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Douglas-Fir Dwarf Mistletoe

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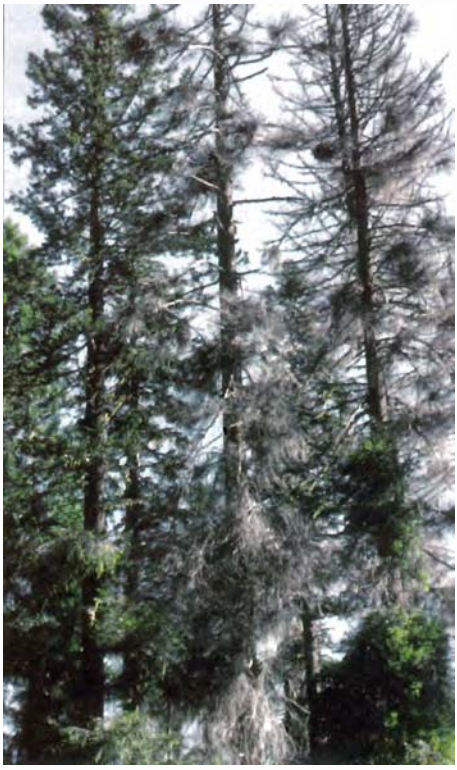
Douglas-fir dwarf mistletoe, *Arceuthobium douglasii* Engelm., is a destructive native parasite of Douglas-fir and is the primary disease agent affecting this tree over most of its range. With the exceptions noted below, its distribution essentially coincides with that of Douglas-fir from southern British Columbia to central Mexico. The parasite is not found in the Douglas-fir stands east of the Continental Divide in Montana, most of Wyoming, northern Colorado, and west of the Cascade Range (except near the crest) and north of the Siskiyou Mountains of Oregon. It is the only dwarf mistletoe that occurs in all of the western states (Figure 1). The dwarf mistletoe occurs on many different Douglas-fir ecologic, successional, and topographic types.



Douglas-fir is the principal tree species affected by Douglas-fir dwarf mistletoe. True firs and spruces are rarely infected where they are associated with infected Douglas-firs, but the parasite is of little or no economic importance on these species. Douglas-firs are rarely infected by mistletoes other than Douglas-fir dwarf mistletoe.

Douglas-fir dwarf mistletoe has increased in abundance since the late 1800s. Douglas-fir stands are much more widespread in the Inland West largely as a result of nearly a century of fire suppression. Prior to this time, fires restricted the

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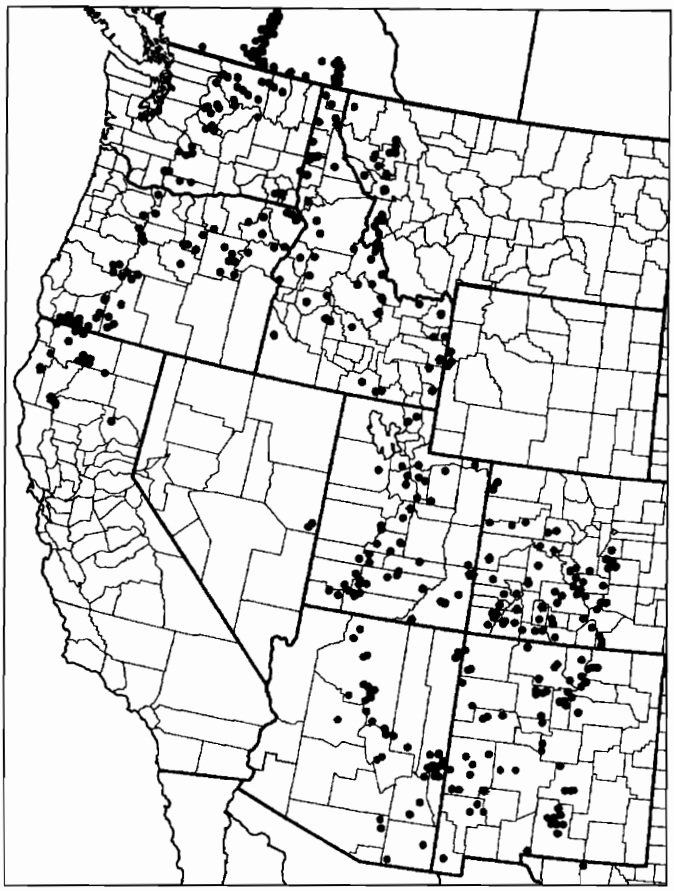

Fig. 1. Distribution of Douglas-fir dwarf mistletoe in the western United States and Canada.

distribution of Douglas-fir and dwarf mistletoes, especially on drier sites dominated by ponderosa pines. Frequent fires killed the small Douglas-firs, especially those infected by dwarf mistletoe. Fire suppression has enabled Douglas-fir to survive and dominate on millions of acres where once it was a relatively minor stand component.

