Arceuthobium tsugense subsp. *amabilae*, a New Subspecies of Hemlock Dwarf Mistletoe (Viscaceae) from Oregon

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Abstract. The dwarf mistletoe severely parasitizing Pacific silver fir in Oregon is described as a new subspecies of hemlock dwarf mistletoe. This classifi cation is based on morphological and host range differences between hemlock dwarf mistletoe, *Ar ceuthobium tsugense* (Rosendahl) G. N. Jones subsp. *tsugense*, and the new subspecies, Pacific silver fir dwarf mistletoe, *Arceuthobium tsugense* subsp. *am abilae* Mathiasen & C. Daugherty.

Key words: *Arceuthobium*, Hemlock dwarf mis tletoe, IUCN Red List, mountain hemlock, noble fir, Oregon, Pacific silver fir, Viscaceae, western hem lock.

The taxonomic classification of the dwarf mistletoes severely parasitizing Pacific silver fir (*Abies amabilis* Douglas ex J. Forbes) in Oregon and Washington has been unclear for many years (Hawksworth, 1987; Hawksworth & Wiens, 1972, 1996). These mistletoes were first classified by Gill (1935) as *Arceuthobium campylopodum* Engelmann f. *abietinum* (Engelmann) L. S. Gill. Gill based his classification of *A. campylopodum* on his host form concept, and all dwarf mistletoes found on Pacific silver fir were placed in the form that included parasites of *Abies* species (f. *abietinum*). In their monograph of *Arceuthobium* M. Bieberstein, Hawksworth and Wiens (1972) classified the dwarf mistletoe parasitizing Pacific silver fir in the Pacific Northwest as hemlock dwarf mistletoe (*Arceuthobium tsugense* (Rosendahl) G. N. Jones), whose principal host is western hemlock (*Tsuga heterophylla* (Rafinesque) Sargent). Hawsk worth and Wiens noted that infection of Pacific silver fir by *A. tsugense* was most common when this tree was growing in close association with infected hemlocks. They also noted that many of the reports of fir dwarf mistletoe (*Arceuthobium abietinum* Engelmann ex Munz) on Pacific silver fir from Washington should be attributed to *A. tsugense*, and they did not consider *A. abietinum* to be a parasite of Pacific silver fir. Hawksworth and Wiens (1972) only included white fir (*Abies concolor* Lindley & Gordon), grand fir (*Abies grandis* (Douglas ex D. Don) Lindley), California red fir (*Abies magnifica* A. Murray), and noble fir (*Abies procera* Rehder) as hosts of *Arceuthobium abietinum* in Oregon; they included only grand fir in Washington.

Hawksworth (1987) summarized the taxonomy of *Arceuthobium tsugense* and separated this species into three different races: a western hemlock race, a shore pine race, and a mountain hemlock race. Hawksworth indicated that only the western hemlock race parasitized species of *Abies*. Hawksworth et al. (1992) presented another interpretation for the classification of *A. tsugense*. They described the western hemlock and mountain hemlock races pro posed by Hawksworth (1987) as subspecies of *A. tsugense*: western hemlock dwarf mistletoe (*A. tsugense* subsp. *tsugense*) and mountain hemlock dwarf mis tletoe (*A. tsugense* (Rosendahl) G. N. Jones subsp. *mertensianae* Hawksworth & Nickrent), but they maintained the dwarf mistletoe parasitizing shore pine (*Pinus contorta* Douglas ex Loudon var. *contorta*) as a race of subspecies *tsugense*. They reported that *A. tsugense* subsp. *mertensianae* was also a common parasite of Pacific silver fir, noble fir, and subalpine fir (*Abies lasiocarpa* (Hooker) Nuttall), but only where these hosts were associated with infected mountain hemlocks. Both subspecies of *A. tsugense* were considered to be principal parasites of Pacific silver fir and noble fir by Hawksworth et al. (1992).

