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# Management of Ponderosa Pine Infected with Western Dwarf Mistletoe in Northeastern Oregon

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Caring for the Land and Serving People

**BMZ-96-07**

# MANAGEMENT OF PONDEROSA PINE INFECTED WITH WESTERN DWARF MISTLETOE IN NORTHEASTERN OREGON

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Wallowa-Whitman NF, R-6
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## Introduction

Ponderosa pine (*Pinus ponderosa* Dougl. ex Laws.) is a component in a variety of forest plant communities in northeastern Oregon. Pine is a minor seral component in some wet communities, becoming increasingly common as a later seral species on warmer and dryer sites. Ponderosa pine is an early seral component in most grand fir communities, a major component in the Douglas-fir series and the dominant climax species in the ponderosa pine series (Johnson and Simon 1987; Johnson and Clausnitzer 1992). In eastern Oregon, there are over 4.6 million acres in pine forest type, comprising 44 percent of the commercial forest land (Barrett 1979). Because of it's wide range of ecological amplitude and prominence, relative pest resistance, and value, management of pine has been stressed on the east-side of the Cascades. Restoration of pine dominance on sites that have succeeded to fir, especially the "park-like" conditions of spaced large trees, is advocated by many.

Ponderosa pine has been harvested throughout its range in central and eastern Oregon for most of the last century. Large diameter mature pine, representing the most valuable and prized timber of the area, has been the primary focus of the wood products industry in the commercial forests of this region. In the pure pine type and mixed conifer type as well, selective harvesting of dominant, mature to overmature, or overstory trees, often as a salvage entry, or removal of trees at risk to western pine beetle (*Dendroctonus brevicomis* LeConte) attack, typifies the history of management of this species (Miller and Keen 1960).

Western dwarf mistletoe (*Arceuthobium campylopodum* Engelm.) is among the most widespread diseases of ponderosa pine in eastern Oregon. In the absence of natural disturbance regimes, successful long-term management of ponderosa pine in stands affected by *A. campylopodum* requires an active program of stocking level control, sanitation, and cleaning, especially if unevenage management is directed.

Ponderosa pine heavily infected with dwarf mistletoe have substantially lower growth rates than uninfected trees. Severely infected trees may be sufficiently weakened that they are killed outright, or they may be predisposed to mortality caused by other agents. Bark beetles, especially the mountain pine beetle (*Dendroctonus ponderosae* Hopkins) and the western pine beetle, are especially effective in locating and successfully attacking weakened, stressed pine (McCambridge *et al.* 1982; Frye and Landis 1975). Most importantly, loss of natural disturbance regimes, direction to both retain infected large trees and manage stands to an unevenage structure, will increase the incidence and severity of western dwarf mistletoe.

## Biology and Ecology of Western Dwarf Mistletoe

### Hosts

In eastern Oregon, western dwarf mistletoe primarily infects ponderosa pine. Jeffrey pine (*Pinus jeffreyi* Grev. & Balf.) is also a primary host of *A. campylopodum.* The northern limit of this host is in southwest Oregon, and it will not be covered here. Ponderosa pine is an occasional host for lodgepole dwarf mistletoe (*A. americanum* Nuttal ex Engelmann) and larch dwarf mistletoe (*A. laricis* (Piper) St. Johns). The infection rates of these dwarf mistletoes are low enough on ponderosa pine that they are not considered management concerns.

### Life Cycle

Figure 1. A female *A. campylopodum* plant with mature seed capsules.

