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Dwarf Mistletoes (*Arceuthobium* spp.), Rust Diseases, and Stem Decays in Eastern Oregon and Washington

Abstract

Considerable information is available on the four dwarf mistletoe species of concern in eastern Oregon and Washington: Douglas-fir dwarf mistletoe, larch dwarf mistletoe, western dwarf mistletoe, and lodgepole pine dwarf mistletoe. Dwarf mistletoe can be controlled by cutting infected trees and planting non-susceptible tree species. Timely pruning of brooms and use of hormones that cause abcision of dwarf mistletoe plants are feasible only on individual trees in small areas. Models are available for dwarf mistletoe effects and landscape vulnerability.

Of over 50 species of rusts in the Pacific Northwest, only a few cause significant effects: white pine blister rust on five-needle pines; western gall rust, stalactiform rust, and comandra rust on lodgepole pine and ponderosa pine; fir broom rust on true firs; spruce broom rust on spruces; and incense-cedar rust on incense-cedar. Genetic resistance and tree species manipulation can be used as a means to control some rusts, and infected branches can be eliminated by pruning. Site hazard ratings based on habitat type and elevation are available.

Timber losses from heart rot (stem) decay are greater than from all other diseases, but infected trees, both living and dead, provide valuable wildlife habitat. Species of greatest concern are *Phellinus pini* and *Echinodontium tinctorium* (Indian paint fungus) with *Fomitopsis officinalis* being less common. Harvesting trees when younger than 90 years old and limiting wounds on remaining trees may decrease infection.

Although all these tree diseases can cause tree deformation, growth loss, and tree mortality, the brooms and specific wood decay conditions they form promote ecological and structural diversity. Ongoing research is evaluating ways to manage these diseases in ways that maximize their benefit to forest ecosystems while limiting their detrimental effects on forest resources.

Dwarf Mistletoes

Dwarf mistletoes are important host-specialized pathogens that infect the dominant early-seral conifer species in eastern Washington and Oregon. Douglas-fir dwarf mistletoe (*A.douglasii*), larch dwarf mistletoe (*A. laricis*), western dwarf mistletoe (A. *campylopodum*), and lodgepole pine dwarf mistletoe (*A. americanum*) may extensively influence landscapes where they occur (Weir 1916, Pierce 1960, Gast et al. 1991). In eastern Washington and Oregon about one-quarter of the ponderosa pine, one-half of the western larch, and 40% of the Douglas-fir and lodgepole pine are infected with dwarf mistletoe (Bolsinger 1978).

Dwarf mistletoes are seed plants that are parasites on conifers. As plants they have roots, stems, and reproduce by seeds. The major function of aerial shoots is reproduction. Although the aerial shoots may contain chlorophyll, little food is produced for the parasite. As a result they rob their host of water and nutrients. Dwarf mistletoes also produce chemicals that result in abnormal branches termed "witches-brooms." These processes cause a variety of dysfunctions in conifers including growth loss, top-killing, large knot size from the abnormal branches, and eventually mortality (Tinnin and Knutson 1985, Filip et al. 1989, Hawksworth and Wiens 1996). The important role that dwarf mistletoes play in forest ecosystems and specific associations between dwarf mistletoes and wildlife (Bull et al. 1997, Parks and Bull 1997, Parks et al. 1999), arthropods (Filip et al. 1993), and fungi, are increasingly being reported (Hawksworth and Wiens 1996).

The area colonized by dwarf mistletoes does not change markedly from year to year. Dwarf mistletoes spread slowly, at a rate that averages one to two feet per year. Dwarf mistletoes depend on living trees for survival and can be manipulated through silviculture (Pierce 1960, Schmitt and Goheen 1991, Tinnin et al. 1999). In the past, extensive suppression efforts have focused on "sanitizing" stands, including large clear-cuts, to rid areas of dwarf mistletoe infection. The current focus by managers is to employ silvicultural strategies that include allowing for some level of dwarf mistletoe infestation in stands without putting the stand at risk to the debilitating effects of severe mistletoe infestation (Bull et al. 1997). Because dwarf mistletoes are host-specific pathogens, their spread can be contained by making a buffer of non-host tree species around a group of infected trees, or by making a treeless buffer. Studies have evaluated removing dwarf mistletoe plants by applying plant hormones that cause the plants to abscise, and pruning brooms (Parks and Hoffman 1991). Management by these methods is considered feasible only on individual trees located in recreation areas or around administrative sites. Indeed, large brooms present a hazard to visitors in developed sites. The timing of pruning should avoid the flight period of Douglas-fir beetles as the beetles may temporarily be attracted to the pruned trees (Hadfield and Flanagan 2000).

