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Dwarf Mistletoe and Host Tree interactions in Managed Forests of the Pacific Northwest

EDITOR'S
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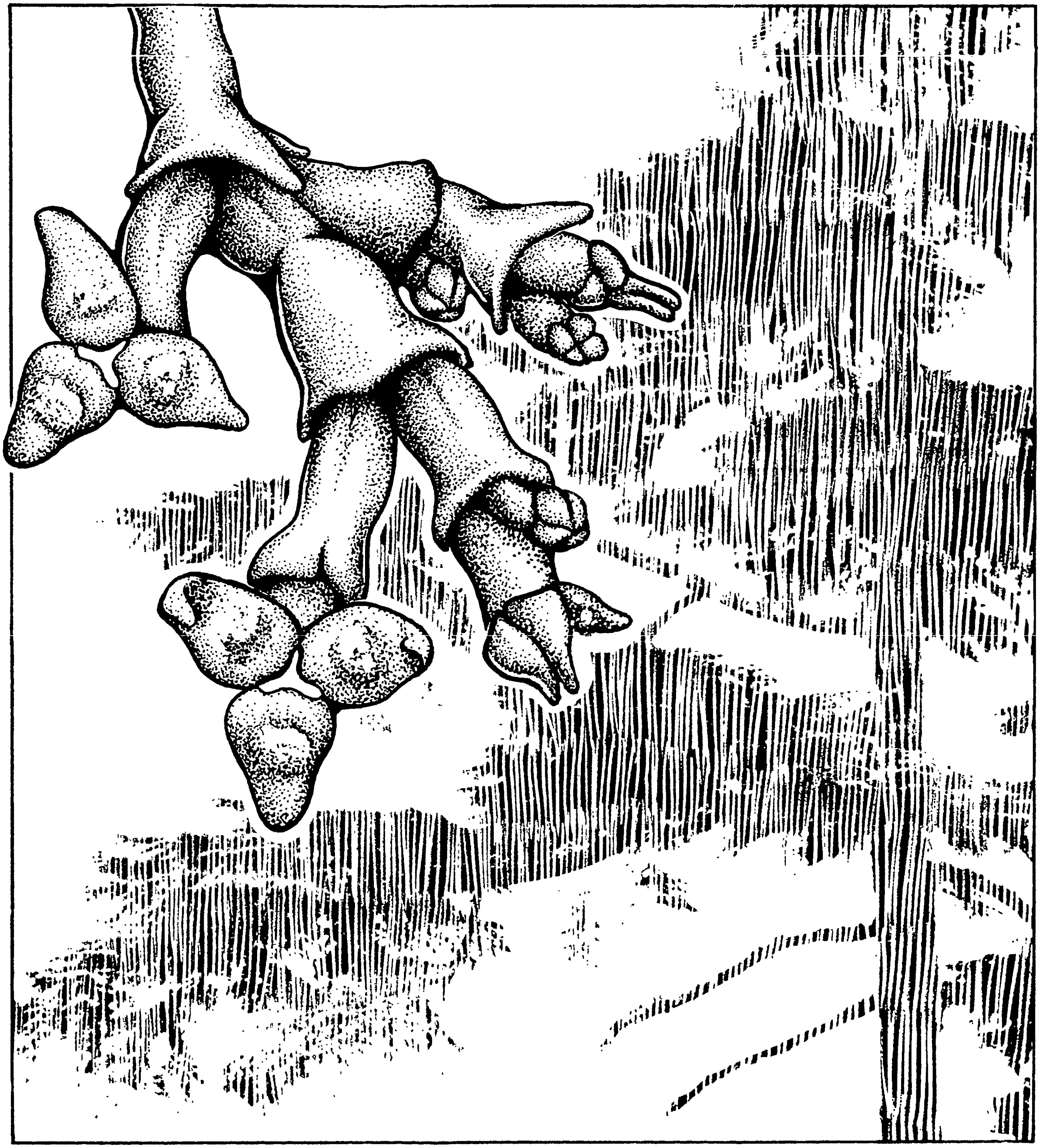

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Abstract

Dwarf mistletoes in the Pacific Northwest infect true firs. larch. pine. Douglas-fir, and hemlock. Forty-one percent of all stands east of the crest of the Cascade Range and 10 percent of west-side stands are infected. General characteristics of dwarf mistletoe are discussed. including mortality and growth losses. rate of spread within a tree and within stands. relation of site class and growth loss. and the effect of management activities.

Contents

Introduction

Dwarf mistletoes[1] are parasites of coniferous species, primarily of the family Pinaceae. The group has many common features, and thus some general principles useful to forest management can be stated.

The important common biological features for dwarf mistletoes in the Pacific Northwest are that they all:

- are flowering parasites that remove and use organic and inorganic nutrients and water from host trees.
- produce sticky seeds in the fall and shoot them through the air. Some of the seeds stick to the branches of trees on which they were produced or on branches of nearby trees.
- are somewhat host specific. That is, each kind of dwarf mistletoe (eight in the Pacific Northwest) can parasitize only a certain set of coniferous species.

In one sense, dwarf mistletoe should be relatively easy to control because survival depends on living trees; removing trees destroys the mistletoe. The association of western conifers and dwarf mistletoe is an ancient one, however, dating at least back to the Pleistocene. Since then, the dwarf mistletoes have spread throughout the West and adapted to their hosts; currently 40 percent of all stands east of the crest of the Cascade Range are infected, and 10 percent of west-side stands are infected.

Management activities have also influenced distribution of dwarf mistletoe. For many years, stands were thinned to 12-foot spacing--almost the optimum spacing for mistletoe spread from tree to tree. Thus, previous management choices have probably exacerbated the problems in second-growth stands, which will require additional management in the next 20 years. Seriously infected stand's often produce only two thirds of their potential volume. We can minimize these problems by basing current management prescriptions on the best information available on the biology of dwarf mistletoe.

These are general statements about dwarf mistletoe. If, after reading this report, you need more specific advice, we recommend that you contact the Division of Forest Insect and Disease Management at Region 6 headquarters in Portland, Oregon. Additional information useful to field managers is also available in a report by Scharpf and Parmeter (1978).

Field personnel working in the infested stands are best able to confirm or modify the general principles we have stated about dwarf mistletoe. We encourage all readers to tell us how to improve them.