All species of *Arceuthobium* have a similar life cycle, although there are differences between species in age at maturity, timing of seed maturation and distance of seed dispersal. Female *A. campylopodum* plants produce numerous fruits (capsules) at the ends of relatively large and well developed aerial shoots (Fig. 1). Inside of each capsule is a single seed. Fruits mature in late September and seeds are forcibly expelled from capsules as they detach from the aerial shoots. Seeds may be discharged for maximum distances of 120 to 130 feet, but effective spread is usually less than 35 feet from the tops of overstory trees (Childs and Wilcox 1966; Parmeter and Scharpf 1972) and 20 feet from smaller trees. Initial velocity is about 90 feet/second, generated by high hydrostatic pressure within the fruit. Seeds have a viscous coating that cause them to adhere to almost anything they happen to hit. Seeds that have stuck to pine needles will slide with gravity as moisture lubricates the viscous coating. Depending on needle orientation, some seeds may fall to the ground while others will slide to the fascicle at the base of the needle and remain there over winter. In the spring, seeds that eventually cause infection will germinate, each producing a single radicle that penetrates the cortex of the host on the branch and develops into haustorial strands. From these, sinkers are produced that penetrate the cambium and current year xylem. The haustorial strand network is called the endophytic system and it is perennial, remaining active as long as the host tissue is alive.

During the summer of the second year, swelling may begin to appear at the site of infection. A year later, again in the summer, the first aerial shoots may start to appear, although in some cases, several years may elapse between infection and production of aerial shoots. Another year or two may pass between initial production of aerial shoots and flowering. Differentiation between male and female plants become apparent the year after shoots first emerge. Staminate plants are brownish (Fig. 2) and pistillate plants tend to be greenish. Anthesis occurs and peaks in mid-September, and seeds are produced starting the next year. Aerial shoots are branched, average 3 inches in length but may be up to 5 inches long, and are produced on very pronounced spindle-shaped swellings on branches, and less frequently on boles of small trees. Aerial shoots of *A. campylopodum* are the largest and most visible of any *Arceuthobium* species in the Pacific Northwest. Clusters of aerial shoots are usually quite visible to the unaided eye even when in the upper crowns of large trees. The development and persistence of large brooms indicate decades of infection (Fig 3, 4).

Figure 2. A male *A. campylopodum* plant.

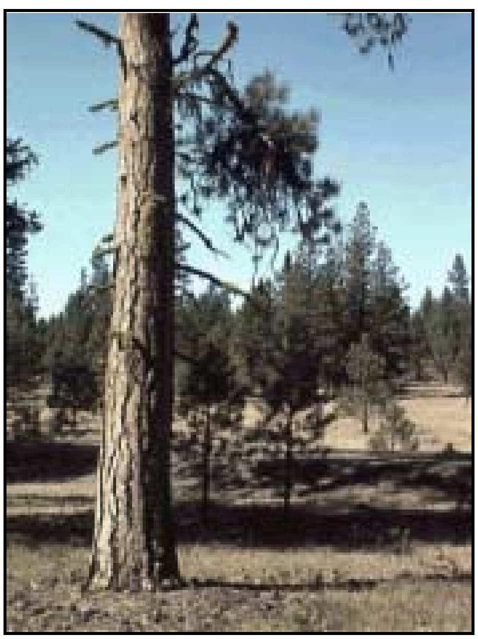

Figure 3. A well-developed broom on an infected tree.

Figure 4. A large dead broom on a living tree.

Spread

Western dwarf mistletoe spreads most effectively to sites lower in the canopy or crown. Most new infections result as spread from overstory trees to smaller trees. Spread can also occur between nearby trees of similar crown class, especially if they are within 35 feet of each other. Most effective spread between trees is from plants high in the crowns; those in dominant or codominant trees. This is simply due to the typical trajectory of the expelled seed. Spread between trees is limited in understocked stands, but spacing required to avoid spread between trees would require an unacceptably understocked condition, especially on better sites.

Upward spread of dwarf mistletoe, especially within infected trees, is much less effective than downward spread. Susceptible branch tips are shielded by older needles when seeds are expelled from below (Roth and Barrett 1985). Upward spread in trees, is not considered significant and will remain largely restricted to progressively lower portions of the crown if the host is able to grow 10-12" in height annually (Barrett and Roth 1985; Graham 1967).

Long distance spread of dwarf mistletoes has been attributed to seed dispersal by animals and birds. Zilka and Tinnin (1976) found four species of birds, including Cassin's finch, mountain chickadee, red crossbill, and steller's jay; all of which occur in eastern Oregon forest stands, to be potential vectors of dwarf mistletoe seeds. Birds in this study apparently inadvertently acquired seeds when roosting in dwarf mistletoe brooms at night. However, seeds eaten by birds are rendered nonviable as they pass through their digestive system, apparently due to lethal temperature and pH (Hudler *et al.* 1979; Ostry 1978). Lemons (1978) found that 50 percent of red squirrels in heavily-infected stands on the Malheur National Forest carried seeds, and hypothesized that effective squirrel-caused dispersal of infection was 500 feet.