A west-wide Dwarf Mistletoe Impact Modeling System is available (Hawksworth et al. 1995), and Hessburg et al. (1999) suggest an approach to modeling landscape vulnerability to disturbance by dwarf mistletoes.

Rust Diseases

Conifer rust diseases are caused by fungi that infect living hosts through the needles and then spread to woody tissue. Most rust fungi are obligate parasites that alternate between the conifer host and a botanically unrelated host plant to complete their life cycle. Disease transmission is by airborne spores. Mature acciospores are capable of infecting an alternate host hundreds of miles distant. Spread of spores from the alternate host to the host conifer is more localized and may depend upon interspersed rangelands where the alternate host is common (Laycock and Krebill 1967).

Rusts can cause bole deformation, branch brooming, growth loss, dead tops, tree mortality, and infection courts for other plant pathogens to enter. Rust cankers may be fed upon by rodents and lagomorphs (Powell 1982), presumably because of increased carbohydrate concentration. Parks and Bull (1997) found 13% (186) of rest locations of radio-collared American marten located in brooms of dwarf mistletoe or rust. Sixty-nine percent of the broom rest sites were in rust brooms of subalpine fir or Engelmann spruce.

Of the rusts found in the Pacific Northwest, white pine blister rust is the most damaging and is considered by plant pathologists to be among the most serious conifer rust diseases in North American forests. Synecology of many forests has been significantly and permanently altered by the accidental introduction in the 1890s and 1900s of this exotic pathogen (Mielke 1943).

More than 50 species of rusts occur in the Pacific Northwest (Ziller 1974, Scharpf 1993, Allen et al. 1996). Only a few of these potentially cause significant effects: white pine blister rust (*Cronartium ribicola*) on five-needle pines; western gall rust (*Endocronartium harknessii*), stalactiform rust (*Cronartium coleosporioides*), and comandra rust (*Cronartium comandrae*) on lodgepole pine and ponderosa pine; fir broom rust (*Melampsorella caryophyllacearum*) on true firs; spruce broom rust (*Chrysomyxa arctostaphyli*) on spruces; and incense-cedar rust (*Gymnosporangium libocedri*) on incense-cedar.

White Pine Blister Rust

White pine blister rust infects five-needle pines throughout North America. In the Northwest, these include western white, whitebark, limber, and sugar pines. Girdling of cambial tissue by the fungus results in branch flagging, which is often the first symptom to be observed. Diagnostic cankers are orange-colored and may be resinous. Most cankers on western white pine occur within 2.5 m of the ground due to the higher humidity found at ground level. White pine blister rust alternates between its conifer hosts and *Ribes* spp. On infected *Ribes* spp., uredinia appear as yellow-orange pustules on the lower surface of leaves. These are replaced by brown telial columns in late summer.

White pine blister rust readily kills hosts by girdling the bole or by killing a majority of the limbs. This disease has caused western white pine to be largely replaced by other conifers such as Douglas-fir. In parts of its range, especially northern Idaho and northeastern Washington, this has led to an increase in incidence and severity of Armillaria root disease and to a recent large-scale outbreak of Douglas-fir beetle. Owing to white pine blister rust and effective fire suppression, the elevation at which whitebark pine is dominant has been steadily increasing in the northern Rockies (Keane and Arno 1993) and to a lesser extent in the Cascades (Hadfield et al. 1996). This disease has an important ecological role because it is an introduced disease to which native hosts are not adapted. It is premature to assess the impact of white pine blister rust, but native hosts will probably never return to their former levels of abundance.

Western Gall Rust

Primary hosts of western gall rust are ponderosa pine and lodgepole pine. Branch flagging occurs if the gall encircles the branch. The gall is woody and globose with fissures. Spores can spread for many miles, and the alternate host is not required for disease transmission.

Tree growth is unaffected unless branch galls are numerous. Young trees may be killed or deformed by stem infections, and are predisposed to breakage at the gall. Mature trees are not usually killed by infections. Sites with high humidity are at higher hazard than are arid sites. This is the most commonly found rust in conifer forests. Host conifers do not achieve stand dominance on high-hazard sites.

Stalactiform Rust

Primary hosts of stalactiform rust are ponderosa pine and lodgepole pine. Alternate hosts are paintbrush and cow-wheat. Cankers are elongate and diamond-shaped and aecial blisters release orange aeciospores. Sunken, dead bark may be associated with the cankers.

Small stems and branches may be girdled, and young stands may be thinned by infections. Defects in older trees reduce wood quality and predispose trees to breakage. Rodents chew on cankers during the winter when other food sources become scarce.

Comandra Rust

Comandra rust causes swelling, cracking, and resinosis on ponderosa pine and lodgepole pine. Elongate cankers are perennial. Bastard toadflax is the alternate host.

