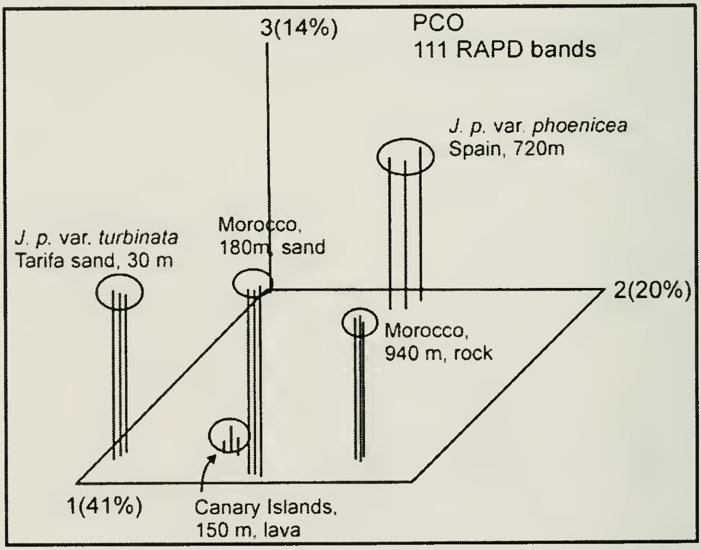

Figure 2. PCO ordination of *J. phoenicea* populations based on 111 RAPD bands.

The purpose of this study was to report on the volatile leaf oil compositions of populations of *J. phoenicea* from several islands in the Canary archipelago and Madeira, and to contrast these oils with *J. p.* var. *phoenicea* (Iberian Peninsula, Spain) and var. *turbinata* (Tarifa sand dunes, Iberian Peninsula, Spain) oils. The distribution of *J. phoenicea* in Madeira and the Canary Islands is shown in figure 3.

Figure 3. Distribution of *J. phoenicea* in Madeira and Canary Islands.

MATERIALS AND METHODS

Plant material - J. phoenicea Madeira Island: 32° 48.822'N, 16° 52.627'W, ca 100 m, *R. P. Adams 11502, 11503,* cultivated at Botanic Garden in Funchal, ex Porto de la Cruz, 32° 39.08'N, 16° 47.14'W, ca 100 m, *R. P. Adams 11503*; Canary Islands: Tenerife, volcanic rock, ca. 150 m, *R. P. Adams 8147-8149*, La Palma Island, Santa Lucia, loose volcanic pumice, 28° 44.250'N, 17° 44.198'W, 283 m, *R. P. Adams 11514-11516*, La Gomera Island, volcanic rock, 28° 11.358'N, 17° 12.320'W, 370 m, *R. P. Adams 11528-115230;* Spain, limestone soil, 25 km e. Guadahortuna, 720 m, El Penon, *R. P. Adams, 7077-7079*; Morocco, red clay, 20 km sse Marrakech, 31° 21.033'N, 07° 45.893'W, 940 m, *R. P. Adams 9408-9410;* Spain, *J. phoenicea* var. *turbinata*:

Tarifa sand dunes, 15 km w. of Tarifa, 30 m, 36° 04.996'N, 5° 42.104' W, *R. P. Adams, 7202-7204*. Voucher specimens are deposited at the Herbarium, Baylor University (BAYLU).

Isolation of Oils - Fresh leaves (200 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.

Chemical Analyses - Oils from 10-15 trees of each of the taxa were analyzed and average values are reported. The oils were analyzed on a HP5971 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 5 for operating details). Identifications were made by library searches of our volatile oil library (Adams, 2006), 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.

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RESULTS AND DISCUSSION

All of the oils from the Canary Islands and Madeira were very similar (table 1). The volatile leaf oils were dominated by α-pinene (57.3 - 76%) as was the oil from Morocco (65.4%). α-pinene was higher in concentration in than in *J. p.* var. *phoenicea*, Spain (41.2%) or var. *turbinata*, Spain, (25.8%). The Madeira and Canary Island oils had moderate amounts of β-phellandrene (0.5 - 8.0%), myrcene (2.3 - 3.3%), α-terpinyl acetate (trace - 5.0%), (E)-caryophyllene (0.4 - 1.4%), and trans-totarol (0.1 - 2.1%).

The oil from Morocco was the only oil with camphor (1.3%, table 1). The oil of *J. p.* var. *phoenicea*, Spain, contained a large concentration of manoyl oxide (22.0%). The oil of *J. p.* var. *turbinata*, Spain, contained large amounts of β-phellandrene (31.5%) and α-terpinyl acetate (13.1%) along with the smallest amount of α-pinene (25.8%).

Only two compounds seem to separate the oils of Madeira and Canary Islands from continental oils: (E)-2-hexenal and (Z)-3-hexenol (table 1). However, these very volatile components are easily lost during transport and distillation, so the lack of these compounds in the oils from Morocco and Spain (table 1) may not be so significant.

The *J. phoenicea* oil from Madeira shows differentiation from the Canary Islands in having higher concentrations of β-phellandrene (8.0%), linalool (1.0%), α-terpinyl acetate (5.0%) and α-eudesmol (0.9%, vs. absent in the Canary Island oils, table 1). In general, these compounds point to a similarity to the oil of *J. p.* var. *phoenicea* from Spain.

To better understand the similarities among the oils, similarity measures were computed and the matrix of associations was factored. Eigenroots were extracted and accounted for 31.08, 19.50, 18.77, and 13.0% of the variance among the seven samples. The eigenroots appeared to asymptote after the fourth eigenroot, implying that five groups may be present. Principal Coordinate Ordination (PCO) of the samples (Fig. 3) shows that the oils from the Canary Islands (La Gomera, La Palma and Tenerife) are very similar (0.77 - 0.84). The next most similar oil is from Madeira (0.73 to La Palma). The Canary Islands oils are then linked to Morocco (0.70). *Juniperus phoenicea* var. *turbinata* (Tarifa sand dunes, Spain) are the least similar and link to Madeira (0.60) just smaller than the link of *J. p.* var. *phoenicea*, Spain to Madeira (0.64). There is certainly considerable variation in the volatile leaf oil compositions from various populations of *J. phoenicea* from the populations sampled in this study. It is not clear if there is sufficient differentiation in the Canary Islands to support the recognition of *J. phoenicea* subsp. *canariensis* at this time.

Geographic variation among the samples was further analyzed by plotting a minimum spanning network onto a geographic map. The samples from the Canary Islands are, geographically, the nearest neighbors and their oils high similarities reflect the co-differentiation and genetic isolation of the Canary Islands from Africa and Madeira (fig. 5).

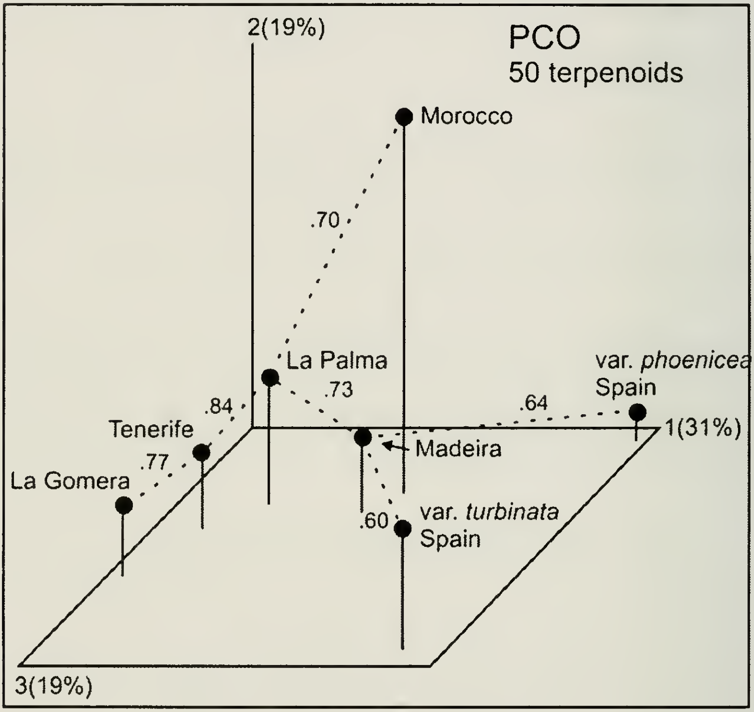

Figure 4. PCO ordination based on 50 terpenoids with the minimum spanning network super-imposed.

However, the linkage of the Canary Islands populations to Madeira is larger than its linkage to Africa (fig. 5). This may reflect more gene flow from north - south bird migrations (and seed cone dispersal) than from the east-west bird migrations to Morocco.

Alternatively, the linkage to Madeira may reflect co-evolution in similar climates of the Canary Islands and Madeira.

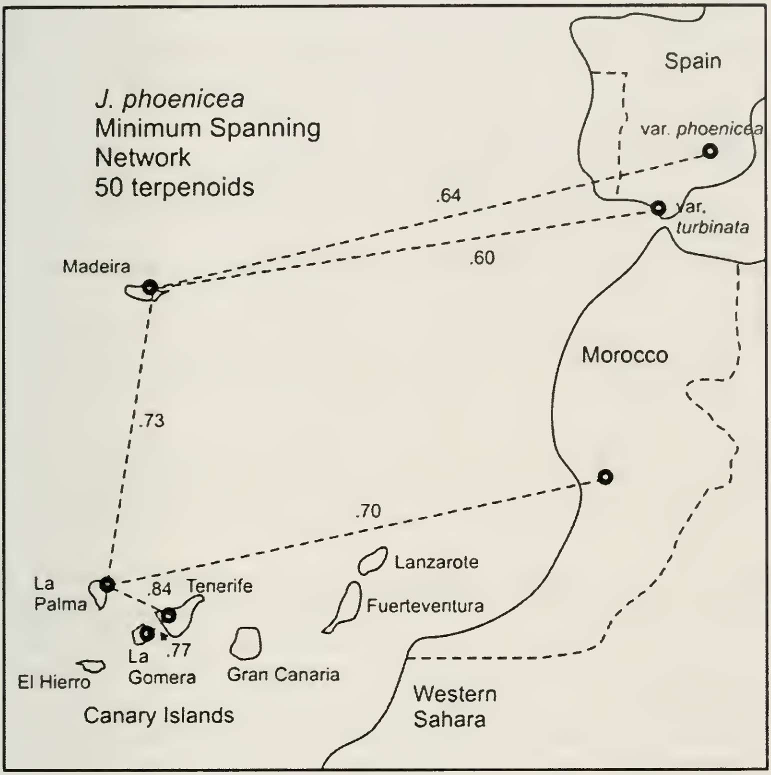

Figure 5. Minimum spanning network based on 50 terpenoids.

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Table 1. Composition of the leaf oils of *J. phoenicea* from Madeira and the Canary Islands: Tenerife, La Palma and La Gomera compared with *J. phoenicea* from Morocco and Spain and *J. phoenicea* var. *turbinata*, Tarifa, Spain.

AI	Compound	Madeira	Tenerife	La Palma	La Gomera	Morocco	Spain	*turbinata*
844	(E)-2-hexenal	0.2	t	t	0.3	-	-	-
850	(Z)-3-hexenol	-	0.1	0.2	0.3	-	-	-
921	tricyclene	0.1	0.2	0.2	0.1	0.3	0.1	0.1
932	**α-pinene***	**57.8**	**67.9**	**76.0**	**57.3**	**65.4**	**41.2**	**25.8**
945	α-fenchene	0.1	0.1	0.1	t	0.2	0.1	t
946	camphene	0.3	0.4	0.5	0.5	0.6	0.1	0.2
953	thuja-2,4-diene*	0.2	0.1	0.1	0.2	0.5	0.1	-
961	verbenene	-	-	-	-	-	0.3	0.1
969	sabinene	0.2	0.4	t	t	0.2	0.1	t
974	β-pinene*	1.2	1.6	1.4	1.5	0.8	2.1	1.3
988	**myrcene***	**3.3**	**2.7**	**2.8**	**2.3**	**1.7**	**3.2**	**6.6**
1001	δ-2-carene	0.1	t	0.1	t	0.2	0.1	0.5
1002	**α-phellandrene***	**1.1**	-	-	-	-	**0.7**	**4.4**
1008	**δ-3-carene***	-	**0.3**	**t**	**t**	**2.3**	**1.5**	-
1014	α-terpinene*	0.1	0.1	t	t	0.1	0.1	0.3
1020	p-cymene*	0.5	0.1	0.3	0.3	0.6	0.4	1.3
1024	limonene*	0.9	1.9	1.9	0.6	0.9	0.6	t
1025	**β-phellandrene***	**8.0**	**1.2**	**1.3**	**0.5**	**0.6**	**4.9**	**31.5**
1044	(E)-β-ocimene	0.3	0.2	0.1	0.1	-	-	t
1054	γ-terpinene	0.3	0.3	0.5	0.3	0.4	0.2	0.3
1083	fenchone*	t	t	t	-	1.0	-	-
1086	terpinolene*	1.0	0.6	0.6	0.6	-	0.7	1.8
1095	linalool*	1.0	0.4	t	t	0.3	1.0	0.1

AI	Compound	Madeira	Tenerife	La Palma	La Gomera	Morocco	Spain	*turbinata*
1095	linalool	1.0	0.4	t	t	0.3	1.0	0.1
1100	n-nonanal	t	0.1	t	-	-	-	-
1106	cis-rose oxide	-	t	t	-	0.1	-	-
1114	endo-fenchol	-	-	-	-	-	0.1	t
1118	cis-p-menth-2-en-1-ol*	-	-	-	-	-	0.2	0.6
1122	chrysanthenone	-	-	-	-	0.1	-	-
1122	α-campholenal*	0.7	0.1	0.4	0.3	0.5	0.2	0.1
1122	trans-rose oxide	-	-	-	-	t	-	-
1132	cis-limonene oxide (furanoid)	-	-	-	-	-	t	-
1135	trans-pinocarveol*	0.7	0.1	0.4	0.3	0.5	0.3	0.5
1137	cis-verbenol	t	-	-	0.1	0.2	t	-
1139	$C_{10}OH$, $\underline{41}$,55,81,95,152*	-	-	-	-	-	1.4	-
1140	trans-verbenol*	0.1	0.1	0.4	0.8	0.6	-	-
1141	**camphor***	-	-	-	-	**1.3**	-	-
1148	citronellal	-	-	-	-	-	0.1	-
1155	iso-pulegol	-	-	-	-	-	0.1	-
1158	trans-pinocamphone*	t	-	t	0.1	0.2	0.1	-
1160	pinocarvone	t	t	0.1	t	0.2	-	-
1165	borneol*	-	-	-	-	-	0.6	-
1166	p-mentha-1,5-dien-8-ol	0.4	0.1	0.3	0.3	0.3	-	0.1
1172	cis-pinocamphone	-	-	-	-	0.2	0.2	-
1174	terpinen-4-ol	t	0.2	t	t	0.3	0.1	0.2
1178	naphthalene	t	0.2	t	0.2	-	t	-
1179	p-cymen-8-ol	0.1	t	0.1	t	-	0.1	0.4
1186	**α-terpineol***	**t**	**0.2**	**0.1**	**0.2**	-	**2.3**	**0.4**
1195	cis-piperitol	-	-	-	-	-	-	0.2
1195	myrtenal	-	t	0.1	0.1	t	-	-

AI	Compound	Madeira	Tenerife	La Palma	La Gomera	Morocco	Spain	*turbinata*
1195	myrtenol	0.1	-	0.1	0.1	t	0.1	-
1204	verbenone*	0.3	0.2	0.2	0.6	0.3	0.2	-
1207	trans-piperitol	-	-	-	-	-	-	0.3
1215	trans-carveol	0.1	-	0.1	0.1	0.2	0.1	t
1218	endo-fenchyl acetate	t	-	0.2	0.1	-	-	0.1
1223	citronellol	0.1	t	t	t	1.4	0.5	0.6
1232	thymol, methyl ether	-	0.2	t	t	-	-	-
1233	pulegone	-	-	-	-	-	0.1	-
1235	trans-chrysanthenyl acetate	-	-	-	-	-	-	0.1
1249	piperitone	-	-	-	-	-	0.2	0.3
1255	(4Z)-decenol*	0.7	0.6	t	t	0.5	0.2	0.5
1259	(4E)-decenol	-	-	-	-	0.1	-	-
1274	neo-isopulegyl acetate*	0.2	t	t	t	0.1	-	0.8
1287	bornyl acetate	0.4	0.4	0.4	0.3	0.1	-	0.2
1287	trans-linalool oxide acetate (pyranoid)	-	-	-	-	-	-	0.2
1292	(E,Z)-2,4-decadienal	-	-	-	-	-	-	-
1309	decadienol isomer	-	0.2	t	t	t	0.3	0.3
1315	(E,E)-2,4-decadienal	-	-	-	-	t	t	-
1335	δ-elemene	-	-	-	-	0.1	-	-
1341	$C_{15}OH$, $\underline{43}$,134,59,91,115	-	-	-	-	-	-	0.8
1345	α-cubebene	-	0.1	t	0.1	0.2	-	-
1346	**α-terpinyl acetate***	**5.0**	**0.2**	**t**	**0.1**	-	**0.1**	**13.1**
1374	α-copaene	-	-	-	-	0.1	-	-
1387	β-bourbonene	-	-	-	-	0.1	-	-
1387	β-cubebene	-	t	t	t	-	-	-
1389	β-elemene	-	-	-	-	-	0.1	-

AI	Compound	Madeira	Tenerife	La Palma	La Gomera	Morocco	Spain	*turbinata*
1400	β-longipinene	-	-	-	-	0.1	0.2	-
1417	(E)-caryophyllene*	0.9	0.6	0.4	1.4	0.8	1.2	0.1
1429	cis-thujopsene	0.2	t	t	t	0.2	-	-
1448	cis-muurola-3,5-diene*	t	0.5	0.3	0.6	0.3	-	-
1452	α-humulene*	0.7	0.6	0.4	1.1	0.2	-	-
1475	trans-cadina-1(6),4-diene*	-	0.6	0.3	0.6	0.4	-	-
1478	γ-muurolene	0.1	-	0.1	-	0.5	-	-
1484	germacrene D*	-	-	-	-	-	0.5	0.2
1493	trans-muurola-4(14),5-diene	0.1	1.2	0.5	1.3	0.5	-	-
1493	epi-cubebol*	0.2	0.6	0.5	-	0.4	-	-
1495	γ-amorphene	-	-	-	-	-	-	0.1
1500	α-muurolene	0.2	0.3	0.1	0.4	0.3	-	0.1
1509	$C_{15}OH,\underline{41},55,81,161,220$	-	-	-	-	0.1	0.3	0.1
1513	cubebol*	0.3	1.2	1.1	1.9	0.4	-	-
1513	γ-cadinene*	0.5	1.6	-	1.6	-	0.1	0.1
1522	δ-cadinene*	-	-	0.8	-	1.1	0.2	0.4
1528	zonarene	-	-	t	-	0.2	-	-
1531	Z-nerolidol	-	0.4	-	0.5	-	-	-
1531	cis-calamenene	-	-	-	-	0.4	-	-
1533	trans-cadina-1,4-diene	-	0.2	0.2	0.2	-	-	-
1535	**$C_{15}OH,\underline{41},69,105,161,204$***	-	-	-	-	-	**1.0**	**0.1**
1548	**elemol***	**0.3**	**0.1**	**0.1**	**0.1**	**0.7**	**1.8**	**0.6**
1559	germacrene B*	-	-	-	-	-	0.6	0.2
1561	(E)-nerolidol*	-	-	-	-	0.9	t	-
1574	germacrene-D-4-ol*	0.5	0.2	0.3	0.6	0.1	0.2	0.2
1582	caryophyllene oxide*	0.4	0.5	0.4	1.4	0.6	1.0	0.1
1608	humulene epoxide II*	0.1	0.3	0.2	0.7	0.1	-	-

AI	Compound	Madeira	Tenerife	La Palma	La Gomera	Morocco	Spain	*turbinata*
1625	$C_{15}OH$, <u>43</u>,119,161,204,220*	0.4	2.3	1.3	2.0	1.2	0.4	0.3
1630	γ-eudesmol	-	-	-	-	-	0.2	0.1
1638	epi-α-cadinol	0.2	0.5	0.3	0.6	0.2	0.2	0.1
1638	epi-α-muurolol	0.3	0.5	0.3	0.5	0.2	0.1	0.2
1645	cubenol	-	-	0.3	0.4	t	-	-
1649	β-eudesmol	0.2	-	0.2	-	0.2	0.4	0.2
1652	**α-eudesmol***	**0.9**	**-**	**-**	**-**	**0.2**	**0.3**	**0.2**
1652	**α-cadinol***	**-**	**1.0**	**0.8**	**1.4**	**0.2**	**0.3**	**0.3**
1670	bulnesol	-	-	t	0.1	t	0.1	-
1685	**germacra-4(15),5,10(14)-trien-1-al***	**0.6**	**0.7**	**0.6**	**t**	**t**	**0.1**	**-**
1688	shyobunol*	1.0	-	0.3	1.3	0.5	1.5	0.8
1715	(2Z,6E)-farnesol*	-	-	-	-	0.1	1.2	-
1968	sandaracopimara-8(14),15-diene	-	-	-	-	-	0.1	0.1
1978	**manoyl oxide***	**-**	**1.1**	**-**	**2.4**	**2.6**	**22.0**	**0.4**
2009	epi-13-manoyl oxide	-	-	-	-	0.1	0.1	-
2056	manool	-	-	-	-	0.1	-	-
2055	abietatriene	0.3	0.1	-	0.3	-	0.1	t
2087	abietadiene	0.4	t	-	0.4	-	0.1	0.1
2298	4-epi-abietal	0.4	0.2	0.2	0.4	0.1	0.2	-
2314	trans-totarol*	2.1	0.4	0.1	2.0	0.1	0.2	0.2
2331	trans-ferruginol	0.2	-	-	0.2	-	-	-

AI = Arithmetic Index on DB-5 column. *Used in numerical analyses. Compositional values less than 0.1% are denoted as traces (t). Unidentified components less than 0.5% are not reported. Those compounds that appear to distinguish taxa are in boldface.

SCHRADERANTHUS, A NEW GENUS OF SOLANACEAE

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ABSTRACT

Saracha viscosa Schrader, of Mexico and Central America, has been positioned in a variety of genera since it was first described, most notably *Athenaea, Jaltomata* and *Leucophysalis*. Arguments are presented for the exclusion of the taxon from those genera and tis recognition as a new genus, *Schraderanthus.*
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KEY WORDS; Solanaceae, *Athenaea*, *Chamaesaracha*, *Jaltomata*, *Leucophysalis*, *Physalis*, *Saracha*, *Witheringia*, Mexico.

A Mexican and Central American species that in most recent literature has been treated as *Athenaea viscosa* or *Leucophysalis viscosa* has been placed in seven different genera since its description as *Saracha viscosa* in 1832. It also was treated as a species of *Physalis*, requiring a new specific epithet because of the earlier name, *P. viscosa* L. *Saracha viscosa* was described from plants grown from seeds collected in Mexico but the species extends into Guatemala. Current data and generic concepts provide strong support for the recognition of this problematic species as a new monotypic genus. While the single species concerned is reasonably well-known, the following synopsis is provided.

Schraderanthus Averett, **Gen. nov**.

Herbae vel frutices usque ad 1-2.5 m altae; inflorescentiae fasciculatae axillares; calyx accrescens fructificans campanulatus, basi rotundatus, lobis 5 aequalibus, ad apiceum acutis, in fructu maturo campanulato-retrorsis, baccam rubro-aurantiaca, 10-15 mm diametro; semina ca 50-75.

Erect herbs or soft-wooded shrubs 1.0-2.5 m tall, viscid, glandular-pubescent; inflorescences fasciculate with 6-8 (-10) flowers per axil, corolla 5-lobed with greenish maculations in the throat, ca 4 cm in diameter, rotate; anthers bluish (drying to a yellow-green), the filaments inserted at the base; flowering calyx accrescent, exceeding the length of the corolla, deeply lobed to ca ¾ the length of the calyx, lobes acute; fruiting calyx broadly campanulate, deeply lobed, exceeding the berry but becoming reflexed at maturity, exposing the berry; berry bright red to orange-red, seeds ca 50-75, reniform, brown, ca 2 mm long, the testa rugose-reticulate.

The most distinctive aspects of this novel genus are the 6-8 flowers in fascicles, as opposed to 1-2 per axil in some related genera and the bright red to orange-red berries surrounded by an accrescent calyx which initially loosely envelops the fruit and then opens into a broad campanulate to reflexed structure beneath the berry. These are features unknown in any of the genera to which the entity has been previously aligned. The nature of the calyx, in particular, is not always captured on dried specimens (including the type), and is not illustrated by Hunziker (2001), but is well illustrated in the Flora de Veracruz (Nee, 1986).

The genus is named for Heinrich Schrader who first described the species concerned.

Type species: *Schraderanthus viscosus* (Schrad.) Averett, **Comb. nov.**

Basionym: *Saracha viscosa* Schrader, Index Seminum [Göettingen] 5. 1832. TYPE: Cult., Hort. Göettingen, *Schrader s.n.* (MO, not seen;. phototype seen on TROPICOS).

Synonymy:
Physalis schraderiana Bernh., Linnaea 13: 361. 1839.
Witheringia viscosa (Schrad.) Miers, Ann. Mag. Nat. Hist., ser. 2, 11(62): 92. 1853
Athenaea viscosa (Schrad.) Fernald, Proc. Amer. Acad. Arts 35: 567. 1900.

Jaltomata viscosa (Schrad.) D'Arcy & Til. Davis, Ann. Missouri Bot. Gard. 63: 363. 1976[1977].
Leucophysalis viscosa (Schrad.) Hunz., Kurtziana 21: 283. 1991.
Chamaesaracha viscosa (Schrad.) Hunz., Lorentzia 8: 8. 1995.

Complete descriptions of the species are provided by D'Arcy (1976) as *Jaltomata viscosa*, and as *Leucophysalis viscosa* (Hunziker, 2001). The species is also described as *Athenaea viscosa* in the Flora of Guatemala (Gentry and Standley, 1974) and in Spanish in the Flora de Veracruz (Nee, 1986). It is a very distinct species and unlikely to be confused with anything else except, perhaps, *Brachistus nelsonii* (Fernald) D'Arcy, J. Gentry & Averett and further description does not seem required. *Schraderanthus viscosus* occurs in the Mexican states of Chiapas, Oaxaca and Veracruz and extends into Guatemala. The location in Veracruz is from cited material (Nee, 1986); the later notes that the species as rare and little-known in Veracruz.

ADDITIONAL SPECIMENS: **GUATEMALA**: **Baja Verapaz**: Uníon Barrios, west of km 154 on the Cobán road, 12 Apr 1975. *Lundell & Contreras 19171* (LL); **MEXICO**: **Chiapas**, Mpio. La Independencia, logging road from Las Margaritas to Campo Alegre, 2300 m, 18 Feb 1973, *Breedlove 33631* (NY, TEX); **Oaxaca**, Distr. Mixe, 2 km N de San Miguel Metepec, 8 Apr 1984, *Torres & Martínez 4967* (LL); Oaxaca, ca 6 km S of Totontepec, 18 Feb 1992, *Panero & Campos 2761* (TEX); Distr. Ixtlán, Mpio. Santiago Comaltepec, Soyalapan, 100 m, 17°45'N, 96°30'W [imprecise], 16 May 1988, *E. López G. 120* (NY); Distr. Ixtlán, Sierra de Juárez, camino de Calpulalpan a Llano Verde, 12 km al NO de Calpulalpan, 2500 m, 29 May 1983, *Lorence & Cedillo 4195* (NY); Sierra Mazateca, Mpio. Mazatlán Villa de Flores, San Pedro de los Encinos, 18°04'05.3"W, 96°52'41.9"W, 2325 m, 23 Apr 2002, *X. Munn-Estrada & Mendoza 2263* (NY); 50 km S de Valle Nacional, sobre la carretera a Oaxaca, 2250 m, 28 Jun 1975, *Rzedowski 33382* (NY); Distr. Mixe, 5.2 km NE de la desviación a Zacatepec, 2380 m, 23 Apr 1983, *Torres & Cedillo 2680* (NY); Distr. Mixe, 7 km NE de la desviación a Zacatepec, 2380 m, 23 Apr 1983, *Torres & Cedillo 2697* (NY); Distr. Villa Alta, 11.7 km N de Maravillas a 39.7 km al N de Zoogocho, 2020 m, 15 May 1983, *Torres et al. 2938* (NY); Distr. Mixe, 20 km N de Yacochi, camino a San Andrés Yaa, 2290 m, 8 Aug 1985, *Torres et al. 7108* (NY). **Veracruz**, Mpio.

Atzalan, La Calavera, Carretera Altotonga-Tlapacoyán, *Cházarp & Dorantes 94* (ENCB). **U.S.A.** **Massachusetts**: "Hort. Cantab." [Botanical Garden at Cambridge, Harvard University], 1849, *A. Gray s.n.* (NY). **Missouri**: St. Louis Co., St. Louis, cult. by W. G. D'Arcy for the Second International Solanaceae Conference ("780425-2"), 6 Aug. 1982, *M. Nee 25507* (NY); **Switzerland**. HBBasil [Botanical Garden at Basil], 29 Jun 1863, *s.c. s.n.* (NY).; **Australia**. **South Australia**: Southern Lofty Region, Tusmore (suburb of Adelaide), pot grown, provenance unknown, 1 May 1991, *D. E. Symon s.n.* (NY).

DISCUSSION

Saracha was once broadly construed to include a group of herbs widely distributed throughout Mexico, Central and South America that are now generally referred to *Jaltomata* (Gentry, 1973). *Saracha* is now recognized as a small genus of two species occurring at high elevations in South America with broadly or narrowly campanulate corollas and non or minimally accrescent calyces; it is part of a complex of several woody, mostly Andean genera, including *Iochroma*, *Dunalia* and *Acnistus* (Smith & Baum, 2006).

D'Arcy and Davis (D'Arcy, 1976), following Gentry's restoration of the genus *Jaltomata* and recognizing the species as separate from *Saracha*, transferred the species to the former as *Jaltomata viscosa*. He acknowledged, however, that its placement within *Jaltomata* was problematic. D'Arcy provided an excellent account of its history, with an expanded description of the taxon. Between the original description of *Saracha viscosa* and its transfer to *Jaltomata*, the species, besides to *Physalis*, had been assigned to *Witheringia* and *Athenaea* which, as constituted today, differ in a number of floral features and are clearly separate.

Subsequent to the work of D'Arcy and Davis, Mione (pers. comm.) grew and became familiar with the species in question. Mione noted that the taxon has red fruit, which are absent in all Mexican *Jaltomata*; because of this, and characters of the fruiting calyx, he rejected placement of the species in *Jaltomata.* Molecular studies (Mione et al., 1994) provide strong additional support for exclusion of

S. viscosus from that genus. *Jaltomata* possesses umbellate inflorescences which are not present in *Schraderanthus*, and the accrescent calyx is spreading in fruit.

Hunziker (1991) transferred *Jaltomata viscosa* to *Leucophysalis* and subsequently (1995) to *Chamaesaracha.* In his *Genera Solanacerum* (2001), Hunziker returns the species to *Leucophysalis,* where he notes that the systematic position of the species has been in dispute and assigned to six different genera, mostly without explanation, which, it seems, would include his own transfers. Hunziker also notes the peculiar disjunctions within *Leucophysalis. Leucophysalis grandiflora*, the generiotype, has the northernmost distribution of any North American Solanaceae, while *L. viscosa* is neotropical.