The author has seen isolated pockets of western dwarf mistletoe infestations in Oregon that appeared to have been spread by birds or possibly mammals rather than typical tree-tree spread. It is believed that the main role of such spread is probably long-range dispersal into uninfected areas, and establishing new sites of infection, rather than contributing significantly to spread within stands.

<u>Occurrence</u>

Dwarf mistletoe infection of ponderosa pine occurs throughout most of the host range in eastern Oregon. Considerable variability exists in the level of infestations. In the Blue Mountains of Oregon, western dwarf mistletoe is most common and severe in the pine dominated forests of the Baker and Unity Ranger Districts on the Wallowa-Whitman National Forest and the Prairie City and Bear Valley Ranger Districts on the Malheur National Forest. Almost no infected stands are known in the northern Blue and Wallowa Mountains. The southern edge of the Malheur, which is nearly pure pine, has relatively little western dwarf mistletoe. It is most likely that this is the result of a relatively recent large-scale stand replacement fire.

Several investigators have correlated incidence of ponderosa pine dwarf mistletoe infection and infection severity with plant community and habitat types. Daubenmire (1961) found *A. campylopodum* on the driest two of seven habitat types with ponderosa pine in eastern Washington and northern Idaho. These two, *Pinus ponderosa/Purshia tridentata* and *Pinus ponderosa/Agropyron spicatum*, also provide for the slowest pine growth rates. Daubenmire and Daubenmire (1968) added the occurrence of *A. campylopodum* to two additional habitat types, the *Pinus ponderosa/Festuca idahoensis* and *Pinus ponderosa/Stipa comata* types, and postulated that ponderosa pine was susceptible to dwarf mistletoe only where it was associated with xerophytic grasses and *Purshia*, possibly since pine grows slowly on these sites. Schlatterer (1972) reported that *A. campylopodum* was most prevalent in low productivity habitat types in central Idaho. Merrill (1983) and Merrill and Hawksworth (1987) found that southwestern dwarf mistletoe (*A. vaginatum* subsp. *cryptopodum* (Engelm.) Hawksw. & Wiens), which commonly infects ponderosa pine in the southwestern United States, was most common in the *Pinus ponderosa/Muhlenbergia montana* habitat type; that being one of the most xeric habitat types of the ponderosa pine series in Colorado.

In the Blue mountains, there are scattered occurrences of pine infestation in mixed conifer stands, however, most substantial concentrations of western dwarf mistletoe infection occur in plant communities of the ponderosa pine series, where pine is the dominant conifer; assuming both a seral and climax role. Impacted pine stands include some of the more productive plant communities in the pine series, as well as some marginal sites. In the Blue Mountains, it does appear that *A. campylopodum* is common on a wider range of pine sites than is reported in other parts of the western United States. Other site and stand factors probably influence mistletoe distribution and abundance, especially past harvest and fire history, successional stage, and site topography.

<u>Ecological Concerns</u>

Roles of fire, dwarf mistletoe, and the host are interdependent. Dwarf mistletoe ecological relationships are directly related to that of its host, and the host's stand composition and structure determines mistletoe dynamics. Ponderosa pine series plant communities always are stocked with near pure pine stocking; thus, there is always a host component. This condition helps benefit maximum spread of *A. campylopodum*. Some of the warm/dry plant communities in the grand fir and Douglas-fir series have a major component of ponderosa pine only in early successional stages. Historically, these stands had been maintained in pine-dominated conditions by frequent light ground fires. Theoretically, such a condition favored mistletoe infestation by selecting for a pure host type, but also selecting against pockets of severely-infected understory because of their susceptibility to crowning during a fire. Fire suppression in the last century has allowed shade-tolerant Douglas-fir and true firs to become established and dominate understory vegetation. Such conditions likely limit the perpetuation of *A. campylopodum* by eliminating the host in the understory. Unfortunately, such conditions are not encouraged in management since shade tolerant grand fir and Douglas-fir are susceptible to a number of insects and diseases when they invade pine sites and such situations and resulting losses are frequently catastrophic. Also, current management direction and recent and planned cultural activity strives to restore stands to within their natural range of variability (NRV), which usually includes reestablishing a dominant pine understory while removing most of the Douglas-fir and true fir understory.