Cankers affect trees of all ages, producing defects and causing mortality. Outbreaks are sporadic due to the distribution of the alternate host and fluctuations in environmental conditions. Forest nurseries and plantations have been seriously damaged.

Rodents feed on cankers, sometimes hastening girdling by removing bark. Cavity nesting birds often make nest and roost cavities in large branches killed by this rust.

Fir Broom Rust

Fir broom rust infects true firs. Chickweed, sandwort, and starwort are alternate hosts. This rust is easily recognized by the systemic, perennial brooms formed in crowns of infected trees. Branches and stems are swollen at the base of the broom, and needles in the broom are shortened, thickened, and chlorotic.

Trees of all ages are susceptible to infection. Fir broom rust has the potential to cause growth loss and mortality, but seldom does. Fir rust brooms serve as wildlife habitat.

Spruce Broom Rust

Spruce broom rust primarily infects Engelmann spruce. Kinnikinnick is the alternate host. This rust is easily recognized by the conspicuous perennial brooms formed in crowns of infected trees. Brooms may be up to 2 m in diameter. Needles within the broom are pale green in spring, orange in summer, and are shed in autumn.

Stem deformation, growth reduction, broken tops, and tree mortality may result from an infection. Broken tops serve as potential infection courts for *Phellinus pini*. Brooms are used as wildlife habitat.

Incense-Cedar Rust

Incense-cedar rust alternates between incense-cedar and rosaceous shrubs such as *Amalanchier* spp. Small infected branches appear discolored in early spring. Resultant bushy witches-brooms are erect.

Heavily infected trees with many brooms may be seriously weakened, but except on a few sites in western Oregon, trees are seldom killed. Main stem infections produce a defect.

This disease has had more effect on alternate hosts, such as cultivated pears.

Management of Rust Diseases

Most of the native rusts are widely distributed and have a minor ecological role. Rusts can increase to outbreak levels and thereby assume economic and ecological significance. The leading management technique for rust diseases depends on tree breeding. Genetic resistance has been documented for some rusts, including western gall rust (Hoff 1990, van der Kamp and Tait 1990) and white pine blister rust (Bingham 1983).

The non-native white pine blister has been the subject of a Forest Service screening and breeding program to develop resistance to the disease since the late 1950s. Since then, over 10,000 western white pine and sugar pine parent trees have been phenotypically selected in forests, screened for resistance, seed orchards established, breeding work begun to help further increase resistance, and resistant seed supplied to help meet the restoration and reforestation needs. Objectives of the resistance program include identifying the amount and type of genetic resistance present in natural populations of western white pine, and developing durable resistance to this exotic pathogen while retaining the broad genetic diversity within the species.

Because humidity affects disease spread (Hirt 1935), sites can be hazard rated for some rusts by habitat type and elevation (Beard et al. 1983, Goddard et al. 1985, Hagle et al. 1989), and non-host conifer species can be regenerated. Branch infections may be eliminated by pruning (Childs 1968, Geils and Jacobi 1990). Distal infections are less threatening than are infections proximal to the bole.

Stem Decays

Stem decays or "heart rots" are caused by fungi that infect living trees through fresh wounds to branches or stems. Heart rot fungi are spread by airborne spores produced by fruiting bodies—either conks or mushrooms. The spores colonize freshly exposed wood at wounds or dead branch stubs. Although spores of heart-rot fungi are abundant in forest stands of all ages, old-growth stands have a much higher incidence of heart rot than do young stands. Most tree species are susceptible to only a few heart rot fungi. Non-resinous species such as the true firs are more prone to stem decay than are species such as Douglas-fir, pines, or larch. Grand (white) fir is the most susceptible species and several species of fungi cause stem decay in this tree species (Aho 1977, Aho et al. 1987). Hepting (1971) provides a complete list of the decay fungi associated with forest trees in the United States.

Living trees with heart rot or dead trees that were infected by heart-rot fungi when alive can serve as important or critical wildlife habitat. Woodpeckers most often select large trees or snags with heart rot for excavating nest and roost cavities. Once abandoned by the woodpeckers these cavities are used by a number of secondary cavity nesting birds, mammals, and invertebrates. Heart rot decay can progress in trees, living or recently dead, until the tree becomes hollow. Hollow trees have special importance to some wildlife, such as black bear, pileated woodpeckers, or Vaux's swifts (Bull et al. 1997).

Trees with limited decay are still merchantable for fiber but typically not suitable for dimension lumber. Timber losses due to stem decay are considered greater than those due to all other diseases combined. Decayed trees located in high recreation areas are undesirable because, while they may appear healthy, they may have poor structural integrity and be prone to break. Older trees are more susceptible to windthrow because much of their volume is made up of decay-susceptible heartwood.