[1]Scientific names of all plants mentioned are in appendix table 6.

Reproduction, Seed Characteristics and Effects of Broom

Dwarf mistletoe spreads by seeds produced on female plants. Pollen from male plants is transferred by wind and by insects to female flowers (Penfield et al. 1976). Seed maturation takes two seasons. Seeds ripen in August and September and are explosively cast into the air; they have a sticky coating (viscin) that can hold them to almost any surface they strike. Seeds that adhere to susceptible host trees overwinter there and can infect the wood when growth begins in spring. Typically, seeds land on needles and, when wetted by winter rains, slide down to the twig. Mistletoe seeds cannot infect needles or older twigs that have thick bark. The probability of infection of a given seed is low; less than 5 percent of all mistletoe seeds on ponderosa pine in Arizona, New Mexico, and Colorado actually survived, infected, and produced new plants (Hawksworth 1961). Dwarf mistletoe seeds are frequently eaten by insects, killed by fungi, or simply removed by snow, rain, or wind (Wicker 1967).

Dwarf mistletoes often stimulate adventitious budding of host trees. These buds produce a dense growth called a witches' broom, which reduces tree growth and vigor. In heavily infected ponderosa pine, brooms caused more reduction in diameter growth than branch infections (broomy trees: 59 percent reduction; nonbroomy trees: 14 percent reduction): no difference was noted in lightly infected trees (Hawksworth 1969). In another report, the diameter growth of a Douglas-fir increased after a large broom was removed (Weir 1916). In lodgepole pine, heavy brooming did not affect growth more than a comparable degree of individual branch infections (Baranyay and Safranyik 1970).

Common Hosts Important To Forest Managers

The common hosts important to forest managers in the Pacific Northwest are larch, ponderosa pine, lodgepole pine, Douglas-fir, western hemlock, mountain hemlock, and the true firs (table 1).

Dwarf mistletoes are largely specific to one or two hosts. Infections of other hosts are called cross-infections. Cross-infections can be locally severe, but are not usually a management problem.

Locally severe cross-infections have been noted in the following locations:

Hemlock dwarf mistletoe on shore pine in British Columbia (Smith, 1976).

Hemlock dwarf mistletoe on the true firs in the Cascade Mountains of Oregon and Washington, principally in the Willamette, Mt. Hood, Gifford Pinchot, Mt. Baker, Snoqualmie, and Olympic National Forests (personal communication, J. Hadfield, USDA For. Serv., Portland, Oreg.). The mistletoe causes little damage to the true fir but readily moves back to the hemlock understory.

Larch dwarf mistletoe infects grand fir, subalpine fir, and lodgepole pine, produces viable seed, and reinfects larch in the Colville National Forest, Washington (personal communication, O. Dooling, USDA For. Serv., Missoula, Mont.).

Other locally severe cross-infections may occur. Managers should remain alert to the potential for such infections in their districts.

Genera of the Cuppressaceae (in North America) and Taxodiaceae are entirely immune: Chamaecyparis, Cuppressus, Juniperus, Libocedrus, Thuja, and Sequoia.

Table 1--Species of dwarf mistletoe and their common and infrequent hosts in the Pacific Northwest (adapted from Hawksworth and Wiens 1972)

Dwarf mistletoe	Hosts	
	Common	Infrequent
Douglas-fir	Douglas-fir	Grand and subalpine fir
Hemlock	Western and mountain hemlock	Grand, noble, Pacific silver, and subalpine fir; Brewer spruce; lodgepole, western white, and white bark pine
Larch	Western larch	Subalpine fir; Englemann spruce; lodgepole, ponderosa, and white bark pine; mountain hemlock
Lodgepole pine	Jack and lodgepole pine	Limber, ponderosa, and white bark pine
Red fir	California red fir (noble fir)[1]	None
Sugar pine	Sugar pine	Brewer spruce and western white pine
Western	Jeffrey, knobcone, and ponderosa pine	Lodgepole pine
White fir	Grand and white fir	Pacific silver and subalpine fir

[1] Designation in question.

Distribution and Volume Losses

Distribution and Frequency

The dwarf mistletoes are widely distributed in Western North America from Guatemala (on pine) to Alaska (on hemlock). Six species are widely distributed in the Pacific Northwest (fig. 1). Dwarf mistletoe was found on 23 percent of almost 17,000 forest inventory plots in Oregon, Washington, and California (Bolsinger 1978). In Oregon and Washington, 41 percent of the stands east of the Cascade crest and 10 percent of those west of the Cascade crest were found to be infected.

Douglas-fir stands were the most frequently infected among types of conifer stands in the three west coast states (table 2). The percentage of this forest type actually infected was lowest however, because the Douglas-fir forests west of the Cascade crest are largely free of dwarf mistletoe (Tinnin and Knutson 1973).

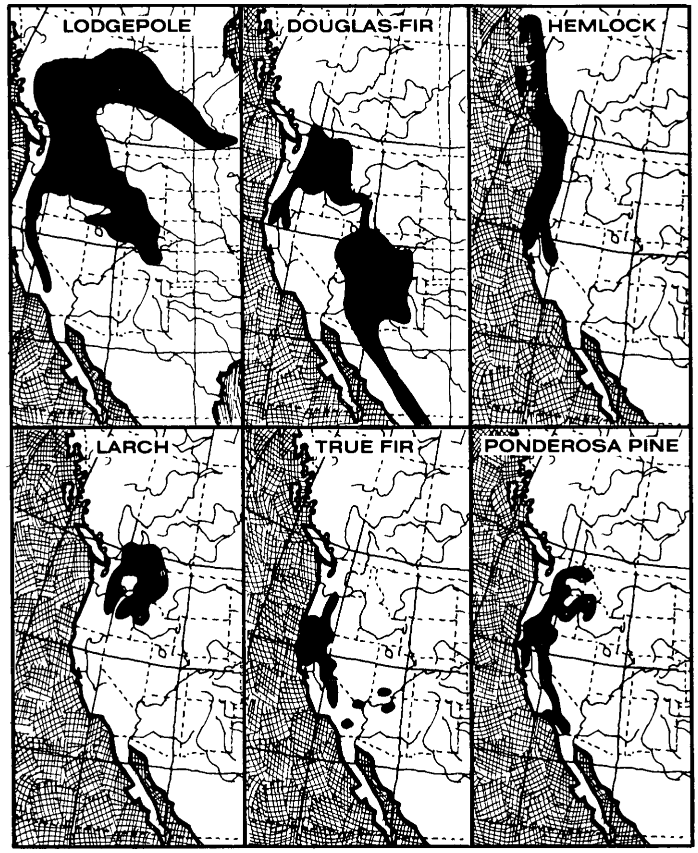

Figure 1.--General distribution of the six principal dwarf mistletoe species found in the Pacific Northwest (adapted from Hawksworth and Wiens 1972). Outline map used with permission of the Denoyer-Geppert Company, Chicago.