The characters that distinguish *Schraderanthus* from *Jaltomata* also distinguish it from *Leucophysalis* and *Chamaesaracha.* Excepting two doubtful species of sect. *Capsicophysalis* of the latter, red fruit are absent in *Chamaesaracha* and *Leucophysalis.* The flowers, with the broken green maculations at the base of the petals and distinctly lobed margins, also differ. Further, the wide disjunction between *L. grandiflora* and *Schraderanthus* and suggests a different origin.

Whitson and Manos (2005) conducted a two-gene analysis from selected physaloid species that showed a close relationship between *Leucophysalis grandiflora* and *L. nana,* and a distant relationship between both species and *Schraderanthus viscosus.* A phylogenetic analysis of morphological characters by Axelius (1996) provided some evidence for a closer relationship between *L. grandiflora* and *S. viscosus*, but additional analyses of fruit and calyx characters of the fruit would be useful. Unfortunately, there are few phylogenetic analyses that include *S. viscosus* and the two species of *Leucophysalis.* In short, *Chamaesaracha,* including the type, *C. coronopus*, is clearly a distinct assemblage.

Gentry (1974) treated *S. viscosus* as *Athenaea viscosa* and noted that it to be morphologically similar to a group of *Physalis* species that have a 5-lobed corolla and mostly several flowers from individual axils, but lacking the inflated fruiting calyx. A similar observation was made by Nee (1986) and Mione et al. (1994).

Schraderanthus may be most closely related to *Brachistus, Darcyanthus*, and one or two species Hunziker (2001) have been treated as *Chamaesaracha* sect. *Capsicophysalis*; all have red or orange-red fruit and share other characters (Table 1). However, lacking any clear evidence that any are congeneric, it seems most appropriate to recognize *Schraderanthus* as and distinct genus. Table 1 summarizes the salient characters of *Schraderanthus* and closely related genera.

ACKNOWLEDGEMENTS

I am grateful to Drs. Robert Hattaway, Thomas Mione, and Michael Nee for critical reviews of the manuscript. Dr. Mione also shared photographs and alcohol-preserved material of *Schraderanthus* which were especially helpful in understanding the floral and fruiting characters. Specimens were borrowed from the University of Texas Plant Resources Center (LL, TEX). Dr. Nee provided localities and other label data for the specimens at New York Botanical Garden (NY).

Table 1. Comparison of characters of *Schraderanthus* and related genera.

	Schraderanthus	*Leucophysalis*	*Chamaesaracha* sect, *Chamaesaracha*	*Brachistus*
Habit	Erect, woody or herbaceous, annual/perennial	Erect, annual or spreading perennial herb	Ascending or spreading perennial herb	Erect shrubs or small trees
Inflorescence	Fasciculate, from axils	1 or 2 flowers from axils	1 or 2 flowers from axils	Fasciculate, from axils
Corolla	Rotate and reflexed, 5-lobed to parted	Rotate, little lobed, margins nearly entire	Rotate, slightly 5-lobed, not parted	Campanulate, 5-parted
Fruit	Red, fleshy berry	Green, fleshy berry	Green, dry berry	Red, fleshy berry
Fruiting calyx	Accrescent, reflexing under the berry at maturity, red	Accrescent, closely appressing and partially or enclosing the berry, green	Accrescent, closely appressing and partially enclosing the berry, green	Accrescent, appressed to and enclosing the berry, green

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POINT OF VIEW
AUTHORS' INITIALS IN SCIENTIFIC NAMES WITH MULTIPLE AUTHORITIES

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An authority is added to a scientific name to provide clarity in the identity of the taxon by indicating its nomenclatural history. Names of botanical authorities in abbreviated form have been used since the Linnaean era to make scientific names less cumbersome, and Brummitt and Powell (1992, Authors of Plant Names, Royal Botanic Gardens, Kew) have provided a guide toward standardization of authors' names, including abbreviated forms. *Phytologia 91(1):62-63 (April, 2009)*.

To differentiate between botanical authorities when two or more phytographers have the same last name, addition of initials for many authors has become widely accepted (even required) in current publication. Different botanists are contrasted in "DC." (Augustin Pyramus de Candolle) vs. "A. DC." (Alphonse Louis Pierre Pyramus de Candolle), "A. Gray" (Asa Gray) vs. "Gray" (Samuel Frederick Gray), and "S.F. Blake" (Sidney Fay Blake) vs. "Blake" (Joseph Blake).

As a single authority, "B.L. Turner" justifiably includes initials because more than one Turner has been a phytographer. On the other hand, reference to B.L. Turner is unequivocal in "*Aphanostephus ramosissimus* var. *ramosus* (DC.) Turner & Birdsong" because no other combination of these names exists in botanical history. Similarly, *Gutierrezia pomariensis* (S.L. Welsh) S.L. Welsh is appropriate, but initials for the parenthetical Welsh are unnecessary in *Gutierrezia petradoria* (Welsh & Goodrich) S.L. Welsh. In uncommon instances where there might be confusion about the precise identity of one authority among others in a multiple authority, online resources usually enable one to quickly view the entire citation for a scientific name's publication, including the author's full name or names (with initials) and, in many cases, even the text of the entire publication.

Full citation of authorities with initials is appropriate to dispel ambiguity in the protologues of new taxa and in new combinations. But rather than adding critical clarity to the identity of the taxon, additions of initials in citations of multiple authors such as the following load up text with unnecessary and ponderous details:

Abronia bolackii N.D. Atwood, S.L. Welsh, & K.D. Heil
Antennaria dimorpha (Nutt.) Torrey & A. Gray
Xanthisma spinulosum var. *chihuahuanum* (B.L. Turner & R.L. Hartm.) D.R. Morgan & R.L. Hartm.

Those names are cited more readably and with equal clarity as the following:

Abronia bolackii Atwood, Welsh, & Heil
Antennaria dimorpha (Nutt.) Torrey & Gray
Xanthisma spinulosum var. *chihuahuanum* (Turner & Hartman) Morgan & Hartman

And because each of these names has been used only once, the taxa concerned also are identified with complete unambiguity by the following:

Abronia bolackii
Antennaria dimorpha
Xanthisma spinulosum var. *chihuahuanum*

Format in the Flora of North America North of Mexico volumes requires that all author citations are maximally formal, with last names in completely unabbreviated form. In general, however, insistence on extended forms of author citations in all situations seems unnecessary, especially where brevity and easy comprehension are concerns.

I greatly appreciate comments and suggestions for clarification from John Strother and Jim Reveal, but the little plaint registered here is mine, not theirs.

NOTES ON THE TAXONOMY OF *MAYTENUS PHYLLANTHOIDES* (CELASTRACEAE)

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ABSTRACT

Maytenus phyllanthoides var. *ovalifolia* Loes. (= *M. texana* Lundell) of southern Texas and adjacent Tamaulipas, Mexico, is considered here to be a distinct entity appropriately treated at varietal rank. They differ from typical plants in their oblong-elliptic to obovate-elliptic, short-petiolate leaves rounded at the base and their consistent tendency to grow as prostrate shrubs.
Phytologia 91(1):64-68 (April, 2009).

KEY WORDS: *Maytenus phyllanthoides*, *M. phyllanthoides* var. *ovalifolia*, *M. texana*, Texas

Maytenus phyllanthoides occurs widely in coastal and near-coastal Mexico—along the Gulf and Pacific coasts—as well as saline sites in some inland areas (e.g., Coahuila, Nuevo León, Puebla, Hidalgo, Querétaro). It extends eastward to Cuba, the Bahamas, and Florida, where it occurs in 10 peninsular and Keys counties (Wunderlin & Hansen 2008). A closely similar form occurs in five counties of southernmost Texas (Turner et al. 2003)—along the Gulf Coast in both areas.

Over its whole range, plants of typical *Maytenus phyllanthoides* are erect shrubs to small trees 1–3 meters tall, monoecious with unisexual flowers. The leaves are coriaceous, evergreen, and obovate with entire margins, rounded apices, and long-tapering, straight-sided bases.

The Texas populations were described in 1939 as *Maytenus texana* Lundell; the same population system had been named in 1910 as *M. phyllanthoides* var. *ovalifolia* Loes., based on a collection from immediately adjacent Tamaulipas, Mexico. Lundell (1939, p. 307) noted that "The oblong-elliptic or obovate-elliptic, short-petiolate leaves rounded at the base, and the smaller rufous-punctate flowers distinguish *M. texana* from *M. phyllanthoides* Benth., its closest relative. In the latter, the leaves are obovate, cuneate at the base, larger, and have much longer petioles." Loesener's diagnosis described the same leaf morphology later noted by Lundell as characteristic: "Foliis ellipticis vel ovalibus vel obovatis basi rotundatis vel obtusis neque cuneatus a typo recedens." The difference in leaf shape between typical *M. phyllanthoides* and the variants is confirmed here and a distinction in growth habit also is evident.

Correll and Johnston (1970) described the species in Texas as "A much-branched spreading or prostrate shrub," and various collectors have made similar observations.

Correll 38283 (TEX): "creeping on ground and forming low shrubs"
Correll & Johnston 17955 (LL): "repent or widely decumbent shrub forming growths 2–4 ft. in diameter"
Correll & Wasshausen 27676 (LL, MO): "sprawling on ground"
Cory 54601 (LL): "shrub 3 dm. high or less"
Ertter 5242 (TEX): "spreading to prostrate"
Lundell 1255 (MO): "shrub up to 2 m high, erect or prostrate, rooting at the nodes of prostrate branches"
Lundell 10708 (LL): "erect or prostrate, rooting at the nodes of prostrate branches"
Lundell 14926 (LL): "prostrate shrub"
Runyon 2315 (TEX): "erect, prostrate shrub"
Traverse 1040 (MO, TEX): "shrub-vine, 20 cm, crawling on ground, ultimate twigs upright"

Other collections by Lundell (LL) have described the Texas plants simply as "shrubs" varying in height from 1 to 6 feet).

In contrast, Florida plants consistently are described as shrubs to small trees 1–3 meters high. Felger et al. (2001) described *M. phyllanthoides* in northern Sonora as "Mound-shaped hardwood shrubs or sometimes small trees 4–6(–8) m," and other collections from

Mexico are characterized as trees 2–7 meters high, shrubs 2–6 feet high, and shrubs 12 feet high. I have examined 120 collections (MO, TEX, LL) of typical *M. phyllanthoides* from Florida and Mexico—none was described as prostrate or decumbent.

Lundell (1969) and Correll and Johnston (1970) treated the Texas/Tamaulipas plants as *Maytenus texana* Benth., citing *M. phyllanthoides* var. *ovalifolia* Loes. as a synonym. Richardson (1995), Turner et al. (2003), and the PLANTS Database (USDA, NRCS 2008) have identified them as *M. phyllanthoides*. Leaf morphology and habit of these plants, however, contrast with typical *M. phyllanthoides* and it is useful to recognize them as a taxon distinct from the typical expression. Still, the differences are relatively slight compared to those between other species of *Maytenus*, and even though the Texas/Tamaulipas population system appears to be geographically separated from typical populations, there are seemingly intermediate plants in San Luis Potosí that are erect shrubs but that have obtuse leaf bases.

Mexico: San Luis Potosí. 1 km N of Huizache Jct, alkaline desert flat, 7 Nov 1960, *Johnston 6034* (LL, TEX); ca 2 km airline SE of Huizache Jct, ca 5 km W of El Huizache, matorral, 1400 m, 19 May 1973, *Johnston et al. 11113* (LL).

Treatment of the Texas/Tamaulipas plants at varietal rank is appropriate, although a case might be made for recognizing them at specific rank.

Maytenus phyllanthoides Benth., Bot. Voy. Sulphur 54. 1844.
Tricerma phyllanthoides (Benth.) Lundell, Wrightia 4: 158. 1971. Type: Mexico. Baja California Sur: Bay of Magdalena, 1837, *R.B. Hinds s.n.* (holotype: K).

Flowering Feb–Aug or probably all year in some areas. Dunes, inland margins of mangrove, along coastal bays and inlets, near-coastal arroyos and salt scrub, alkaline desert flats, gypseous soil along stream beds, matorral (*Larrea-Flourensia*, *Agave-Larrea-Dasylirion-Opuntia*), cedar forests, mesquite woods; (2 m, dunes) 720–2200 meters elevation. U.S.A. (Florida); Mexico (Baja California Sur, Chiapas, Coahuila, Hidalgo, Jalisco, Nuevo León, Puebla, Querétaro, Quintana Roo, San Luis Potosí, Sinaloa, Sonora, Veracruz, Yucatan); Cuba; Bahamas. I have examined specimens from all of the Mexican states except Veracruz and Jalisco.

Maytenus phyllanthoides var. **ovalifolia** Loes., Repert. Spec. Nov. Regni Veg. 8: 291. 1910. Type. Mexico. Tamaulipas. Rincon del Toro on the "Laguna Madre," Jun [1905], *R. Endlich 552* (holotype: B). Endlich's collection was made about 45 miles south of Brownsville.

Maytenus texana Lundell, Phytologia 1: 306. 1939. *Tricerma texana* (Lundell) Lundell, Wrightia 4:158. 1971. Type: U.S.A. Texas. Cameron Co.: mesquite woods between Los Fresnos and Port Isabel, 23 Apr 1933, *E.U. Clover 986* (holotype: MICH).

Flowering Mar–Jun, fruiting Jun–Aug(–Dec). Shrublands and thickets, commonly with *Acacia* and *Forestiera*, mud flats, salt flats, low ridges, clay mounds, clay dunes, loamy sand, sandy clay, saline clay; 2–10 meters elevation. U.S.A. (southern Texas); Mexico (northeastern Tamaulipas). Illustrations are published in Lundell (1969, line drawing), Richardson (1995, color photo), and Everitt et al. (2002, color photo).

I have seen only a single collection of var. *ovalifolia* from Mexico: Tamaulipas. Coastal flats S of Matamoros, 9 Feb 1939, *LeSueur 529* (TEX).

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TWO ADDITIONS TO THE VASCULAR FLORA OF TEXAS

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ABSTRACT

Euthamia caroliniana is reported as new to Texas, while *Rhynchospora chapmanii* is reported as new to Texas and the West Gulf Coastal Plain. *Phytologia 91(1):69-72 (April, 2009)*.

KEY WORDS: Asteraceae, Cyperaceae, *Euthamia*, *Rhynchospora*, Louisiana, Texas, West Gulf Coastal Plain.

The following species are reported as new to Texas.

Euthamia caroliniana (L.) Greene ex Porter & Britton (Asteraceae).

Euthamia caroliniana (Haines 2006) is distributed from Nova Scotia and Maine, south to Florida, and west to Michigan, Illinois, and Louisiana. Until now, it has not been reported in Texas (Correll & Johnston 1970, Turner et al. 2003, Haines 2006). The species was collected at Candy Abshier Wildlife Management Area adjacent to Smith Point. This location is approximately 180 km west of the nearest known occurrence of *E. caroliniana* in Jefferson Davis Parish, Louisiana, where it is treated under the synonym *Euthamia tenuifolia* (Pursh.) Nuttall (Thomas and Allen 1996).

Euthamia caroliniana occurred infrequently in a wet sandy coastal prairie and adjoining salt pan (slicks) in small patches that typically consisted of 5--10 plants. Several larger patches with 50--100 plants were also present. The site was dominated by *Bigelowia nuttallii*, *Borrichia frutescens*, *Boltonia diffusa*, *Dichanthelium acuminatum*, *Eupatorium glaucescens*, *Fimbristylis castanea*, *Fuirena breviseta*, *Hypericum drummondii*, *Iva angustifolia*, *Liatris acidota*, *Lythrum alatum*, *Morella cerifera*, *Rhynchospora plumosa, Scleria georgiana, Schizachyrium tenerum, Solidago tortifolia*, and *Xyris stricta.*

Voucher specimen: TEXAS. **Chambers Co.:** Candy Abshier Wildlife Management Area, Smith Point at the southwestern tip of FM 562 at Galveston Bay, 4 Nov 2007, *Singhurst 15467* (BAYLU).

Euthamia is a small genus of five species, closely allied to, but distinct from *Solidago* (Haines 2006). Other species of the genus known to occur in the state include *E. gymnospermoides* Greene and *E. leptocephala* (Torrey & A. Gray) Greene (Turner et al. 2003, Haines 2006). A third species, *E. graminifolia* (L.) Nuttall is cited as occurring in Texas by Turner et al. (2006), but is excluded from the state by Haines (2006). A key to species and further information is available in Haines (2006).

Rhynchospora chapmanii M.A. Curtis (Cyperaceae)

In Godfrey and Wooten (1979) and Kral (2000) *Rhynchospora chapmanii* is considered to be endemic to the United States where it occurs from North Carolina, south to Florida, and west to extreme eastern Louisiana. There are, however, unpublished reports in the TROPICOS Database of the species occurring in Belize and Nicaragua (MOBOT 2008). Until the present paper, *R. chapmanii* had only been documented in the Southern Atlantic and Eastern Gulf Coastal Plains. The record cited below constitutes the first known report of the species not only in Texas, but in the West Gulf Coastal Plain as defined by Bailey et al. 1994. This distribution pattern is common to a number of other Eastern Coastal Plain species, such as *Agrimonia incisa*, *Platanthera chapmanii*, and *Xyris smalliana*, all present as disjuncts in southeast Texas, but with the major part of their distributions being from southeast Louisiana and eastward.

Rhynchospora chapmanii was collected in a shallow wetland in a sandy coastal prairie in Candy Abshier Wildlife Management Area adjacent to Smith Point. The site was dominated by *Anthaenantia rufa*, *Panicum rigidulum*, *Rhynchospora* spp., *Fuirena* sp., and *Eleocharis* sp. This location is about 450 km west of the nearest known occurrence of *R. chapmanii* in St. Tammany Parish, Louisiana (Thomas and Allen 1993).

TEXAS. **Chambers Co.:** Smith Point, Candy Abshier Wildlife Management Area, Take IH 10 E to SH 61 at Hankamer, S on SH 61 for four miles to FM 562, turn onto FM 562 and continue S then W for 22 miles on FM 562 to Smith Point, 01 Nov 2007, *Rosen 4660* (BRIT, TEX, VDB.

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ROMULEA ROSEA (IRIDACEAE): ADVENTIVE IN TEXAS

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ABSTRACT

Romulea rosea is reported as adventive in Texas. *Phytologia 91(1):73-75 (April, 2009)*.

KEY WORDS: Iridaceae, *Romulea*, Texas, invasive plant.

Romulea is a genus of about 90 species that is distributed in Africa, southern Europe, and the Middle East (Goldblatt 2002). One species, *R. rosea*, the sand crocus, a native of South Africa, is naturalized in Europe, the British Isles, Australia, New Zealand and in several coastal counties of California (The Nature Conservancy 2005). Based upon the specimens cited below, this species may now be reported as adventive in Texas.

***Romulea rosea* (L.) Eckl.** (Iridaceae).

Voucher specimens: TEXAS. Henderson Co.: West side of County Road 3520, ca. 200 yards south of the junction of County Road 3520 and FM 2339, 24 Mar 2005, *Fleming 1211* (BAYLU); West side of County Road 3520, ca. 200 yards south of the junction of County Road 3520 and FM 2339, 25 Mar 2005, *Fleming 1212* (BAYLU).

In 2005, the population consisted of approximately twenty individuals scattered over about one-half hectare under closed, undisturbed forest canopy dominated by *Pinus taeda*, *Liquidambar styraciflua*, *Quercus* spp., and *Carya* sp. In March 2008, the population was estimated to be "at least 100 plants over a larger area" (Fleming, pers. obs.).

Five varieties of *Romulea rosea* are recognized by de Vos (1972). The specimens reported here correspond to variety *R. australis* (Ewart) M. P. de Vos. Goldblatt (2002) mentions that this variety has become a common weed of lawns, pathways, and roadsides in Australia, where it is a pest. He further mentions that, to date, this situation does not seem to be the case for the parts of California where the species occurs. While at present there is no evidence of the species becoming a pest in Texas, its invasive nature in Australia justifies that its presence in the state be closely monitored.

Romulea rosea exhibits a pattern of spread that is similar to several other species reported as adventive in Texas. These species were initially reported as adventive to California (or the west coast), then later discovered in eastern Texas. However, the source of the plants adventive in Texas is unknown. Plants with this pattern of distribution include *Bellardia trixago* (L.) All. (Scrophulariaceae) (Lipscomb & Ajilvsgi 1982, Do et al. 1996), *Centaurium muhlenbergii* (Griseb.) Piper (Gentianaceae) (Holmes & Wivagg 1996), and *Parentucellia viscosa* (L.) Caruel (Scrophulariaceae) where it appears to have been a "late" entry into the Manual of the Vascular Plants of Texas (Correll & Johnston 1970). Inclusion in the manual was based upon a 1969 collection (*Correll 37239*, TEX) of the species in Jasper Co. Tracing the application of the name in the state was complicated by the name not being included in the index of the manual.

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TAXONOMY OF *IVA ANGUSTIFOLIA* AND *I. ASPERIFOLIA* (ASTERACEAE)

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ABSTRACT

Iva angustifolia and *I. asperifolia* are treated as belonging to a single species, *I. asperifolia*. The species is treated as having three varieties: var. *angustifolia*, widespread in the south-central U.S.A.; var. *latior*, largely confined to the beaches of southern Texas; and var. *asperifolia*, confined to the coastlines of central Mexico, with an introduced outlier in Wakulla Co., Florida. Keys to the taxa are provided, along with maps showing their distribution.
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KEY WORDS: Asteraceae, *Iva angustifolia, I. asperifolia, I. texensis*, Texas, Mexico, Florida

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Strother (2006), in his treatment of *Iva* for the Flora of North America, provided a taxonomic account of *I. angustifolia* Nutt. ex DC. In this he did not provide for infraspecific categories, nor did he discuss its relationship to its closest congener, *I. asperifolia*, a taxon from dune sands along the Gulf Coast of Mexico. He did place in synonymy under his broad interpretation of *I. angustifolia* the names *I. a.* var. *latior* Shinners and *I. texensis* R.C. Jackson, both typified by material from sandy or clay saline dunes of southernmost coastal Texas.

Jackson (1960) proposed the name *Iva texensis* (typified by *Jackson 2505* from saline soils ca. 8 mi S of Falfurrias, Brooks Co., Texas). Oddly, other than the type, he listed numerous additional collections, these introduced with the statement that "A number of specimens from the coastal regions of Texas are tentatively assigned to

I. texensis. These plants have a woody stem, but in involucral length and plant height are not always in agreement with the type."

Shinners (1964) inexplicably described again Jackson's *Iva texensis* with his proposal of *I. angustifolia* var. *latior*, the latter also typified by specimens from Brooks Co., Texas. Indeed, Shinners did not mention *I. texensis* in his account of the proposed variety, although he did cite Jackson's revision of *Iva* in which the name was first proposed.

Strother's account of *Iva angustifolia* for the U.S.A. is confounded by the earlier name, *I. asperifolia* Lessing, this proposed in 1830. Strother did comment upon the latter, noting in the introduction to his treatment, that "Records of *Iva asperifolia* Lessing from Florida are evidently based on specimens that are treated as members of *I. angustifolia*." A similar sentiment was expressed by Wunderlin (1998) who thought the name *I. asperifolia*, was "misapplied" to plants from Wakulla Co. Florida, that he took to be *I. angustifolia*. This, in spite of the fact that Jackson (1960) stated, "The specimens of *I. asperifolia* from Florida may represent an introduction [of *A. asperifolia*] from Mexico." Plants grown from seeds by Jackson in his greenhouse (the seeds provided by Dr. R. K. Godfrey from Wakulla Co.) reportedly "gave plants with procumbent terms (sic)." Jackson further noted that the Mexican plants, which he observed along the beaches of Veracruz, Mexico, were similarly decumbent perennials that root at the nodes. One must assume that Jackson knew what he was talking about, hence the comments of Clewell (1985), no doubt bowing to the judgment of Jackson to the effect that the Wakulla populations, which he took to be *I. asperifolia*, are "decumbent perennials rooting at the nodes;" Clewell further noted that the plants occur in tidal marshland and were "Probably introduced from Mexico." I have also examined collections from the Florida populations concerned and they appear to be closer **in habit** to *I. asperifolia* than to *I. angustifolia*, as noted by Jackson.

Miao, Turner and Mabry (1995) examined chloroplast DNA variation in all species of *Iva*, except for the mostly Cuban, *I. cheiranthifolia*. Their study included all four species of sect. *Linearibractea* R.C. Jackson, which included *I. angustifolia, I. asperifolia, I. texensis,* and *I. microcephala*. Indeed, in their sequence divergence study the four species of sect. *Linearibractea* formed a tight cluster, the most distinct being *I. microcephala*, which was found to be the most divergent member of the tetrad. The remaining three taxa were found to have few differences among them. In particular, the two herbaceous taxa, *I. angustifolia* and *I. asperifolia*, were found to differ by only one restriction site mutation. Unfortunately, DNA data for *I. asperifolia* was obtained from the Wakulla Co. population, which Jackson accepted as an introduction from the Mexican beaches. The taxonomic status of the latter population is controversial, as noted in the above. Considering the Pleistocene history of the southeastern U.S.A., it is possible that the Wakulla population is but an isolated relic of a once more widespread, highly variable, var. *angustifolia*, perhaps deserving of its own formal varietal name. Additional study of the *I. asperifolia* complex is clearly needed, especially from Tamaulipas where the two taxa presumably intergrade.

With the above as an introduction, I hasten to add that I also (Turner et al. 2003) recognized Texas populations of the *I. asperifolia* complex as *I. angustifolia*, largely following the work of Jackson. Unlike Strother, I did recognize the more robust, seemingly perennial, var. *latior* of Shinners, with the assumption that it intergraded northwards along the shores of Texas into the typical var. *angustifolia*, as also noted by Jackson. I also believe that the var. *latior* intergrades southwards along the Gulf beaches of Mexico into var. *asperifolia*. This suggested by a single intermediate, cited below. I provide herein a synopsis of the *I. asperifolia* complex as currently understood, along with a nomenclature that appears to fit the biology.

IVA ASPERIFOLIA Lessing, Linnaea 5: 151. 1830.

TYPE: **MEXICO. VERACRUZ: Mpio. Veracruz**, “In pascuis pr. Vera-Cruz.” Jul. *Scheide 332* (holotype B; fragment and drawing, GH).

Jackson (1960) provided a detailed description of the taxon, positioning it in his sect. *Linearbractea*.

Key to infraspecific taxa:

1. Plants annuals mostly 0.75 m high or less; south-central U.S.A. (Kan., Okla., Tex., Ark., La.)............................var. **angustifolia**
1. Plants perennial herbs to 1.5 m high; Gulf Coastal dunes, southernmost Texas, northern Mexico and panhandle Florida......(**2**)

2. Stems decumbent, rooting at the nodes; leaves mostly oblong-lanceolate; involucres without markedly spreading, broad-based hairs; coastal Tamaulipas and Veracruz, Mexico......var. **asperifolia**
2. Stems stiffly erect, only rarely rooting at the nodes; leaves mostly lanceolate; involucres with markedly broad-based spreading hairs, rarely not; northern coastal Tamaulipas, Mexico, and southern Texas ....var. **latior**

IVA ASPERIFOLIA var. **ANGUSTIFOLIA** (Nutt. ex DC.) B.L Turner, **stat. & comb. nov.** Fig. 1
Based upon *Iva angustifolia* Nutt. ex DC., Prodr. 5: 529. 1836.
TYPE: **U.S.A. ARKANSAS:** without locality, *Nuttall s.n.* (holotype: G-DC; isotype NY)

Jackson (1960) provided an adequate account of this taxon, noting in his key the principal differences that distinguish it from var. *latior*, the latter being larger, mostly perennial, plants having somewhat larger involucres, the latter well endowed with spreading hairs. In my opinion, var. *angustifolia* grades into var. *latior* in regions of near contact, as noted below, hence their treatment as but populational variants (or variety) of a widespread *Iva asperifolia*.

Varity *angustifolia* is highly variable and, other than habit, is best recognized by a suite of characters, most having to do with the involucre, as noted below and by Jackson (1960).

IVA ASPERIFOLIA Lessing var. **ASPERIFOLIA** Fig. 1, 2

As noted in Figures 1 and 2 (based upon specimens at MEXU, TEX), this taxon is restricted to the Gulf Coastal area of northern Tamaulipas and Veracruz, Mexico, with an isolated population in

Wakulla Co., Florida. In Tamaulipas, Mexico, it seemingly grades into the var. *latior*, to judge from the following collection: Mpio. Altamira, *Dunas 856* (MEXU, TEX).

The taxonomic status of the Florida populations of var. *asperifolia* is in doubt. According to label data on *Godfrey 70060* (TEX), the Wakulla population occurs "On a large flat area into which spoils from dredging of the St. Marks River had been placed; very abundant; St. Marks." The DNA voucher of Miao et al. (1995) was obtained "In limestone piles of spoil, St. Marks, just west of end of county Road 363 and north of St. Marks River." Both of the aforementioned collections are seemingly perennial. The Godfrey collection has a capitulescence much resembling var. *angustifolia*; the Miao voucher (*Garland 751*, TEX) has an atypical capitulescence. Based on the DNA data from the latter voucher and the comments of Jackson (1960), it would appear that the Wakulla population is closest to var. *asperifolia.* Alternatively, it is remotely possible that the Wakulla populations represent a localized yet undescribed variety of *I. asperifolia*, as noted above.

IVA ASPERIFOLIA var. **LATIOR** (Shinners) B.L. Turner, **comb. nov.** Fig.1

Based upon *Iva angustifolia* var. *latior* Shinners, Sida 1: 378. 1964. TYPE: **U.S.A. TEXAS: Brooks Co**., "south of Falfurrias." 15 Sep 1942, *Lundell & Lundell 11947* (holotype SMU; isotypes LL!)

Iva texensis R.C. Jackson, Univ. Kansas Sci. Bull. 41: 807. 1960. TYPE: **U.S.A. TEXAS: Brooks Co.,** 8.1 mi S of Falfurrias along U.S. highway 281, 24 Aug 1957, *Jackson 2505* (holotype KANU; isotype SMU)

Jackson's *Iva texensis* was published prior to Shinner's var. *latior*; unfortunately nomenclatural priority is predicated upon rank; were the present taxon recognized as a species, its correct name would be *I. texensis*!

Variety *latior* is a perennial herb to 1.5 m high, largely confined to the Gulf Coastal region of Texas, mostly occurring in sandy or clay dunes along the beach front; numerous collections are in the herbarium at TEX (35 from along the coastal areas of Cameron, Kenedy and Nueces counties).

The earliest collections of var. *latior* were made by Robert Runyon in Cameron County between the years 1924-1945 (TEX, LL). He noted that the taxon was sufficiently well known as to have received the local common name "Pelocote." And that the taxon occurs "only along sea shore as colonies on sand dunes;" and describes its habit as an "erect branched herb," or "fruticose herb." Nevertheless, it also occurs sporadically inland into the Tamaulipan Biotic Province of southern Texas, as indicated in Fig. 1. Occasional intergrades between var. *latior* and var. *angustifolia* in this area are discerned (e.g., *Carr 22574*, Refugio Co., TEX). The more strictly coastal populations of var. *latior* pass into var. *angustifolia* near Galveston, Texas, the latter becoming strictly taprooted annual herbs mostly 0.5 m high or less, having smaller involucres with mostly shorter appressed hairs.