In a revision of their monograph on *Arceuthobium*, Hawksworth and Wiens (1996) maintained the classification of *A. tsugense* as proposed by Hawks worth et al. (1992). However, Wass and Mathiasen (2003) classified the race of *A. tsugense* parasitizing shore pine in southern British Columbia and north western Washington as a subspecies of *A. tsugense*: *A. tsugense* subsp. *contortae* Wass & Mathiasen. There fore, the most current classification of hemlock dwarf mistletoe consists of three subspecies: western

hemlock dwarf mistletoe (subsp. *tsugense*), mountain hemlock dwarf mistletoe (subsp. *mertensianae*), and shore pine dwarf mistletoe (subsp. *contortae*). The subspecies are primarily distinguished by differences in plant height, time of flowering and seed dispersal, and host range (Hawksworth et al., 1992; Hawksworth & Wiens, 1996; Wass & Mathiasen, 2003). Hawksworth and Wiens (1996) classified Pacific silver fir as a principal host of subspecies *mertensianae* and as a tentative principal host of subspecies *tsugense*. Mathiasen and Daugherty (2005) provided quantitative data demonstrating that Pacific silver fir is only an occasional host of subspecies *tsugense* in the Cascade Range of Oregon and Washington but reported that some large Pacific silver firs are severely infected when growing in close association with infected western hemlocks. The latter situation has resulted in confusion regarding the natural susceptibility of Pacific silver fir to subspecies *tsugense* in the Pacific Northwest.

In 1997, we began intensive studies of the morphology and host range of *Arceuthobium tsugense* throughout its geographic range. Based on this work, we describe the dwarf mistletoe commonly parasitizing Pacific silver fir in central Oregon as another subspecies of *A. tsugense*.

Arceuthobium tsugense (Rosendahl) G. N. Jones subsp. **amabilae** Mathiasen & C. Daugherty, subsp. nov. [Pacific silver fir dwarf mistletoe]. TYPE: U.S.A. Oregon: Linn County, Bunchgrass Mountain at jct. of forest roads 2655 and 503, Willamette Natl. Forest, parasitic on *Abies amabilis*, 44°18′59″N, 122°05′05″W, ca. 1380 m, 26 Sep. 2004, *R. L. Mathiasen & C. M. Daugherty 0462* (holotype, ASC; isotypes, MO, UC, US).

Plantae 6 18(10) cm altae; surculi principales basi 2 6(3.3) mm diam.; internodiis tertiis 7 26(14.4) mm longis, 2 mm latis; fructus maturi 4.7 × 3.1 mm; anthesis mense Julio Septembri; fructus maturitas Septembri Octobri; in *Abies amabilis* parasiticae.

Plants 6 18 cm in height (mean ca. 10 cm); basal diam. of dominant plants 2 6 mm (mean 3.3 mm); third internode length 7 26 mm (mean 14.4 mm) and 2 mm wide; staminate plants primarily green brown, but some yellow green; pistillate plants primarily green, but some green brown or, rarely, yellow green; staminate flowers 3 or 4 partite, flower diam. 2.5 5.8 mm (mean 3.5 mm); mature fruit length 3.2 6 mm (mean 4.7 mm) and 2.4 3.9 mm wide (mean 3.1 mm).

Phenology. Anthesis from mid July through mid September with peaks in late July to mid August; seed dispersal from early September to late October with peaks in late September to early October.

Habit. Parasitic principally on *Abies amabilis*, *A. procera*, and *Tsuga mertensiana* (Bongard) Carrière. Secondarily parasitic on *A. lasiocarpa*, occasionally parasitic on *T. heterophylla* and *A. lowiana* (Gordon) A. Murray, and rarely parasitic on *A. grandis* and *Pinus monticola* Douglas ex D. Don.

Distribution. *Arceuthobium tsugense* subsp. *amabilae* occurs in Oregon from near Mount Hood south through the western Cascade Range to ca. 13 km south of the Umpqua River in Douglas County. It is most common in the western Cascade Range of central Oregon south of Tombstone Summit on State Route 20 and north of the Calapooya Mountains. The population of dwarf mistletoe on noble fir near the summit of Mary's Peak in the Oregon Coast Range is considered to represent a western outlier of the Pacific silver fir dwarf mistletoe. Elevational range is from ca. 1100 m on Mary's Peak to as high as 1700 m on Warner Mountain in the western Cascade Range of south central Oregon.