Table 2--Percentage of commercial forest infected with dwarf mistletoe in California, Oregon, and Washington (adapted from Bolsinger 1978)

Host	Area infested with dwarf mistletoe	Portion of forest type with infected trees
	Million acres	Percent
Douglas-fir	3.6	13
Firs, true	1.9	21
Hemlock, mountain and western	1.3	21
Larch, western	1.0	47
Pine, Jeffrey and ponderosa	3.2	26
Pine, lodgepole	1.5	42

Volume Reductions

Volume losses can be large. Smith (1969) estimated a volume **loss** of 37 percent over a 2-year period for western hemlock. Because yield reductions result from a complex of interacting factors, however, precise **predictions** are difficult. Growth reductions are infiuenced by amount of infection, how long a tree has been infected, location of infections in the crown, age of the tree, the site, and stand density. The longer a tree is infected, for example, the greater its volume is reduced compared with a healthy tree (fig. **2)**.

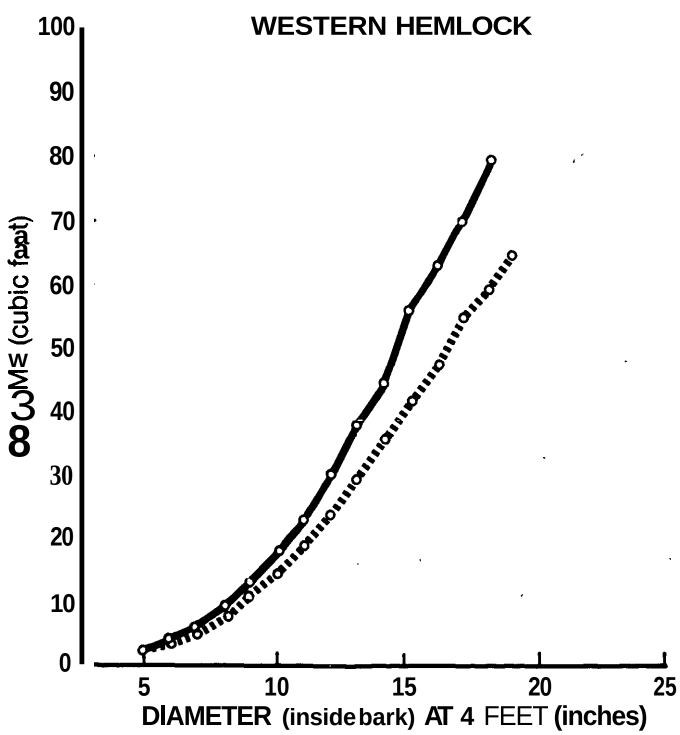

Figure 2.--Volume loss from dwarf mistletoe increased with the duration ***of*** *infection (Smith 1969). Data from Vancouver Island, British* ***Columbia.***

Mortality

Mortality is higher in infested stands. Forest survey data from the Okanogan National Forest showed that over a period of 10 years Douglas-fir on infested plots had a mortality rate 10 percent higher than on uninfested plots (Knutson, unpublished data on file at **the** Forestry Sciences Laboratory, Corvallis, Oregon 97331). Mortality in infested lodgepole pine stands in Alberta ranged from 0 to **26** percent higher than in healthy stands, depending upon stand age, level and duration of infection, and site (Baranyay and Safranyik 1970).

Mortality rates are related to severity of infection; severely infected trees are most likely to die (table 3). Higher mortality is associated with low vigor trees (table **4**). After dwarf mistletoe has caused a general decline in host vigor, death ***is*** often caused by Armillaria mellea root rot or bark beetle infestations (Knutson, unpublished data on file at the Forestry Sciences Laboratory, Corvallis, Oregon 97331).

Table 3--Percent of dead ponderosa pine and Douglas-fir in New Mexico by infection classes (from Hawksworth and Lusher 1956)

Dwarf mistletoe rating	Ponderosa pine	Douglas-fir
	Percent	
0 (no infection)	1	1
1	1	1
2	2	4
3	4	8
4	9	13
5	12	24
6 (severe infection)	38	45

Table 4--Mortality of ponderosa pine over a 40-year period in California as related to tree vigor (from Wagener 1961)

Tree vigor	Mortality
	Percent
Vigorous	0
Thrifty	5
Moderate	42
Poor	100

Spread Of Infection Within A Tree

Rate of Vertical Spread

New mistletoe infections develop upward in a tree at rates of about 1-2 feet or less per year (table 5). If tree height growth exceeds the rate of spread of the mistletoe, a relatively infection-free crown can develop in time.

Table 5--Average rates of vertical spread of dwarf mistletoe

Species	Vertical distance/year	Reference
	Feet	
Western hemlock (British Columbia)		Richardson and Van der Kamp (1972)
Dense stand (304 trees/acre)	1.0	
Open stand (101 trees/acre)	2.1	
California red fir (California)	<0.3	Scharpf and Parmeter (1976)

Potential for Infection of Upper Crown

Mistletoe plants in the upper crown of hemlock produce the most aerial shoots (Smith 1969) and are in a position for good seed production (Richardson and Van der Kamp 1972) and distribution. Seeds produced in the upper crown thus have a high potential to produce other infections.

Spread Of Infection Through Stands

From Stand Boundaries

Infection from residual stands into regenerated clearcuttings of the same species can occur many feet from the stand margin (fig. 3). Dwarf mistletoe seeds have been found 145 feet from the edge of the residual stand, but 20 to 40 feet is usual (Scharpf and Parmeter 1967). The average rate of spread through young, even-aged stands was 1.2 feet per year in very dense stands, and 1.7 feet per year in open stands (Hawksworth 1958, 1961) because of the screening effect of the tree crowns in reducing seed movement. When the foliage of ponderosa pine trees is 8-15 feet apart, spacing is optimum for transfer of dwarf mistletoe seed from tree to tree (Strand 1974).