A history of selective harvesting with removal of more valuable ponderosa pines, western larch, and large diameter Douglas-firs has also contributed to the increases in dwarf mistletoe by leaving small or poor quality infected Douglas-firs in which the parasite flourished and spread.

Life History

Douglas-fir dwarf mistletoe is a small, inconspicuous, seed-bearing parasitic plant. The aerial system of this parasite found on infected branches and stems consists of slender, olive-green, perennial shoots. They are most commonly found nestled among needles on infected branches. The average length is only 0.75 in. (2 cm), about the length of fir the needles, but they are rarely up to 3 inches (8 cm) (Figure 2). Although shoots contain chlorophyll, they produce little food for the parasite. The major function of the aerial shoots is reproduction. Individual aerial shoots can live for several years.

Aerial shoots arise from a network of root-like strands imbedded in host tissues. This network, called the endophytic system, consists of cortical strands growing within the living bark and sinkers embedded in the wood. The endophytic system takes nutrients and water from the host tree. The endophytic system lives as long as adjacent host tissues are alive and may produce aerial shoots for many years.

Male and female flowers are small and produced on separate plants. Flowering takes place in May and June. Insects and wind are both involved in pollination. Fruits complete their development 17 to 18 months after pollination. Only the female plants bears the fruits and seeds that spread the parasite. Berry-like fruits are olive-green and contain one seed averaging less than 0.1 inch (2 mm) long.

At maturity in September and October, the elastic outer case of the fruit, which is

under high internal water pressure, abscises from its base, contracts rapidly, and explosively propels the seed into the air.

Most seeds are shot upward and outward. Initial seed velocity is about 72 feet (22 m) per second. Seeds may travel 30 to 40 feet (10-13 m), but most land within 10-15 feet (3-5 m) of the disseminating shoot.

Seeds have a sticky hygroscopic coating called viscin which enables them to stick to most objects they strike. Foliage is the most common receiving surface.

Viscin, when first moistened by rains, acts as a lubricant. Seeds slide downward and either fall off needles or become lodged at the base of needles. Seeds are fastened in place when the viscin dries and they overwinter in a dormant state. Many of the seeds are removed by rain, snow and ice or are eaten by birds, insects and fungi.

The seeds germinate in early spring. Radicles grow along twig surfaces until an obstruction, usually a needle base, is encountered or the food supply is exhausted. When radicle extension is obstructed small mounds of tissue called holdfasts are formed. Infection pegs that develop from the holdfasts then infect the host by penetrating through the thin bark during the summer. After the bark has been penetrated the mistletoe's root or endophytic system grows in the cortex and wood of the host. Infection occurs most readily in twigs and stems less than 5 years old.

About 2 to 5 years pass before the first aerial shoots appear at infection sites. Infections on branches exposed to direct sunlight probably produce shoots quicker than shaded infections. Infections that have not yet produced aerial shoots are termed latent infections.

The typical length of time needed for female plants to complete their life cycle from initial establishment to dissemination of the first seed crop is 4 to 6 years.

Symptoms of Infection

The first symptom of Douglas-fir dwarf mistletoe infection is a slight swelling at the infection site 1 to 2 years after infection occurs. Initially these can be difficult to see. As time passes and the endophytic

Fig. 2. Aerial shoots of Douglas-fir dwarf mistletoe.

system of the parasite becomes more extensive, the form of the infected branch or stem becomes distorted.

Douglas-fir dwarf mistletoe typically becomes systemic within the host when the endophytic system invades tree buds at the infection site. Masses of invaded buds are stimulated to grow and develop long twigs, which eventually form witches' brooms. The mistletoe endophytic system grows apically at the same rate as the infected twigs. Aerial shoots can be found on branch growth segments ranging from 2 to 7 years old.

Fig. 3. Large witches' broom in a Douglas-fir.

The most striking symptoms of dwarf mistletoe infection on Douglas-fir are witches' brooms, which are noticeable within 10 years after infection takes place. Broom shapes vary but start out as fan-shaped and eventually tend to become somewhat spherical.

Branches in witches' brooms may become long and droopy and attain lengths of 10 feet (3 m), but are typically only about one-quarter inch in diameter (these are locally called "rat tails"). Large brooms may be several feet in diameter and compared to healthy branches have very large surface areas.