IUCN Red List category. Because *Arceuthobium tsugense* subsp. *amabilae* is distributed from northern Oregon near Mount Hood through the west side of the Cascade Range as far south as the Umpqua River in south central Oregon, its IUCN Conservation Status is best represented as: Least Concern (IUCN, 2001). Our observations south of Tombstone Summit and north of the Calapooya Mountains divide indicate there are many populations of this dwarf mistletoe in this region, and many of the infested Pacific silver fir stands we have observed are severely infested. Many of the infected Pacific silver firs have hundreds of infections and mature plants on them. In addition, both noble fir and mountain hemlock are principal hosts of the dwarf mistletoe, and in several locations these hosts are severely infected as well. Because large scale and intensive logging, including clearcutting, of these forests has been drastically curtailed in the past 10 years, it is not likely that populations of this dwarf mistletoe will be affected unless widespread and intensive logging of these forests resumes.

Pacific Silver Fir Dwarf Mistletoe

A total of 16 populations of *Arceuthobium tsugense* subsp. *amabilae* were sampled from within its geographic range in Oregon (Fig. 1). From each population, 20 to 40 infections were collected, and the dominant shoot from each infection was used for morphological measurements. For each population, 10 or 20 male and female infections were collected.

In order to make a comparison with the morphological characters of *Arceuthobium tsugense* subsp.