As suggested by its dune-site proclivities in Kenedy and Cameron counties, it is almost certain that southwards var. *latior* grades into var. *asperifolia*, as suggested by the intermediate specimen cited above. Even among the Texas coastal populations, some degree of past introgression is likely, to judge from the variation in leaf shape and pubescence noted among the Cameron county populations.

ACKNOWLEDGEMENTS

I am grateful to my colleagues, Guy Nesom and John Strother for reviewing the paper and providing helpful comments. Thanks also to MEXU for the loan of specimens, these critical in the construction of distribution maps for *Iva asperifolia* var. *asperifolia.*

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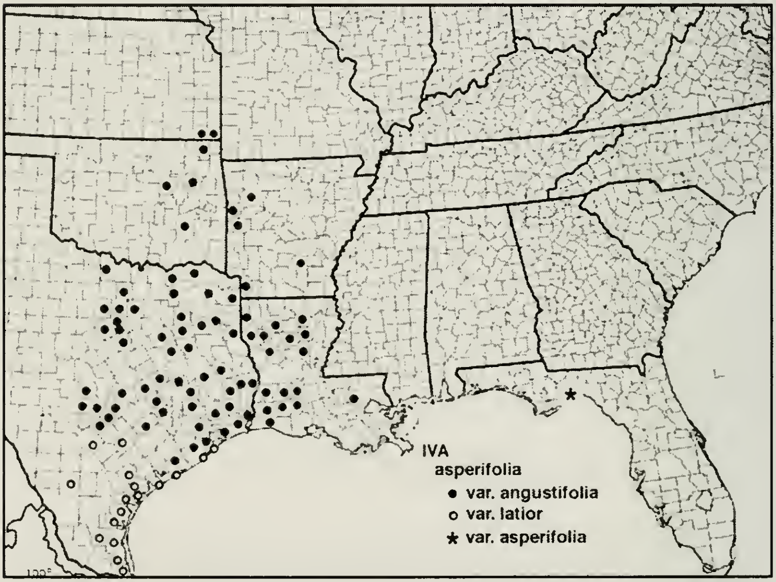

Fig.1. Distribution by county (and parish) of *Iva asperifolia* in the U.S.A.

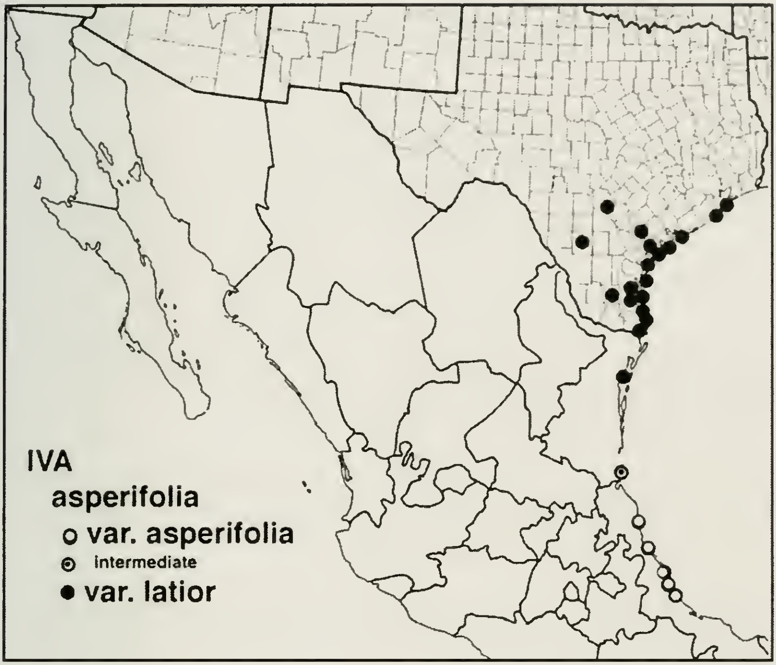

Fig. 2. Distribution of *Iva asperifolia* in Mexico.

A NEW SPECIES OF *TRIXIS* (ASTERACEAE: MUTISIEAE) FROM JALISCO, MEXICO

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Preparation of a treatment for the Mutisieae of Mexico has occasioned description of the following novelty:
TRIXIS JALISCANA B.L. Turner, **sp. nov.** Fig. 1

Trixi haenkei Schultz-Bip. similes sed foliis juvenilibus subtus dense villosis (vs moderate vel sparsim villosis), setis pappi fulvis (vs albis), et capitulescentia congestae (vs expansae).

TYPE: **MEXICO. JALISCO: Mpio. Mascota**, 1 km E of Mascota, "dry, shrubby slopes," 1230 m, 1 Mar 1970, *W.R. Anderson & C. Anderson 5905* (Holotype: LL).

Shrub 1-3 m high, "branching from the base and from lax branches." **Stems** wingless, densely soft-pubescent. **Leaves** lanceolate, 5-15 cm long, 1-4 cm wide; petioles 0-10 mm long. **Capitulescence** a terminal, tightly congested, corymbose panicle, the ultimate peduncles 0-1 mm long. **Accessory bracts** 2-4, lanceolate, mostly half as long or less than the involucre. **Involucral** bracts 8, ca 12 mm long, their apices abruptly acute. **Receptacle** ca 2 mm wide, pubescent with hairs up to 2 mm long. **Florets** 10-20 per head; corollas yellow, the upper lip 3-4 mm long, the tube 8-10 mm long. **Achenes** pubescent throughout, 6-9 mm long; pappus of numerous tawny bristles 8-10 mm long.

ADDITIONAL SPECIMENS EXAMINED: **MEXICO. JALISCO: Mpio. Chapala**, "Barranca proxima a Ajijic," 1650 m, 12 Nov 1978, *Luna 9370* (TEX). **Mpio. Jocotepec**, "Ladera sur al norte de la barranca del Huazoyo." 7 Mar 1993 *Machuca N. 6923* (TEX). **Mpio. Mixtlan**, between Ameca and Atenguillo, 5100-5500 ft., 4 Mar 1987, *Daniel & Bartholomew 4830* (TEX). **Mpio. San Sabastian**, N of Mascota on road to San Sebastian, 1450-1730 m, 1-3 Mar 1970, *Anderson & Anderson 5951* (TEX).

In her seminal treatment of Mexican *Trixis*, Anderson (1972) clearly called to the fore the present novelty. She noted that the type of *T. haenkei* was probably collected by Seemann "in the mountains along the Sinaloa-Durango border, east of Mazatlan." At the time of her study Anderson knew of only two collections from the area of the type locality concerned, the type and *Anderson & Anderson 6177*. She further noted that the latter collection differed from "the type as well as from the Jalisco collections" in having a white pappus, and inflorescence branches which bear small corymbs that are more than twice as long as those in specimens from Jalisco. I have examined the *Anderson & Anderson* collection and one additional collection from the area of the type locality: *Rito Vega 3624* (TEX), this from Sinaloa between km 240 and 256 along the Ojo de Agua to la Guayamera highway. Both of these collections are very similar, and the characters called to the fore by Anderson hold for both. I have not examined the holotype itself, which is reportedly at Kew, nor did Anderson. She did, however, examine a photo of the holotype, as have I. From the photo I found it difficult to judge the characters called to the fore by Anderson. I did, however, borrow what I take to be an isotype from GH and found this to be closely akin to the other two collections from the Sinaloa-Durango border. In short, all material from along the Sinaloa-Durango border is clearly the same and is not to be confused with the presently described *T. jaliscana*, *T. haenkei* occurring in tropical deciduous forests (600-800 m) "just below the oak zone," and *T. jaliscana* occurring in pine-oak forests at much higher elevations (1200-2000 m). Further, among the Jalisco collections I detected no intermediates between the two regional populations concerned, which leads me to believe that the taxa are sufficiently distinct, both morphologically and ecologically, for specific recognition (as opposed to varietal).

1. Young leaves moderately to sparsely densely villous beneath; pappus bristles white; capitulescence open; deciduous forests below the oak zone..**T. haenkei**
1. Young leaves densely villous beneath; pappus bristles tawny; capitulescence tightly congested; pine-oak forests..........**T. jaliscana**

Fig. 1. Holotype of *Trixis jaliscana*.

ACKNOWLEDGEMENTS

I am indebted to Guy Nesom for the Latin diagnosis, and for improving the manuscript itself. I am also grateful to GH for loan of type material.

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Fig. 2. Distribution of *Trixis haenkei* (circles) and *T. jaliscana* (dots).

CARMINATIA PAPAGAYANA (ASTERACEAE: EUPATORIEAE), A NEW SPECIES FROM WESTERN GUERRERO, MEXICO

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Routine identification of Mexican Asteraceae has revealed the following novelty:

CARMINATIA PAPAGAYANA B.L. Turner, **sp. nov.** Fig. 1

Carminatia recondita McVaugh similis sed differt capitulescentia stricta laxa corymboidei capitulis in pedunculis ultimis 1-4 cm longis portatis (vs. capitulis congestis in pedunculis 1-3 mm longis).

Annual herbs 20-70 cm high. **Stems** (lower) ca 3 mm across, pubescent with crinkly hairs. **Leaves** (lower) 4-5 cm long, 2-3 cm wide; petioles 2-3 cm long, glabrous or nearly so; blades broadly ovate to deltoid, glabrous above and below , the margins somewhat or weakly dentate. **Capitulescence** a terminal array of stiffly erect peduncles, the ultimate peduncles 1-4 cm long, pubescent like the stems. **Heads** cylindric, containing ca 15 florets, ca 14 mm high, 4-5 mm across. **Involucres** ca 12 mm high, glabrous; outer bracts 4-8, 1-6 mm long. **Receptacle** ca 1 mm across, glabrous. **Corollas** white, glabrous, cylindrical, 7-8 mm long, ca 0.8 mm wide. **Achenes** 4-5 ribbed, minutely pubescent with very short, broad-based hairs; pappus of ca 15 white, plumose, bristles ca 7 mm long; chromosome number, $2n = 20$.

TYPE: **MEXICO. GUERRERO: Mpio. Tierro Colorado,** "Acapulco. Autopista del Sol Mexico-Acapulco, zona rocosa a unos metros del puente sobre el Rio Papagayo. ..Selva baja caducifolia.

Occasional 280 m," 17 08 02.9 N 99 33 24.2 W, 9 Oct 1995, *Jose L. Panero 6193* [with C. C. Clevinger] (Holotype: TEX).

As indicated in Fig. 1, the present novelty differs from all previously described species in having its heads arranged in stiffly erect peduncles 1-3 cm long. It also appears to be restricted to deciduous forests along the lower slopes of the Sierra Madre of western Guerrero. Yet other species of the genus in Guerrero occur at higher, more eastern locales, as noted in Fig. 2, the latter based upon specimens at LL, TEX and those mapped in Turner (1997). Strother and Panero (2001) report a chromosome number of 2n = 20 for the type (identified as *C. recondita* McVaugh), this consistent with previous reports for the genus.

The taxon is named for the Papagayo River, from whence the type and only known collection.

ACKNOWLEDGEMENTS

I am grateful to Guy Nesom for the Latin diagnosis and helpful comments on the manuscript itself.

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Fig. 1. *Carminatia papagayana*, holotype.

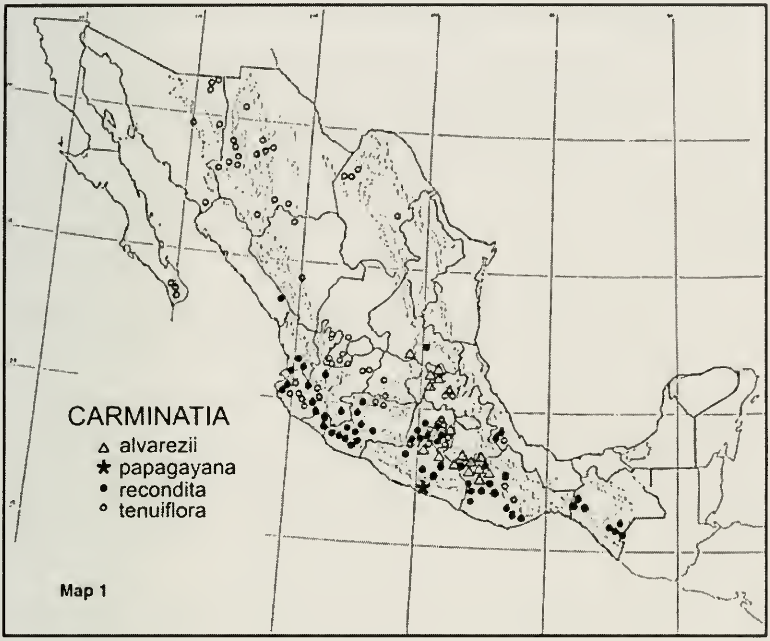

Fig. 2. Distribution of *Carminatia* spp. in Mexico.

DELWIENSIA, A NEW GENUS OF ASTERACEAE

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KEY WORDS: Asteraceae, *Artemisia pattersonii*, *Delwiensia pattersonii. Phytologia 91(1):92-94 (April, 2009)*.

The genus *Delwiensia* is proposed to accommodate *Artemisia pattersonii* A. Gray on cytological and morphological grounds.

Delwiensia W. A. Weber & R. C. Wittmann, *gen. nov.*, Asteraceae. Type, *Artemisia pattersonii* A. Gray, Syn. Fl. N. Amer. ed. 2, 1(2):453.1886. The genus name honors Delbert Wiens, contemporary American plant taxonomist, specialist in the Viscaceae, plant reproduction concerning embryonic abortion, and pollination by small mammals.

Herba aspectu speciei Artemisiae in subgenere Absinthio, numero chromosomatico n = 7, habitu inflorescentiae determinato.

Herb with the appearance of a species of *Artemisia* in the subgenus *Absinthium*, with the chromosome number n = 7, and with the inflorescence determinate.

Delwiensia pattersonii (A. Gray) W. A. Weber & R. C. Wittmann, *comb. nov.* Basionym: *Artemisia pattersonii* A. Gray.

Delwiensia is a monotypic genus endemic to the alpine tundra of Colorado, Wyoming, and New Mexico. It is superficially similar to *Artemisia scopulorum* but is amply distinct morphologically, its most obvious characters being the smaller number of heads in determinate rather than indeterminate arrays. Wiens and Richter (1966) point out that the root systems of the two species differ, *A. pattersonii* reproducing vegetatively from branched rhizomes and *A. scopulorum* having an unbranched caudex. Furthermore, *A. pattersonii* is unique in *Artemisia* in having a chromosome number of n = 7. The known base numbers in *Artemisia* are x = 8 and predominantly x = 9. The details of the karyotype did not support the notion that the two species are related. In *Sphaeromeria* (see discussion below) the chromosome number is x = 9. It is of course possible that *Delwiensia pattersonii* might be found in the Asiatic flora and thus would be considered a Tertiary relic (Weber 2002), but cytological and morphological information need to be obtained for the numerous Asiatic species of *Artemisia*-like genera and species. Rydberg (1929) had the following pungent remarks about the inflorescences (from *Scylla or Charybdis*).

> This lumping, advocated by Hall and Clements, has also been practiced by them. They include *Sphaeromeria* Nutt., *Vesicarpa* and *Chamartemisia* in *Tanacetum*. The only characters that Hall and Clements have left to separate *Tanacetum* and *Artemisia* are "Inflorescence cymose, the cyme occasionally reduced to a single head" in *Tanacetum* and "Inflorescence racemose-paniculate" in *Artemisia*. The inflorescence, strictly speaking, is neither cymose nor racemose-paniculate in either, for both have the flowers in heads. In my own treatise of the group I have used the word corymbiform instead of cymose, which I think is much better. Whether the heads are arranged cymosely or racemosely is hard to tell. If cymosely, the terminal and central head should be best and first developed. In such a case *Artemisia pattersonii* should be included in *Tanacetum*. The heads of that species have exactly the same arrangement as in *Chamartemisia compacta* or *Sphaeromeria simplex*, that is, usually one or two heads, the terminal one the larger. If the heads are congregated into a spherical cluster as in *Artemisia glomerata* and *A. globularia* and *Sphaeromeria capitata* (according to Hall and Clements a *Tanacetum*), it would be hard for anyone to tell whether the heads are arranged cymosely or racemosely. In *Vesicarpa potentilloides* (also a *Tanacetum*) [*Sphaeromeria potentilloides* (A. Gray) Heller] I cannot tell if the inflorescence is racemose

> or cymose and I have dabbled in taxonomy for 50 years.

Shultz (2006) distinguishes *A. scopulorum* (heads in spiciform arrays, and corolla lobes hairy) from *A. pattersonii* (heads being borne singly or 2–5, spreading to nodding, pedunculate, in paniculiform or racemiform arrays, and corollas mostly glabrous). The inflorescence can be better described as being determinate versus indeterminate. Rydberg's explanation is to this point.

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We thank Patricia Eckel for refining our Latin description.

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ZAMIA FLORIDANA (ZAMIACEAE), THE CORRECT NAME OF THE FLORIDA CYCAD

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ABSTRACT

The view is accepted that the *Zamia* native to the West Indies consists of several species, one of which is native also to Florida. The earliest available binomial for the Florida taxon is *Zamia floridana* A. DeCandolle (1868). An earlier binomial, *Zamia integrifolia* Linnaeus filius in Aiton (1789), by citation in synonymy of the prior *Zamia pumila* Linnaeus (1763), was superfluous when published and is thus illegitimate. *Phytologia 91(1):95-104 (April, 2009)*.

KEY WORDS: Zamia floridana, Zamiaceae, nomenclature.

INTRODUCTION

The West Indian complex of cycads in the genus *Zamia* (Zamiaceae) has been treated by Eckenwalder (1980) as composed of a single species with populations that vary in leaflet width and vein number but are not appropriately divided into more than a single species, *Z. pumila* L. (1763). This interpretation has been accepted by some authors (e.g. Wunderlin, 1998; Wunderlin & Hansen, 2000), and *Z. pumila* is frequently used in Florida horticulture.

A subsequent review of the West Indian cycads by Stevenson (1987a; 1987b; 1991), which incorporated leaflet shape and denticulation and cone shape and color, was able to distinguish 6 species within that area, one of which (his *Zamia integrifolia*) ranges to Florida. Landry (1993) in the influential *Flora North America* followed Stevenson in recognizing the Florida plant as specifically distinct from the all-inclusive *Z. pumila* of Eckenwalder; Landry too employed *Z. integrifolia.*

The present author has long been of the opinion that *Zamia integrifolia* L. f. in Ait. (1789) was nomenclaturally superfluous when published, in that Linnaeus filius (in Aiton) had erred (by modern rules) by citing in his synonymy a pre-existing name, *Zamia pumila* L. (1763). In this belief, the present author (1968; 1979; Burch et al., 1988) has consistently used a later available name, *Z. floridana* A. DC. (1868). In need of an infraspecific name for a non-typical Florida population, he made the combination, *Z. floridana* var. *umbrosa* (Small) D. B. Ward (2001). The authors of a recent, highly acclaimed systematics text (Judd et al., 1999: 151) have accepted this judgment, also using *Z. floridana.*

DISCUSSION

A circumstance has now arisen that compels presentation of a full defense of *Zamia floridana.* The recent proposal by a colleague to use this name in a floristic survey has by editorial review triggered an intense reconsideration of its nomenclatural underpinnings. To satisfy all parties that this name is correct calls for a full discussion of the background facts and provisions of the International Code of Botanical Nomenclature (McNeill et al., 2006) that justify this conclusion.

The facts of publication seem not in dispute. In 1763 Linnaeus published the name *Zamia pumila.* He accompanied the name with a 7-word Latin phrase: *Spadix more fructus Cupressi divisus in floscules* ("Infructescence [=cone] larger than [that of] *Cupressus*, divided into florets [=?microsporophylls]"). He stated its source: *Habitat in America meridionali.* He then listed four earlier authors (P. Miller, J. Commelin ("Commelijn"), L. Plukenet, and C. J. Trew), with the phrase-names used by each. Two centuries later the illustration of one of these cited authors, that of Commelin (1697), was designated by Eckenwalder (1980: 715) as the lectotype for *Z. pumila.*

Linnaeus filius' treatment of *Zamia* was wholly independent of that of his father. He is known to have worked in London with William Aiton (Stafleu, 1971) and to have assisted in the writing of Aiton's *Hortus Kewensis* (1789); each of the five descriptions of *Zamia* in that publication was credited to him. In this endeavor he had access to living plants (he noted *Z. integrifolia* to have been introduced from "East Florida" by John Ellis in 1768). His description of *Z. integrifolia* (*foliolis subintegerrimis obtusiusculis muticis rectis nitidis, stipite inermi*) was original and appropriate to Florida plants. He cited only one reference, the *Z. pumila* of his father, but for this he stated "exclusis synonymis." This two-word Latin phrase is the genesis of all later nomenclatural uncertainty regarding the Florida *Zamia*.

The third name involved here is *Zamia floridana* A. DC. (1868). Its author reported it from "E. Florida" and its label data (Eckenwalder, 1980) further narrowed its source to "Fort Brooke," a Seminole War army encampment at the head of Tampa Bay on the west coast of peninsular Florida, as collected by "Hulse." (In the 18th and early 19th century, all of peninsular Florida was in the political district of "East Florida." Gilbert White Hulse, a correspondent of John Torrey in New York, was a physician known to have been stationed at Fort Brooke.) The legitimacy of *Z. floridana* has not been challenged; but it rises from synonymy only in the event of the illegitimacy of the prior *Z. integrifolia*.

On the surface, Linnaeus filius' inclusion of an available name would appear to trigger citation of I.C.B.N., Art. 52.1, which states that if an old name cited in synonymy could have been used for the new taxon, the new name is superfluous and illegitimate. Were *Zamia integrifolia* illegitimate, the later *Z. floridana* would succeed. Correspondents (largely via e-mail), however, have raised a number of questions and arguments directed toward invalidation of the apparent I.C.B.N. citation, in part by invocation of the related Art. 52.2, thus retaining *Z. integrifolia* as legitimate. These communications have been widely circulated within the taxonomic/nomenclatural community, and have come to form a "gray literature" suggesting the validity of

Zamia integrifolia is established. It is these questions and arguments that must here be detailed and refuted.

Since the written (e-mail) statements of correspondents had not been polished for publication, and at times perhaps exhibit whimsy over precision, their specific authorship is withheld. Unattributed statements, of course, are atypical within scientific discourse. To mitigate the conflicting goals of confidentiality and verifiability, a full copy of communications has been provided the editor. Where possible, statements of correspondents are cited exactly, as indicated by enclosure within quote marks.

The following eight arguments well summarize the range of views expressed by the correspondents. The associated responses attempt to relate these remarks with relevant provisions of the I.C.B.N.

Argument #1. That Linnaeus filius "meant to say just the opposite, i.e. 'excluding *Z. pumila* L. except the synonyms.' Perhaps a Latin scholar could refute my supposition that 'exclusis synonymis' can be read as 'including only the synonyms.'"

Response. No deep schooling in Latin is needed to know that "exclusis" cannot be interpreted to mean "including only." The logic and motive of Linnaeus filius in excluding his father's references is apparent, in that some addressed quite different plants (one became *Zamia furfuracea* L. f. in Ait.) and in any event were surely inferior to the far greater wealth of materials (living and dried) available to him in London.

Argument #2. That Eckenwalder's designation of the 1697 Commelin illustration as the lectotype of *Zamia pumila*, which Linnaeus filius had excluded from his treatment of *Z. integrifolia*, removes the critical element -- the type -- from the citation, thereby expunging any prior superfluity.

Response. Eckenwalder's lectotypification is irrelevant in determination of superfluity. If *Zamia integrifolia* were illegitimate prior to Eckenwalder's designation, barring certain circumstances it must remain so in perpetuity. Article 6.4 provides that: "A name which according to this Code was illegitimate when published cannot become legitimate later" (unless conserved or sanctioned).

Argument #3. That Linnaeus filius had in effect created a nomen nudum by exclusion of his father's cited references. [First correspondent]: "When L. f. excluded all the synonyms of *Z. pumila*, he automatically excluded all the type elements that would otherwise cause the superfluity." [Second correspondent]: "Since Aiton clearly excludes the type of *Zamia pumila* of Linnaeus by excluding all the synonymy of *Z. pumila*, he created a new and valid name, *Zamia integrifolia* Aiton."

Response. This argument is in reference to Art. 52.2, the companion of Art. 52.1, where conditions are set under which citation of an old name in synonymy will cause the new name to become superfluous. Citation of the name itself is specifically stated to be sufficient to cause superfluity, "unless the type is at the same time excluded either explicitly or by implication."

But with *Zamia pumila* no type existed at publication. Nor was the legitimacy of that name impaired by its absence. Even without the synonyms, the citation of *Z. pumila* still encompassed a full circumscription: the name, the source, and the seven-word diagnosis. At that time, 1789, no "type element" was essential for valid publication; designation of a type was not required until 1958 (Art. 37.1). An abundance of early names, some by Linnaeus, many by Rafinesque and Thomas Walter among others, are based solely (if insecurely) on a name and its diagnosis.

Though there is a seductive logic in equating the references cited by Linnaeus -- from which a later type-equivalent may be chosen -- with a type itself, the provisions of Art. 52.2, read critically, do not support the argument.

Argument #4. That a party other than the original author has the power to cause the type of a name used in synonymy to be excluded. That is, the requirements of the I.C.B.N. for a superfluitycausing synonym to be intentionally included are not met if a second party can cause the exclusion.

Response. This argument, also in reference to the companion Art. 52.2, though not expressly stated by any correspondent, is implicit if the act of lectotypification can assign the type to a component of the original material of *Zamia pumila* that Linnaeus filius had excluded. Yet Art. 52.2 clearly indicates otherwise. Though the language is passive -- "unless the type is at the same time excluded either explicitly or by implication" -- there is no provision for parties other than the original author to cause such exclusion. Nor, of course, can a later party act "at the same time" as the original author.

Argument #5. [First correspondent]: That "*Z. integrifolia* is not illegitimate because it did not include ALL the elements that might become the lectotype. In short, it was not superfluous at birth." [Second correspondent]: "Since Aiton's reference to *Z. pumila* excludes all the synonyms (and their type materials), *Z. integrifolia* may be treated as legitimate."

Response. Though differently worded, this argument is a variant of Argument #3. Again, there is no requirement before 1958 that elements suitable for lectotypification be present. Had Linnaeus (1763) published *Zamia pumila* as he did but without inclusion of any references, the name would still be legitimate. The removal of his references by Linnaeus filius (1789) creates no reduced state of legitimacy.

It is obvious that the failure of an author to designate a specimen that can serve as its type, or citation in his original materials of other publications in which such specimens may be referred, creates a significant uncertainty in assignment of the name to a definite taxon. The I.C.B.N. addresses this deficiency, by the process of neotypification (Art. 9.6). Where no specimen or suitable reference exists, the rules permit a specimen never seen by the author to be selected as a neotype. By this action a legitimate name that lacks clear meaning can be linked with a specimen and thereby be made precise.

Argument #6. "If the [lectotypic] element (Commelijn's t. 58 in this case) were to be included in any taxon published between 1762 [sic?] and 1980 (*Z. integrifolia* in this case), such an inclusion does not cause illegitimacy (Art. 52, Note 2). ...L. f. did not include this element for *Z. integrifolia*; therefore, the question of illegitimacy never arises."

Response. The thrust of this argument is not entirely clear. The claim appears to be that by exclusion of the synonym the basis for the name was also excluded. This view was supported by reference to a rarely cited provision of the I.C.B.N., Art. 52.2, Note 2: "The inclusion, in a new taxon, of an element that was subsequently designated as the type of a name which, so typified, ought to have been adopted...does not in itself make the name of the new taxon illegitimate."

The cited reference is irrelevant. A note as employed by the I.C.B.N. does not create a rule or restriction; it merely clarifies the meaning of the relevant Article. Plain reading of Note 2 creates no new content; it says merely that a special stated circumstance does not make the name illegitimate, though the implication is left that other circumstances may still do so.

Argument #7. That the absence of known type material can be interpreted to mean there never was such material, in which event *Zamia pumila* would indeed be based on the cited references. "If there were evidence from the protologue of *Z. pumila* that there must have been original material, additional to that represented by the synonyms, then even if this material is no longer extant, I would agree that this situation would not meet the exclusionary requirements of Art. 52.2, and *Z. integrifolia* would be illegitimate. But...this has not been demonstrated."

Response. This argument is the most interesting and potentially destabilizing of all offered. Whether or not Linnaeus had seen living or dried materials of the West Indian cycad is not known. He did not include the plant in his earlier (1737) treatment of plants he had studied at Hartecamp, Holland (in which his solitary cycad, later named *Cycas circinalis*, was placed between the palms *Corypha* and *Phoenix*). And following his death, no specimen was present in his herbarium (LINN).

Linnaeus, however, did not employ a single word from the phrase-names which he cited; his brief diagnosis was fully original. Nor was his epithet, *pumila*, of prior use. And none would claim that he saw nothing at Hartecamp other than those entities he knew well enough to describe at that time. Even his herbarium, between his death in 1778 and its arrival into the hands of Sir James Smith in 1784, suffered losses of many damaged sheets (Stafleu, 1971: 113). It thus cannot be ruled out that he may have been guided in whole or in part by materials no longer extant.

Further, even if one were to assume the circumscription of *Zamia pumila* had been entirely fabricated, the I.C.B.N. does not provide for a distinction in treatment between such a baseless, illusory name and one whose type material had been lost. Nor does the I.C.B.N. require that evidence be provided that there had once been original material. Again, the logic is seductive that such a difference must call for different treatment. But in a real-world analysis it is impossible to document this distinction, and instability would be the only product of any effort to do so.

Argument #8. That it is best to retain *Zamia integrifolia* because that name has been employed by some of the correspondents in the past. "*Z. integrifolia* was accepted in *Flora of North America* vol. 2 (1993: 348). ...If the name is illegitimate, it needs to be conserved with a different type, for stability."

Response. This proposal, aside from its implied lack of confidence by the correspondent, must be left to the judgment of other parties.

CONCLUSION

No arguments have been put forward in support of *Zamia integrifolia* that are firmly based on specific language of the I.C.B.N. None, it would appear, can stand in contravention to the clear language of Arts. 52.1 and 52.2, that an author's name is to be rejected if it was nomenclaturally superfluous when published, and that superfluity is caused by citation in synonymy of an earlier available name whose type was not excluded by the author. *Zamia integrifolia* L. f. in Ait. must be interpreted under modern rules as a name that was illegitimate when published and is unavailable for use either in Florida or in the West Indies.

But a cautionary note stands before unequivocal acceptance of *Zamia floridana* A. DC. as a replacement name for the Florida cycad. DeCandolle's name is preceded by a series of other binomials (Eckenwalder, 1980). Though none before *Z. floridana* is based on Florida materials, the taxon also occurs widely in the Bahamas and West Indies (Stevenson, 1987a). Should further investigation firmly assign one of these earlier names to Bahamian or West Indian materials of the Florida taxon, the Florida cycad may again require nomenclatural attention.