Broom development is most rapid in infected branches exposed to direct sunlight. Witches' brooms on lower branches in dense stands develop slowly and tend to be small.

Trees may have one to many witches' brooms. Most extensive development of witches' brooms is usually in the lower half of tree crowns. Brooms can become so large and numerous that they make up entire tree crowns (Figure 3). Branches

with big witches' brooms develop large diameters at their junction with the main stem to support the weight, which can be several hundred pounds. Infected branches are kept alive because of the ability of the parasite to obtain food and water from the tree. In severely infected trees, branches with witches' brooms are generally the last to die.

Severely infested Douglas-fir stands typically have many trees with stunted growth, witches' brooms, dying and dead tops, and dead trees.

Spread and Intensification

Spread is movement of mistletoe from one tree to another; intensification is the increase of mistletoe populations within a tree. Nearly all Douglas-fir dwarf mistletoe spread is local and results from explosive discharge of seeds. Wind exerts a minor influence on distance and direction of seed travel. Birds and other animals are responsible for some long-distance spread when seeds that stick to them are later rubbed off onto susceptible trees.

Several factors affect spread of Douglas-fir dwarf mistletoe. These include stand structure, tree size, species composition of stands, tree spacing, infection position, and topography. In single storied stands, horizontal spread averages 1.5 to 2 feet (0.5-0.6 m) per year. Spread in multistoried Douglas-fir stands is more rapid because understory firs are showered with dwarf mistletoe seeds from infected overstory trees. Seeds discharged from plants high up in tree crowns travel farther than those originating from lower positions.

Presence and arrangement of nonsusceptible tree species can slow the spread of Douglas-fir dwarf mistletoe. Spread rates in dense stands are less than in more open stands because dwarf mistletoe seed production is usually lower due to more shading and poorer host vigor, and many seeds are trapped within the foliage of the infected trees rather than escaping to adjacent trees. Spread tends to be more rapid from ridgetops than narrow valley bottoms. Douglas-firs less than 4 feet (1.2 m) tall are small targets for seed deposition and have low infection rates, even though trees of all sizes and ages are susceptible .

The 6-class dwarf mistletoe rating (DMR) system is commonly used to categorize intensity of infection in Douglas-fir trees and stands. For this system, the live crown of the tree is visually divided into thirds and each third rated as: 0 = no visible infection, 1 = light infection (less than half of the branches infected), or 2 = severe infection (more than half of the branches infected). The three ratings are then added to obtain a tree rating.

A tree severely infected in each third would be rated class 6. Because Douglas-fir dwarf mistletoe shoots are small and often difficult to observe, particularly in large trees, witches' brooms are usually used as an indication that a branch is infected when determining the rating for each crown third. The tree ratings of all live trees (including uninfected ones) are averaged to obtain a stand or plot rating.

Douglas-fir dwarf mistletoe infection increases about one DMR class per decade for individual trees, however this can be highly variable. Infection intensifies most rapidly in saplings and pole- size trees under infected larger trees in stands with openings. Mistletoe populations increase within trees as a result of continued deposition of seeds from adjacent infected trees and from seeds produced by plants in the trees.

Most initial infections are located in the lower portions of crowns because this material is older and has been exposed to infection longer and represents a larger surface area for seeds to strike. Infections resulting from these initial plants tend to spread upward in the crowns at a rate of 4 to 6 inches (10-15 cm) per year.

Effects of Infection

Infection of Douglas-fir by dwarf mistletoe alters tree form, reduces vigor and growth rates, reduces seed production, increases susceptibility to other damaging agents, and results in topkilling and tree death. These effects result from the parasite taking food and water from the host, thus reducing the amount of energy available for the tree's normal growth, reproductive, and protective processes.

The effects of Douglas-fir dwarf mistletoe infection are progressive. Lightly infected trees do not differ much from healthy trees, however they become moderately then severely infected with the passage of time, resulting in gradual tree and eventually stand deterioration.

The effects of dwarf mistletoe on tree growth increase with severity of infection. In western Montana it was found that light infection resulted in a 14 percent reduction in basal area growth. Medium and severe levels of infection caused reductions of 41 and 69 percent, respectively. Height growth was similarly affected.

In the Southwest, severely infected (tree ratings of DMR 5-6) sawtimber size trees have 50 to 65 percent less 10-year periodic annual volume increment than lightly infected (DMR 1-2) or healthy trees. Because severe Douglas-fir dwarf mistletoe infection causes marked reductions in height and radial growth, severely infested sites look less productive than they actually are.