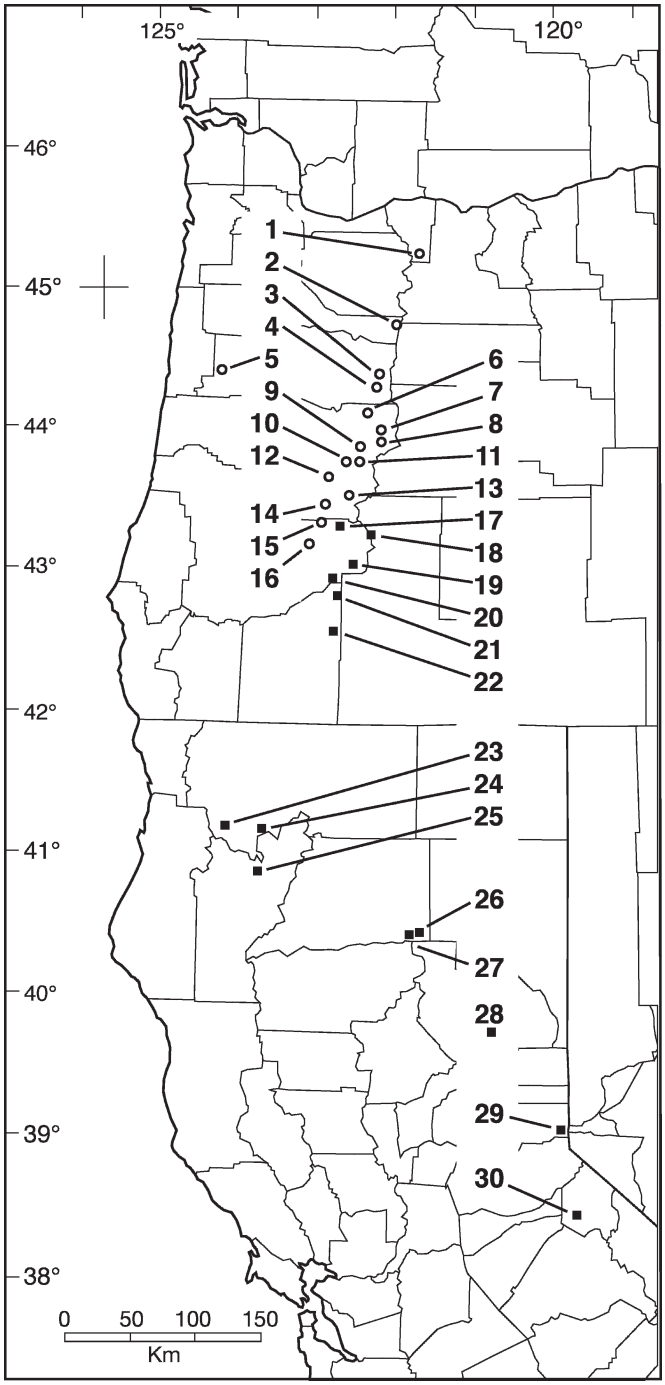

Figure 1. Approximate locations of populations sampled for *Arceuthobium tsugense* subsp. *amabilae* and *A. tsugense* subsp. *mertensianae* in Oregon and California. Open circles indicate populations of subspecies *amabilae*, and closed squares represent populations of subspecies *mertensianae*. OREGON: 1. Bennett Pass. 2. Skyline Road. 3. Wildcat Mountain. 4. Bunchgrass Mountain. 5. Mary's Peak. 6. Frissell Point. 7. Olallie Ridge. 8. Pat Saddle. 9. Lowell Mountain. 10. Huckleberry Mountain. 11. Blair Lake. 12. Holland Meadow. 13. Hemlock Butte. 14. Warner Mountain. 15. Staley Ridge. 16. Snowbird Camp. 17. Calapooya Ridge. 18. Windigo Pass. 19. Mount Thielsen Trail. 20. Beaver Meadow on State Route 230. 21. Huckleberry Campground. 22. Mount McLaughlin Trail. CALIFORNIA: 23. Chimney Rock. 24. Eaton Lake. 25. Snowslide Lake. 26. Kings Creek. 27. Diamond Peak. 28. Long Lake. 29. Alpine Meadows Ski Area. 30. Mosquito Lakes.

Table 1. Principal morphological and physiological differences between Pacific silver fir dwarf mistletoe (subsp. *amabilae*), western hemlock dwarf mistletoe (subsp. *tsugense*), and mountain hemlock dwarf mistletoe (subsp. *mertensianae*).

Characters	subsp. *amabilae*	subsp. *tsugense*	subsp. *mertensianae*
Mean plant height, cm			
Male	9.4	7.8	5.7
Female	10.6	8	6.1
Mean basal diam., mm			
Male	3.1	2.6	1.9
Female	3.4	2.7	2.2
Mean length of third internode, mm			
Male	12.6	11.8	8
Female	15	12.3	9.8
Mean flower diam., mm	3.5	3.6	2.7
Mean fruit length, mm	4.7	4.4	3.8
Plant color			
Male	green-brown/yellow-green/green	yellow-green	yellow-green/green-brown
Female	green/green-brown	yellow-green/purple	green-brown/green
Host susceptibility[1]			
Pacific Silver Fir	principal host	occasional host	immune
Western hemlock	occasional host	principal host	occasional host
Mountain hemlock	principal host	occasional host	principal host
Noble fir	principal host	occasional host	unknown
Western white pine	rare host	rare host	occasional host
Peak seed dispersal	2 weeks earlier than subsp. *tsugense*	2 weeks later than subsp. *amabilae* and subsp. *mertensianae*	2 weeks earlier than subsp. *tsugense*

[1] Host susceptibility system follows Hawksworth and Wiens (1972, 1996). Host classifications for subsp. *amabilae* are based on data from field observations. Host classifications for subsp. *tsugense* are based on data presented by Mathiasen and Daugherty (2005) and Shaw (1982). Host classifications for subsp. *mertensianae* are based on data from Mathiasen and Hawksworth (1988) and from field observations. Earlier classifications of Pacific silver fir and noble fir as principal hosts of subsp. *mertensianae* are based on the classification of subsp. *amabilae* as subsp. *mertensianae* in Oregon (Mathiasen, 1994; Hawksworth & Wiens, 1996).

mertensianae, a total of 14 populations of subspecies *mertensianae* were sampled from central and northern California and southern Oregon (Fig. 1). From each population, 20 to 40 infections were collected, and the dominant shoot from each infection was used for morphological measurements. For each population, 10 or 20 male and female infections were collected.

Morphological data for *Arceuthobium tsugense* subsp. *tsugense* were collected for a total of 20 populations from British Columbia (6 populations), Washington (6 populations), and Oregon (8 populations) by Wass and Mathiasen (2003). The subspecies *tsugense* populations had 10 male and 10 female infections sampled from each population.

The dwarf mistletoe plant characters measured were those used by Hawksworth and Wiens (1996) for taxonomic classification. The following morphological characters were measured: (1) height, basal diameter, third internode length and width, and color of the tallest male and female shoot from each infection collected; (2) mature fruit length, width, and color; (3) seed length, width, and color; (4) staminate flower diameter; (5) number, length, and width of staminate perianth lobes; (6) anther distance from the perianth lobe tip; and (7) anther diameter. Plants were measured within 24 hours after collection and were measured using a digital caliper, a dissecting microscope with a micrometer, or with a Bausch and Lomb 7× hand lens (Rochester, New York) equipped with a micrometer.