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MORUS MURRAYANA (MORACEAE): A NEW MULBERRY FROM EASTERN NORTH AMERICA

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ABSTRACT

Mulberry trees (*Morus*: Moraceae) growing in relatively undisturbed, open woodland areas of western Kentucky exhibit exceptionally large leaves (blades often >15 cm long). Fruit size is also longer than reported for other species, and leaf vein patterns are unique. Field observations, combined with the use of herbarium specimens and molecular data warrant the establishment of a new species designation, *Morus murrayana* D.E. Saar and S.J. Galla (Murray State's Mulberry). *Phytologia 91(1):105-116 (April, 2009)*.

KEY WORDS: *Morus*, Moraceae, mulberry, *murrayana*, Kentucky, internal transcribed spacer, ITS

Mulberry trees (*Morus* L.: Moraceae) in western Kentucky and the surrounding states, identified as *M. rubra* L., were observed with exceptionally large leaves. In a search of plant keys (Jones, 2005; Mohlenbrock, 2002; Wunderlin, 1997; Swink & Wilhelm, 1994; Gleason & Cronquist, 1991; Radford et al., 1968; Steyermark, 1963; Britton & Brown, 1913) and detailed, authoritative books (Kurz, 2003; Dirr, 1998; Elias, 1987), only Wunderlin (1997) reported leaves of *M. rubra* over 15 cm in length. He listed the usual size as 7.5-18 cm but occasionally to 36 cm. Wunderlin assumed, based on his examination of herbarium specimens, that the large leaves were due to shade/sun forms or were perhaps associated with other growing conditions (pers. comm. to DES). It should be noted that leaf size is only mentioned in Wunderlin's (1997) species description for *M. rubra* and he did not include this feature in the diagnostic characters given in the keys for species identification. For the current study, the authors had the advantage of first-hand field observations of these trees growing in their natural habitat. Additional field data and DNA analysis demonstrate that this is a separate species from *M. rubra* and all others previously recognized.

MORUS MURRAYANA D.E. Saar and S.J. Galla, **sp. nov.** Fig. 1.

Arboles ad 20 m alto; folia alternatum, unifolius-quinquelobus, lamina ad 38 cm longus, serrulatus; fructus ad 4 cm longus, nigellus purpureus.

TYPE: **USA. KENTUCKY: Calloway Co.** Frequent in open mesic woodlands dominated by *Quercus* spp. and *Carya* spp. along both sides of Watersport Rd. between gate to Racer Point and boat landing on Kentucky Lake, near Hancock Biological Station, Murray State University, ca. 25 km NW of Murray, KY (36° 43.87' N; 088° 07.35' W), 13 May 2006, *Dayle E. Saar 3606* (Holotype: MUR; isotypes, BEREA, BRIT, EKU, F, MO, NCU, NY, TENN, US).

Trees to 20 m tall with a single trunk, open crown vase-shaped to rounded. **Sap** milky. **Bark** on saplings smooth, medium brown with tan lenticels, becoming grayish-brown with very thin, long and narrow scaly plates. **Winter buds** with pseudoterminal present, dull brown, scales glabrous with minutely ciliated margins. **Leaves** alternate, simple; stipules light brown, membranous to 1.1 cm long and early deciduous; petioles 2.5-6 cm long; blades to 38 cm long, widest at or below the middle, unlobed to as many as five lobes, caudate at tip and oblique at base, serrate but occasionally double serrate, scabrous above and softly pubescent on veins and lamina below, pubescence on larger veins generally restricted to sides of veins, versus the dorsal peak (Fig. 1B); basal lateral veins larger than other laterals but smaller than the midvein, veins branching from two large lower laterals (tertiary) and other laterals from midvein (secondary) curve towards the tip as they approach the blade margin without entering a tooth and only the finest veins end in a tooth (Fig. 2C). **Inflorescences** of unisexual flowers axillary on short peduncles; individuals varying from monoecious to polygamodioecious to dioecious. **Fruit** multiple, blackish purple with dark reddish-purple juice at maturity, to 4 cm long and 1.5 cm wide but often thinner, with much variation in size on a single individual. The

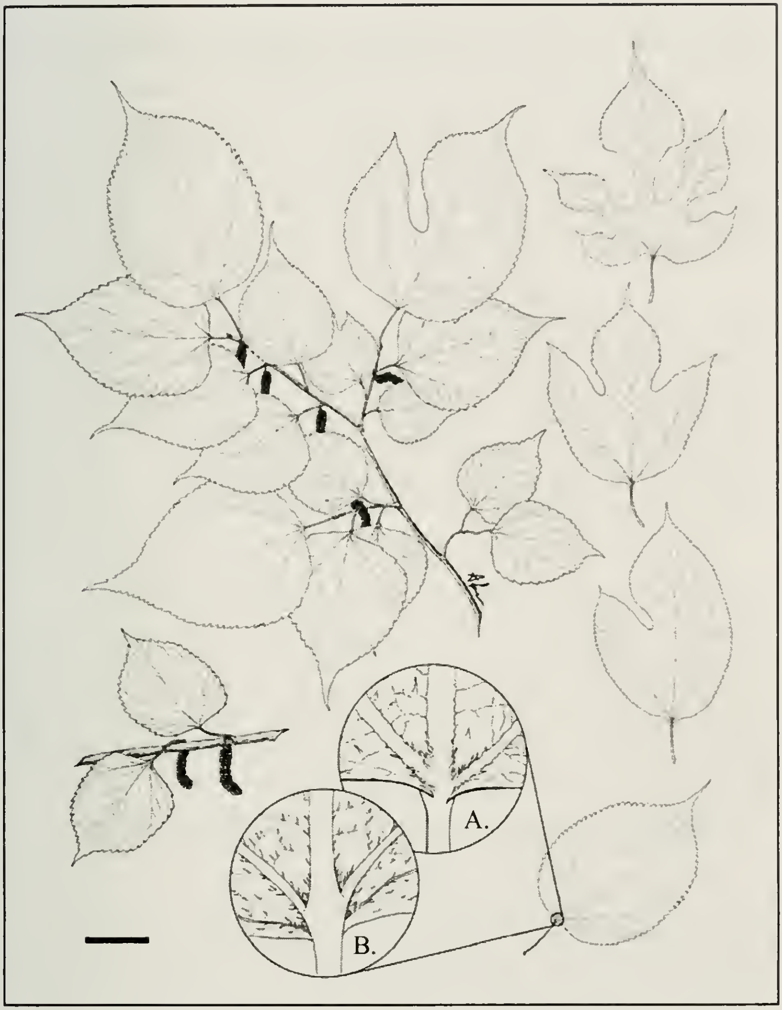

Figure 1. *Morus murrayana* with mature fruit showing variation in leaf morphology (leaves not at maximum size when fruit begins to mature); A. abaxial surface; B. adaxial surface. Scale bar = 5.0 cm.

specific epithet, *murrayana*, was chosen to honor Murray State University, Murray, KY (Murray State's Mulberry).

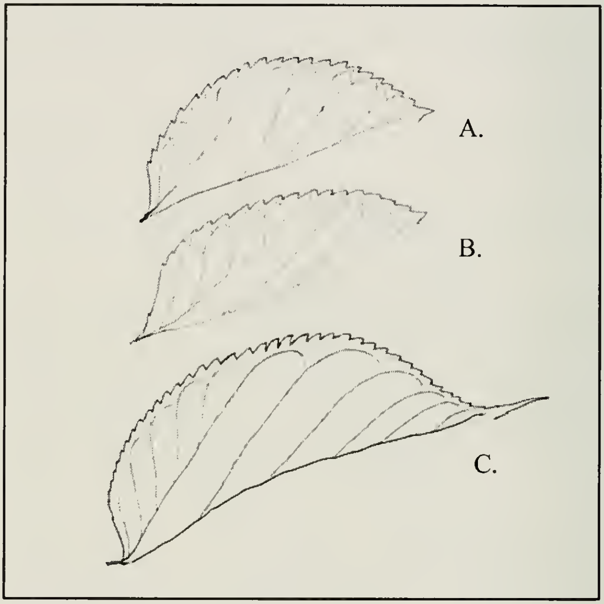

Figure 2. Leaves of A. *Morus rubra*; B. *M. alba*; and C. *M. murrayana* showing differences in veining patterns. Leaves not drawn to scale with each other. See text for further descriptions.

GENERAL MORPHOLOGY AND NATURAL HISTORY

Many individuals of *Morus murrayana* were observed growing in wet-mesic to dry-mesic open woodlands, in partly shaded to sunny locations; the few individuals located in heavy shade were growing poorly. They are virtually absent where Red Maple (*Acer rubrum* L.) has come in under overstories dominated by oaks (*Quercus* L. spp.) and hickories (*Carya* Nutt. spp.) and completely filled-in the canopy. *M. murrayana* occurs in natural as well as mildly disturbed localities, but generally is not in high disturbance places such as fence rows. Individuals observed for this study ranged in age from saplings to large trees; none were stump-sprouts. In other words, no correlation has been detected between the large leaves and the trees' age, condition, and/or habitat including soil type.

The morphological extremes in blade shape can be observed on the same branch next to each other. However, almost all trees produce either >80% lobed leaves or are >80% unlobed; few individuals display anything that approaches equal proportions of lobed and unlobed leaves. In fall, the leaves turn medium yellow, the smaller internal leaves falling first.

Trees produce either predominately staminate or carpellate inflorescences, but the presence of some staminate inflorescences on carpellate trees and vise-versa is common, especially on large saplings and older individuals. Both staminate and carpellate inflorescences may occur on the same large branch, usually separated on different twigs. This is in contrast with *M. rubra*, which is monoecious (Elias, 1987; Jones, 2005). Fruit ripens in western Kentucky during June and early July.

Morus murrayana has been sighted by one or more of the authors in Kentucky, Tennessee, Missouri, and Illinois. Herbarium specimens were also used to locate additional occurrences. Specimens of *M. murrayana* were readily recognizable among the accessions based on overall leaf size, caudate blade tips, and the venation pattern. Specimens confirm that this species has existed or currently exists in the four states personally documented by the authors, plus an additional six states that include Indiana, Mississippi, Louisiana, Virginia, North Carolina, and Alabama. The oldest specimen of *M. murrayana* (identified as *M. rubra*) was collected in the southern Illinois city of Carbondale in 1870. Other historical specimens date back to 1889, 1919, and 1937, in addition to those collected more recently. None of the label descriptions indicate a disturbed habitat, although habitat details were omitted on many labels. Most large-leafed specimens were identified as *M. rubra*, presumably due to the similar pattern of leaf pubescence. However, these trees were clearly problematic to taxonomists. Some specimens were identified as *M. alba* L., a few were listed as *M. rubra* x *M. alba*, and some had notations of "*Morus* sp." or "could not be determined." Many had annotations different than the original label identification (*M. alba* to *M. rubra* and vise-versa).

OTHER SPECIES OF *MORUS* IN NORTH AMERICA

Morus consists of about 12 species (Mabberley, 1997), only two of which (*M. rubra* and *M. microphylla* Buckley) are native to the United States, Canada, and Mexico; other species are native to Asia with some ranges extending west into Europe. *M. microphylla* is a small shrub or small tree with leaves to 5 cm in length. *M. murrayana* is most often confused with *M. rubra.* It can be distinguished from *M. rubra* based on leaf vein pattern (Fig. 2), leaves longer than 15 cm with caudate tips (vs. leaves <15 cm with cuspidate to broadly acute or acuminate tips), and fruits longer than 3 cm (vs. ≤3 cm).

Another species, *Morus alba*, is naturalized from Asia and is widespread in many areas of North America, as a result of escapes from cultivation as a street planting and from an unsuccessful attempt in the 1830s to establish a silk industry in the United States (Federico, 1997), as the leaves are used to feed larvae of the silkworm, *Bombyx mori* L. *M. alba* has leaves that are shiny above and pubescence below is either absent or scattered in vein axils or sparse along the larger veins.

Morus nigra L. and *M. alba* var. *multicaulis* (Perr.) Loudon (syn. *M. multicaulis* Perr.) also have been documented in the US (Wunderlin, 1997; Jones, 2005). Unlike *M. murrayana*, *M. nigra* has dark brown bark and elliptic fruit to 2.5 cm long and wide (H. Sang, 2003). Further, Wunderlin (1997) reports that *M. nigra*, occasionally cultivated in North America, is not known to naturalize. *M. alba* var. *multicaulis* has leaves to 30 cm (L. Sang, 2003). However, the blades are thick and wrinkled, which does not describe *M. murrayana*, and the pattern of restricted pubescence below and glabrous above is consistent with *M. alba* (not *M. murrayana*). Also, live specimens of *M. murrayana* show no tendency for multiple trunks.

Plants of *Morus rubra* and *M. alba* are known to hybridize and produce intermediate pubescence patterns on leaves, but they did not produce large leaves and fruit (Burgess et al., 2005). *M. murryana* was not observed with *M. rubra*, but in the few instances where it occurred in the vicinity of *M. alba*, intermediates were not present.

MOLECULAR ANALYSIS AND COMPARISONS

Materials and Methods:

The entire herbarium collection of *Morus* at the Missouri Botanical Garden (MO) was inspected for similar leaf and fruit characteristics by DES.

Sequences for the internal transcribed spacer region (ITS) of nuclear ribosomal DNA (nrDNA) are available in GenBank (www.ncbi.nlm.nih.gov) for the species of *Morus* native to the Eastern Hemisphere. For this study, DNA was extracted from two individuals of *M. rubra* and three of *M. murrayana* using Quagen DNeasy kits. Amplification was carried out following the protocol detailed in Saar et al. (2003). DNA was sequenced in the DNA Core Facility at Northern Illinois University, DeKalb, Illinois, on a Beckman-Coulter capillary sequencer. All sequences of *M. rubra* and *M. murrayana* were aligned with Clustal X software (Thompson et al., 2003). There were differences between the sequences of *M. rubra* and *M. murrayana*, but there was no intraspecific variation. Therefore, only one sequence of *M. murrayana* was necessary for comparison to existing GenBank accessions using a BLAST search (Altschul et al., 1990). The closest matches from GenBank, together with the new sequences of *M. rubra* and *M. murrayana*, were also aligned in Clustal X.

Results:

There were no herbarium specimens at MO with similar morphological characteristics from any continent, except those identified as *Morus rubra*.

The BLAST search indicates the closest species to *M. murrayana* are *M. macroura* Miq., *M. lhou* Koidz., *M. bombycis* Koidz., *M. cathayan* Hemsl., *M. atropurpurea* Roxb., *M. alba*, *M. nigra*, *M. australis* Poir., and *M. multicaulis*. Nucleotide polymorphisms are summarized in Fig. 3.

DISCUSSION

From the list of species whose sequences most closely match *M. murrayana* (Fig. 3), *Morus atropurpurea*, *M. bombycis*, *M. lhou*,

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                             18S       ITS 1         5.8S      ITS 2
                            ----/-------------------/--/---------------/
Base Number (reading dn.)→  0000000000000000000112222334444445555566666
                            0233567777777788888891239280127793479900001
↓GenBank No.(species)↓      6017823456789012349010932124301681325334675
AM042006 (M. bombycis)      CA---T-------------CCCA-CTCCAC--CGCGCCC-TTC
AM042001 (M. cathayana)     CA---T-------------CCCA-CTCCAC--CGCGCCC-TTC
AM042004 (M. australis)     CA---T-------------CCCA-aaCCAC--CGCGCCC-TTC
AM041999 (M. lhou)          CA---T-------------CCCA-CTCCAC--CGCGCCC-TTC
AM041998 (M. alba)          CA---T-------------CCCA-CTCCAC--CGCGCCC-TTC
AM042002 (M. nigra)         CA---T-------------CCCA-CTCCAC--CGCGCaC-TTC
AM042000 (M. macroura)      CA---T-------------CCCA-CTCCAC--CGCGCCC-TTC
AM042003 (M. multicaulis)   CAcaaT-------------CCCA-CTCCAC--CGCGCCCcTTC
FJ605516 (M. rubra)         CA---T-------------CCCA-CTCCAC--CGCG-CC-TTC
AY345145 (M. atropurpurea)  -A---T-------------CCCA-CTCCAC--CGCGCC--TTC
FJ605515 (M. murrayana)     Cg---cgtgcgcaatgcgctttgtCTttt-gttataCCGc--t