Figure 5. Grand fir invading a once pure ponderosa pine site. Note the open fire scar that indicates frequent fire periodicity.

Aggressive fire suppression has probably resulted in higher infection levels and more widespread dwarf mistletoe. Under natural historic conditions, prior to aggressive fire suppression, pine stands experienced fire at frequent intervals, with varying intensities in different portions of the stands. Frequent fire periodicity maintained near-pure ponderosa pine stocking and considerably lower density levels. Under conditions of frequent light burns, fuel is sparse and discontinuous. Thus, surface fires exhibit irregular, spotty, or finger-like burn patterns. This allows groups of saplings to survive, and over time, gives rise to multi-canopy level structure. In other words, the result was the development and maintenance of an uneven-age structure of scattered different, relatively evenaged groups of developing understory in beetle or fire caused holes. Trees that developed mistletoe brooms in the lower crown were predisposed to crowning during light burns. Crowning would likely carry to adjacent trees, which were probably also infested. Fire suppression has resulted in much lower fire periodicity than occurred under natural conditions; excessive stocking in the understory over much of the pine type is one result of fire exclusion. A dramatic shift in species dominance occurs on sites that support climax grand fir or Douglas-fir. Where fire had maintained relatively pure pine, fire exclusion has resulted in dominance of firs in the younger age classes (Fig. 5). Selective logging of pines in such situations has often resulted in a loss of dominant pines (Arno *et al.* 1995). Such sites are among those with the highest levels of *A. campylopodum* in the Blue Mountains.

## Impacts

### Understory Effects

Understory pine are readily infected and can be affected by substantial impacts. Wagener (1965) found that understory ponderosa pine and Jeffrey pine growing in partial sunlight were more readily infected with dwarf mistletoe than those growing in full light. Roth (1971, 1974) found that uninfected seedlings were taller than infected individuals after 12 years of observation. Severely infected small trees, especially on poor sites, are unlikely to develop normally, as height and diameter growth are retarded, and deformation can occur (Fig. 6). Groups of severely infected trees will become stunted.

Figure 6. Stem infection and the effect on form.

Probability of dwarf mistletoe infection is largely a function of the infection hazard and the size of the susceptible seedling; the larger the individual, the greater the probability of intercepting ejected mistletoe seeds. For years, pest management specialists have used a 3' tall or 10-year old rule-of-thumb threshold for infection. They recommend that an infected overstory should be killed or removed before the new understory reaches this size/age threshold.

Snow melt is believed to play a role in minimizing infection of trees shorter than the height of the typical snow pack (re: the three foot rule). Spring melt of the covering snow tends to wash most mistletoe seeds from the foliage before they germinate. and actual infection occurs. Infections are not as common on the lower branches of saplings as they are above three feet in their crowns.

Other Host Effects

Growth

Both height and diameter growth are impacted by moderate to severe dwarf mistletoe levels. Shea (1964) investigating diameter increment in mistletoe-infected pine, found that reduction in diameter growth was directly related to severity of infection. In mixed-sized stands, smaller trees were impacted to a greater degree than dominants. Average diameter growth for a tree of a DMR of 5 or 6 was 60 percent of healthy. Lightly-infected (DMR 1 and 2) and moderately-infected (DMR 3 and 4) trees had diameter increments that were 89 and 87 percent of healthy, respectively. Broomed trees were found to show especially profound diameter growth reduction. Studies in thinned stands show that lightly to moderately infected trees (DMR 1-4) will respond to thinning identically to healthy trees. Severely infected trees (DMR 5 and 6) are less responsive to thinning and exhibit lower diameter increment following thinning (Shea and Belluschi 1965). Barrett and Roth (1985) concluded that following thinning, even severely-infected trees will respond to release if site quality allows at least 10" of annual terminal growth, and that few pine stands on average and especially those on better quality sites have such extremely severe levels of infestation that removal of undesirable trees would leave the stand understocked. This study was done in even-age stands and findings would likely be different under unevenage conditions.