Plants of *Arceuthobium tsugense* subsp. *amabilae*, subspecies *tsugense*, and subspecies *mertensianae* appear morphologically similar, but they have several consistent morphological differences (Table 1). Male and female plants of subspecies *amabilae* are consistently larger than subspecies *tsugense* and much larger than subspecies *mertensianae*. In addition, the color of female plants of subspecies *amabilae* is frequently green or green brown, while the color of female plants of subspecies *tsugense* is consistently yellow green or purple (Hawksworth & Wiens, 1996; Wass & Mathiasen, 2003). Staminate flowers of

subspecies *amabilae* are similar in size to those of subspecies *tsugense*, but both of these subspecies have flowers that are consistently larger than the flowers of subspecies *mertensianae* (Table 1). Although Hawksworth et al. (1992) and Hawksworth and Wiens (1996) reported that staminate flower diameters of subspecies *mertensianae* are similar to those of subspecies *tsugense*, our measurements indicate that the staminate flowers of subspecies *mertensianae* are consistently smaller than those of the other subspecies.

The principal hosts of *Arceuthobium tsugense* subsp. *amabilae* are clearly Pacific silver fir, noble fir, and mountain hemlock, and western hemlock is only an occasional host using the host susceptibility system of Hawksworth and Wiens (1972, 1996) (Table 1). *Arceuthobium tsugense* subsp. *amabilae* severely parasitizes Pacific silver fir in several areas where noble fir and mountain hemlock are not present, which indicates that this dwarf mistletoe does not require all of its principal hosts to be present in an area to survive and spread. We have never found subspecies *amabilae* in a location parasitizing only mountain hemlock, however. But on Mary's Peak it does parasitize noble fir without Pacific silver fir or mountain hemlock present. Pacific silver fir, noble fir, and mountain hemlock have all been classified as occasional hosts of subspecies *tsugense* (Shaw, 1982; Mathiasen & Daugherty, 2005). Pacific silver fir has not been observed to be infected by subspecies *mertensianae* in central or southern Oregon, where Pacific silver fir commonly occurs near infected mountain hemlocks. Another host susceptibility difference between the subspecies of *A. tsugense* is that western white pine is an occasional host of subspecies *mertensianae* in southern Oregon and California, and at some locations large western white pines are severely infected (Mathiasen & Hawksworth, 1988). However, western white pine is only rarely infected by subspecies *amabilae* and subspecies *tsugense* in Oregon (Gill, 1935; Hawksworth & Wiens, 1996). Thus far, we have only found two cases of infection of western white pine by subspecies *amabilae* in central Oregon. The host susceptibility differences among Pacific silver fir, noble fir, mountain hemlock, and western hemlock to subspecies *amabilae*, *tsugense*, and *mertensianae* represent physiological discontinuities between these dwarf mistletoes that also have taxonomic significance.

Giving *Arceuthobium tsugense* subsp. *amabilae* taxonomic status at the subspecific level is consistent with the classification of the other subspecies of *A. tsugense* (Hawksworth et al., 1992; Wass & Mathiasen, 2003). Differences in plant size and host range have been the principal characters used to separate subspecies of *A. tsugense*, and these are the same characteristics that distinguish *A. tsugense* subsp. *amabilae* from subspecies *tsugense* and subspecies *mertensianae* (Table 1). Therefore, the classification of *A. tsugense* subsp. *amabilae* is consistent with the interpretation for *A. tsugense* proposed by Hawksworth et al. (1992) and Wass and Mathiasen (2003) and with the taxonomic framework established in Hawksworth and Wiens's 1996 monograph of *Arceuthobium*.