                   Notes:    *   *******************  **********  *#***
```

Figure 3. Summary of single nucleotide polymorphisms from 627 aligned bases from closest sequences to *Morus murrayana*, based on a BLAST search of GenBank. Sequences of *M. rubra* and *M. murrayana* from this study; others from GenBank accessions. In this alignment, ITS 1 begins at base 53; 5.8S gene begins at base 241; ITS 2 begins at base 402; 26S gene begins at base 625.

Notes: * unique base is *M. murrayana*; # unique base is *M. murrayana* and one other species.

and *M. multicaulis* are synonyms or varieties of *M. alba* (Ghafoor, 1985; Shu, 2003; Index Kewensis). All species from this list can be separated from *M. murrayana* based on morphology. *M. macroura* has yellowish-white fruit when mature, 6-12 cm long (Ghafoor, 1985; N. Sang, 2003). (*M. murrayana* fruits are blackish-purple and ≤ 4.0 cm.) The Trade Winds Fruit Company (www.tradewindsfruit.com) reports that *M. macroura* is only hardy to about 18-25°F (varies by individual). Western Kentucky and southern Illinois are in USDA zone 6 (average low of -10-0°F). *M. cathayana* has leaves 8-20 cm long, but they are thick and papery and winter buds are white pubescent (S. Sang, 2003), again, unlike *M. murrayana*. Morphologic distinctions from *M. alba* and *M. nigra* have been discussed previously. The fruits of *M. australis* are <2.5 cm long and plants are shrubs or small trees (Shu, 2003; J. Sang, 2003) with twisted branches (Dirr, 1998).

In addition to *M. alba*, ten other species from Asia are described in Flora of China (Shu, 2003). All species and varieties have leaves ≤ 15 cm except for *M. nigra* with 6-12(-20) and *M. cathayana* with 8-20 cm leaves (both discussed previously). Four species are included in the Flora of Pakistan. One of these species, *M. serrata* Roxb. (syn. *M. alba* var. *serrata* (Roxb.) Bureau), which is confined to the Indo-Pakistan subcontinent, has leaves 5-15 cm long. However, this species has longer stipules (1.5-2.5 cm long) and smaller fruits (0.8-2.5 cm long) (Ghafoor, 1985) than does *M. murrayana*.

The DNA sequence data separate *M. murrayana* from all others in the GenBank database. Sequences of *M. rubra* and the Asian species are similar, whereas *M. murrayana* has a notable 13-base insertion plus five 1-2 base indels and 16 single base substitutions (Fig. 3). It is clearly the most distinctive sequence of the entire group.

Although it is somewhat unusual to describe a new, wide-ranging, tree-sized species from the US, it is not without precedent. Due in part to the fact that there are so few species of *Morus* found in North America, very few characters are required to separate them. For example, the most common sympatric species ranges include *M. rubra* and *M. alba*, which can be separated based on leaf pubescence, thereby eliminating the need to elaborate with additional descriptions. With so few diagnostic characters utilized, *M. murrayana* falls within the parameters of virtually all plant keys for this genus in North America and falls under *M. rubra*. Thus, skepticism may be minimal because it is seemingly a good "fit" with the key. We have not observed *M. rubra* growing with *M. murrayana*, which could have facilitated direct comparisons. Further, with only two native species, *Morus* is not a particularly attractive candidate for taxonomic study in North America. The reputation of our native *M. rubra* may suffer due to a close resemblance with its weedy, non-native congener, *M. alba*.

Further studies are underway to learn more about the natural history of this species, and to produce a more detailed and extensive distribution map.

Key to Native and Introduced Species in North America:

1. Leaves 2-5 cm in length, strongly bicolored (dull dark green above, pale green below); shrubs or small straggly trees to 7 m; trees of the American SW and N Mexico. . . . *M. microphylla*
1. Leaves 3.8-14 cm long or longer, not strongly bicolored; trees. . . 2

   2. Leaves glabrous above and often lustrous, glabrous below or pubescence restricted to scattered hairs in vein axils or scattered along larger veins; mature fruit white through pink to blackish purple. . . . . *M. alba*
   2. Leaves scabrous on upper surface and soft pubescent below. . 3

3. Leaves with cordate bases; fruits elliptic to long ovoid, ≤ 2.5 cm long, maturing from red to black; landscape plant . . . . . *M. nigra*
3. Leaf bases variously oblique to slightly cordate; fruits cylindrical and >2.5 cm long; mature fruits blackish purple.. . . . 4

   4. Leaves to 15 cm long but often <10 cm, acute to acuminate at tip, lateral veins (secondary) above lowest lateral fairly straight and ending in a tooth; mature fruit to 3 cm long. . . . . *M. rubra*
   4. Leaves to 38 cm long, outer three leaves on branchlets almost always ≥ 15 cm, caudate, lateral veins curve before reaching margins, only tiniest veins end in a tooth; mature fruit to 4 cm long and 1.5 cm wide but often thinner, with much size variation on a single individual. . *M. murrayana*

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ANALYSES AND TAXONOMIC UTILITY OF THE CEDARWOOD OILS OF THE SERRATE LEAF JUNIPERS OF THE WESTERN HEMISPHERE

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ABSTRACT

Analyses of the wood oils of the serrate leaf margined *Juniperus* of the western hemisphere (21 species, 3 varieties and 1 form) are presented. All taxa have considerable amounts of cedrol, widdrol, cis-thujopsene, α-cedrene and β-cedrene. In general, there was little correlation between cedarwood oil compositions and phylogeny in this section of *Juniperus*. *Phytologia 91(1):117-139 (April, 2009)*.

KEY WORDS: *Juniperus*, Cupressaceae, wood oils, taxonomy, serrate leaf, cedrol, widdrol, cis-thujopsene, α-cedrene and β-cedrene.

The serrate leaf margined junipers of the western hemisphere appear to represent a natural sub-group of *Juniperus* (Adams, 2008). A phylogenetic tree (Fig. 1) shows the relationships among these junipers based on nrDNA and trnC-trnD sequences. These junipers evolved at the margins of deserts in the southwestern US and Mexico. The southwestern US - Mexico, the northern-Mediterranean, and central-Asia - western China are the three centers of biodiversity of *Juniperus*. The serrate leaf junipers appear to be the most recent species of the genus (Adams, 2008). The group is composed of: *J. angosturana* R. P. Adams, *J. arizonica* (R. P. Adams) R. P. Adams, *J. ashei* Buchholz, *J. a.* var. *ovata* R. P. Adams, *J. californica* Carriere, *J. coahuilensis* (Martinez) Gaussen ex R. P. Adams, *J. comitana* Martinez, *J. compacta* (Mart.) R. P. Adams, *J. deppeana* Steudel var. *deppeana*, *J. d.* forma *elongata* R. P. Adams, *J. d.* forma *sperryi* (Correll) R. P. Adams, *J. d.* forma *zacatacensis* (Mart.) R. P. Adams, *J. d.* var. *gamboana* (Mart.) R. P. Adams, *J. d.* var. *patoniana* (Martinez) Zanoni, *J. d.* var. *robusta* Martinez, *J. durangensis* Martinez, *J. flaccida* Schlecht., *J. grandis* R.

P. Adams, *J. jaliscana* Martinez, *J. martinezii* Perez de la Rosa, *J. monosperma* (Engelm.) Sarg., *J. monticola* Martinez forma *monticola*, *J. m.* forma *orizabensis* Martinez, *J. occidentalis* Hook., *J. osteosperma* (Torr.) Little, *J. pinchotii* Sudworth, *J. poblana* (Martinez) R. P. Adams, *J. saltillensis* M. T. Hall, and *J. standleyi* Steyermark.

Although the leaf essential oils of *Juniperus* have been extensively utilized for taxonomic purposes (Adams, 1991a; Adams, 2008), the wood oils have not received much taxonomic attention. Adams (1987, Adams, 1991b) examined the wood oils of junipers from the United States as potential sources of cedarwood oil and reviewed the literature on early analyses of *Juniperus* wood oils.

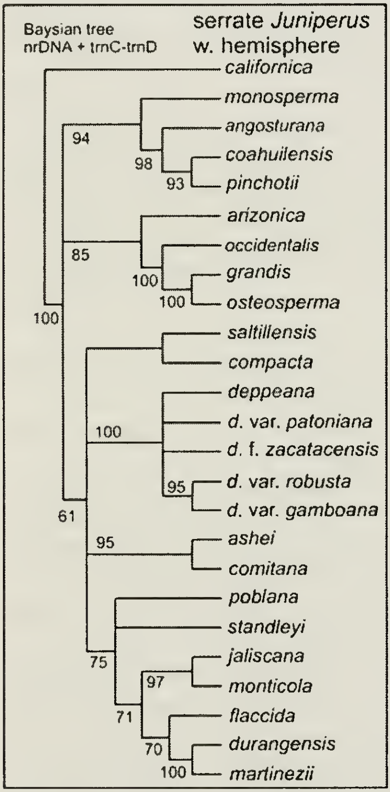

Figure 1. Phylogenetic tree of the serrate junipers (from Adams, 2008).

Commercial cedarwood oils have been obtained from 3 genera of Cupressaceae: *Juniperus* (Texas, Virginia and African oils); *Cupressus* (China) and *Cedrus* (Morocco, India) according to Bauer and Garbe (1985). However, Texas (*Juniperus ashei* Buch.), Virginia (*J. virginiana* L.) and Chinese (putatively, *Cupressus funebris* Endl.) cedarwood oils account for almost all the cedarwood oil commercially produced today (Lawrence, 2003). The heartwood oils of the Cupressaceae are well known for having the same components across the family (i.e., evolutionally conserved), so the occurrence of similar oils in different genera is not surprising. It is probably due to the conservation of the principal commercially important components (cedrol, widdrol, cis-thujopsene, α-cedrene and β-cedrene) that the wood oil compositions have not been utilized for taxonomic purposes.

A second reason that wood oils have not been widely utilized is the difficultly in taking samples. Leaf sampling does not harm a tree. But to obtain a wood sample requires cutting down the tree, cutting off a limb, or taking a coring sample. Taking tree cores is the least destructive, but presents a problem if steam distillation is utilized to obtain the wood oil, as a core sample consists of only a few grams of wood and the oil can easily be lost on the walls of the steam distillation apparatus. Comparison of steam distillation versus solvent extraction using wood from the same tree (*J. ashei*) is shown in Table 1. Notice that the highest yield was obtained from steam distilled wood shavings and that 24 h of pentane extraction of wood chips removed only about one- half of the oil obtained by steam distillation of wood shavings. Using finely ground wood, resulted in about the same yield as using wood chips.

Table 1. Comparison using *J. ashei* wood for yields (oven dry wt basis) and the concentrations of key components of oils obtained by steam distillation (24 h), vs. various wood chip sizes and extractions with pentane .

variable	steam distilled shavings[1]	Pentane extractions wood chips ext'd 24 h[2]	 wood from [2] re-ext'd +72h[3]	 ground wood ext'd 24h[4]
per cent yield	3.7%	1.6%	1.6%	1.6%
α-cedrene	7.0	2.4	4.2	1.8
β-cedrene	1.7	1.1	2.0	1.0
cis-thujopsene	14.6	5.6	10.8	27.7
cedrol	48.1	64.3	66.1	47.2
cis-thujopsenic acid	0.6	10.4	4.8	1.1

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[1] shavings obtained from original wood, then steam distilled 24 h.

[2] wood cut into 25 mm x 3 mm x 3mm wood chips, pentane extracted by shaking, 24 h. (# 9696)

[3] wood from 1st 24 h extraction ([2]), then the extracted wood chips were ground in a coffee mill and a second, 72h, pentane (# 9697) performed.

[4] original sample wood ground in coffee mill, then pentane extracted pentane for 24 h (#9700).

None of the pentane extractions gave exactly the same results as the steam distillation (Table 1). However, steam distillation can result in decomposition (Adams, 1991b), whereas solvent extraction is a very gentle method. This is shown in the marked increase of cis-thujopsenic acid in the solvent extracts (Table 1). Free acids may be dissolved in the steam condensate and return to the boiling chamber or they may decompose during distillation (Adams, 1991b). If all the wood samples are extracted in the same manner (ex. 24 h, shaking in pentane, cut to uniform sizes), solvent extraction should produce a reasonable snapshot of the profile of the wood oils.

The purpose of this paper was to present analyses of the wood oils of all the serrate junipers of the western hemisphere and evaluate these data for use as taxonomic characters.

MATERIAL AND METHODS

Samples used in the study: *J. angosturana*, 10.5 km e of Villa Juarez (road from Cerritos to Rio Verde), thence s 1.3 km, San Luis Potosi, Mexico, Lab # 9743 *Adams 8714*, *J. arizonica,* Rock Hound St. Park, Luna Co., NM, Lab # 9725, *Adams 7637*, *J. ashei*, 1.6 km e of Llano R., on I10, east of Junction, Kimble Co., TX, Lab #9721., *Adams 5010*, *J. californica*, 13 km n of I40 on road to Kelso, San Bernardino Co., CA, Lab # 9750, *Adams 5071*, *J. coahuilensis*, 32 km n of Alpine, TX, Jeff Davis Co., Lab # 9723, *Adams 4994*, *J. comitana*, 14 km s of Comitan and thence 14 km e on rd to Montebello, Chiapas, MX, Lab # 9737, *Adams 6862*, *J. compacta*, near the summit of Cerro Potosi, Nuevo Leon, MX, Lab # 9742, *Adams 6898*, *J. deppeana* var. *deppeana*, 32 km nw of Ft. Davis on Tex 118, Jeff Davis Co., Lab # 9744, *Adams 4983*, *J. d.* var. *gamboana*, 17 km n of Comitan on Mex. 190, Chiapas, MX, Lab # 9735, *Adams 6864*, *J. d.* var. *patoniana*, km 152 on Mex. 40, 52 km w of El Salto, Durango, MX, Lab # 9738, *Adams 6838*, *J. d.* var. *robusta*, west of Creel, Chihuahua, MX, Lab # 9728, *Adams 6826*, *J. d.* forma *zacatacensis*, 18 km w of Sombrerete, between km 178 & 179 on Mex. 45, Zacatecas, MX, Lab # 9740, *Adams 6840*, *J. durangensis*, nw side of Mex. 40, km 152, 52 km w of El Salto, Durango, MX, Lab # 9749, *Adams 6832*, *J. flaccida*, 20-25 km e of San Roberto Jct., on Mex. 60, Nuevo Leon, MX, Lab # 9745

Adams 6892, *J. grandis*, at Sonora Bridge Campground Rd., 2 km w of Jct of CA 108 and US 285 on CA 108, Mono Co., CA, Lab # 9734, *Adams 5061*, *J. jaliscana*, 19 km e of Mex. 200, on road to Cuale, Jalisco, MX, Lab # 9739, *Adams 6846*, *J. martinezii*, on La Quebrada Ranch, 40 km n of Lago de Moreno off Mex. 85 to Amarillo, thence 10 km e on dirt rd to La Quebrada Ranch, Jalisco, MX, Lab # 9727, *Adams 8709*, *J. monosperma*, 1.6 km w of Santa Rosa, on I40, Guadalupe Co., NM, Lab # 9748, *Adams 5028*, *J. monticola* forma *monticola*, 1 km n of jct of Mex. 105 and El Chico Natl. Park, on road to El Chico Natl. Park (8 km ne of Pachuca), Hidalgo, MX, Lab # 9747, *Adams 6874*, *J. occidentalis*, 58 km w of Juntura on US 20, Malheur Co., OR, Lab # 9724, *Adams 5085*, *J. osteosperma*, 25 km e of Monticello, on US 666, San Juan Co., UT, Lab # 9741, *Adams 5053*, *J. pinchotii* Sudw., 10 km w of Sheffield, on I10, Pecos Co., TX, Lab # 9722, *Adams 5004*, *J. poblana*, at KM 62 on Mex. 190, 62 km s of Oaxaca, Oaxaca, MX, Lab # 9729 *Adams 6871*, *J. saltillensis*, 14 km e of San Roberto Jct., on Mex. 60, Nuevo Leon, MX, Lab # 9726, *Adams 6887* and *J. standleyi*, 24 km nw of Huehuetango on road to San Juan Ixcoy (s of El Oro), Guatemala, Lab # 9746, *Adams 6852*. Vouchers are in the herbarium, Baylor University (BAYLU).

Wood samples were radially cut in 1 cm segments using a band saw. The radial sections were then cut linearly into 2 x 5 mm (x 1 cm) pieces. The wood (25 g) was placed in a 125 mL screw cap bottle to which 50 mL of pentane was added. The bottles were shaken for 24 h on a rotary shaker. The pentane extract was filtered and the pentane evaporated by use of nitrogen. The extracted wood was oven dried 48 h, 100 ^{O}C for use in the oven dry weight calculations. Percent yields were determined on an oven dry weight basis as: 100 x oil wt./(oil wt. + oven dry wood wt.). All oil samples (including commercial cedarwood oils) were dissolved in diethyl ether (10% oil solution) and stored at -20^{O}C until analyzed.

The extracts were analyzed on a HP5971 MSD mass spectrometer operated in the EI mode, scan time 1sec., acquisition mass range: 41-500, 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, 0.2 µL injected of a 10 % solution in diethyl ether, and split 1/10, injector: 220 °C, transfer and MSD: 240 °C, column temperature linearly programmed: 60° - 246 °C/ 3 °C min. Identifications were made by library searches of our volatile oil library (10), using the HP Chemstation library search routines, coupled with retention time data of authentic reference compounds. Quantitation was by use of the HP Chemstation software. Normally one would report the data as FID values, but considering the difficultly of the peaks overlapping such that quantitation involved using single ion chromatograms to estimated the concentrations (eg. cedrol/ widdrol, etc.), it was not practical to quantitate the components by GC-FID.

RESULTS AND DISCUSSION

Tables 2 and 3 show the complete analyses of the cedarwood oils of all 25 taxa of serrate leaf margined junipers of the western hemisphere. Due to the use of a liquid extraction, considerable amounts of cis-thujopsenic acid (and other acids) were present in the extracts. It appears much of the cis-thujopsenic acid is degraded or left in the water condensate during steam distillation (Table 1). Although most taxa have considerable amounts of cedrol, widdrol, cis-thujopsene, α-cedrene and β-cedrene, there are many un-identified sesquiterpenoids. However, it is surprising to find such a large number of un-identified compounds. Often, an un-identified compound was present in only one or twice taxa. It appears that there may be considerable synthesis of non-specific products in the wood. Keeling and Bohlmann (2006) discuss the defense nature of terpenoids and note that maintaining a diverse array of chemicals may be effective as a plant defense.

The major components useful in commercial cedarwood oils are cedrol, widdrol, cis-thujopsene, α-cedrene and β-cedrene. Table 4 shows the compositions of these five constituents in the 25 taxa of this study. Notice that even in phylogenetically similar taxa (Figure 1, *arizonica, occidentalis, grandis* and *osteosperma*), there is considerable variation in the amounts of these components. In fact, it seems that there is as much variation among these presumably closely related species as among other more distantly related species (Table 4).

The sum of cedrol, widdrol, cis-thujopsene, α-cedrene and β-cedrene gives one some indication of the oils' utility as cedarwood oil. The sums range from 22% of the total oil (*J. jaliscana*, Table 4) to 70.4% *(J. angosturana*, Table 4). The species with low sums generally have considerable amounts of unknown compounds. The percent yields ranged from 0.04% (*J. deppeana* var. *patoniana*) to 3.4% (*J. standleyi*). As a reference, the source of Texas cedarwood oil, *J. ashei*, had a 1.7% oil yield. The product of the sum of the key components x % yield (S x %, Table 4) is an index to the relative commercial potential of a species. This index varied from 2.0 (*J. deppeana* var. *patoniana*) up to 169.4 for *J. angosturana* with *J. ashei* having an index value of 104.9. Although *J. angosturana* (169.4), *J. d.* var. *gamboana* (128.6) and *J. standleyi* (143.1), all from Mexico, scored higher than *J. ashei* from the United States (mostly Texas), they are generally not found in large enough populations to sustain continued harvest of trees for cedarwood oil. *Juniperus arizonica, J. californica, J. grandis, J. monosperma, J. occidentalis* and *J. pinchotii* are weedy, widespread junipers of the western US but these are either lacking a high concentration of the key compounds or their percent yields are low and do not appear suitable for commercial cedarwood oil production.

In conclusion, the cedarwood oils in this section of *Juniperus* do not seem to be useful to taxonomy at the specific level. It would be interesting to examine geographic variation within a species to determine if the wood oils might be useful for populational studies.

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Table 2. Composition of cedarwood oils from the serrate leaved *Juniperus*. cailf = *J. californica*, mono = *J. monosperma*, ango = *J. angosturana*, coah = *J. coahuilensis*, pine = *J. pinchotii*, ariz = *J. arizonica*, occi = *J. occidentalis*, gran = *J. grandis*, oste = *J. osteosperma*, salt = *J. saltillensis*, comp = *J. compacta*.

AI	Compound	calif	mono	ango	coah	pine	ariz	occi	gran	oste	salt	comp
1178	naphthalene	0.4	0.6	0.1	0.1	4.3	0.1	0.1	0.4	0.3	0.1	0.1
1186	α-terpineol	-	-	-	-	-	-	-	-	-	-	0.1
1232	thymol methyl ether	-	-	-	-	0.2	-	-	t	-	-	-
1387	α-duprezianene	1.0	-	0.1	-	0.4	0.4	t	0.1	t	0.1	0.1
1390	7-epi-sesquithujene	-	-	0.1	0.2	-	-	-	t	-	-	-
1400	β-longipinene	-	-	-	-	-	t	-	-	-	-	-
1402	α-funebrene	-	-	-	-	-	-	-	-	-	t	-
1405	sesquithujene	-	-	-	0.1	-	-	-	-	-	-	-
1410	α-cedrene	1.2	0.7	1.4	1.1	3.6	1.9	0.9	1.4	1.3	1.2	0.4
1411	2-epi-β-funebrene	-	-	-	-	-	-	-	-	-	-	0.3
1413	β-duprezianene	1.3	-	-	-	-	0.6	-	-	-	t -	0.3
1419	β-cedrene	0.6	0.5	0.7	0.5	1.6	0.6	0.8	0.9	0.7	0.7	0.4
1429	cis-thujopsene	2.2	9.0	17.5	18.4	12.0	14.5	6.4	15.4	13.7	9.0	2.5
1436	isobazzanene	-	-	-	-	-	-	-	-	-	t	-
1449	α-himachalene	-	-	0.2	0.3	-	0.3	t	0.2	t	0.1	-
1454	(E)-β-farnesene	-	-	0.2	-	-	-	-	-	-	-	-
1464	thujopsadiene	0.2	0.6	-	0.8	0.6	0.7	0.2	0.4	0.3	0.4	0.1
1464	α-acoradiene	-	-	0.2	0.1	-	-	-	-	-	-	-
1469	β-acoradiene	-	-	-	-	t	-	-	-	-	-	-
1470	10-epi-β-acoradiene, isomer	-	-	t	-	-	-	-	-	-	-	-
1479	β-chamigrene	0.2	0.3	-	0.3	0.3	t	0.2	-	-	0.2	-

AI	Compound	calif	mono	ango	coah	pinc	ariz	occi	gran	oste	salt	comp
1479	ar-curcumenene	-	-	-	0.1	-	-	0.1	-	-	-	-
1481	γ-himachalene	-	-	0.2	-	-	0.5	-	0.3	0.2	-	-
1485	11-αH-himachala-1,4-diene	-		-	-	0.5	-	-	-	-	-	-
1489	β-selinene	0.6	-	-	-	-	-	0.1	0.2	-	-	0.1
1498	β-alaskene	-	-	-	0.1	-	-	-	-	-	-	-
1498	α-selinene	-	-	-	-	-	0.3	0.2	0.1	-	-	-
1499	pseudowiddrene	-	-	-	-	-	0.5	-	0.1	0.2	0.3	-
1500	β-himachalene	0.4	-	0.7	0.3	0.9	0.4	-	0.2	0.2	-	-
1502	trans-β-guaiene	-	0.2	-	-	-	-	-	-	-	-	-
1503	α-chamigrene	-	-	-	-	-	t -	t	0.1	-	1.7	-
1504	cuparene	4.8	1.3	0.3	1.2	2.4	1.7	0.9	1.4	1.1	1.2	0.8
1512	α-alaskene	-	-	0.1	0.2	-	0.5	-	0.2	t	0.1	-
1514	butylated hydroxy toluene*	-		-	-	1.3	-	-	t	t	-	-
1521	trans-calamenene	-	0.5	-	-	0.7	0.3	t	t	t	t	-
1522	δ-cadinene	-	-	-	-	-	-	0.2	t	-	-	-
1532	γ-cuprenene	-	-	0.3	-	-	-	-	-	-	-	-
1536	italicene ether	0.3	0.5	-	0.3	-	-	-	t	-	0.4	-
1540	sesquiterpenol 43,44,95,220	-	-	-	0.6	-	-	-	-	-	-	-
1541	sesquiterpenol 43,97,205,220	-	-	-	-	-	1.3	-	-	-	-	-
1541	8,14-cedranoxide	0.3	0.8	-	-	0.5	-	-	-	-	-	-
1542	δ-cuprenene	-	-	0.1	-	-	-	0.3	0.1	t	-	-
1546	elemol	-	0.2	-	0.6	-	-	-	-	-	-	-
1562	longicamphenylone	-	-	-	-	-	-	-	-	-	-	0.2
1582	caryophyllene oxide	-	0.3	-	0.4	0.4	-	0.1	-	-	-	-
1589	allo-cedrol	2.2	1.7	0.9	2.0	1.4	1.0	0.9	1.2	1.0	1.0	4.1

AI	Compound	calif	mono	ango	coah	pinc	ariz	occi	gran	oste	salt	comp
1595	cis-dihydro-mayurone	0.5	t	-	-	0.1	0.3	0.3	0.2	0.3	0.2	-
1599	widdrol	11.7	7.1	t	-	4.2	7.6	t	-	t	t	-
1600	cedrol	11.7	14.1	51.0	17.4	38.6	3.1	43.3	41.8	36.3	46.9	54.2
1612	β-biotol	0.6	1.3	0.5	0.5	t	-	t	0.4	-	0.3	-
1618	epi-cedrol	-	-	0.6	0.6	0.4	t	1.2	1.1	0.3	0.3	1.3
1622	sesquiterpenol 111,43,69,220	-	-	-	0.6	-	-	-	-	-	-	-
1634	α-acorenol	0.8	5.7	3.6	5.9	3.2	3.4	4.0	3.1	3.1	6.8	0.7
1636	β-acorenol	0.7	1.8	0.8	1.6	1.2	0.9	1.0	0.8	0.8	1.3	0.4
1639	1,7-di-epi-α-cedrenal	-	-	-	-	-	-	-	-	-	-	0.5
1641	3-iso-thujopsanone	0.8	-	-	-	-	-	-	0.3	-	-	-
1648	sesquiterpenol 119,43,204,220	-	-	-	1.7	-	-	-	0.9	-	0.5	-
1649	sesquiterpenol, 43,119,71,220	-	1.5	0.8	-	1.9	-	0.9	-	-	-	-
1649	β-eudesmol	1.8	6.9	0.6	3.2	0.2	-	0.4	-	3.7	-	-
1652	α-eudesmol	-	1.4	-	1.4	t	-	-	-	1.5	-	-
1658	selin-11-en-4α-ol	1.3	-	-	-	-	-	0.7	-	-	0.9	-
1660	sesquiterpen-ol 135,79,220	-	-	0.8	-	-	-	-	-	-	-	-
1662	sesquiterpenal 43, 123, 236	4.1	-	-	-	-	-	-	2.3	-	-	-
1663	sesquiterpenal 135,91,69,236	-	-	-	-	-	2.2	2.0	-	-	-	1.9
1665	intermedeol	-	-	-	-	0.6	-	-	-	-	-	-
1665	sesquiterpenal 43,123,95,236	-	3.2	-	1.6	1.9	-	-	-	-	-	-
1666	sesquiterpenal 43,69,135,236	-	-	-	-	-	-	-	-	1.9	-	-
1666	sesquiterpenol 119,41,93,220	-	-	0.7	-	-	-	-	-	-	-	-
1667	sesquiterpenol 105,91,119,218	-	-	-	-	-	4.4	1.4	-	-	-	-
1668	sesquiterpenol 41,69,91,220	-	-	-	0.7	-	-	-	-	-	-	-
1675	cadalene	0.3	-	-	-	-	-	-	-	-	-	-

AI	Compound	calif	mono	ango	coah	pinc	ariz	occi	gran	oste	salt	comp
1683	epi-α-bisabolol	-	1.5	0.2	0.5	0.4	-	0.6	0.5	-	-	-
1685	α-bisabolol	-	-	0.2	0.5	-	-	0.1	t	-	-	-
1688	8-cedren-13-ol	-	-	-	-	3.2	-	-	0.4	1.1	-	0.4
1689	sesquiterpenol 43,121,132,222	-	-	-	-	-	-	-	-	-	-	0.8
1692	junicedranol	-	0.8	-	-	-	-	-	-	-	-	-
1694	sesquiterpenol, 41,91,135,220	2.5	-	-	-	-	-	-	-	-	2.6	-
1699	sesquiterpenol 135,79,105,220	-	1.5	3.6	4.0	-	3.7	-	2.6	3.5	-	1.0
1701	cis-thujopsenol	-	4.3	4.8	4.4	-	-	-	2.4	2.5	2.6	-
1703	mayurone	18.5	4.3	-	-	3.5	-	-	-	-	-	1.2
1708	cis-thujopsenal	-	-	-	1.1	-	-	-	-	1.7	2.5	-
1709	sesquiterpenal 123,41,218	3.2	2.3	-	-	1.5	0.9	-	0.8	-	-	-
1714	sesquiterpene 43,135,207232	4.2	2.7	-	-	1.2	-	-	-	-	-	0.4
1716	sesquiterpenol 43,135,207,222	-	-	-	1.1	-	-	-	-	-	-	-
1724	(Z)-nuciferol	-	-	-	-	-	-	-	-	1.1	-	-
1726	sesquiterpenal 43,137,218,236	2.8	2.2	-	-	0.5	-	-	t	-	-	-
1729	sesquiterpenal 119,147,162,236	-	-	-	2.3	-	-	1.6	t	-	-	0.4
1748	sesquiterpenal 123,55,41,234	-	1.0	-	-	-	-	-	-	-	-	-
1751	sesquiterpenol 105,41,147,220	-	-	0.8	-	-	-	1.1	-	1.0	-	-
1751	cuparenal	0.8	0.8	-	-	0.4	-	-	-	-	-	-
1762	β-acoradienol	4.6	- -	0.5	-	-	1.2	-	0.5	-	0.8	0.7
1765	β-costol	-	-	-	-	-	-	-	0.3	0.3	-	0.5
1766	sesquiterpenal 41,55,107,234	-	1.7	-	-	0.6	-	-	0.2	-	-	-
1773	α-costol	0.4	-	-	-	-	-	0.6	-	-	-	-
1789	sesquiterpenol 123,41,135,220	-	-	0.6	-	-	-	-	-	-	-	-
1793	sesquiterpenal 189,43,207,236	-	-	-	4.8	-	-	0.5	-	-	-	-

AI	Compound	calif	mono	ango	coah	pinc	ariz	occi	gran	oste	salt	comp
1796	sesquiterpenal 148,131,41,218	-	-	-	-	0.7	2.8	0.6	0.6	-	-	-