Topkill is common in severely infected trees. Foliage in tops of trees with large witches' brooms lower in the crowns gradually become sparse and off-color as the dwarf mistletoe plants and brooms use large amounts of water and nutrients needed for tree growth. Eventually the tops become so weakened they die.

Mortality of Douglas-fir in severely infested stands (stand ratings of DMR 4 or higher) is 3 to 4 times greater than that in comparable non-infested stands in the Southwest. Even stands with mean dwarf mistletoe ratings of 2 or 3 show increased mortality rates over uninfested or lightly infested (stand DMR 1) stands.

Seedlings and saplings, especially those with main stem infections, readily succumb to the parasite. Those weakened by numerous branch infections or large witches' brooms cannot compete successfully with surrounding trees and die.

Severely infected trees typically produce few cones and those that are produced are smaller than normal. Cones from severely infected trees weigh only about one-third of those from healthy trees and have about half as many viable seeds.

Other forest values are affected adversely by Douglas-fir dwarf mistletoe. Risk of wildfires is increased because of the long, thin twigs in witches' brooms in the lower portions of crowns, accumulation of fallen witches' brooms around the bases of infected trees, and increased tree mortality.

Witches' brooms provide fuel ladders for flames to spread upward into tree crowns. The small diameter dead twigs in brooms ignite easily and can serve to spot fires well ahead of the main fire. Mistletoe infected trees are less likely to survive fires than healthy trees.

Large witches' brooms can increase the hazard potential in recreation sites because they are more prone to break and fall than healthy branches as a result of collecting snow and ice or presenting large dense surface areas for wind to blow against.

Dead and dying trees detract from visual quality. Severely infected trees are less capable of resisting attacks by other diseases and insects.

There seems to be no strong relationship with the Douglas-fir beetle *(Dendroctonus pseudotsugae)* but severely mistletoe-infected trees are frequently attacked and killed by secondary insects, such as the flatheaded fir borer *(Melanophila drummondi).*

Benefits of Douglas-fir dwarf mistletoe have been recognized. The shoots and fruits are eaten by some birds, especially grouse. They also serve as a food source for several species of insects, fungi, rodents and mammals.

Some rodents, such as porcupines and squirrels, feed on bark tissues at infection sites because of the accumulations of starch and nutrients at these locations. The large witches' brooms caused by the parasite are used for hiding, thermal cover, and nesting sites by grouse, hawks, owls, squirrels, porcupines, martens and other wildlife. Northern spotted owls east of the Cascades show an attraction to Douglas-fir witches' brooms for nest sites.

Management

Management of Douglas-fir dwarf mistletoe should consider the role that it plays in the tree, stand, and overall ecosystem in which it resides. Douglas-fir dwarf mistletoe can serve as an important disturbance agent, food for other species, and provide habitat for a variety of organisms. It is a "pest" only when it interferes with accomplishment of management objectives.

In stands where good timber production or intensive recreation use are major considerations, control of dwarf mistletoe may be necessary in order to meet management objectives. However, in areas where timber production or high recreation use are not the principal concerns, Douglas-fir dwarf mistletoe may not adversely influence management objectives and actions could be developed to maintain or possibly increase Douglas-fir dwarf mistletoe populations for wildlife habitat.

The presence of Douglas-fir dwarf mistletoe can thwart accomplishment of tree, stand, and forest management objectives. When this occurs, control of the parasite should be considered. Many traits of Douglas-fir dwarf mistletoe can be used to develop successful management practices: 1) the parasite is host specific, essentially only infecting Douglas-fir, 2) it is an obligate parasite that requires a living host for its survival, 3) spread and intensification are slow and predictable, 4) it is more vigorous in full sunlight than under shade and 5) the disease is rather easily detected because it causes distinct symptoms, the witches' brooms.

Douglas-fir dwarf mistletoe can be managed with cultural treatments that change the vegetative conditions of the tree, stand, or forest. No practical chemical or biological controls are available for treating infected trees and stands.

Good timber volume production is almost impossible in multi-storied, infested Douglas-fir stands. Treatments designed to produce stands with a single canopy layer of Douglas-firs offer the best prospects of preventing unacceptable losses to dwarf mistletoe.

The most effective methods for managing Douglas-fir dwarf mistletoe in timber-producing stands involve killing of all infected trees by cutting (harvesting) and/or burning. Infected trees can be girdled and left standing if they are needed for snags. Dwarf mistletoe plants in a single overstory tree with a crown diameter of 30 feet (10 m) could cast seeds over 6,400 square feet (0.15 acre or 0.06 ha).