Paratypes. All citations based on *Abies amabilis* except as noted. U.S.A. **Oregon:** Hood River Co., Bennett Pass Sno-Park, 2004, *Mathiasen & Daugherty 0467* (female) (ASC), on *Tsuga mertensiana*, *Mathiasen & Daugherty 0468* (female) (ASC); Sahalie Falls below Mt. Hood Meadows Ski Area, 1991, *Mathiasen 9102* (UC), on *T. mertensiana*, 1991, *Mathiasen 9101* (UC); Marion Co., Skyline Rd. near N fork of Breitenbush River, 2004, *Mathiasen & Daugherty 0466* (male) (ASC), on *T. mertensiana*, 2004, *Mathiasen & Daugherty 0465* (male) (ASC); Linn Co., Wildcat Mtn., 1997, *Mathiasen 97158* (male) (ASC), 2004, *Mathiasen & Daugherty 0458* (female) (ASC), 1989, *Hawksworth 2355*, *2357* (UC), on *A. procera*, 1997, *Mathiasen 97159* (male) (ASC), 1989, *Hawksworth 2356* (UC); Bunchgrass Mtn., 2004, *Mathiasen & Daugherty 0462* (female) (ASC), 2005, *Mathiasen & Daugherty 0557* (male) (ASC), on *A. procera*, 1998, *Mathiasen 98123* (male) (ASC), 2004, *Mathiasen & Daugherty 0463* (female) (ASC), 2005, *Mathiasen & Daugherty 0558* (male) (ASC), on *T. mertensiana*, 1997, *Mathiasen 97160* (male) (ASC), 2004, *Mathiasen & Daugherty 0464* (female) (ASC); Benton Co., Mary's Peak, on *A. procera*, 2004, *Mathiasen & Daugherty 0461* (female) (ASC); Lane Co., Frissell Point, 1989, *Hawksworth 2360* (UC), 1997, *Mathiasen 97162* (male) (ASC), 2004, *Mathiasen & Daugherty 0425* (male), *0456* (female) (ASC), on *A. procera*, 1989, *Hawksworth 2361* (UC), 2004, *Mathiasen & Daugherty 0426* (male), *0457* (female) (ASC); Olallie Ridge, 2004, *Mathiasen & Daugherty 0454* (female) (ASC), on *A. procera*, 2004, *Mathiasen & Daugherty 0455* (female) (ASC); Pat Saddle, 1997, *Mathiasen 97164* (male) (ASC), 2004, *Mathiasen & Daugherty 0453* (female) (ASC), on *A. procera*, 1997, *Mathiasen 97166* (male) (ASC); Lowell Mtn., 1997, *Mathiasen 97170* (male) (ASC), 2004, *Mathiasen & Daugherty 0424* (male), *0451* (female) (ASC), on *T. mertensiana*, 2004, *Mathiasen & Daugherty 0423* (male), *0452* (female) (ASC); Huckleberry Mtn., 2004, *Mathiasen & Daugherty 0448* (female) (ASC), 2005, *Mathiasen & Daugherty 0555* (male) (ASC), on *T. mertensiana*, 2004, *Mathiasen & Daugherty 0449* (female) (ASC); Blair Lake, 1997, *Mathiasen 97168* (male) (ASC), 2004, *Mathiasen & Daugherty 0422* (male), *0446* (female) (ASC), on *T. mertensiana*, 1997, *Mathiasen 97169* (male) (ASC), 2004, *Mathiasen & Daugherty 0421* (male), *0447* (female) (ASC); Holland Meadow, 2004, *Mathiasen & Daugherty 0450* (female) (ASC); Hemlock Butte, 2000, *Mathiasen 0041* (male) (ASC), 2004, *Mathiasen & Daugherty 0444* (female) (ASC), on *T. mertensiana*, 2000, *Mathiasen 0042* (male) (ASC), 2004, *Mathiasen & Daugherty 0445* (female) (ASC); Warner Mtn., 2000, *Mathiasen 0038* (male) (ASC), 2004, *Mathiasen & Daugherty 0442* (female) (ASC), on *T. mertensiana*, 2004, *Mathiasen & Daugherty 0443* (female) (ASC); Douglas Co., Staley Ridge, 2000, *Mathiasen 0039* (male) (ASC), 2004, *Mathiasen & Daugherty 0440* (female) (ASC); Snowbird Camp, 2004, *Mathiasen & Daugherty 0438* (female) (ASC), 2005, *Mathiasen & Daugherty 0553* (male) (ASC).

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