Uneven crown height (fig. 4) has an effect similar to reduced crown density, allowing movement of mistletoe seeds from tree to tree (Hadfield and Russell 1978, Parmeter 1978).

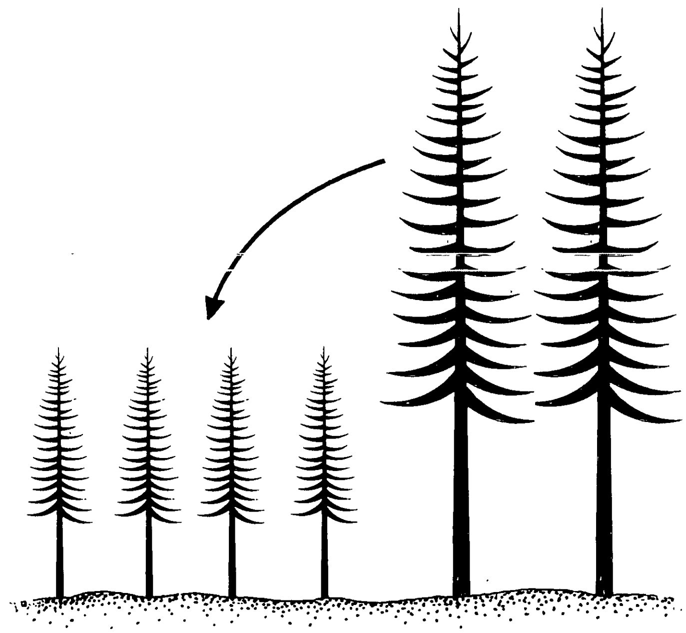

Figure 3.--Infection of regenerating clearcuttings from infected trees along the boundary.

To Understory From Overstory

Infection of understory from overstory trees occurs whenever susceptible young trees grow under infected trees. This process is especially important to forest managers when infected trees remain after harvest. Predictably, the density of dwarf mistletoe seeds drops rapidly with distance from these source trees (figs. 5 and 6), as does the number of mistletoe plants in the understory that result from the overstory seed source (Smith and Baranyay 1970).

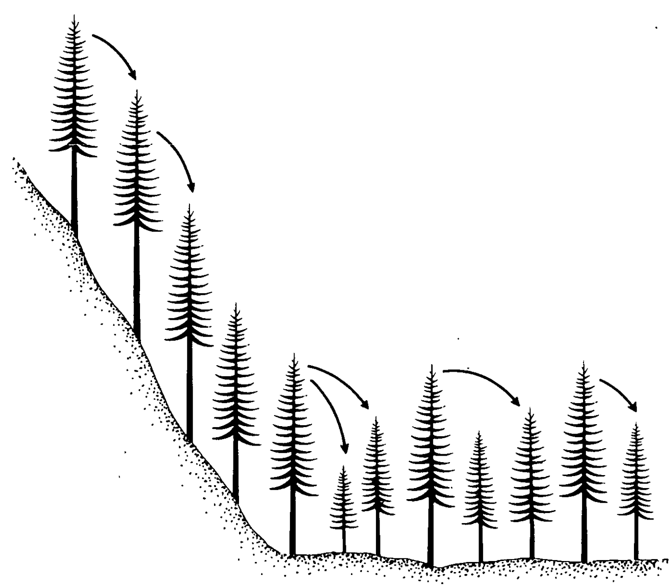

Figure 4.--Infection of trees on slopes and in uneven-aged stands.

In the presence of an infected overstory, the percentage of understory trees infected increases with their height and diameter (figs. 7 and 8). The larger the tree, the greater is the chance of its being infected because it is more likely to be struck by a dwarf mistletoe seed. Also, large trees tend to be older and thus exposed for a longer time.

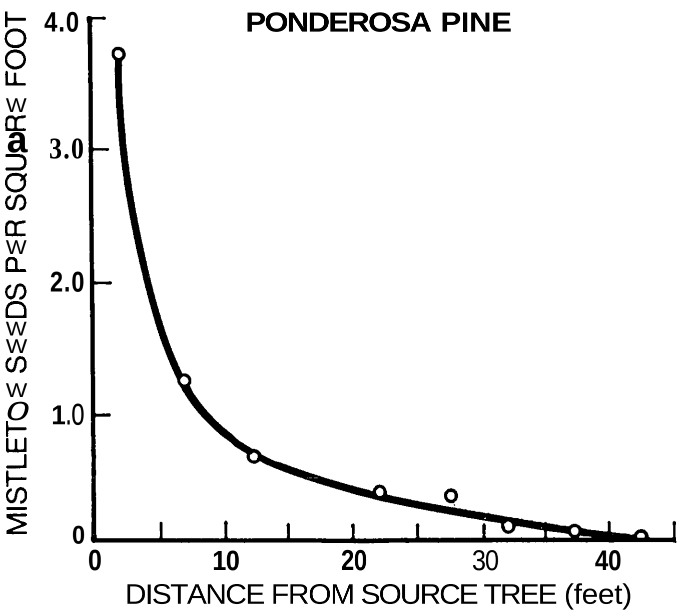

Figure 5.--Density of dispersed seeds of southwestern dwarf mistletoe relative to distance from the source tree (Hawksworth 1961). Data from Colorado.

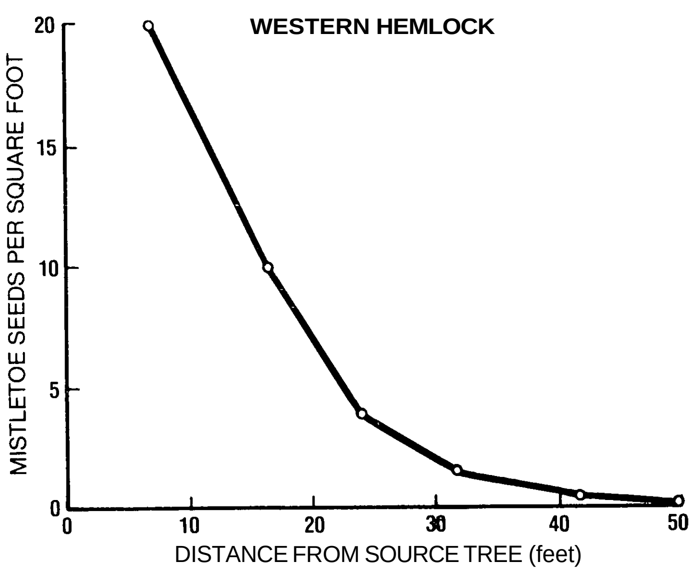

Figure 6.--Density of dispersed seeds of hemlock dwarf mistletoe relative to distance from the source tree (Smith 1973). Data from British Columbia.