1797	sesquiterpenal 43,189,207,236	-	3.1	-	-	-	-	-	-	1.2	-	2.8
1801	sesquiterpene 95,91,171,232	1.3	-	-	-	-	-	-	-	-	-	-
1802	sesquiterp..ol 121,136,177,220	-	-	1.8	1.1	0.6	0.8	1.0	0.8	0.6	1.4	0.5
1805	sesquiterpenal 121,136,177,234	-	0.8	-	-	-	-	-	-	-	-	-
1810	sesquiterpenal 55,135,234	0.8	-	-	-	-	-	-	-	-	-	-
1813	cryptomeridiol	-	0.6	0.3	0.8	-	-	-	-	0.5	-	-
1815	sesquiter. acid 149,91,105,234	1.0	-	-	-	-	1.0	0.5	1.3	-	1.3	-
1831	sesquiterpenol 91,105,135,220	-	-	0.5	-	-	-	-	-	-	-	-
1836	sesquiterpene 43,119,190	0.7	-	-	-	-	-	-	-	-	-	-
1837	sesquiterpene 119,161,43,191	-	-	-	-	-	2.1	-	-	-	-	-
1863	cis-thujopsenic acid	1.7	3.6	0.9	1.8	0.7	6.7	5.9	5.5	6.6	5.8	0.1
1889	cedrane-8S,14-diol	2.2	1.8	-	3.1	-	-	2.7	2.1	2.7	-	15.2
1897	cedrane-8S,13-diol	-	t	-	1.0	-	-	-	0.3	0.1	-	0.7
1911	sesquiterpenal 41,123,211,234	1.6	-	-	-	-	-	-	-	-	-	-
1917	sesquiterpenal 41,123,149,234	-	3.0	-	0.6	-	-	-	0.5	-	-	-
1929	sesquiterpenal 121,136,191,234	-	-	-	-	-	-	0.7	0.8	0.7	1.1	-
1932	cuparenic acid	0.6	-	-	-	-	-	-	-	-	-	-
1945	sesquiterpenal 121,136,191,234	-	-	-	-	-	1.4	0.8	1.4	-	1.6	0.6
1953	sesquiterpene 43,135,181,256	2.4	-	-	-	-	-	-	-	-	0.7	-
1959	nootkatin	-	-	-	1.8	-	-	-	-	-	-	-
1959	sesquiterpene 135,43,181,256	-	1.4	-	-	-	-	-	-	-	-	-
1960	sesquit. acid 121,136,191,234	-	-	-	-	-	-	-	-	1.5	-	-
1962	sesquiterp. acid 41,43,135,256	-	-	-	-	-	-	-	0.8	-	-	-

AI	Compound	calif	mono	ango	coah	pinc	ariz	occi	gran	oste	salt	comp
1964	sesquiterp. acid 135,43,163,234	-	-	-	1.1	-	5.3	-	-	-	-	-
2158	octadecanoic acid	t	-	-	-	-	-	-	-	-	-	-
2331	trans-ferruginol	-	-	-	-	-	-	-	0.1	-	-	0.4

For unknown cpds., base ion (100%) is underlined, next ions are major ions, *butylated hydroxy toluene is normally considered a non-natural product, RI = Arithmetic Index on DB-5 (= SE54). column. Compositional values less than 0.1% are denoted as traces (t). Unidentified components less than 0.5% are not reported.

Table 3. Composition of cedarwood oils from serrate leaves *Juniperus*. depp = *J. deppeana*, dpat = *J. d.* var. *patoniana*, dzac = *J. d. f. zacatacensis*, drob = *J. d.* var. *robusta*, dgam = *J. d.* var. *gamboana*, ashe = *J. ashei*, comt = *J. comitiana*, pobl = *J. poblana*, stan = *J. standleyi,* jali = *J. jaliscana*, mont = *J. monticola*, flac = *J. flaccida*, dur = *J. durangensis*, mart = *J. martinezii.*

AI	Compound	depp	dpat	dzac	drob	dgam	ashe	comt	pobl	stan	jali	mont	flac	dur	mart
932	α-pinene	-	-	-	-	-	-	-	-	-	-	-	-	-	0.1
969	sabinene	-	-	-	-	-	-	-	-	-	-	-	-	-	0.1
1024	limonene	-	-	-	-	-	-	-	-	-	-	-	-	-	0.1
1178	naphthalene	0.4	1.4	0.6	0.3	0.1	0.1	0.1	0.1	0.4	0.1	0.2	0.2	0.3	0.1
1298	carvacrol	-	0.1	-	-	-	-	-	-	-	-	-	-	-	-
1380	2-epi-α-funebrene	0.1	-	0.1	-	-	-	-	-	0.1	-	-	-	-	-
1387	α-duprezianene	0.3	0.1	0.4	0.2	0.1	-	t	0.1	-	-	0.2	0.1	0.2	0.2
1389	β-elemene	-	-	-	-	-	-	0.4	-	-	-	-	-	-	-
1390	7-epi-sesquithujene	-	-	t	-	-	-	-	-	0.1	-	-	-	-	-
1400	β-longipinene	-	-	0.1	0.1	t	-	-	-	-	-	-	-	-	-
1402	α-funebrene	-	-	-	t	-	t	-	-	-	-	-	-	-	-
1405	sesquithujene	-	-	-	-	-	-	-	-	0.1	-	-	-	-	-
1410	α-cedrene	7.6	1.5	4.1	3.9	2.5	0.6	0.5	3.3	2.6	2.6	1.9	3.5	1.2	2.0
1413	β-duprezianene	-	t	-	t	-	-	-	-	-	0.6	t	-	-	-
1417	(E)-caryophyllene	-	-	-	-	-	-	0.1	-	-	-	-	-	-	-
1419	β-cedrene	2.0	0.8	1.4	0.9	1.0	0.4	0.2	0.9	1.2	0.7	0.9	1.0	0.9	0.9
1424	sesquiterpene 107,131,187,202	-	-	-	-	-	-	0.5	-	-	-	-	-	-	-
1429	cis-thujopsene	9.1	7.2	10.3	6.3	5.5	12.0	2.9	6.6	10.3	7.6	14.3	4.8	7.9	6.8
1436	isobazzanene	-	-	t	-	-	-	-	-	0.1	-	-	-	-	-

AI	Compound	depp	dpat	dzac	drob	dgam	ashe	comt	pobl	stan	jali	mont	flac	dur	mart
1449	α-himachalene	0.2	-	t	0.1	-	0.1	-	-	-	0.1	-	0.1	-	-
1454	(E)-β-farnesene	-	-	t	-	-	-	-	-	-	-	-	-	-	-
1464	thujopsadiene	-	0.6	0.1	-	-	0.3	0.2	0.1	-	0.2	0.3	0.1	0.2	0.3
1464	α-acoradiene	1.1	-	0.6	0.6	t	-	-	0.3	0.7	0.1	0.3	0.1	0.2	-
1469	β-acoradiene	0.3	-	0.5	0.2	t	-	-	0.1	0.1	-	t	t	-	0.1
1476	β-chamigrene	-	0.3	0.7	0.4	0.2	-	-	0.1	-	0.4	0.3	t	t	0.3
1479	ar-curcumenene	-	-	-	0.2	-	t	-	0.1	-	-	-	t	-	0.1
1481	γ-himachalene	0.3	-	t	-	-	0.3	-	-	-	-	-	-	-	-
1485	11-αH-himachala-1,4-diene	-	-	-	-	-	-	t	-	-	-	-	-	-	-
1489	β-selinene	-	-	-	-	-	-	0.5	-	-	-	-	-	-	-
1498	β-alaskene	0.2	-	-	0.1	-	-	-	t	-	t	-	-	-	-
1498	α-selinene	-	-	0.7	-	-	-	0.4		-	-	-	-	-	-
1499	pseudowiddrene	0.6	-	0.7	-	-	0.2	-	0.6	-	0.7	0.5	-	-	0.4
1500	β-himachalene	0.5	0.4	-	1.2	0.5	0.2	0.2	-	0.4	0.6	-	0.6	0.4	0.5
1503	α-chamigrene	t	-	t	t	-	t	-	t	0.2	0.2	t	-	-	t
1504	cuparene	1.6	1.3	2.1	1.2	0.8	1.2	0.3	1.1	0.6	1.0	1.0	1.0	3.0	0.8
1512	α-alaskene	0.7	-	0.4	0.5	0.1	0.1	-	-	0.2	0.3	0.2	0.2	-	0.2
1513	γ-cadinene	-	-	-	-	-	-	0.2	-	-	-	-	-	-	-
1514	butylated hydroxy toluene*	-	0.7	-	-	-	-	-	-	-	-	-	-	-	-
1520	7-epi-α-selinene	-	-	-	-	-	t	-	-	-	-	-	-	-	-
1521	trans-calamenene	0.1	0.3	-	0.5	0.1	0.1	0.1	0.1	-	-	-	0.1	-	-
1522	δ-cadinene	-	-	-	-	-	0.1	0.1	-	-	-	-	-	-	0.1
1532	γ-cuprenene	0.1	-	-	-	-	-	-	-	0.1	0.1	-	-	-	0.3
1536	italicene ether	-	0.5	-	-	-	-	-	-	-	-	0.1	-	0.7	-

AI	Compound	depp	dpat	dzac	drob	dgam	ashe	comt	pobl	stan	jali	mont	flac	dur	mart
1541	sesquiterpenol 43,97,205,220	-	0.8	1.1	-	-	-	-	-	-	-	-	-	-	-
1542	sesquiterpenol 43,95,164,207	-	-	-	-	0.7	-	-	-	-	-	-	-	-	-
1542	sesquiterpenol 43,55,69,222	0.4	-	-	-	-	-	-	-	-	-	-	-	-	-
1541	8,14-cedranoxide	-	-	-	-	-	-	-	0.1	-	0.7	0.1	-	0.2	-
1542	δ-cuprenene	-	-	-	-	-	0.1	-	-	-	-	-	-	-	0.2
1582	caryophyllene oxide	-	-	-	-	-	-	0.2	-	-	-	-	-	-	-
1586	thujopsen-2α-ol	-	-	-	-	-	0.1	-	-	-	-	-	-	-	-
1589	allo-cedrol	0.3	1.0	0.3	0.3	0.5	1.4	1.2	0.3	1.0	0.3	1.0	0.4	2.0	0.6
1595	cis-dihydro-mayurone	0.1	0.3	0.5	0.2	0.2	t	-	0.3	0.2	0.5	0.4	0.3	0.4	-
1599	widdrol	12.0	10.0	16.0	15.6	0.1	12.0	-	20.6	25.2	10.0	7.0	32.0	5.0	3.7
1600	cedrol	25.7	30.4	1.3	2.0	55.2	36.7	43.2	21.0	2.8	1.1	10.4	15.9	21.9	34.0
1612	β-biotol	0.4	0.5	-	0.2	-	-	0.9	-	-	-	-	0.5	-	-
1615	β-himachalene oxide	-	-	-	0.2	-	-	-	0.3	-	0.2	-	-	-	-
1618	epi-cedrol	1.2	0.7	-	0.5	0.4	0.5	-	0.6	0.8	0.2	1.2	1.4	0.8	1.1
1622	sesquiterpenol 85,43,111,204	-	-	-	-	-	0.5	-	-	-	-	-	-	-	-
1623	sesquiterpenol 43,111,69,207	-	-	-	-	-	-	0.5	-	-	-	-	-	-	-
1634	α-acorenol	3.7	3.4	1.2	3.3	1.6	4.9	1.2	2.1	19.7	0.8	4.3	1.3	3.6	2.3
1636	β-acorenol	1.6	1.1	0.9	1.4	0.7	2.0	0.4	1.0	3.2	0.4	1.6	1.0	1.1	1.0
1638	sesquiterpenal 135,41,79,236	-	-	-	-	-	-	-	-	-	-	-	1.6	-	-
1640	epi-α-muurolol	-	-	-	-	-	-	0.5	0.2	-	0.2	-	0.4	-	0.7
1640	sesquiterpene 41,171,48,161	-	-	-	-	-	-	-	-	-	-	-	-	0.8	-
1648	sesquiterpenol 119,43,204,220	-	-	-	-	0.3	2.7	-	0.2	-	-	-	-	-	-
1649	sesquiterpenol 43,119,71,220	-	0.6	-	-	-	-	-	-	-	-	-	-	-	-
1649	β-eudesmol	-	0.6	-	-	-	-	-	-	-	-	-	-	-	-

AI	Compound	depp	dpat	dzac	drob	dgam	ashe	comt	pobl	stan	jali	mont	flac	dur	mart
1650	sesquiterpenol 41,59,91,220	-	-	0.7	-	-	-	-	-	0.4	0.7	-	-	-	-
1650	cedr-8(15)-en-10-ol	-	-	-	-	-	-	-	0.4	-	-	-	-	-	-
1652	α-cadinol	-	-	-	-	-	0.3	0.9	-	-	-	-	-	-	-
1652	himachalol	-	-	-	0.2	-	-	-	-	-	-	-	-	-	-
1652	sesquiterpenol 41,69,107,220	-	-	-	0.9	-	-	-	-	-	-	-	-	-	2.0
1653	3-thujopsanone	-	-	-	-	-	-	-	-	-	-	0.3	-	-	-
1658	selin-11-en-4α-ol	0.3	0.8	-	0.3	0.2	-	-	-	-	-	-	-	-	-
1660	sesquiterpen-ol 135,79,220	-	-	-	-	1.3	-	-	-	-	0.9	-	-	-	-
1661	sesquiterpenal 135,41,91,218	-	-	1.2	-	-	-	-	-	-	-	-	-	-	1.4
1662	sesquiterpenal 43,123,218,236	-	0.7	-	-	-	-	-	-	-	-	-	-	2.6	-
1662	sesquiterpenal 135,79,91,236	-	-	-	-	-	-	-	0.6	-	-	-	-	-	-
1663	sesquiterpenal 41,79,81,236	-	-	-	-	-	-	1.4	-	-	-	-	-	-	-
1664	sesquiterpenal 41,135,79,236	0.7	-	-	1.1	-	-	-	0.6	1.1	0.8	2.4	-	-	-
1664	sesquiterpenal 41,157,218	-	0.8	-	-	-	-	-	-	-	-	-	-	-	-
1664	junicedranone	0.2	-	-	-	-	-	-	-	-	-	-	-	-	-
1665	intermedeol	-	-	-	-	-	1.3	-	-	-	-	-	-	-	-
1665	sesquiterpenal 43,123,95,236	-	-	-	-	-	1.6	-	-	-	-	-	-	-	-
1666	sesquiterp..al 157,143,105,218	-	-	-	-	-	-	7.0	-	-	-	-	-	-	-
1668	14-hydroxy-9-epi-(E)-caryophyllene	-	-	-	-	1.4	-	-	-	-	-	-	-	-	0.8
1668	sesquiterpenol 41,119,91,220	-	-	-	0.6	-	-	-	-	-	-	-	-	-	-
1683	epi-α-bisabolol	-	-	-	0.3	-	0.7	-	-	-	-	-	-	-	-
1685	α-bisabolol	-	-	-	0.4	-	0.1	-	-	-	-	-	-	-	-
1688	8-cedren-13-ol	0.1	-	-	4.2	-	-	-	4.2	-	9.5	0.9	1.4	-	1.4

AI	Compound	depp	dpat	dzac	drob	dgam	ashe	comt	pobl	stan	jali	mont	flac	dur	mart
1689	sesquiterpenol 43,121,132,222	-	-	-	-	-	-	-	-	-	-	-	-	1.0	-
1694	sesquiterpenal 135,71,41,220	-	-	-	-	-	-	-	-	2.9	-	-	-	-	-
1699	sesquiterpenol 135,79,105,220	1.4	2.6	5.1	4.5	4.8	0.8	1.1	5.5	-	5.4	4.1	5.7	3.0	4.1
1700	sesquiter..al 107,91,119,218	-	-	-	-	-	-	6.8	-	-	-	-	-	-	-
1701	cis-thujopsenol	-	-	-	3.8	2.5	4.4	1.4	2.6	4.0	-	-	2.3	-	2.8
1703	mayurone	1.5	5.8	1.4	-	-	-	-	-	-	-	3.8	-	9.7	-
1708	cis-thujopsenal	-	-	-	-	-	2.2	-	-	-	2.3	-	-	-	-
1709	sesquiterpenal 123,41,218,220	1.3	1.2	2.2	1.8	2.1	-	-	-	-	0.5	1.4	1.6	1.1	0.5
1714	sesquiterpene 43,135,207,232	-	2.2	0.8	0.7	-	-	-	-	-	0.3	-	-	4.1	-
1714	sesquiterpenal 123,55,206,236	-	-	-	-	-	-	-	1.2	-	-	-	-	-	-
1716	sesquiterpenol 43,135,207,222	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1724	(Z)-nuciferol	-	-	-	-	-	-	-	0.5	-	-	1.3	-	-	-
1726	sesquiterpenal 43,137,218,236	-	-	-	-	-	-	-	-	-	-	-	-	0.5	-
1729	sesquiter..al 119,147,162,236	-	-	-	-	-	-	-	-	-	-	-	2.0	-	1.2
1736	sesquiterpenal 43,123,132,218	-	-	-	-	-	-	-	-	-	-	-	-	0.6	-
1745	γ-costol	-	-	-	-	-	-	1.0	-	-	-	-	-	-	-
1751	sesquiterpenol 105,41,147,220	0.4	-	0.8	1.4	1.5	-	-	-	-	0.7	-	1.2	-	-
1751	cuparenal	-	0.7	-	-	-	-	-	-	-	-	-	-	-	-
1753	sesquiterpenol 105,41,79,222	-	-	-	-	-	-	-	-	2.4	-	-	-	-	-
1759	sesquiterpenal 119,93,238	0.5	-	1.2	-	-	-	-	-	-	-	-	-	-	-
1762	β-acoradienol	-	-	-	-	-	0.9	-	1.3	-	-	0.9	-	-	0.9
1765	β-costol	-	-	-	-	-	0.6	2.9	-	-	-	-	-	-	-
1766	sesquiterpenal 41,55,107,234	-	1.4	-	-	-	-	-	-	-	-	0.3	-	3.9	-
1771	sesquiterpenal 119,93,160,234	-	-	1.6	1.7	-	-	-	-	-	0.5	-	-	-	-

AI	Compound	depp	dpat	dzac	drob	dgam	ashe	comt	pobl	stan	jali	mont	flac	dur	mart
1773	α-costol	-	0.5	-	-	-	0.2	1.8	-	-	-	-	-	-	-
1774	sesquiterpenal 91,41,69,235	-	-	-	0.7	-	-	-	-	-	-	-	-	-	-
1779	14-hydroxy-α-muurolene	-	-	-	-	-	-	-	-	-	-	-	-	-	0.6
1781	sesquiterpenal 119,93,234	-	-	-	0.6	-	-	-	-	-	1.8	-	-	-	-
1784	sesquiterp..al 159,119,220,234	-	-	-	-	-	-	-	-	-	0.9	-	-	-	-
1785	sesquiterp..al 121,136,41,218	-	-	-	-	-	0.6	-	-	-	-	-	-	-	-
1787	sesquiterp..al 119,93,234	-	-	-	-	-	-	-	-	-	0.6	-	-	-	-
1793	sesquiterpenal 189,91,133,234	-	-	-	2.5	1.3	-	-	1.0	-	-	-	1.3	-	0.5
1793	sesquiterpenal 189,43,207,236	-	-	1.9	-	-	-	-	-	-	3.9	-	-	-	-
1793	sesquiterpenal 41,55,79,232	-	1.2	-	-	-	-	-	-	-	-	-	-	-	-
1794	sesquiterpenal 91,79,105,218	-	-	-	-	-	-	1.9	-	-	-	-	-	-	-
1796	sesquiterpenal 148,131,41,218	-	-	-	-	0.4	2.0	-	1.7	-	-	-	-	-	-
1797	sesquiterpenal 43,189,207,236	-	-	-	-	-	-	-	-	-	-	0.6	-	1.3	-
1799	sesquiterp..al 189,148,165,236	-	-	-	2.4	-	-	-	-	-	-	-	-	-	-
1802	sesquiterp..ol 121,136,177,220	-	0.7	1.1	-	1.4	1.9	0.6	2.1	1.9	-	-	1.8	0.5	0.8
1803	sesquiterp..al 189,121,43,236	-	-	-	-	-	-	-	-	-	3.9	-	-	-	-
1805	sesquiterpenal 121,136,177,234	1.0	-	-	5.4	-	-	-	-	-	-	-	-	-	-
1806	nootkatone	-	-	-	-	-	-	1.0	-	-	-	-	-	-	-
1810	sesquiterpenal 41,91,95,234	-	-	-	-	-	-	4.1	-	-	-	-	-	-	-
1815	sesquiter. acid 149,91,105,234	3.0	0.5	0.9	-	-	-	-	-	-	-	2.2	-	-	-
1821	sesquiterpenal 123,43,205	-	0.6	-	-	-	-	-	-	-	-	-	-	-	-
1821	sesqui..acid 149,105,191,234	-	-	-	1.1	-	-	-	-	-	-	-	1.0	-	-
1837	sesquiterpene 119,161,43,191	-	-	-	-	-	-	-	-	-	-	0.3	-	-	-
1863	cis-thujopsenic acid	7.1	2.3	17.8	8.3	4.4	2.1	0.4	6.0	2.4	5.4	11.0	5.6	1.4	6.4

AI	Compound	depp	dpat	dzac	drob	dgam	ashe	comt	pobl	stan	jali	mont	flac	dur	mart
1880	sesquiterpenal 43,55,93,236	-	-	-	-	-	-	0.6	-	-	-	-	-	-	-
1883	sesquiterp..al 105,147,219,234	0.9	-	1.2	-	0.2	-	-	-	0.8	-	-	-	-	-
1889	sesquiterp..al 119,43,132,234	-	-	-	-	-	-	1.3	-	-	-	-	-	-	-
1889	cedrane-8S,14-diol	0.6	3.9	-	0.9	-	0.3	1.3	1.4	2.7	5.4	6.9	0.7	5.5	-
1897	cedrane-8S,13-diol	-	-	-	-	-	-	-	-	-	2.4	-	-	-	-
1905	sesquiterp..al 105,147,191,234	-	-	-	-	-	-	-	0.8	-	-	-	-	-	-
1910	sesquiterp..al 149,105,91,234	-	-	-	0.8	-	-	-	0.6	-	-	-	-	-	-
1917	sesquiterpenal 41,123,149,234	-	-	-	-	-	-	-	-	-	-	-	-	1.0	-
1919	sesquiterpenal 43,68,105,234	-	-	-	-	-	-	-	-	-	0.8	-	-	-	-
1923	sesquiterpenal 123,41,201,234	-	0.9	-	-	-	-	-	-	-	-	-	-	-	-
1925	sesquiterp..al 123,136,191,234	-	0.5	-	-	-	-	-	-	-	-	-	-	-	-
1928	sesquiterp..al 121,41,135,234	-	-	-	-	-	-	-	-	4.4	-	-	-	-	-
1929	sesquit..acid 121,136,191,234	1.0	-	2.5	2.2	0.4	0.5	-	-	-	-	-	-	-	-
1932	sesquiterp..al 105,173,191,234	-	-	-	-	-	-	-	-	-	1.2	-	-	-	-
1941	sesquiterp..al 43,135,162,234	-	-	-	-	-	-	1.2	-	-	-	1.2	-	-	-
1944	sesquit..acid 41,91,121,234	-	-	-	0.7	-	-	-	-	-	-	-	-	-	-
1945	sesquit..acid 121,136,191,234	1.6	-	3.7	2.7	1.4	0.3	-	1.4	2.0	1.7	1.2	0.7	0.7	-
1946	sesquiterp..al 135,43,121,234	0.6	-	-	-	-	-	-	-	-	-	-	-	-	-
1948	sesquiterp..al 158,157,143,234	-	-	-	-	-	-	2.6	-	-	-	-	-	-	-
1953	sesquiterpene 43,135,181,256	-	-	8.0	-	-	-	-	-	1.0	-	-	-	-	-
1953	sesquit. acid 135,43,181,234	-	-	-	-	-	-	-	-	-	-	-	-	3.0	-
1959	nootkatin	-	-	-	-	-	-	0.9	-	-	-	-	-	-	-
1958	sesquit. acid 121,136,191,232	-	-	-	-	-	-	-	2.8	-	-	-	-	-	-
1960	sesquit. acid 121,136,191,234	-	-	-	3.4	-	-	-	0.5	-	1.5	-	1.1	-	1.3

AI	Compound	depp	dpat	dzac	drob	dgam	ashe	comt	pobl	stan	jali	mont	flac	dur	mart
1984	sesquit..acid 135,43,181,256	-	-	-	-	-	-	-	-	-	11.6	4.7	-	-	-
2077	sesquiterp..al 59,149,105,234	-	-	-	-	-	-	-	-	1.0	-	-	-	-	-
2082	sesquiterpene 43, 202/203,234	-	-	-	0.7	-	-	-	-	-	-	-	-	-	-
2141	oleic acid	-	-	-	-	-	-	-	-	-	-	-	-	-	2.7
2158	octadecanoic acid	-	-	-	-	-	-	-	-	-	-	-	-	-	5.0
2269	sandaracopimarinol	-	0.2	-	-	-	-	-	t	-	-	-	-	-	-
2314	trans-totarol	-	-	-	-	-	-	-	-	-	-	-	-	0.1	-
2331	trans-ferruginol	0.2	0.2	-	0.2	-	-	0.4	0.3	0.3	-	t	0.2	-	-

Table 4. Comparison of the major oil components among taxa.
ACDR = α-cedrene, BCDR = β-cedrene, THJP = cis-thujopsene,
WDRL = widdrol, CDRL = cedrol, CTJA = cis-thujopsenic acid.
%yld = % yield on oven dry wt basis (oil/(extracted wood, dried 48h, 100°C).

	ACDR	BCDR	THJP	WDRL	CDRL	Sum	%yld	S x %
J. californica	1.2	0.6	2.2	11.7	11.7	25.4	0.2	5.0
J. monosperma	0.7	0.5	9.0	7.1	14.1	31.4	0.3	9.4
J. angosturana	1.4	0.7	17.5	t	51.0	70.6	2.4	169.4
J. coahuilensis	1.1	0.5	18.4	-	17.4	37.4	1.6	59.8
J. pinchotii	3.6	1.6	12.0	4.2	38.6	60.0	0.2	12.0
J. arizonica	1.9	0.6	14.5	7.6	3.1	27.7	0.6	16.6
J. occidentalis	0.9	0.8	6.4	t	43.3	51.4	0.5	25.7
J. grandis	1.4	0.9	15.4	-	41.8	59.5	0.2	11.9
J. osteosperma	1.3	0.7	13.7	t	36.3	52.0	0.3	15.6
J. saltillensis	1.2	0.7	9.0	t	46.9	57.8	0.1	5.8
J. compacta	0.4	0.4	2.5	-	54.2	57.5	1.0	57.5
J. deppeana	7.6	2.0	9.1	12.0	25.7	56.4	0.3	16.9
patoniana	1.5	0.8	7.2	10.0	30.4	49.9	0.04	2.0
zacatacensis	4.1	1.4	10.3	16.0	1.3	33.1	0.5	16.6
robusta	3.9	0.9	6.3	15.6	2.0	28.7	0.7	20.1
gamboana	2.5	1.0	5.5	0.1	55.2	64.3	2.0	128.6
J. ashei	0.6	0.4	12.0	12.0	36.7	61.7	1.7	104.9
J. comitana	0.5	0.2	2.9	-	43.2	46.8	1.0	46.8
J. poblana	3.3	0.9	6.6	20.6	21.0	52.4	1.8	94.3
J. standleyi	2.6	1.2	10.3	25.2	2.8	42.1	3.4	143.1
J. jaliscana	2.6	0.7	7.6	10.0	1.1	22.0	1.4	30.8
J. monticola	1.9	0.9	14.3	7.0	10.4	34.5	0.7	24.2
J. flaccida	3.5	1.0	4.8	32.0	15.9	57.2	0.9	51.5
J. durangensis	1.2	0.9	7.9	5.0	21.9	36.9	0.2	7.4
J. martinezii	2.0	0.9	6.8	3.7	34.0	47.4	1.2	56.9

RELATIONSHIPS AND NOMENCLATURAL STATUS OF THE NOOTKA CYPRESS (*CALLITROPSIS NOOTKATENSIS*, CUPRESSACEAE)

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ABSTRACT

While working on the manuscript of *Conifers Around the World* (in press), the authors encountered classification and nomenclature questions surrounding the Nootka Cypress, originally described as *Cupressus nootkatensis* D. Don, 1824. The combination *Callitropsis nootkatensis* was later implicitly suggested for this taxon by Oersted as the sole species in his new genus *Callitropsis*, but was not published in accordance with the current International Code of Botanical Nomenclature. The combination first appears in the literature in Florin (1944), with the name attributed to Oersted, and was validated by Little (2006), who treated the species as the type of a broader genus including the New World lineage of *Cupressus*. The taxon has long been treated as a species of *Chamaecyparis*, but this placement is supported by only a limited number of non-unique morphological characters and is not supported by more recent molecular comparisons. Based on recent DNA sequence comparisons, the distinctive Nootka Cypress can appropriately be treated in a monotypic *Callitropsis*, in a ditypic genus with the Vietnamese Yellow Cypress (originally published as *Xanthocyparis vietnamensis*), or in a larger generic clade with the New World *Cupressus*. In the following paper we discuss its complex nomenclatural and taxonomic history and morphological distinctness. *Phytologia 91(1):140-159 (April, 2009)*.

KEY WORDS: *Callitropsis*, *Callitropsis nootkatensis*, *Cupressus*, *Xanthocyparis*, Nootka Cypress, Vietnamese Yellow Cypress.

BACKGROUND

In 2005, while working on the manuscript of *Conifers Around the World* (Debreczy and Rácz, in press), the authors came across classification and nomenclature questions surrounding the North American taxon well-known by its common names Nootka Cypress, Alaska Cedar, Yellow Cedar, and Alaska Yellow Cedar (Little, 1980; Rehder, 1940). In this paper we refer to it as Nootka Cypress, following its original scientific name. It was first published as *Cupressus nootkatensis* D. Don in Lambert, Descr. Pinus 2: 18, 1824, and has subsequently been placed in three other genera: *Chamaecyparis* (1841), *Callitropsis* (1864), and most recently, *Xanthocyparis* (2002). Due to its combination of vegetative and reproductive characters sharing some features with both *Cupressus* and *Chamaecyparis*, its taxonomic position has long been debated, and its nomenclature has also been subject to confusion.

NOMENCLATURE OF NOOTKA CYPRESS

Danish botanist Anders Sandoe Örsted (≡Oersted; Fig. 1), in a detailed, richly illustrated 1864 publication, considered the cone structure of Nootka Cypress distinct enough from *Chamaecyparis* for the taxon to be placed in its own genus, which he named *Callitropsis*. Though Oersted gave a Latin diagnosis for the genus *Callitropsis*, and assigned only *Chamaecyparis nootkatensis* ("nutkaensis") to it, he did not directly write out the new combination *Callitropsis nootkatensis* in accordance with the International Code of Botanical Nomenclature (ICBN) rules for pre-1953 publication of botanical names (McNeill et al., 2006). Therefore the combination was not validly published and has been dealt with in a variety of ways by subsequent authors.

The genus name *Callitropsis* Oersted and the combination *Callitropsis nootkatensis* were noted by (Carl) Rudolf Florin (1944) when he published the genus name *Neocallitropsis* as an avowed substitute for the later homonym *Callitropsis* Compton (Compton, 1922, p. 432). Though the name *Callitropsis nootkatensis* was attributed to Oersted, it was apparently first written out by Florin (1944), though not as a "comb. nov." in accordance with the ICBN. Little (2006) cited Florin as the author of the combination (see below), apparently validating the name (Gandhi, pers. comm.). The name *Callitropsis nootkatensis* Oersted was also cited by Erdtman and Norin (1966) in a footnote in relation to its chemical distinctness from *Chamaecyparis*, but not in a nomenclatural context.

The name *Callitropsis nootkatensis* then faded into obscurity, and the species was widely treated as *Chamaecyparis nootkatensis* (D. Don) Spach until evidence was obtained from tropolone and biflavonoid chemistry (Erdtman and Norin, 1966; Gadek and Quinn, 1985) and from phylogenetic analyses of morphology and DNA sequence data (Gadek et al., 2000; Farjon et al., 2002; Little et al., 2004; Xiang and Li, 2005; Little, 2006) that the species was misplaced in *Chamaecyparis*. Even though Florin's substitution of *Neocallitropsis* for *Callitropsis* Compton was widely accepted, the basis of that change, Oersted's name *Callitropsis*, was infrequently used in the literature until Little et al. (2004).

When a new cupressoid conifer was discovered in karst areas of northern Vietnam in 1999, it was soon described as the new genus *Xanthocyparis* Farjon & H. T. Nguyễn and species *Xanthocyparis vietnamensis* Farjon & H. T. Nguyễn (Farjon et al., 2002). These authors found *X. vietnamensis* (Vietnamese Yellow Cypress) to be so similar in cone morphology to Nootka Cypress that they included the latter in the new genus and renamed it *Xanthocyparis nootkatensis* (D. Don) Farjon & Harder. However, Little et al. (2004) pointed out that if treating the two species as members of the same genus, the name *Xanthocyparis* was invalid since *Callitropsis* Oersted had priority.

In February 2006 a proposal to conserve the name *Xanthocyparis* against *Callitropsis* Oersted was published (Mill and Farjon, 2006). Mill and Farjon, while also pointing out that Oersted did not make the new combination in the current manner, acknowledged that *Callitropsis* Oersted was validly published and that it should have been adopted for the new Vietnamese conifer and Nootka Cypress, making their publication of the name *Xanthocyparis* illegitimate according to ICBN Art. 52.1 (McNeill et al., 2006). Thus the present authors believe that the generic name *Callitropsis* Oersted should be given continued priority over *Xanthocyparis* when the two species are placed in the same genus, that *Callitropsis* Oersted is the correct generic name for the Nootka Cypress when the genus is treated as monotypic, and a monotypic *Xanthocyparis* is valid as its type is *X. vietnamensis*, not Nootka Cypress. Although in 2007 the Nomenclature Committee for Vascular Plants of the International Association for Plant Taxonomy (IAPT) voted to recommend conservation of *Xanthocyparis* over *Callitropsis* when the two species are placed in the same genus (Brummitt, 2007), the present authors believe that use of the much earlier generic name *Callitropsis* will cause no undue problems and that the customary rule of priority should be applied. Thus, this issue should be revisited before being voted on by the broader membership of the IAPT at the Eighteenth International Botanical Congress in 2011.

In October 2006, in a paper emphasizing phylogenetic analyses of nuclear and chloroplast DNA as well as morphological data, Little (2006) retained the generic name *Callitropsis*, but applied it to a broader lineage including *C. nootkatensis*, *Xanthocyparis vietnamensis*, and the New World lineage of *Cupressus*, a taxonomic judgment that we discuss under "Generic Classification" below. In 2004 Little et al. cited the combination as "*C*[*allitropsis*]. *nootkatensis* (D. Don) Oerst. Apparently recognizing the problems with the publication of the combination, Little subsequently (2006) attributed *Callitropsis nootkatensis* to Florin. At the top of his Taxonomic Treatment, Little appears to cite the type species of *Callitropsis* Oersted as "*Callitropsis nootkatensis* (D. Don in Lambert) Florin, Regnum Veg. 100: 266. 1979." Regnum Vegetabile 100 is the *Index Nominum Genericorum* (*Plantarum*), in which the type of the genus name is listed as *Cupressus nootkatensis* D. Don. The name *Callitropsis nootkatensis* does not appear there (Farr et al, 1979). Later in his list of combinations recognized in the expanded genus *Callitropsis*, Little more appropriately cites the species as "*Callitropsis nootkatensis* (D. Don in Lambert) Florin, Palaeontographica, Abt. B, Paläophytol. 85:590. 1944". Florin (1944), as previously noted, did write out the combination *Callitropsis nootkatensis* as a name from Oersted, but did not formally propose it as a new combination, instead later referring to the taxon as *Chamaecyparis nootkatensis* (p. 606, l.c.).

One can understandably regard *Callitropsis nootkatensis* (D. Don) Oersted or *Callitropsis nootkatensis* (D. Don) Florin as implicit combinations that were validly published under pre-1953 rules of the ICBN (vide Articles 33.2 and 33.3, McNeill, 2006). However, the combination did not appear in the International Plant Names Index (IPNI) as of 31 December 2008. While preparing this manuscript, a query from author Musial to a colleague to clarify a discrepancy in the D. Don citation eventually led to Dr. Kanchi Gandhi of the Gray Herbarium, Harvard University (also an editor for IPNI). An unexpected outcome of the correspondence on 16 January 2009 was that on 17 January 2009 "*Callitropsis nootkatensis* Oerst. nom. inval." and "*Callitropsis nootkatensis* Oerst. ex Florin" were posted to IPNI. Further queries by Musial led Gandhi to maintain that the validity of the Florin (1944) publication was questionable and that Little (2006) might have inadvertently validated the name (Gandhi, pers. comm.). The complexity of the issue led Gandhi to consult with other IPNI editors and experts (see acknowledgements), and as of 26 January 2009, *Callitropsis nootkatensis* Oerst. ex Florin was also declared nom. inval. and the name validated as *Callitropsis nootkatensis* (D. Don) Florin ex D. P. Little, Syst. Bot. 31(3): 474, 2006; basionym *Cupressus nootkatensis* D. Don in Lambert, Descr. Pinus 2: 18, 1824 (IPNI, 2009). Little had formally recognized the taxon and cited its basionym in accordance with ICBN Art. 33.4, 34.1, and 46.4 (McNeill, 2006). Gandhi (pers. comm.) mentioned two alternative citations: *Callitropsis nootkatensis* (D. Don) Oersted ex D. P. Little or *Callitropsis nootkatensis* (D. Don) D. P. Little. Present authors preference is for Oersted to be credited, and on 27 January 2009 Gandhi agreed and amended the IPNI record to *Callitropsis nootkatensis* (D. Don) Oersted ex D. P. Little (IPNI, 2009).