### Mortality

Mortality rates for ponderosa pine in most Oregon sites differ considerably from those observed in other parts of the country, especially the southwestern United States. Mortality is not common on lightly or moderately infected trees on better pine sites in the region. After developing severe levels of infection, individual trees may grow poorly for decades before eventually being killed. Often other pests, especially bark beetles, actually kill these weakened trees. On sites in south-central Oregon, mortality is more common in severely infected trees, and occurs earlier than observed on the better sites. Childs and Wilcox (1966) reported 10-year mortality levels of 2.8, 5.2, and 12.6 percent, for uninfected, lightly infected, and severely infected trees, respectively.

### Interactions with Other Pests

Reported work in the northwestern United States on the interactions between western dwarf mistletoe and other pests is lacking. Most research on this subject has been done in Colorado; most investigations have been with interactions between bark beetles, especially mountain pine beetle, and mistletoe.

In a couple of Colorado studies, differences were found in dwarf mistletoe infection and incidence of bark beetle attack. Frye and Landis (1975) found mountain pine beetle displaying preference for mistletoe-infected trees. McCambridge *et al.* (1982) found that in one area, 31 percent of killed trees were mistletoe-infected, while 21 percent of uninfected trees had been killed by mountain pine beetle.

### Wood Quality

While no detailed studies have been done on strength of dwarf mistletoe-affected ponderosa pine wood, the assumption can be made that wood is weakened due to shorter trachids, distortion and a higher proportion of ray tissues, based on studies in lodgepole pine (Piirto *et al*. 1974). Of much greater significance is the loss of value in distorted, crooked, or swollen stems, and reduction in grade due to large persistent broomed branches on infected trees.

### Seed and Cone Production

Quantitative data is unavailable, but heavily infected trees produce fewer cones and seed than uninfected trees. Impact is largely due to decreased host vigor.

## Wildlife Issues

Endemic levels of dwarf mistletoe over the landscape benefit various species of wildlife. Bennetts *et al.* (1991a) found a positive correlation between the intensity of dwarf mistletoe in ponderosa pine in central Colorado and both the number of species and the total number of birds. Average dwarf mistletoe rating (DMR) was by far the most significant factor affecting both total number of birds and diversity of bird species. Nests constructed and used by five species of birds were found in brooms of infected trees. Bennetts *et al.* (1991b) found the number of mule deer and elk pellets were higher in mistletoe-infected stands. Brooms caused by dwarf mistletoes are documented as preferred sites for nesting and hiding habitat for a variety of birds and small mammals. Bull *et al.* (1988) found that great gray owls built 20 percent of their stick nests in mistletoe brooms, most of which were in mistletoe-infected western larch but also included ponderosa pine. A variety of mammals, including several species of squirrels and chipmunks, pine marten and porcupine have been reported to feed on mistletoe aerial shoots and/or use brooms for nesting or hiding cover (Spencer 1987). Severely dwarf mistletoe-infected, thus weakened pine are more likely killed by western pine beetles. These standing snags provide prime cavity nesting sites and perches for raptors and other birds. When on the ground they provided large woody material and associated habitat on the forest floor.

Leach (1956) reports on both volume ingested and frequency of occurrence of *A. campylopodum* in the stomach contents of mule deer in the Great Basin of northern California. Porcupine are well documented in eating both aerial shoots of dwarf mistletoe and the bark and cambium of swollen infected branches. Mistletoe plants are apparently an important fall and winter food source (Lawrence 1957, Hooven 1971). Blue grouse in the Blue Mountains are documented as ingesting dwarf mistletoe plants as part of their fall diet. Crawford *et al.* (1986) found mistletoe plant parts in the stomach contents of birds that were probably *A. laricis* (western larch) and *A. douglasii* (Douglas-fir).