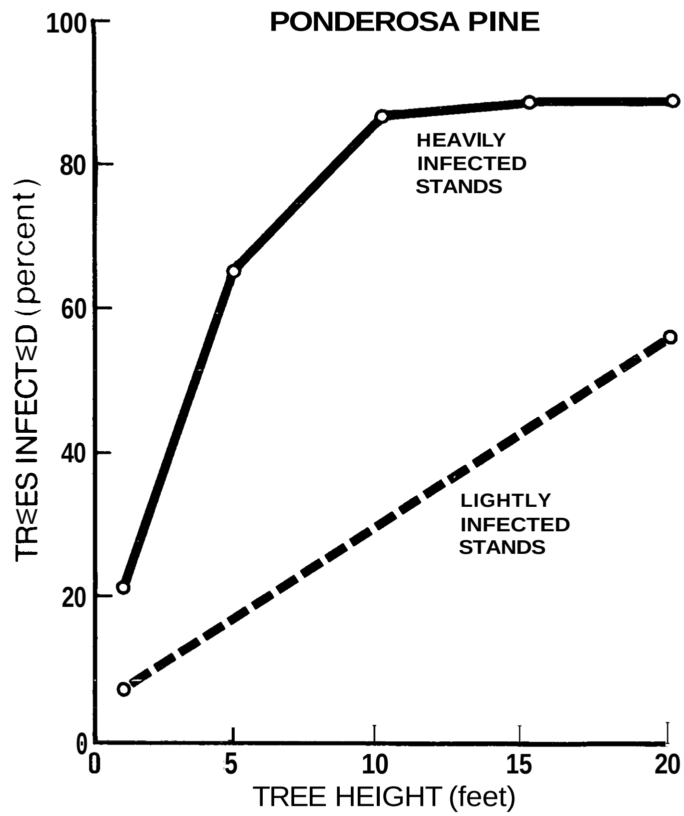

Figure 7.--Percentage of infected ponderosa pine trees in the understory related to tree age (Childs 1963).

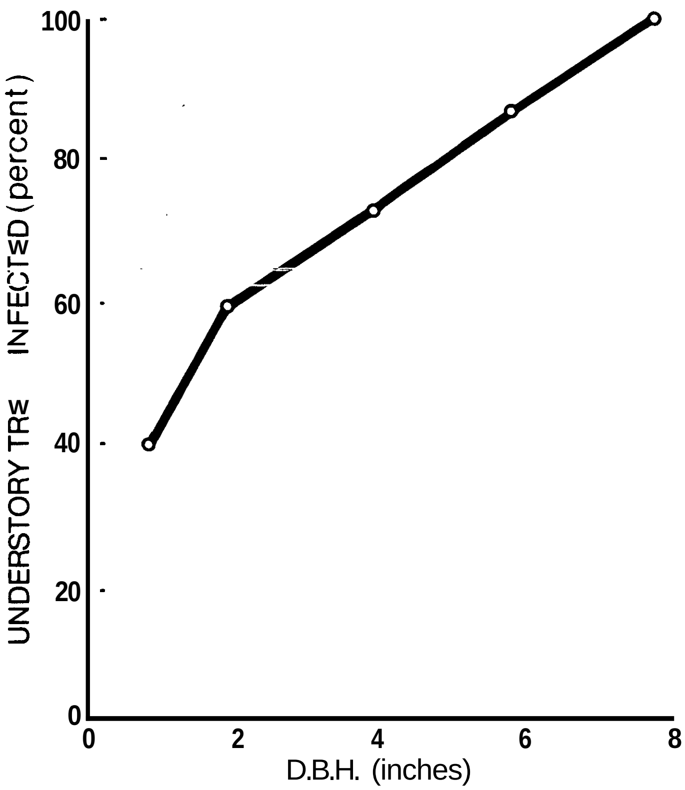

Figure 8.--Percentage of infected ponderosa pine in the understory related to diameter class (Shea 1964). Data from Oregon.

By Animals

Animals, especially birds, are important in long-distance spread of dwarf mistletoe seeds (Hudler 1976, Zilka and Tinnin 1976), but infrequently. Reducing dwarf mistletoe seed production will reduce the probability of spread by animals.

Latent infections

Many mistletoe seeds that infect host trees do not readily produce aerial shoots. These undeveloped sites are called latent infections. The cause of this phenomenon is unknown. We do know that the more advance forms, such as dwarf mistletoe of Douglas-fir, are the least likely to produce aerial shoots. Latent infections are most likely to occur on trees that are severely stressed, such as those in dense, suppressed stands or trees that already have many mistletoe plants. For example, an apparently uninfected, suppressed Douglas-fir tree may have several latent infections, or a small, suppressed ponderosa pine may have 10 obvious mistletoe plants but actually have 20 infections. About a third of all infections are latent in unthinned, infested stands. If 300 apparently infected trees occur per acre, the actual number infected will be about 450 in stand densities from 500 to 3,000 stems per acre (Childs 1963, Shea 1964). Latent infections may remain hidden for years or become active within a year; they produce aerial shoots if growing conditions of the tree improve, as with thinning. Shea (1964) thinned suppressed, stagnant ponderosa pine saplings and attempted to prune out all mistletoe infections. Fifty percent of the leave trees required additional pruning. The more open the stand, the less likely were latent infections.

Site Characteristics

The more heavily infected an individual tree, the more likely it will have latent infections (Childs 1963). To determine whether understory trees are infected, look for aerial shoots, because prominent brooms often do not develop in young trees. The more suppressed the stand, the fewer aerial shoots will be produced. Some commercial species in the Pacific Northwest naturally produce aerial shoots more readily than others, whether or not trees are suppressed. True fir and hemlock dwarf mistletoe are the most likely to have aerial shoots: ponderosa pine, western larch and lodgepole pine are intermediate in aerial shoot production. Douglas-fir dwarf mistletoe often produces very few aerial shoots.