GENERIC CLASSIFICATION OF THE NOOTKA CYPRESS

Generic delimitation in the Cupressaceae *sensu stricto* has been more subjective than in most families of conifers due to the limited number of reproductive and vegetative characters distinguishing the approximately twenty currently recognized genera (Farjon, 2005). DNA sequence comparisons have provided independent appraisals of the relationships among these genera, and support a natural grouping including the cypresses (*Cupressus sensu lato*), junipers, Nootka Cypress, and Vietnamese Yellow Cypress (Gadek et al., 2000; Little et al., 2004; Xiang and Li, 2005; Little, 2006). Within this lineage, ITS sequence comparisons suggest that Nootka Cypress is the closest relative of Vietnamese Yellow Cypress (Little et al., 2004; Xiang and Li, 2005). This is consistent with the similarities in seed cone and pollen cone morphology noted by Farjon et al. (2002), but the support for a ditypic lineage comprising these two species is not strong in the other phylogenetic analyses presented by Little (2006). Thus using a total-evidence approach one can either recognize both as monotypic genera, likely with a long separate evolutionary history but with limited morphological differentiation, or treat them together as a ditypic genus.

There is strong support from several lines of DNA sequence data for the inclusion of these two species in a broader phylogenetic group also including an additional well-supported lineage, the New World species of *Cupressus* (Little et al., 2004; Xiang and Li, 2005; Little, 2006). This has been a surprise to morphological systematists, since the New World *Cupressus* species are characterized by large, many-seeded, serotinous (with few exceptions) seed-cones that are retained for long periods on the shoots, and thus appear more similar to the Old World species of *Cupressus* than to the Nootka Cypress and Vietnamese Yellow Cypress. The molecular groupings are consistent, however, with the fact that the Nootka Cypress is crossable with several species of New World *Cupressus* (Jackson and Dallimore, 1926; Mitchell, 1970). The widely grown Leyland Cypress (*Chamaecyparis nootkatensis* × *Cupressus macrocarpa*) is apparently at least sometimes fertile (Jackson and Dallimore, 1926), which is highly unusual for conifers if these groups are regarded as separate genera, and also suggests that they are closely related. Thus, Little (2006) has treated the Nootka Cypress, Vietnamese Yellow Cypress, and New World

Cupressus in a single genus as species of *Callitropsis*, a rather unorthodox approach given the differences in morphology between these taxa, but fully consistent with the molecular phylogenetic groupings of the taxa without requiring a new generic name for the New World cypresses.

From a macro-morphological aspect Nootka Cypress stands out from both *Cupressus* and *Chamaecyparis* and it has distinct differences from *Xanthocyparis* (see "Morphological Distinctness" below). Nootka Cypress can be considered as a "chamaecyparoid" cypress that, like *Chamaecyparis*, currently occurs in cold-temperate climates; in the case of Nootka Cypress, specifically in cool-wet boreal forests reaching as far north as 60°N. In submediterranean climates (home to regionally adjacent "true cypresses") it is restricted to cool north slopes and high elevations where it even occurs as a groundcover shrub (Griffin & Critchfield, 1976). Occurring from extreme northwestern California to Alaska, Nootka Cypress is one of the most northern-ranging members of the Cupressaceae. The species traditionally placed in *Cupressus* (Old World as well as New World lineages) often occur in zonal to extrazonal mediterranean or submediterranean climates well reflected in their mostly small to medium size and upright raceme-type branchlet system. The subtropical or summer-rain tropical taxa of the genus that are adapted to humid climates and face strong competition from broad-leaved angiosperm trees are large trees with often pendulous fern-like sprays or filiferous foliage, resulting in a relatively large assimilation surface and a rain (or snow) shedding foliage system (e.g. *Cupressus cashmeriana*, *C. funebris*, *C. lusitanica*).

MORPHOLOGICAL DISTINCTNESS OF NOOTKA CYPRESS VERSUS *CHAMAECYPARIS*, *CUPRESSUS*, AND *XANTHOCYPARIS*

Compared with *Chamaecyparis* (Fig. 2). Nootka Cypress is similar to species of *Chamaecyparis* in having flattened branchlets, conduplicate lateral scale-leaves, and small globose cones with few basally developing seeds (2–4 per cone-scale). Nootka Cypress differs significantly from all *Chamaecyparis* species in its wood and leaf chemistry (Erdtman and Norin, 1966; Gadek and Quinn, 1985) and is placed outside of *Chamaecyparis* in a separate lineage with the chemically more similar *Cupressus* and *Juniperus* in DNA sequence comparisons (Xiang and Li, 2005; Little, 2006). Morphologically, Nootka Cypress differs from *Chamaecyparis* in its uniform amphistomatic adult scale-leaves without obvious white stomatal patches on the down-facing sides of the branchlets, the whorl-like arrangement of its 2(–3) pairs of cone-scales, without rudimentary sterile terminal scale pairs but with a free cone-axis tip (columella), and cones maturing in (1–)2 years. *Chamaecyparis* has strongly dimorphic facial and lateral scale-leaves, stomata arranged in (pruinose) patches on the down-facing side of the branchlets, cones with clearly decussately developing (5)6–12 scales (3–6 pairs), with the 2–4 terminal scales sterile and connate to form a column (Jagel and Stützel, 2001). In its overall morphology, Nootka Cypress appears to be more of a "chamaecyparoid" (mesomorphic) *Cupressus*-relative than a cupressoid *Chamaecyparis*. The cones of *Callitropsis nootkatensis* (a, fig. 2, top) have a conspicuous resin-filled conical extension (columella) beyond the base of the terminal cone-scales, a feature otherwise only typical of the Australasian genus *Callitris* and relatives from Cupressaceae subfamily Callitroideae (inset: h, fig. 2, *Callitris rhomboide,* i: vasculature of *Callitris preissii*). In *X. vietnamensis* (b, fig. 2, top) the columella is rudimentary (only a slightly raised area that can barely be considered column-like). The other genera have a longer cone-axis (relative to their cone sizes) associated with a usually larger number of cone-scales with terminal cone-scales fertile (*Cupressus*), or a few pairs form a sterile apical column.

Compared with *Cupressus* (Fig. 2). Nootka Cypress is similar to the New World *Cupressus* species in having more or less globose seed-cones often maturing in 2 years and adult foliage that is uniform with amphistomatic scale-leaves. It differs in having relatively small seed-cones (ca. 1 cm vs. 1–4 cm) that open in 1–2 years rather than often being retained for long periods on the tree and opening in response to fire. The cone-scales in Nootka Cypress are basifixed and not heavily thickened, while they are medifixed (peltate) and often much thickened and woody in *Cupressus*. Seeds are relatively few per cone-scale (2–4), flattened, and broadly winged, versus many per cone-scale (5–20), typically lenticular or faceted, and narrowly winged in *Cupressus*. Pollen cones have only 2(–3) large pollen sacs per sporophyll, vs. 3–6 (up to 10 in *C. macrocarpa*) smaller pollen sacs in *Cupressus*. DNA sequence studies (Xiang and Li, 2005; Little, 2006) strongly indicate that the Nootka Cypress is a close relative of the New World cypress lineage but there is no evidence that it or the related Vietnamese Yellow Cypress is derived from within the New World cypress lineage. Instead they are positioned as the closest outside relatives, as suggested by the morphological differences.

Compared with *Xanthocyparis vietnamensis* (Figs. 3–4). The Nootka Cypress is most similar to the Vietnamese Yellow Cypress in having small more or less globose seed-cones (ca. 1 cm) with 2(–3) pairs of cone-scales on a short axis (thus appearing in whorls) with relatively few seeds per cone-scale (generally 2–4). The seeds of both are flattened and have two thin lateral wings. The pollen cones have 2(–3) relatively large pollen sacs per sporophyll. None of these shared characters are unique in the Cupressaceae and thus they provide only limited support for a distinct phylogenetic lineage consisting of these two species (Little, 2006). The two species differ in several morphological characters with uncertain phylogenetic importance such as scale-leaf, cone, and seed properties but differ most prominently in that leaves of both the needle-like juvenile form and scale-like adult form are commonly found on adult trees of the Vietnamese Yellow Cypress, and this is not the case in the Nootka Cypress or New World cypresses. In Nootka Cypress the columella terminating the cone-axis is usually evident, while it is very reduced or rudimentary in Vietnamese Yellow Cypress (Figs. 3–4). The seeds are smooth in Nootka Cypress but are conspicuously “warty” from tiny resin-blisters in Vietnamese Yellow Cypress

DNA studies of the ITS region tend to support a close sister-group relationship between these two species (Little et al., 2004; Xiang and Li, 2005), but other DNA sequence comparisons place them near one another in an unresolved trichotomy with the New World cypress lineage. The lineage including *Callitropsis nootkatensis* has an extensive fossil record in western North America dating back to ca. 50 MYA in the Eocene Epoch (Edwards, 1983, 1984). The chemistry of the Vietnamese Yellow Cypress is apparently not yet studied, but based on our current knowledge this would be unlikely to resolve generic relationships in the group.

At this time we choose to maintain *Callitropsis nootkatensis* and *Xanthocyparis vietnamensis* as members of closely related monotypic genera, which given their substantial geographic separation have probably had long evolutionary histories. Further study may provide new morphological or molecular characters that are uniquely shared by these two species or these two plus the New World cypresses, which would more strongly support a broader genus *Callitropsis*.

SUMMARY

The tortuous nomenclatural history of *Callitropsis nootkatensis* has apparently been resolved and the combination *Callitropsis nootkatensis* is now considered validly published and should be attributed to (D. Don) Oersted ex D. P. Little. *Xanthocyparis* is a valid name without need of conservation as long as the genus is kept monotypic with *X. vietnamensis* as its sole species. The morphological similarities between these two species, primarily in seed- and pollen-cone structure, are not unique within the family and thus may constitute only equivocal evidence in support of a separate generic lineage. Thus from a classification standpoint, the Nootka Cypress and Vietnamese Yellow Cypress are probably best considered members of closely related monotypic genera (*Callitropsis nootkatensis* and *Xanthocyparis vietnamensis* respectively) until stronger support of their phylogenetic relationship is available.

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Figure 1: Anders Sandoe Örsted (1816–1872), Danish botanist, mycologist, zoologist, and marine biologist. In his long-overlooked study of the differences in cone morphology of *Chamaecyparis nootkatensis* and other cypresses he describes a new genus for Nootka Cypress, *Callitropsis*. Photograph by Johannes Peterson, Courtesy of the Botanical Library, University of Copenhagen, Denmark.

Figs. 2–4 Comparison of *Callitropsis*, *Xanthocyparis*, *Chamaecyparis* and the New and Old World Cypresses.
abbreviations: *ad*=adaxial; *ab*=abaxial; *sd*=seed; *col*=columella; *trp*=terminal resin pit; *axrp*=axillary resin pit; *stcs*=sterile terminal cone-scale.

Figure 2. Longitudinal sections of cones and dissected cone vasculature in *Callitris*, *Callitropsis*, *Xanthocyparis*, *Chamaecyparis*, and representative New World (NW) and Old World (OW) *Cupressus* species. (a) *Callitropsis nootkatensis*, (b) *Xanthocyparis vietnamensis*, (c) *Cupressus macnabiana* (NW), (d) *Cupressus macrocarpa* (NW), (e) *Cupressus sempervirens* (OW), (f) *Chamaecyparis lawsoniana*, (g) *Chamaecyparis obtusa* var. *formosana*, (h) *Callitris rhomboidea,* note that the columella is multi-parted for this species, (i) *Callitris preissii.*

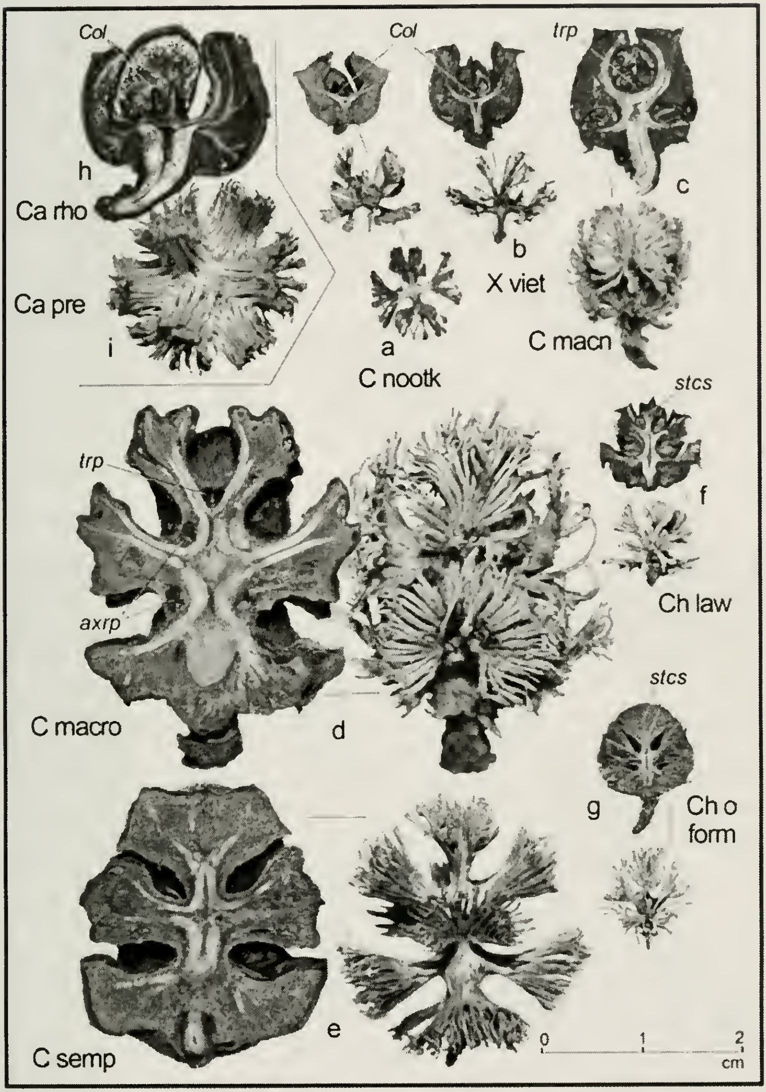

Figure 2. See caption on facing page.

Figure 3: Selected morphological structures of A: *Callitropsis nootkatensis* and B: *Xanthocyparis vietnamensis.* (a) Spray of mature sun branchlets with detail of individual branchlet; (b) detail of shade branchlet; (c) detail of leafy shoot, a leaf, and leaf surfaces from juvenile plant; (d) leafy shoot and detail of leaf from persistent juvenile foliage on mature tree of *X. vietnamensis* (not present in *C. nootkatensis*); (e) conelet; (f) two perpendicularly oriented views of the mature and unopened seed-cone; (g) longitudinal section of seed-cone, showing columella in *Callitropsis* and elevated area as rudimentary columella in *Xanthocyparis* and seeds; (h) seeds in lateral and facial view showing warty resin-glands on the surface of *X. vietnamensis* only.

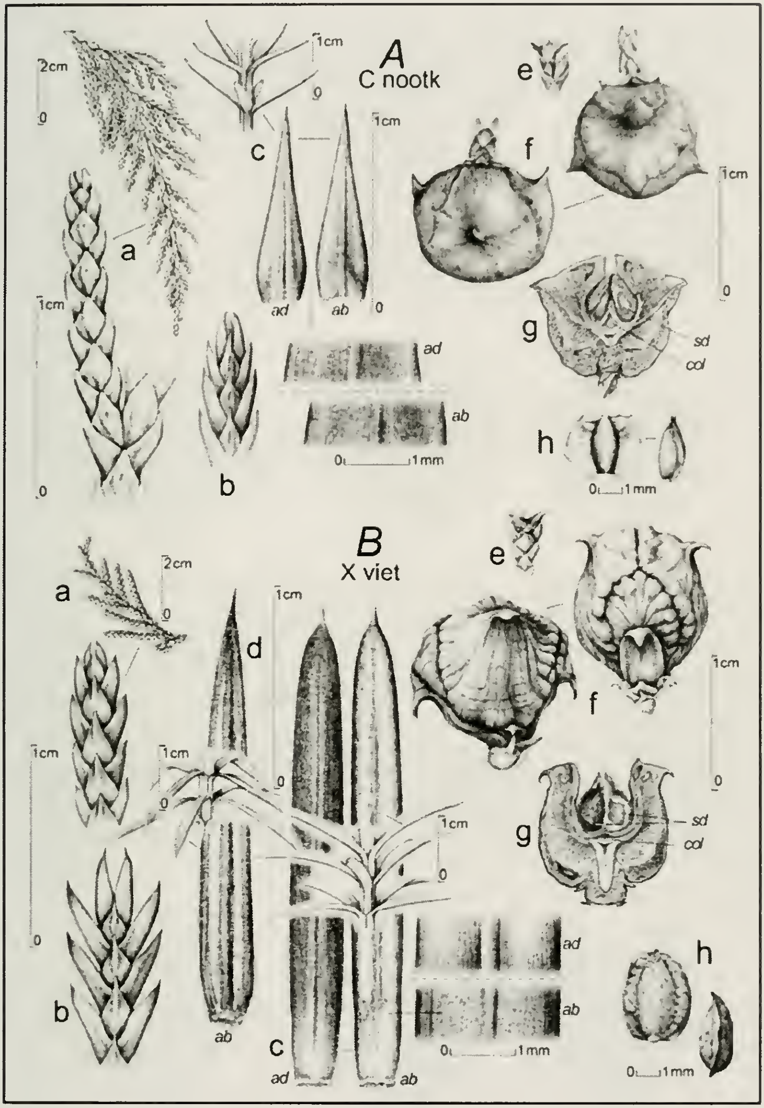

Figure 3. See caption on facing page.

Fig. 4: Selected morphological features of A: *Callitropsis nootkatensis* and B: *Xanthocyparis vietnamensis* in photographs.

A: (a) juvenile branchlets from young plant; (b) semijuvenile foliage of young plant; (c) shade and (d) sun branchlets of adult plant; the same cone from (e) lateral and (f) axial views and (g) longitudinal section with columella (arrow).

B: (a) juvenile branchlets from young plant; (b) juvenile-type foliage from an adult plant; (c) shade and (d) sun branchlets of adult plant; the same cone from (e) lateral and (f) axial views and (g) longitudinal section with columella area with barely visible rudimentary columella thinly filled with resin (arrow).

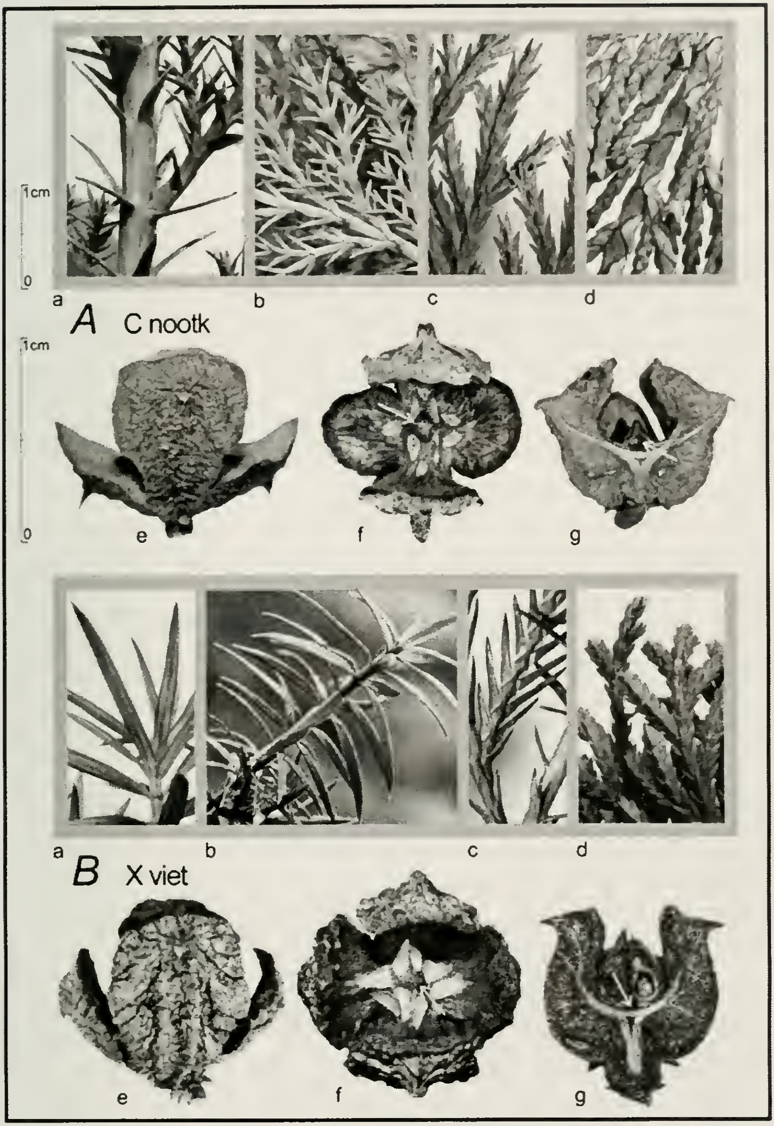

Figure 4. See caption on facing page.

A NEW GENUS, *HESPEROCYPARIS*, FOR THE CYPRESSES OF THE WESTERN HEMISPHERE (CUPRESSACEAE)

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ABSTRACT

Phylogenetic comparisons of three nuclear DNA gene regions (nrDNA(ITS), 4-coumarate: CoA ligase, abscisic acid-insensitive 3) and a chloroplast region (petN-psbM) show that the Western Hemisphere cypresses (*Hesperocyparis*) is a well-supported clade quite separated from the Eastern Hemisphere cypresses (*Cupressus*). Based on these new data and previous data, a new genus, *Hesperocyparis*, is erected for the Western Hemisphere species previously placed in the genus *Cupressus* (*sensu lato*). *Hesperocyparis* is most closely related to the northwestern North American *Callitropsis nootkatensis* and the southeast Asian *Xanthocyparis vietnamensis*. Morphological characters distinguishing *Hesperocyparis* from *C. nootkatensis* and *X. vietnamensis*, and from the Eastern Hemisphere cypresses (*Cupressus*), are presented. *Phytologia 91(1):160-185 (April, 2009*).

KEY WORDS: *Cupressus*, *Callitropsis*, *Chamaecyparis*, *Hesperocyparis*, *Xanthocyparis*, *Juniperus*, nrDNA(ITS), 4-coumarate: CoA Ligase, Abscisic acid-insensitive 3, petN, psbM, sequences, taxonomy.

Attempts to identify and delimit coniferous genera have been "based on limited sets of usually selective characters which were perceived to be informative about evolution and/or phylogeny of the group … under study *a priori*" (Farjon, 2005). Despite the numerous taxonomic works addressing the Cupressaceae *(sensu lato)*, which were described in detail by Farjon (2005), the modern concept of *Cupressus* has remained largely unchanged for more than a century. However, the discovery of a new conifer species on karst limestone in northern Vietnam (Averyanov et al., 2002; Farjon et al., 2002) has led to both excitement and taxonomic difficulties. Farjon et al. (2002) recognized the taxon as a new species and genus, *Xanthocyparis vietnamensis* Farjon & T. H. Nguyên, based on dimorphic leaves; small ovulate cones with 2 or 3 pairs of opposite decussate cone scales; 2 years for seed cone maturation; flattened, winged seeds; and juvenile, transition, and adult leaves found on the same tree.

Farjon et al. (2002) concluded that *Chamaecyparis nootkatensis* (D. Don) Spach was congeneric with *X. vietnamensis* and included the former species in the new genus (overlooking the earlier generic name *Callitropsis* Oersted) and made the new combination *Xanthocyparis nootkatensis* (D. Don) Farjon & D. K. Harder. *Chamaecyparis nootkatensis* has had a variable taxonomic history, having been classified as *Chamaecyparis, Cupressus, Callitropsis* and *Xanthocyparis* (see Little et al., 2004, and Debreczy et al., 2009 for discussion).

Little et al. (2004), using nrDNA(ITS) internal transcribed spacer (ITS) sequence data, found that *Xanthocyparis vietnamensis* and *X. nootkatensis* form a clade sister to the Western Hemisphere cypresses and that the Eastern Hemisphere cypresses and *Juniperus* constitute distinct clades outside this group. Little et al. (2004) reported that *Chamaecyparis nootkatensis* had been previously described as *Callitropsis nootkatensis* (D. Don) Oersted in 1865. Little renamed *X. vietnamensis* as *Callitropsis vietnamensis* (Farjon and Nguyên) D. P. Little. Though Silba (2005) did not address the molecular phylogeny results, he did assert in response to Little et al. (2004) that the splitting of western and Eastern Hemisphere cypresses was "based on superficial data with inaccurate and incomplete field observations." More recently, Mill and Farjon (2006) made a proposal to conserve

Xanthocyparis against *Callitropsis*. The Nomenclature Committee for Vascular Plants voted 14-4 to recommend that the proposal be adopted at the next International Association of Plant Taxonomists congress in 2012 (Brummitt, 2007). So, the matter currently remains unsettled (see Debreczy et al., 2009, for discussion).

Xiang and Li (2005) reexamined *Xanthocyparis, Chamaecyparis, Cupressus* and *Juniperus* using nrDNA(ITS) sequences. Though the authors concluded that "it seems appropriate" to place *Xanthocyparis vietnamensis* and *X. nootkatensis* in *Cupressus (sensu lato)*, they also noted that "Assuming the ITS tree reflects species relationships, we need a new genus name for the New World species of *Cupressus* if *Xanthocyparis* is recognized." While Xiang and Li (2005) submerged *X. vietnamensis* in *Cupressus*, the combination *Cupressus vietnamensis* was made previously by Silba (2005) and remade later by Rushforth (2007).

Prior to the recent spate of publications described above, taxonomic work on *Cupressus* largely was focused on the specific and infraspecific level with considerable disagreement as to the number of distinct species to recognize in the genus (see Wolf, 1948; Little, 1970; Farjon, 2005). The classical monograph by Camus (1914) treated the known species of *Cupressus* on a worldwide basis and also included the distinct but related *Chamaecyparis* as a subgenus of *Cupressus*. The most thorough morphological treatment of the Western Hemisphere species of *Cupressus* is the revision of Wolf (1948), who only included the New World species in his study on the grounds that the Eurasian and African species were not readily accessible for detailed population-based field studies. He also stated that "none of [the Old World species] appears closely related to our New World species."

Silba (1983), after reportedly raising seedlings of the 25 taxa he delimited, noted consistent differences in cotyledon number and shape in all Western versus Eastern Hemisphere cypresses (cotyledons 3-4 and acute, versus 2 and obtuse), though he did not think these characters, alone, warranted dividing *Cupressus* into subsections. However, Silba (1994, 1998) later arranged *Cupressus* into two subgenera and seven sections, and designated *Cupressus lusitanica* as the type for his new subgenus, *Indoamericana*, which included Western

Hemisphere taxa of *Cupressus* with some additional Asian species. The name of this subgenus, *Indoamericana*, reflects the generally discredited belief, which Silba (2006) continues to support, that *C. lusitanica* (which occurs in the wild in Mexico and central America) actually originated in Goa, India, from where seed was purportedly collected and introduced into Portugal (Farjon 1993). Apart from this problem, Silba's (1994, 1998) treatment would place some species in multiple sections (Little, 2006).

Little (2006) expanded the scope and depth of his previous work (Little, et al., 2004) and analyzed cpDNA (*matK, rbcL*, and *trnL*) plus two nuclear gene regions: nrDNA(ITS), and NEEDLY for all 16 species of the Western Hemisphere and 12 species of the Eastern Hemisphere (*Cupressus, sensu lato*). The portions of his trees relating to *Xanthocyparis*, *Cupressus*, and *Juniperus* are depicted in figure 1.

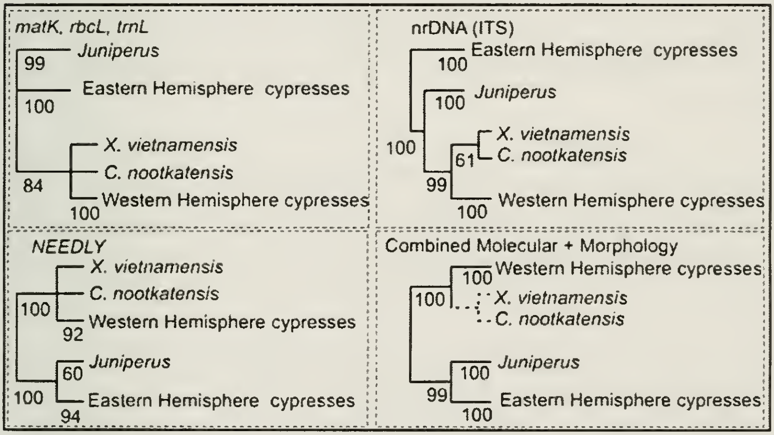

Figure 1. Summary of partial trees extracted from data of Little (2006). Numbers below the branches are strict consensus jackknife frequencies above 50%. Dashed lines in the Combined Molecular + Morphology tree for *C. nootkatensis* and *X. vietnamensis* indicate branches that are collapsed in the strict consensus.

Little (2006) obtained strong support for the Western Hemisphere cypresses as a monophyletic clade in the analyses of each of his molecular data sets. In addition, there was strong support (Fig. 1) that the closest relatives of Western Hemisphere cypresses are *Xanthocyparis vietnamensis* and *Callitropsis nootkatensis*. The Western and Eastern Hemisphere cypresses, and *Juniperus* are each well resolved as distinct clades in each of his molecular analyses, while *X. vietnamensis* and *C. nootkatensis* form an unresolved trichotomy with the Western Hemisphere cypresses in the cpDNA and NEEDLY analyses, and are only moderately well supported (61%) as a 2-species clade in the ITS analysis (Fig. 1). A tree based on morphological data failed to separate eastern from Western Hemisphere cypresses, but a combined analysis of the morphological and molecular data sets did strongly separate these geographic groups (Little, 2006, Fig. 1 above). The results of the molecular and combined analyses also provided strong evidence that *C. lusitanica* is nested well within the Western Hemisphere group, whereas *C. torulosa* is definitely placed within the Eastern Hemisphere lineage contrary to the subgeneric classification of Silba (1994).

In addition to the previously mentioned response to Little et al. (2004) by Mill and Farjon (2006), Farjon (2007) in a letter to a Taxon took issue with Little's 2006 paper because Farjon maintained that the only significant morphological difference between the Western and Eastern Hemisphere cypresses, cotyledon number, did not hold for two Asian species, *C. chengiana* and *torulosa*. Farjon (2007) concluded that there "are no morphological or anatomical differences that justify this generic separation." While acknowledging that "No single characteristic can be used diagnostically," Little (2006) stated that a suite or "series of vegetative characteristics possibly associated with adaption to arid environments (e.g., monomorphic leaves, penultimate and ultimate segments arranged on two planes) unite the New World *Cupressus* species to the exclusion of Old World *Cupressus*, *Juniperus*, and *Callitropsis* [*sensu stricto*]."

Little (2006) decided to include the Western Hemisphere cypresses (*Cupressus*) in *Callitropsis* and published 17 new names from North America. Little (2006) reasoned that giving a new genus name to the Western Hemisphere cypresses (as suggested by Xiang and

Li, 2005) would be "consistent with some but not all resolutions of the polytomy between *Callitropsis* [i.e., *X. vietnamensis* and *Ch. nootkatensis*] and the New World *Cupressus* species." However, only the ITS data (Fig. 1) present *X. vietnamensis* - *C. nootkatensis* as a clade and Little's results did not provide any strong evidence against placing these two taxa in a separate genus (as suggested by Farjon et al., 2002 and Little et al., 2004) or as monotypic genera as suggested by Debreczy et al. (2009).