To slow invasion of young Douglas-fir stands by dwarf mistletoe from infected border trees, the ratio of perimeter to area of treatment sites should be as low as possible. They should not be long, narrow strips. Advantage should be taken of any potential barriers to dwarf mistletoe spread, such as roads, treeless ridge-tops, natural openings, and changes in timber types when laying out the boundaries of treatment units.

Where clearcutting of dwarf mistletoe-infested Douglas-fir stands is not appropriate, shelterwood and seed tree harvests can be effective alternative even-age management methods. Trees selected to provide shelter or seeds should be uninfected or only lightly infected (DMR less than 3).

Infected shelterwood or seed trees should be removed as soon as Douglas- fir seedlings become established. Failure to remove infected overstory trees in a timely manner will contribute to rapid infection of the developing understory Douglas-firs.

As a general rule, it is desirable to remove the infected overstory before the Douglas-firs in the young stand are 3 feet (1 m) tall or ten years old (whichever comes first). However, in the Southwest few Douglas-firs are infected until they reach heights of 4 feet (1.2 m) or 20 years in age.

In mixed species stands that contain Douglas-firs infected by dwarf mistletoe, silvicultural treatments should retain other tree species. Non-hosts left between infected and non-infected Douglas-firs prevent or slow spread and intensification of the parasite.

Sanitation by removal of infected trees can be an effective treatment in young (10 - 30 years old), lightly infested stands. Lightly infested is defined as those stands in which the numbers of desirable dwarf mistletoe-free trees are sufficient to meet management objectives. Typically these stands would have a stand DMR no greater than 2.

Douglas-firs with one-third or more of their crowns infected by dwarf mistletoe generally decline rapidly about 10 years after they are exposed to full sunlight by thinning. Because of their rapid decline, lightly infected trees should not be left when stands are being sanitized unless they can be expected to reach merchantable size within 15 years.

Pruning of infected branches, in conjunction with sanitation, can further reduce dwarf mistletoe populations, but is seldom effective in eliminating the parasite because latent infections will be missed. Re-examination of stands 5 years after sanitation is desirable to determine if additional sanitation is needed. Moderately and severely infested stands (stand DMR greater than 2) should not be sanitized because many trees with latent infections will be missed, and once these trees are released from competition, the number of dwarf mistletoe plants will increase rapidly within their crowns. Such stands should either be regenerated or left unthinned to avoid their rapid decline.

Latent dwarf mistletoe infections in trees in densely stocked stands and in shaded reproduction are very difficult to detect. It should be assumed that understory trees more than 3 feet (1 m) tall that have been overtopped by infected trees for at least 15 years are probably infected.

Retention of living infected trees, particularly those with large witches' brooms, for use as nesting sites and cover for wildlife is a consideration for some stands. Large diameter trees with brooms confined to the lower halves of trees will survive longer than smaller infected trees overtopped by large trees.

The risk of losing the stand or large numbers of trees to wildfires and other damaging agents can be reduced by clumping the distribution of infected trees into small groups separated by much larger areas free from infection.

Stands that have a uniform distribution of Douglas-fir dwarf mistletoe will experience higher rates of tree mortality from the parasite than those where clumps of infected trees are widely separated from each other. Infected trees with large witches' brooms can be killed by girdling and left standing for use by wildlife.

Forested recreation sites, such as campgrounds, with Douglas-fir dwarf mistletoe infestations may need to be treated to maintain Douglas-firs on the sites for many years and to reduce the risk of injuries and damage to users from breaking branches. Pruning infected trees can prolong their lives and slow or even stop

spread of mistletoe to adjacent Douglas-firs. Witches' brooms exert a large drain on infected trees, so their removal by pruning can improve tree vigor and longevity.

All branches with witches' brooms should be cut. Branches below brooms and two whorls above them are also likely to be infected, and should also be pruned, even if brooms are not obvious. Trees may have to be repruned occasionally to remove developing witches' brooms.

The best candidates for pruning are trees with infections only in the lower half of their crowns. In addition to prolonging tree life, pruning can reduce the danger of branches and trees breaking and causing accidents. Pruning branches with large witches' brooms should not be done from January through July to avoid attracting Douglas-fir beetles to the pruned trees. Trees too severely infected to be pruned should be removed if they pose an infection threat to adjacent Douglas-firs or a serious safety hazard to users.

There are natural factors which limit Douglas-fir dwarf mistletoe, including wildfire which has been nature's primary control agent. Several species of insects and fungi attack and kill dwarf mistletoe shoots or fruits. Some of the fungi are common pathogens that can exert considerable local but temporary control of dwarf mistletoe. Environmental factors, currently not completely understood, limit the effectiveness of these fungi to small areas for short durations.

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