After thinning, 90 percent of all latent infections will appear within 5 years--usually within 3 years (Shea 1964). At a second thinning between 5 and 10 years after the first, infected trees will become identifiable and can be removed.

Infection of hosts by dwarf mistletoe produces stress, which can combine with site-related stresses, such as availability of moisture and soil nutrients or severe winter conditions. Some known effects of dwarf mistletoe on trees are:

- Reduced root growth (Knutson and Toevs 1973).
- Higher metabolic rates in infected tree limbs (Clark and Bonga 1970).
- Movement of carbohydrates to the infection sites (Hull and Leonard 1964).
- Reduction of stored carbohydrates (sugars and starches) in host trees (Hull and Leonard 1964).
- Increased water stress of the host. Mistletoe can obtain water from the tree, even when the host xylem is under high water stress (Mark and Reid 1971).

The effect of mistletoe-induced stresses on trees depends on the genetic variation in the tree's tolerance to infection and the number of visible and latent infections per unit of crown. The interactions of site stresses and dwarf mistletoe stresses are unpredictable and cause considerable variation from one area to another in the amount of damage to the host.

The vigor of the parasite is correlated with host vigor: mistletoe growth is greater on healthier trees. In Colorado, for example, dwarf mistletoe of ponderosa pine had larger, more robust aerial shoots and produced more seed on vigorous ponderosa pine than on low-vigor trees. Similarly, the growth rate of its **endophytic** system (that part of the mistletoe plant in the phloem tissue of tne treej is nearly twice as rapid in the main stems of dominant as in suppressed trees. Broom size increased most on the most vigorous trees (Hawksworth 1961). Similarly, true firs at high elevation with short-growing seasons had smaller dwarf mistletoe plants with fewer seeds than at comparable lower elevation sites. This linkage of tree and parasite vigor can also be seen within a single tree, where established dwarf mistletoe plants grow best and produce most seed at sites of highest nutrition (twig tips and near crown apex) and poorest in the lower crown and on the oldest limb wood.

Dwarf mistletoe reduces tree growth most on good sites, assuming the same sized tree and the same number of mistletoe plants per unit of tree crown.

Heavily infected trees on good sites may grow better than uninfected trees on poor sites. Generally growth measurements (height, diameter, or volume) of infected trees are about 25 percent lower on good sites and about **10** percent lower on poor sites than comparable uninfected trees. The effect of dwarf mistletoe infection on tree **growth** on different sites is shown in **fig.** Y for Douglas-fir in Montana (Pierce 1960). Management practices can have the effect of improving site quality. Fertilizing, watering, and reducing stocking improve growth of mistletoe plants already established in the tree. Conversely, infertile soils, high moisture stress, and dense stands decrease the vigor of mistletoe plants. These conditions influence tree and mistletoe alike; after a drought stress, infected lodgepole pine were less able to recover than were uninfected trees (Baranyay and Safranyik 1970).

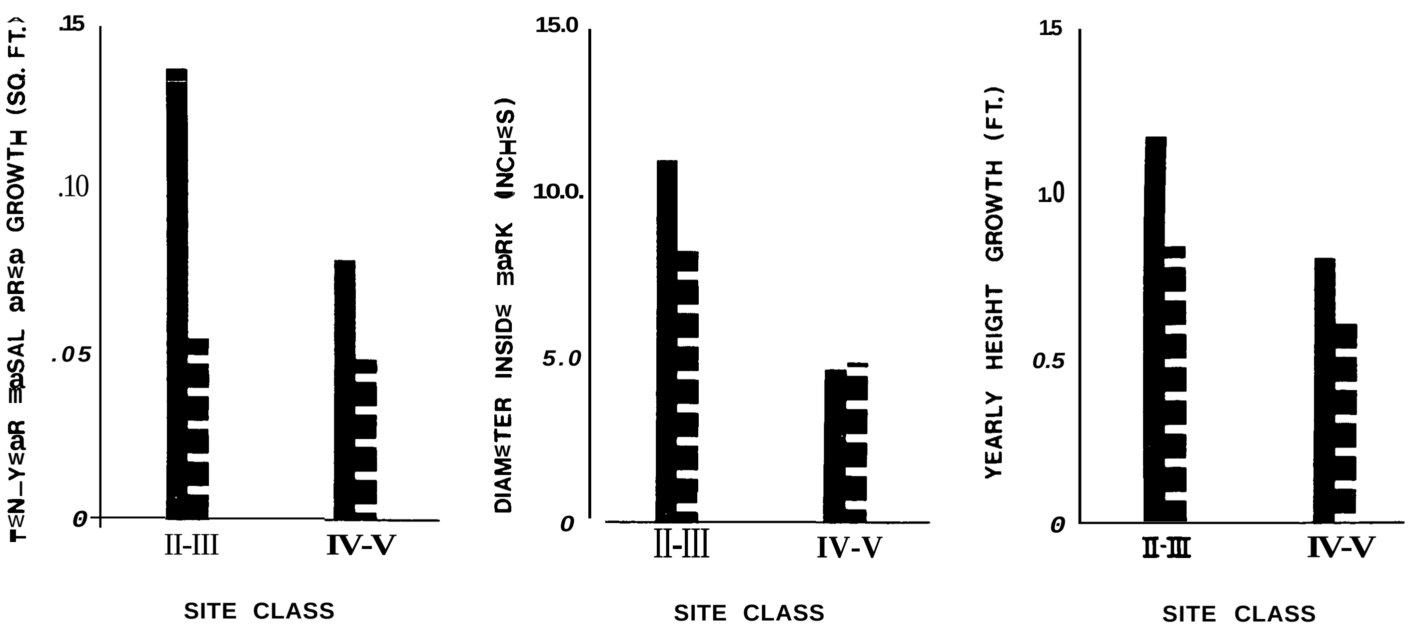

Figure 9.--Dwarf mistletoe reduced growth of Douglas-fir more on good sites than on poor sites. Data from western Montana (Pierce 1960). Solid line = uninfected trees; broken line = infected trees.

Although thinning or fertilizing may promote growth of established mistletoe plants, establishment of new infection depends on foliar characteristics of the tree. If foliage is thin, mistletoe seeds can travel easily through the crown, infecting limbs within the tree and many seeds land on neighboring trees.