In an effort to add additional molecular data to the taxonomic questions, we have sequenced two nuclear genes (4-coumarate: CoA ligase, 4CL and abscisic acid-insensitive 3, ABI3, as well as complete nrDNA(ITS) sequences for additional taxa and a cpDNA region, petN-psbM.

The 4-coumarate: CoA Ligase (4CL) gene family is important in phenylpropanoid synthesis leading to lignin, as well as flavonoids, and other pigments as well as phenolic compounds in essential oils such as safrole, eugenol, etc. (Hamberger and Hahlbrock, 2004; Cukovic et al., 2001) Recently, Peng and Wang (2008) utilized 4CL sequences to study *Thuja* species and *Thujopsis dolabrata*. In *Thujopsis dolabrata* they found the 4CL gene to be composed of 4 exons and 3 introns. Intron 2 was reported as 640 bp (EU183423). Aligning the GenBank sequences for *Thuja plicata* (EU183418, EU183417) and *Thujopsis dolabrata* (EU183423) enabled us to design primers to span intron 2, and resulted in 746 - 823 bp of sequence data.

Lazarova, Zeng and Kermode (2001) reported on the occurrence of an abscisic acid-insensitive 3 (ABI3) gene homologue from *Chamaecyparis nootkatensis* (CnABI3). The ABI3 gene is composed of six exons and five introns, with the intron sizes of 105, 113, 110, approx. 1000, and 142 bp. Primers were designed in exon 4 and exon 5 to amplify intron 4 (see Materials and Methods below) and resulted in 1020 - 1108 bp of sequence data.

The cp region trnC-trnD has been used in phylogenetic studies in *Juniperus* (Adams, 2007; Adams et al., 2007). The partial sequence utilized in this study is the petN - psbM region (included in the trnC-trnD region). This region is much easier to amplify and resulted in approximately 807-854 bp compared to 1400 - 1500 for the full trnC-trnD region.

The purpose of the present study is to bring additional molecular data to bear on the question of the taxonomic status of *Xanthocyparis*, versus the Eastern and Western Hemisphere cypresses.

MATERIALS AND METHODS

Specimens used in this study:

Species	Voucher	Source	GenBank
X. vietnamensis			
nrDNA(ITS)	Little et al. 2004	Vietnam	AY380877
4CL	Rushforth 7745	Vietnam	FJ744493
CnABI3	Rushforth 7745	Vietnam	FJ56803
petN-psbM	Rushforth 7745	Vietnam	FJ46729
C. nootkatensis			
nrDNA(ITS)	Little et al. 2004	AK, USA	AY380858
4CL	*Adams 9086*	WA, USA	FJ744494
CnABI3	*Adams 9086*	WA, USA	FJ56803
petN-psbM	*Adams 9086*	WA, USA	FJ46730
C. atlantica			
nrDNA(ITS)	Little et al. 2004	Morocco	AY988367
4CL	*Adams 8429*	Morocco	FJ744495
CnABI3	*Adams 8429*	Morocco	FJ56805
petN-psbM	*Adams 8429*	Morocco	FJ46731
C. dupreziana,			
nrDNA(ITS)	Little et al. 2004	Algeria ex Hillier Gard.	AY988375
4CL	*Adams 8432*	Algeria ex Hillier Gard.	FJ744496
CnABI3	*Adams 8432*	Algeria ex Hillier Gard.	FJ56806
petN-psbM	*Adams 8432*	Algeria ex Hillier Gard.	FJ46733
C. sempervirens,			
nrDNA(ITS)	*Adams 8434*	Elburz Mts., Iran	FJ705221
4CL	*Adams 8434*	Elburz Mts., Iran	FJ744497
CnABI3	*Adams 8434*	Elburz Mts., Iran	FJ56807
petN-psbM	*Adams 8434*	Elburz Mts., Iran	FJ46732

H. abramsiana			
nrDNA(ITS)	*Adams 9354*	CA, USA	FJ705220
4CL	*Adams 9354*	CA, USA	FJ744498
CnABI3	*Adams 9354*	CA, USA	FJ56808
petN-psbM	*Adams 9354*	CA, USA	FJ46737
H. bakeri			
nrDNA(ITS)	Little et al. 2004	CA, USA	AY988369
4CL	*Adams 9362*	CA, USA	FJ744499
CnABI3	*Adams 9362*	CA, USA	FJ56809
petN-psbM	*Adams 9362*	CA, USA	FJ46739
H. pygmaea			
nrDNA(ITS)	*Adams 9357*	CA, USA	FJ705219
4CL	*Adams 9357*	CA, USA	FJ744500
CnABI3	*Adams 9357*	CA, USA	FJ56810
petN-psbM	*Adams 9357*	CA, USA	FJ46738
J. monticola			
nrDNA(ITS)	*Adams 6876*	HID, MX	FJ705218
4CL	*Adams 6876*	HID, MX	FJ744501
CnABI3	*Adams 6876*	HID, MX	FJ56811
petN-psbM	*Adams 6876*	HID, MX	FJ46736
J. saltillensis			
nrDNA(ITS)	*Adams 6886*	NL, MX	FJ705217
4CL	*Adams 6886*	NL, MX	FJ744502
CnABI3	*Adams 6886*	NL, MX	FJ56812
petN-psbM	*Adams 6886*	NL, MX	FJ46735
J. virginiana			
nrDNA(ITS)	*Adams 6753*	TX, USA	EF608980
4CL	*Adams 6753*	TX, USA	FJ744503
CnABI3	*Adams 6753*	TX, USA	FJ56813
petN-psbM	*Adams 6753*	TX, USA	FJ46734
Thujopsis dolabrata			
nrDNA(ITS)	Peng and Wang	Jiangxi, China	EU183443
4CL	Peng and Wang	Jiangxi, China	EU183423
CnABI3	*Adams 9502*	Japan ex Arn. Arb.	FJ56814
petN-psbM	*Adams 9502*	Japan ex Arn. Arb.	FJ46727

Thuja plicata

nrDNA(ITS)	*Adams 9277*	Vancouver Isl., BC	AY380852
4CL	Peng and Wang	Kew Bot. G. ex USA?	EU183417
CnABI3	*Adams 10311*	Queen Charlotte Isl., BC	FJ56815
petN-psbM	*Adams 10311*	Queen Charlotte Isl., BC	FJ46728

Specimens only used for size determination of 4CL:
C. arizonica, Adams 9378, Pima Co., AZ; *C. benthamii, Adams 8710*, Pachuca, MX; *C. forbesii, Adams 9370*, San Diego Co., CA; *C. glabra Adams 9389*, Gila Co., AZ; *C. goveniana, Adams 11544*, Monterey Co., CA; *C. guadalupensis, Adams 8417,* Guadalupe Isl., MX, ex Berkeley Bot. Garden; *C. lusitanica, Adams 7071,* cultivated, Bussaco, Portugal; *C. macnabiana, Adams 9359*, Napa Co., CA; *C. macrocarpa, Adams 11459*, Crocker Grove, CA; *C. montana, Adams 9660*, Baja, MX; *C. nevadensis, Adams 9367*, Kern Co., CA; *C. sargentii, Adams 9348*, San Luis Obispo Co., CA; *C. stephensonii, Adams 9376*, San Diego Co., CA. Voucher specimens for Adams collections are deposited at BAYLU. Bartel specimens are held in his personal herbarium.

One gram (fresh weight) of the foliage was placed in 20 g of activated silica gel and transported to the lab, thence stored at -20° C until the DNA was extracted. DNA was extracted from juniper leaves by use of a Qiagen mini-plant kit as per manufacturer's instructions.

Amplification and sequencing

ITS (nrDNA), 4CL and trnC-trnD amplifications were performed in 30 µl reactions using 6 ng of genomic DNA, 1.5 units Epi-Centre Fail-Safe Taq polymerase, 15 µl 2x buffer E or K (final concentration: 50 mM KCl, 50 mM Tris-HCl (pH 8.3), 200 µM each dNTP, plus Epi-Centre proprietary enhancers with 1.5 - 3.5 mM MgCl$_2$ according to the buffer used) 1.8 µM each primer.

Gene	Primers	2x buffer	annealing	program	size bp
nrITS	ITSA/ ITSB	K	50ºC	(94-50x30)	1077-1105
4CL	4CL49F/4CL814R	G	55ºC	(94-55x30)	746-823
CnAB13,	CnABI11F/357R	D	55C	(94-55-x30)	1020-1108
petN	petN5F/psbM111R	E	50ºC	(94-50x30)	807-854

Primers (5'-3'):

ITS: ITSA = GGA AGG AGA AGT CGT AAC AAG G;

ITSB = CTT TTC CTC CGC TTA TTG ATA TG.
ITSA and ITSB primers from Blattner (1999).

4CL: 4CL49F AAAGAGCTCATCAAATACAA
4CL814R GAAGAGCTTCCAGCTCAG
4CL primers are from conserved sequences in exon 2 and exon 3 of *Thuja plicata* (EU183418, EU183417) and *Thujopsis dolabrata* (EU1834232) and span intron 2.

CnABI3: CnABI11F AACAATAAGAGCAGGATGTA
CnABI357R CCAGTTTTGGTATCAGAGTA
Addition internal primers utilized:
CnABIint533R CAATATTATCACGCATTTG
CnABIint541R CACAGGAGCAATATTATCAC
CnABIint741R TTACTTGAAACAATCTATTTATGT
CnABI3 primers are from sequences in exon 4 and exon 5 of *Chamaecyparis nootkatensis* (AJ131113) and span intron 4.

petN - psbM:
petN5F: AAC GAA GCG AAA ATC AAT CA
psbM111R: AAA GAG AGG GAT TCG TAT GGA
petN and psbM primers were based on conserved sequences from *Juniperus* species.

The following PCR conditions were used: MJ Research Programmable Thermal Cycler, 30 cycles, 94°C (1 min.), 50°C or 57 ° C (2 min.), 72°C (2 min.), with a final step of 72°C (5 min.). The PCR reaction was subjected to purification by agarose gel electrophoresis (1.5% agarose, 70 v, 55 min.). In each case, the band was excised and purified using a Qiagen QIAquick gel extraction kit. The gel purified DNA band with the appropriate primer was sent to McLab Inc. for sequencing. Sequences for both strands were edited and a consensus sequence was produced using Chromas, version 2.31 (Technelysium Pty Ltd.). Alignments were made using MAFFT (http://align.bmr.kyushu-u.ac.jp/mafft/) and then manually corrected and then re-analyzed using NJ with 1000 bootstrap replications (http://align.bmr.kyushu-u.ac.jp/mafft/).

We included *Thuja* and *Thujopsis* as outgroup taxa in the analyses following the phylogenies of Gadek et al. (2000) and Little et al. (2004).

RESULTS AND DISCUSSION

The overall sequencing efforts are shown in table 1. The number of informative sites and the percent yield varied from largest in nrDNA(ITS) to smallest in petN-psbM. Clearly, nrDNA(ITS) yielded both the most informative sites and the greatest yield for the effort. The single (or low) copy nuclear genes yielded lots of information, being single genes, are difficult to amplify in amounts for preparative yields. The cp DNA (petN-psbM) is multiple copy and very easy to amplify, but the number and yield of informative sites is somewhat smaller.

Table 1. Summary of sequencing results. # of variable and # of informative sites are within the in-group (excluding *T. dolabrata* and *Th. plicata*). % yield of informative sites (% yield) = 100 x # informative / minimum range observed.

gene	range, bp	# variable	# informative	% yield
nrDNA(ITS)	1077-1105	198	158	14.7%
4CL	746-823	124	79	10.6
CnABI3	1020-1108	137	83	8.1
petN-psbM	807-854	84	57	7.1

Sequencing the nrDNA (ITS region) resulted in 1077 to 1105 bp of sequence data. The ITS tree (Fig. 2) is similar to that of Little (2006, Fig. 1, upper right, above), in that the cypresses from the Eastern and Western Hemispheres are 100% supported as distinct clades. There is some support (75%) for the clade of *C. nootkatensis* - *X. vietnamensis* as reported by Little (2006, 61%, Fig. 1 above). The *C. nootkatensis* - *X. vietnamensis*, clade is allied with the Western Hemisphere cypresses using the ITS data (Fig. 2).

Sequencing of the 4-coumarate: CoA ligase intron 2 (4CL) region resulted 746 - 823 bp of sequence data. Examination of the NJ tree reveals four groups (fig. 3) as found with the nrDNA(ITS) data (Fig. 2). The 4CL tree shows a weak association (34%) between *C.*

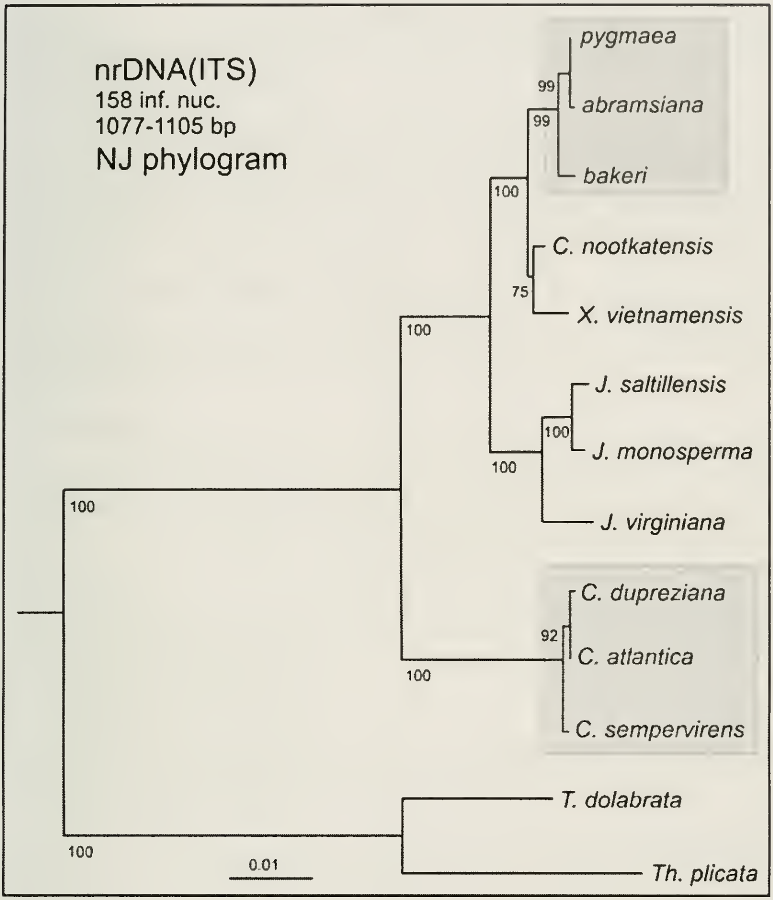

Figure 2. NJ phylogram based on nrDNA(ITS). Numbers below branches are bootstrap probabilities (1000 reps). Eastern Hemisphere cypresses are in the cross-hatched box and Western Hemisphere cypresses are in the shaded box.

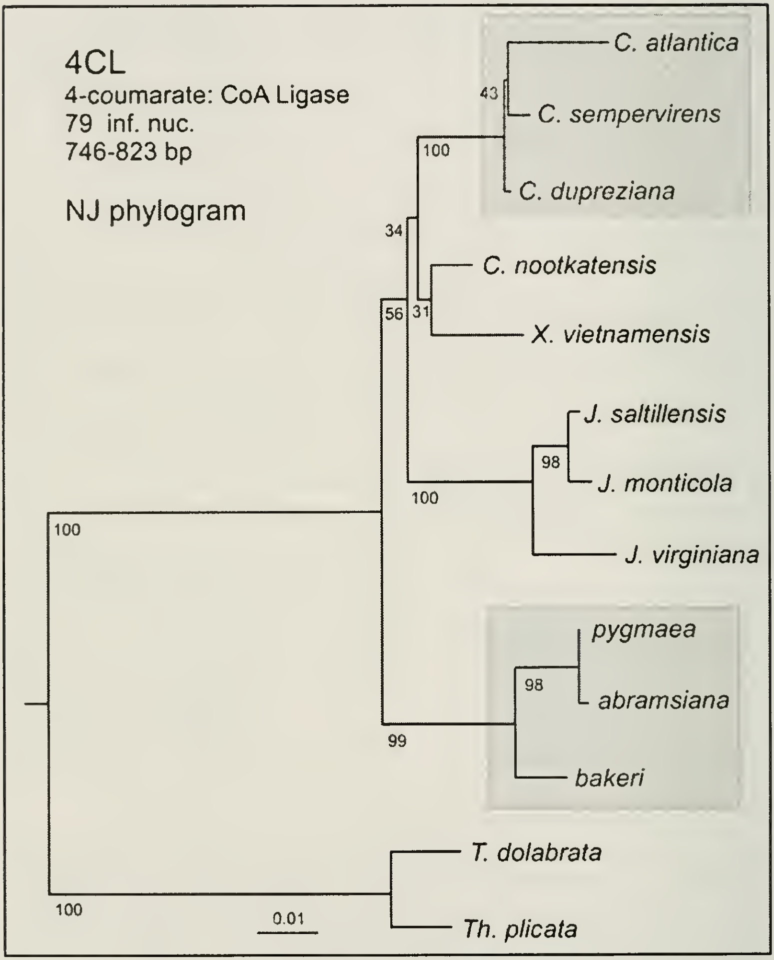

Figure 3. NJ phylogram utilizing sequences from intron 2 of 4-coumarate: CoA ligase (4CL).

nootkatensis-X. vietnamensis and the Eastern Hemisphere cypresses, but again provides substantial support (99%) for the Western Hemisphere cypress clade.

The three Western Hemisphere cypresses (*C. abramsiana, C. bakeri* and *C. pygmaea*) each had a unique 46 bp insert giving them a 4CL length of 817 bp, in contrast, all other taxa that had shorter sequences. A survey of all the other Western Hemisphere cypresses (*C. arizonica, C. benthamii, C. forbesii, C. glabra, C. goveniana, C. guadalupensis, C. lusitanica, C. macnabiana, C. macrocarpa, C. montana, C. nevadensis, C. sargentii, C. stephensonii)* revealed that the length is nearly constant at 817bp, indicating that all these taxa share the 46bp insert.

Sequencing of the CnABI3 intron 4 region revealed several large indels in this data set. The NJ phylogram based on CnABI3 sequence data again shows (Fig. 4) the separate clades of the Eastern and Western Hemisphere cypresses. However, *C. nootkatensis* and *X. vietnamensis* do not form a clade but are well supported as species. The CnABI3 gene sequence supports the contention of Debreczy et al. (2009) that *C. nootkatensis* and *X. vietnamensis* are monotypic genera, since the former forms a strongly supported clade with the Western Hemisphere cypresses (99%).

It is interesting to note that *X. vietnamensis*, *C. atlantica*, *C. dupreziana* and *C. sempervirens* all share a unique 47 bp deletion.

Sequencing petN-psbM of cpDNA resulted lengths ranged from 807 to 854 bp, except for *T. dolabrata* that had only 511 bp. The NJ phylogram (Fig. 5) again shows strong support for separate clades for the Eastern and Western Hemisphere cypresses. Overall, the tree is similar to the cpDNA tree of Little (2006) based on combined sequences from matK, rbcL and trnL (Fig. 1, upper left), but the greater amount of sequence data in Little's tree provides very strong support for the monophyly of the Western Hemisphere cypress lineage (100%), while *C. nootkatensis* and *X. vietnamensis* are not resolved from the Western Hemisphere cypresses in our analysis (Fig. 5). However, again, the Eastern and Western Hemisphere cypresses are in well-supported clades (Fig. 5).

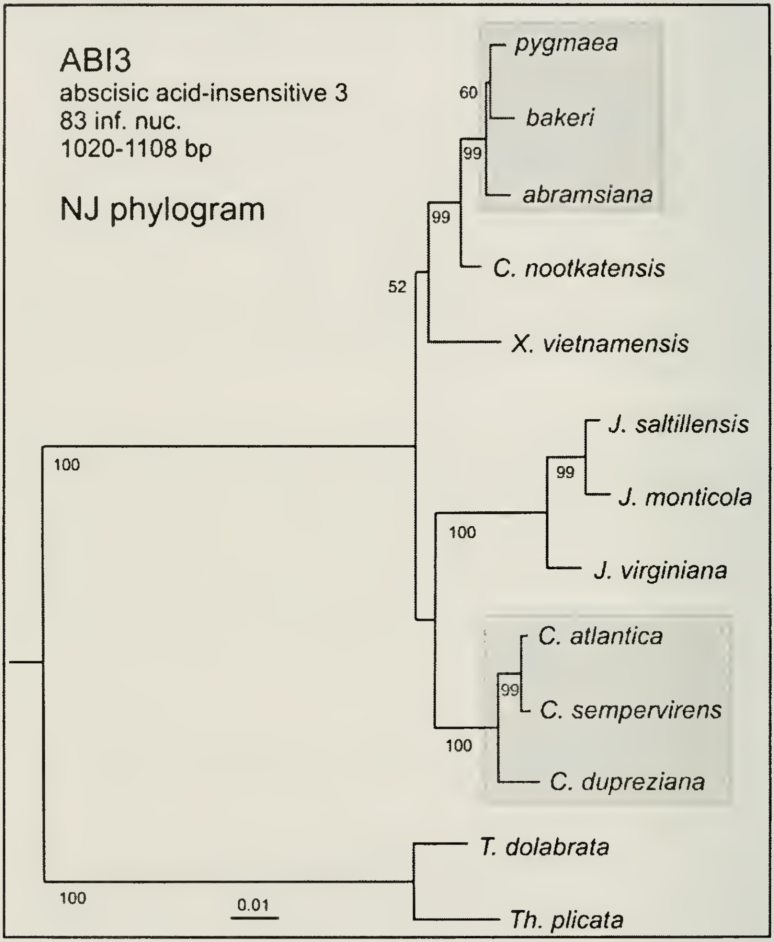

Figure 4. NJ phylogram based on ABI3 intron 4 sequences.

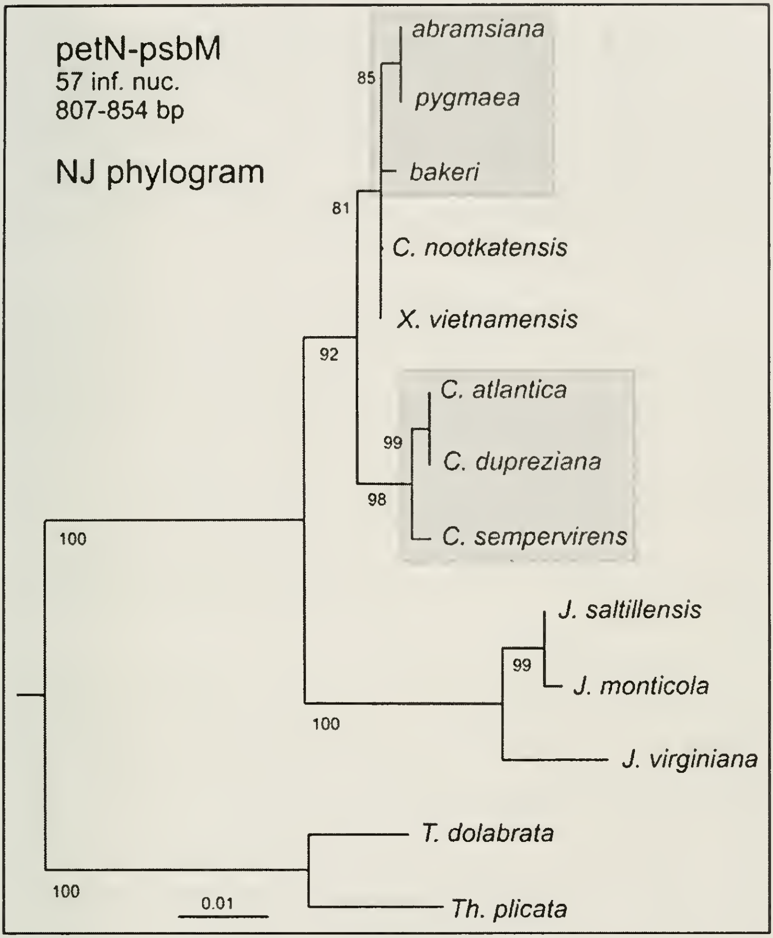

Figure 5. NJ phylogram based on petN - psbM sequences of cp DNA.

An analysis based on combined sequences (nrDNA(ITS), 4CL, CnABI3, petN-psbM) yielding 377 phylogenetically informative nucleotides. The NJ phylogram (Fig. 6) has 100% support for the *T. dolabrata* - *Th. plicata*, Western Hemisphere cypresses, Eastern Hemisphere cypresses, and *Juniperus* clades. It also provides 100% support for the grouping of *C. nootkatensis* and *X. vietnamensis* with the Western Hemisphere cypresses, and is consistent with the proposal by Debreczy et al. (2009) to treat these taxa as monotypic genera.

The separation of *C. nootkatensis* and *X. vietnamensis* is consistent with several morphological characters distinguishing the two: both needle-like juvenile leaves and scale-like adult leaves occur on the mature plant in only the latter, the seed coat has minute warty resin pustules in only the latter, and there is a short but quite distinct resin-filled columella at the center of the mature and open seed cone in only the former (Debreczy et al., 2009). *Callitropsis nootkatensis* and similar extinct forms also have a substantial fossil record dating back to at least 50 MYA in western North America (Edwards, 1983), which may serve to provide a minimum time depth for the split between this group and the Western Hemisphere cypress lineage.

Our results are consistent with those of Little (2006) in providing further support for a distinct lineage of Western Hemisphere cypresses quite separate from the Eastern Hemisphere cypresses and most closely related to *C. nootkatensis* and *X. vietnamensis*. The Western Hemisphere cypresses differ significantly in cone morphology from the latter two species, notably in having cones with many more seeds (typically 5-20 per cone scale and 60-150 per cone versus 2-4 per cone scale and < 15 per cone), woodier and larger peltate cone scales, and cotyledons, with few exceptions, 3-5 in number versus 2. Thus, rather than following Little (2006), who included the Western Hemisphere cypresses plus *C. nootkatensis* and *X. vietnamensis* in an expanded genus *Callitropsis*, we recognize a new genus including only the Western Hemisphere cypress lineage.

The traditional approach of including the Eastern Hemisphere and Western Hemisphere cypress lineages in a genus to the exclusion of

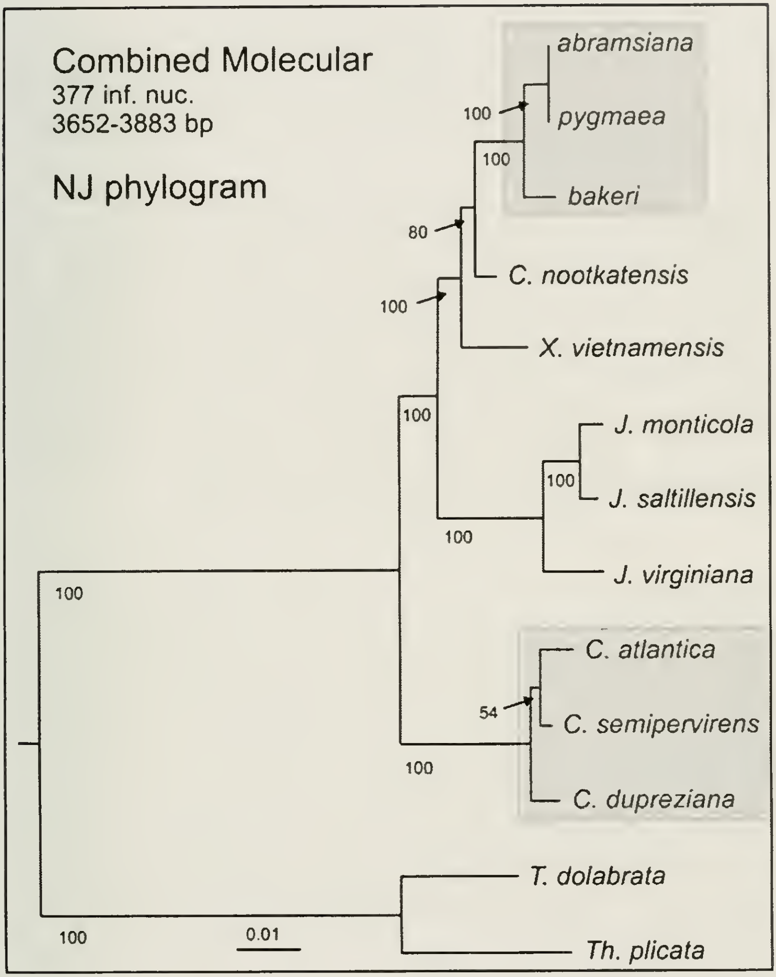

Figure 6. NJ phylogram based on combined sequences (nrDNA(ITS), 4CL, CnABI3, petN-psbM).

Callitropsis, *Xanthocyparis* and *Juniperus* would run contrary to the very likely phylogenetic relationships in the group supported by multiple lines of molecular phylogenetic data, which indicate that *C. nootkatensis* and *X. vietnamensis* rather than the Eastern Hemisphere cypresses are the closest relatives of the Western Hemisphere cypresses (Figs. 1, 6). We believe that the possible alternative approach of including the entire clade of cypresses, junipers, *Xanthocyparis* and *Callitropsis* in a single genus would be unduly disruptive to the nomenclature of horticulturally important taxa, particularly if *Cupressus* is given nomenclatural priority over *Juniperus* (which would require 67 new combinations at the species level; Adams, 2008), and would also tend to obscure rather than elucidate the morphological groupings and major evolutionary lineages in the group. We provisionally recognize 16 species as distinct for purposes of providing new species combinations, following the monographic treatment of Wolf (1948) and the phylogenetic results of Little (2006).

The new genus is cryptic in its macromorphology, being similar to *Cupressus stricto sensu* in its general appearance and cone morphology, but is very distinct in molecular phylogenetic analyses from multiple genes and two genomes. In morphology, it is most evidently distinguished from the majority of species of Cupressus *stricto sensu* in its greater number of cotyledons (3-5), and is distinguished from any taxa of Eastern Hemisphere cypresses that may have parallelisms for this character (*C. torulosa* of Asia has 3-5 cotyledons according to Camus, 1914) by a combination of branchlet characters as described below. *Cupressus torulosa* and all other native Eurasian and African species of the genus are unequivocally placed in the Eastern Hemisphere clade in the molecular phylogenetic analyses of Little (2006). Recognition of new genera as new sources of phylogenetic information emerge to support them as distinct evolutionary units has a long tradition, as witness the segregation of multiple genera of Cupressaceae with similar cone morphology from the classical genus Libocedrus. These segregate genera are now widely recognized (Farjon, 1998, 2005) and are well supported by recent molecular studies (Gadek et al., 2000).

TAXONOMIC TREATMENT

Hesperocyparis Bartel & R. A. Price, **gen. nov.**—
TYPE: *Hesperocyparis macrocarpa* (Hartw. ex Gordon) Bartel.

Differt a *Callitropse* and *Xanthocypare* cotyledonibus 3–5 (vs. 2), squamis strobilis paribus 3–6 (vs. 2–3) peltatis non dense incrassatis (vs. basifixis non dense incrassatis), et seminibus per strobilum generaliter 60–150 (vs. paucioribus quam 15). Differt a *Cupresso* cotyledonibus 3–5 (vs. plerumque 2), testa generaliter glauco (vs. non glauco), ordinibus ultimis duobus segmentis caulinis in fasciculis 3-dimensionalibus, segmentis ultimis caulibus in sectione transversali non complanatis, et foliis monomorphis segmentorum caulinorum ultimorum (vs. ordinibus ultimis duobus segmentis caulinis in asperginibus 2-dimensionalibus aut segmentis caulinis ultimis in sectione transversali complanatis et foliis dimorphis segmentorum caulinorum ultimorum). Plantae Hemisphaerii Occidentalis.

Hesperocyparis differs from *Callitropsis* and *Xanthocyparis* in its cotyledons 3-5 (vs 2), seed cone scales in 3-6 pairs (vs 2-3 pairs), peltate and heavily thickened (vs basifixed and not heavily thickened), and seeds per cone generally 60-150 (vs < 15). *Hesperocyparis* differs from *Cupressus* in its cotyledons 3-5 (vs usually 2), seed coat generally ± glaucous (vs not glaucous), usually ultimate 2 orders of branch segments in 3-dimensional clusters, ultimate branch segments not flattened in cross section, and ultimate branch segments leaves monomorphic (vs usually ultimate 2 orders of branch segments in 2-dimensional sprays, or ultimate branch segments flattened in cross section and ultimate branch segments leaves dimorphic). Plants of the Western Hemisphere.

Shrub or tree to (<1-)4-35(-40) m, multi- to generally single-trunked, monoecious, evergreen. *Bark* on trunk fibrous or leathery and smooth, exfoliating in fibrous strips or irregular-shaped plates, gray to brown to cherry-brown. *Branch segments* (stems and overlapping leaves) terete to quadrangular, ultimate and penultimate branch segments generally in 3-dimensional clusters or rarely in 2-dimensional flattened sprays. *Leaves* of juvenile plants awl- to needle-like, decussate or in whorls of 3; of adult plants decussate, scale-like, appressed, overlapping, generally monomorphic, minutely denticulate or rarely entire, often with a dorsal resin gland, leaves on vigorously growing shoots more elongate and acute-tipped. *Pollen cones*, terminal on separate ultimate branch segments, sub-spheric to elliptic-ovoid to cylindrical, terete to quadrangular, 2.0-6.5 mm long, 1.3-3.0 mm wide, yellow-green; microsporophylls decussate in 3-10 pairs, 3-6(10) sporangia in an irregular row per microsporophyll. *Seed cones* 10-50 mm long, more or less woody, nearly spheric to widely cylindric, maturing in the second year, generally remaining closed at maturity and opening after many years or in response to fire, abscising after opening or after many additional years; scales decussate in (2-)3-6 pairs, thickened, peltate, abutting, shield- or wedge-shaped, boss generally >1 mm (especially prior to maturity), pointed, base level with or rising from edge. *Seeds* many per scale (generally 5-20) per cone, flattened, ovate to lenticular, irregularly faceted due to close packing; seed wings, 2, membranous, narrow, seed body light tan to red brown to brown to dark brown to black, generally glaucous, generally warty with minute resin pustules in the seed coat; cotyledons (2-)3-5(-6), linear, slightly ridged, bluntly pointed at apex. Chromosome number, 2n = 22(23,24).

Hesperocyparis abramsiana (C. B. Wolf) Bartel, **comb. nov.** *Cupressus abramsiana* C. B. Wolf, Aliso 1: 215. 1948. *Cupressus goveniana* Gordon var. *abramsiana* (C. B. Wolf) Little, Phytologia 20: 435. 1970. *Cupressus goveniana* Gordon subsp. *abramsiana* (C. B. Wolf) A. E. Murray, Kalmia 12: 19. 1982. *Callitropsis abramsiana* (C. B. Wolf) D. P. Little, Syst. Bot. 31: 473. 2006.

Hesperocyparis arizonica (Greene) Bartel, **comb. nov.** *Cupressus arizonica* Greene, Bull. Torrey Bot. Club 9: 64. 1882. *Cupressus benthamii* Endl. var. *arizonica* (Greene) Mast., J. Linn. Soc. Bot. 31: 340. 1896. *Callitropsis arizonica* (Greene) D. P. Little, Syst. Bot. 31: 473. 2006.

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1923. *Callitropsis bakeri* (Jeps.) D. P. Little, Syst. Bot. 31: 473. 2006.

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Hesperocyparis guadalupensis (S. Watson) Bartel, **comb. nov.** *Cupressus guadalupensis* S. Watson, Proc. Amer. Acad. Arts 14: 300. 1879. *Cupressus macrocarpa* Hartw. var. *guadalupensis* (S. Watson) Mast., Gard. Chron., Ser. 3 18: 62. 1895. *Callitropsis guadalupensis* (S. Watson) D. P. Little, Syst. Bot. 31: 473. 2006.

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NEW NAMES IN *CHAMAESARACHA* (SOLANACEAE)

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ABSTRACT

Two new names are proposed for *Chamaesaracha*: *C. arida* Henrickson, [*C. coronopus* auct. non (Moric. ex Dunal) A. Gray] and *C. texensis* Henrickson [*C. conoides* auct. non (Moric. ex Dunal) Britt.] *Chamaesaracha villosa* Rydb. is used for the taxon inclusive of *C. crenata* Rydb. *Phytologia 91(1):186-188 (April, 2009*).

KEY WORDS: *Chamaesaracha arida, C. texensis, Solanaceae.*

A new name is needed for a distinct taxon that was included within *Chamaesaracha coronopus* (Moric. ex Dunal) A. Gray by Averett (1973).

CHAMAESARACHA ARIDA Henrickson, **sp. nov**. TYPE: U.S.A. New Mexico: Santa Fe Co., ca. 19 mi. s. of Santa Fe, N.M. on Hwy. 85, 15 Jul 1968, *J.E. Averett & A.S. Tomb 339* (holotype TEX!).

Folia caules pedicellique subglabri pilis dispersis basibus latis distaliter furcatis vel ramosis 0.1-0.3 mm longis, segmentis pilorum superiorum brevis latis obtusisque, raro pilis gradatim angustatis simplicibus vel furcatis ad 1.5 mm longis, foliis linearis vel lineari-lanceolatis vel lineari oblanceolatis marginibus undulatis et dentatis vel pinnati-lobatis.

Leaves, stems, pedicels subglabrous, with scattered, broad-based, distally forked to branched hairs 0.1-0.3 mm long, the upper hair branches short, blunt, rarely with tapering, simple or distally branched hairs; leaves linear to linear-lanceolate, linear-oblanceolate, the margins undulate, toothed or pinnately lobed.

Study of lectotype and syntype specimens of *C. coniodes* (Moric. ex Dunal) Britt. at Geneva (G), show that the taxon is characterized by a dense low vestiture of forked-branched hairs. Averett's (1973) and Rydberg's (1896) usage of the name for a stipitate glandular species is incorrect and a new name is provided herein for the stiptiate glandular species.

CHAMAESARACHA TEXENSIS Henrickson, **sp. nov.** [*Chamaesachara coniodes auct. non* (Moric. ex Dunal) Britt.]. Type: U.S.A. Texas: Kinney Co., open rocky soil near the Nueces River, Hy. 334, 17 Apr 1957, *D.S. Correll 15965 with R.C. Rollins & K. Chambers* (holotype LL!).

A *Chamaesaracha sordida* foliorum juniorum irregulatim dentato-laceratis vel pinnatifidis lobatis integris vel dentatis (non dentatis obtusis vel non profundis paucisque) et tetraploideis (*n*=24) non diploideis (*n*=12) dignoscenda.

From *Chamaesaracha sordida* distinguished by the young leaves being irregularly toothed-lacerate to pinnatifid, with entire to toothed lobes (not entire to bluntly or shallowly few toothed) and tetraploid (*n*=24) (not diploid *n*=12).

I herein combine *C. villosa* Rydb. with *C. crenata* Rydb., and use the name *C. villosa* Rydb. for the inclusive species. Both were published on the same page in Mem. Torr. Bot. Club. 4:368. 1896.

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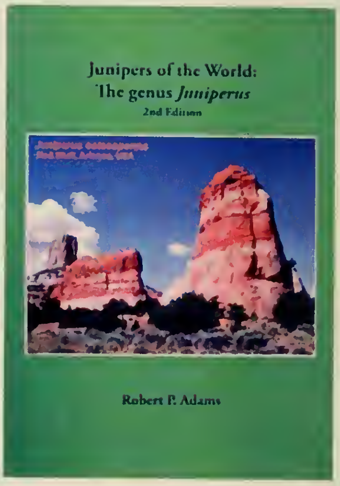

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