Fruiting bodies (conks) of fungi allow for positive identification but are infrequently present on trees and logs with heart rot decay. In the absence of fruiting bodies, broken tops, fire scars, and other wounds on living trees are all indicators of internal decay. In eastern Oregon and Washington, two heart rot decay fungi are of most interest to managers. A summary of observations and research specific to stem decays in eastern Oregon and Washington is found in Filip et al. (1996).

- *Phellinus pini* decays heartwood of most western conifer species. This fungus may be found fruiting on ponderosa pine, lodgepole pine, western white pine, western larch, and Douglas-fir in some areas. The perennial, woody fruiting bodies differ in size and shape but are typically bracketlike or hoof shaped. The lower pore surface is usually a rich, rust-brown. The upper surface is darker brown and is usually marked by several concentric furrows.

  The first symptom of wood decay is a red stain, then the characteristic white, spindle-shaped pockets of decay develop parallel to the wood grain. In advanced stages, the wood has a honeycombed appearance.

- *Echinodontium tinctorium* causes internal decay in grand fir, subalpine fir, and mountain hemlock and is indicated by conks of the

Indian paint fungus. Indian paint fungus causes a characteristic stringy decay that can involve the entire tree trunk. *E. tinctorium* is the most common fungus associated with hollow trees, which are considered highly valuable as wildlife habitat. Fruiting bodies of this fungus are large, black, perennial woody conks with the entire undersurface toothed. The inside of the conk is brick-red. Fruiting bodies are found on the bole on the underside of branches or branch stubs.

The appearance of the wood in infected trees is, early, a brown to reddish-orange rot of heartwood that may significantly weaken the wood. In advanced stages of decay, the wood becomes stringy and eventually takes on a whitish cast.

- *Fomitopsis officinalis*, a less common fungus, causes internal decay of western larch and ponderosa pine. This fungus decays heartwood in large dead trees; it is rarely found in young stands. Conks are large, pendulous or hoof shaped, and chalky in color and texture. Occasionally this fungus is found on Douglas-fir, spruce, and hemlock, and rarely on true firs.

The key factors in the management of heart rot decay are tree age and wounding. The amount of heartwood is age related; older trees have a higher ratio of heartwood to sapwood than do younger trees. Trees less than 90 years old usually have insignificant decay. For many years heart rots were the focus of forest pathology research as demonstrated by the preponderance of heart rot research in the early forest pathology and forestry literature (late 1800s until the 1950s). Previously unentered stands were found to be "decadent" with heart rot decay. The management strategy of the day was to harvest stands on a "pathological rotation." This involved harvesting trees at ages that minimized losses to heart rots and removing all trees with existing heart rot decay to be piled in roadside "cull" piles.

Today, incidence of heart rot decay and hollow trees is high in old-growth forests and unmanaged forests but is low or absent in younger managed stands. With less than 3% of old growth remaining in eastern Washington and Oregon, the landscape that once held an abundance of trees with heart-rot decay now holds few. Because of their value as critical wildlife habitat, the absence of, rather than the abundance of, larger trees with heart rot in managed forests at a landscape scale may be the more critical issue. The exception may be the development of heart rot decay in grand fir communities located on wet sites, which tend to have the highest rates of infection and resulting decay. Trees that have been suppressed for more than 50 years are most vulnerable to infection. Filip et al. (1983) found that true firs in communities currently or previously dominated by ponderosa pine had less decay and infection than those growing on sites historically dominated by overstory firs.

Trees with heart rot do not usually show symptoms because the living, functional parts of the tree are not infected. Wounds, broken tops, and broken branches are indicators of heart rot, but detection is difficult without the presence of sporocarps (conks). Increment cores may be used to detect signs of heart rot fungi if the heart rot occurs at the location of the core sample. Bull et al. (1997) and Parks et al. (1997) describe methods for detecting trees with heart rot that may be most valuable to wildlife. Hessburg et al. (1999) suggest a model for risk rating stands for heart rot decay of grand fir and hemlocks caused by *Echinodontium tinctorium*.

Treatment options to reduce heart rot decay are limited because the airborne spores of heart rot fungi are abundant and ubiquitous. To reduce associated decay, trees are harvested at ages that minimize decay development. Because wounds are the entry court for new infections, taking care to limit wounding of residual trees during thinning or harvest activities may limit new infections. On the other hand, because heart rot in young managed stands is limited, managers are testing methods to create trees with heart rot for wildlife use (Parks et al. 1996a, Bull et al. 1997, Lewis 1998) in landscapes where they are lacking.

Other useful sources of information include Etheridge and Craig (1976), Filip and Schmitt (1990), Gast et al. (1991), Parks et al. (1996b), and Hansen and Lewis (1997).

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Note

This special issue of *Northwest Science* is a set of papers reviewing the state of knowledge about disturbance processes in eastern Oregon and Washington, related management practices, and effects on key management issues.

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