If tree foliage is dense, mistletoe seeds are often trapped by needles near the source (fig. 10). This reduces the rate of new infection in the distant part of the crown. Trees with sufficiently dense crowns can grow away from the mistletoe, especially if crown closure occurs and the lower, infected limbs become shaded. Mistletoe seed production is reduced and eventually the shaded limbs die.

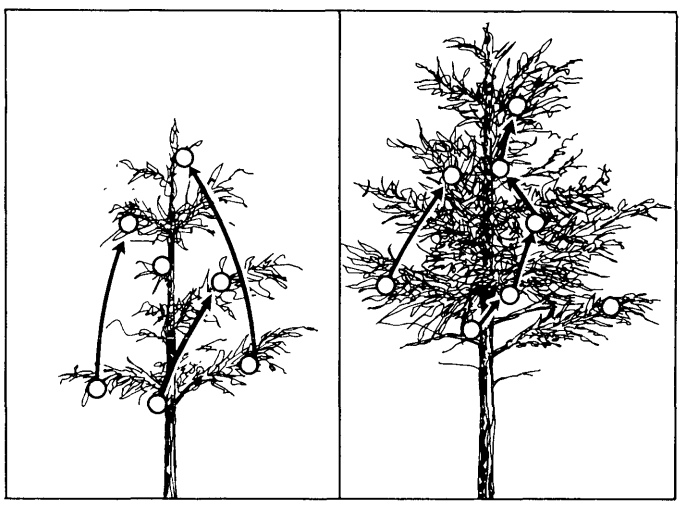

Figure 10.--Dense crowns can impede the movement of dwarf mistletoe seeds upward.

Dynamic Relations With Host Trees

In any natural stand, the trees and mistletoe are related in a type of dynamic equilibrium, which forest management activities, such as thinning or partial harvesting, modify. The vigor of the parasite is linked to host vigor: mistletoe growth is greater on healthier trees. Management practices can indirectly improve the growth of mistletoe, so care must be taken to avoid that.

Management Favoring Trees

Activities that favor trees and are deleterious to dwarf mistletoe include:

- Removing infected overstory from dense understory and thinning the understory, leaving the most mistletoe-free trees with good crowns for crop trees.
- Maintaining mixed-species stands--whether or not cross-infections occur.
- Favoring tree species that are immune when thinning mixed stands, or favoring species with the least amount of dwarf mistletoe. For example, true firs may grow well when released, even with many infections throughout the crown (Scharpf and Parmeter 1976, Scharpf 1978). Some species or some age classes (such as western hemlock in southwestern Oregon) do not respond well to release with or without dwarf mistletoe, and they are poor choices for crop trees.
- Planting Douglas-fir under infected overstories of any other tree species, Douglas-fir is immune to all other mistletoes, and Douglas-fir mistletoe is never a serious problem on any other tree species.
- Favoring, among infected shelterwood leave trees, those without infections in the upper half of the crown. Note that determining whether mistletoe infections are present high in the crown is very difficult especially in species that do not always develop prominent brooms--such as hemlock, true fir and, sometimes ponderosa pine.

- Maintaining tightly closed canopies in western hemlock stands. This causes death of lower branches, which are usually the most heavily infected. Infected trees of all species are disadvantaged and will be eliminated from stands under conditions of high competition. Infected trees have poorly developed root systems and impaired photosynthetic apparatus compared with uninfected trees.
- Top-pruning, which allows infection-free crowns to develop (Knutson 1975). The pruning procedure is as follows (fig. 11):
  1. Remove all limbs from the top 10-15 feet of crown. The branches that remain may be infected (fig. 11a).
  2. In time, a new treetop develops. Mistletoe seeds shot from the lower crown have a low probability of hitting the small target of new top foliage (fig. 11b).
  3. After sufficient top has developed, remove the remaining lower branches. The result is a tree with very little mistletoe and healthy foliage (fig. 11c).

Traditional pruning is also helpful but often leaves infected limbs high in the crown, where they are apt to cause other infections and damage the host.

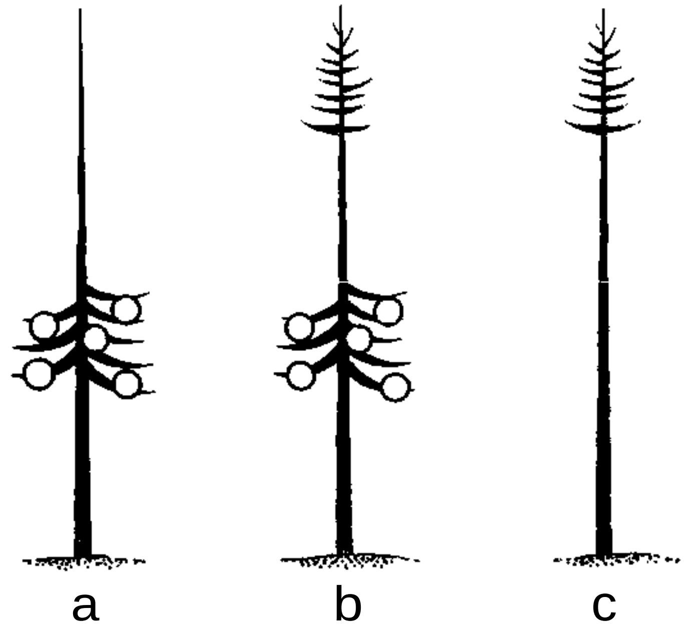

Figure 11.--Top-pruning to control dwarf mistletoe: A, *remove all branches from top* 10-15 *feet of bole;* B, *allow new top growth to develop; and* C, *remove all old branches.*

Management Favoring Dwarf Mistletoe

Activities favorable to dwarf mistletoe include:

- Partially removing the infected mature overstory. Mistletoe seed production will increase with improved nutrition of the infected leave trees. The open stand will promote regeneration, and the new trees--if of the same species--can become infected by the dwarf mistletoe seeds. In addition, increased mortality can occur in the remaining overstory trees; some heavily infected trees seem unable to adjust to release from competition.
- Leaving trees with mistletoe plants high in the crown. These plants will produce many seeds situated for efficient distribution. In addition, young thinned trees with mistletoe plants within 2 feet of the apical shoot of the tree tend to have a high rate of mortality.

- Spacing trees for optimum spread of mistletoe seeds between adjacent trees. "Step-laddering" (fig. 12) is slower in mixed-species stands. Hawksworth (1961) proposed a hypothetical relation between stand density and rate of spread of southwestern dwarf mistletoe (fig. **13**). Although the position of the curve will vary from species to species, the shape of the curve should be approximately correct for other tree-mistletoe combinations. For ponderosa pine in Oregon, the highest probability of infection occurs when a mistletoe plant on one tree and foliage on another tree are 12 feet apart (Strand 1974).

Our statements about the dwarf mistletoes are a compromise between generality and precision. We have stressed generality at the expense of precision, because precision is both difficult to obtain and--although desirable--is not necessary for improved management of most infested stands. Research is continuing to obtain more and better information on the biology of dwarf mistletoes and on management of infested stands.

We encourage field managers to help us add to and improve the accuracy of these general principles.

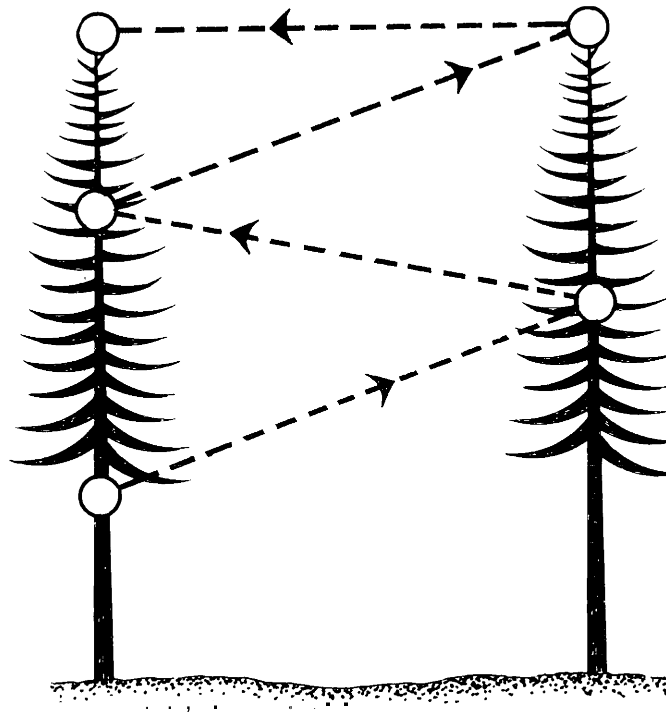

Figure 12.--Certain stand densities can favor the vertical rate of spread of dwarf mistletoe.

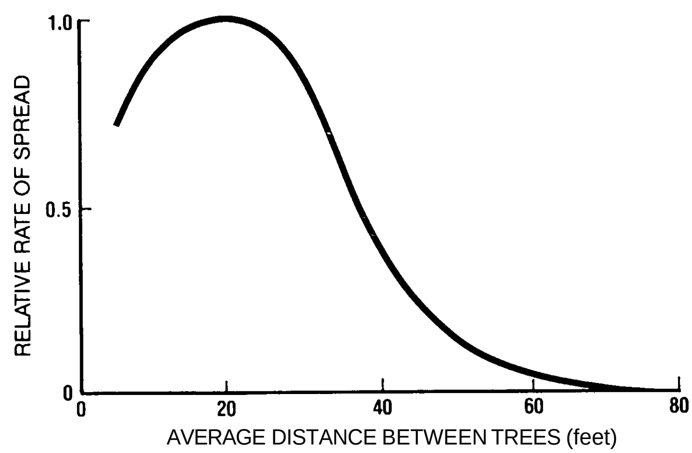

Figure 13.--Hypothetical relation of stand density to rate of spread of dwarf mistletoe in ponderosa pine (Hawksworth 1961). The curve will shift to the left for younger stands and to the right for older stands.

Acknowledgments

We appreciate the many contributions of Forester Floyd Peterson (Rogue River National Forest). His understanding of dwarf mistletoe and the management of infested stands have strengthened this manuscript.

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Appendix

Table 6--Common and scientific names of trees and dwarf mistletoes

Common name	Scientific name
TREES	
Douglas-fir	*Pseudotsuga menziesii* (Mirb.) Franco
Fir	
Grand	*Abies grandis* (Dougl. ex D. Don) Lindl.
Noble	*A. procera* Rehd.
Red, California	*A. magnifica* A. Murr.
Silver, Pacific	*A. amabilis* (Dougl.) ex Forbes
Subalpine	*A. lasiocarpa* (Hook.) Nutt.
White	*A. concolor* (Gord. & Glend.) Lindl. ex Hildebr.
Hemlock	
Mountain	*Tsuga mertensiana* (Bong.) Carr.
Western	*T. heterophylla* (Raf.) Sarg.
Larch	
Western	*Larix occidentalis* Nutt.
Pine	
Jack	*Pinus banksiana* Lamb.
Jeffrey	*P. jeffreyi* Grev. & Balf.
Knobcone	*P. attenuata* Lemm.
Limber	*P. flexilis* James
Lodgepole	*P. contorta* Dougl. ex Loud. var. *latifolia* Engelm.
Ponderosa	*P. ponderosa* Dougl. ex Laws.
Shore	*P. contorta* Dougl. ex Loud. var. *contorta*
Sugar	*P. lambertiana* Dougl.
White, western	*P. monticola* Dougl. ex D. Don
Whitebark	*P. albicaulis* Engelm.
Spruce	
Brewer	*Picea brewerana* Wats.
Engelmann	*P. engelmannii* Parry ex Engelm.
DWARF MISTLETOES	
Douglas-fir	*Arceuthobium douglasii* Engelm.
Hemlock	*A. tsugense* (Rosendahl) G. N. Jones
Larch	*A. laricis* (Piper) St. John
Lodgepole pine	*A. americanum* Nutt. ex Engelm.
Red fir	*A. abietinum* Engelm. ex Munz f. sp. *magnificae* Hawksworth & Wiens
Southwestern	*A. vaginatum* subsp. *cryptopodum* (Engelm.) Hawksworth & Wiens
Sugar pine	*A. californicum* Hawksworth & Wiens
Western	*A. campylopodum* Engelm.
White fir	*A. abietinum* Engelm. ex Munz f. sp. *concoloris* Hawksworth & Wiens

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