Dwarf mistletoe and its effects are best managed within the context of historical abundance and levels of intensity. Watershed-level landscapes that have been thoroughly sanitized of infections will not provide historical levels of wildlife benefits. Conversely, excessive levels of mistletoe will effect stand growth and increase the risk of catastrophic fire. Providing the benefits of endemic levels of infection in stands to various species of wildlife should be part of management direction in most situations. Reynolds *et al.* (1992) puts this in the proper context with recommendations for managing stands for the northern goshawk in the southwestern United States. While some of the changes induced by mistletoe infestation on ponderosa pine stands benefits a variety of wildlife, over time, mistletoe related changes can be detrimental to some goshawk prey species, and are not desirable in post-fledging family and foraging areas. As an example, severely infected stands may stagnate and not develop to late and old structure. Management recommendations for developing desired future conditions could include sanitation thinning treatments. The risk of stand replacement fire is much greater in severely-infected stands and should be a primary concern where wildlife use values are high.

**Methods of Control**

Some of the earliest reports on dwarf mistletoe concerned effects in unmanaged stands (Weir 1916). Growth and mortality impacts on unmanaged stands were well documented by the early 1970's (Childs and Edgren 1967; Childs and Wilcox 1966; Roth 1971).

<u>Response to Thinning</u>

Thinning of ponderosa pine is a commonly-used silviculture tool to release most desirable trees and reduce risk to bark beetle attack in overstocked stands. Pine normally regenerates in dense thickets which are continually thinned as they mature by a variety of factors including biotic and abiotic agents, as well as attrition of suppressed individuals. During this century, suppression of once-frequent ground fires has undoubtably accentuated the problem of overstocking of pine stands. High stocking levels in stands of small to medium sized pines frequently predispose trees to epidemic attacks by several species of bark beetles. In recent years, dwarf mistletoe-infected stands may have been mechanically thinned as a bark beetle control measure, or more recently, as a sanitation treatment for mistletoe.

The objective of initial thinning of dwarf mistletoe infected stands may have been to eradicate the infestation, although this was never achieved (Shea and Lewis 1971). Until recent years, there was considerable difference of opinion regarding effectiveness of and response to thinning infected stands. Much of the skepticism resulted from the apparent proliferation of mistletoe plants several years following thinning. As a result, some early reports question the effectiveness of thinning (Shea and Lewis 1971). Later, work focused on the positive growth response of infected trees following thinning rather than the lack of success in eradicating infection. Roth and Barrett (1985) investigated the response after thinning ponderosa pine in central Oregon. They found this if crowns enlarged at a faster rate than dwarf mistletoe propagates, thinned trees would grow quite productively (Fig. 7). Following thinning, latent mistletoe infections soon become apparent, first as branch swellings and later as aerial shoots in response to increased light and possibly tree vigor. They found that while the population of dwarf mistletoe plants increases dramatically following thinning, it does so at about the same rate as the increase in the size of the tree crown. The ratio of number of plants to crown size stays relatively constant. The net result was no detectable effect on height growth in an even-age stand.

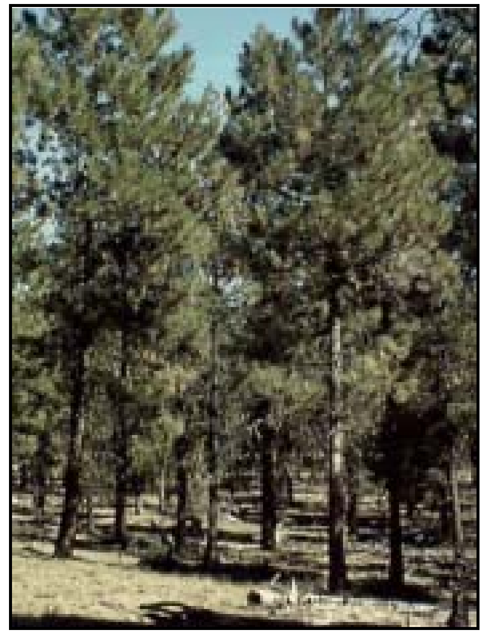

Figure 7. Thinned infected stand with excellent growth response.

A dramatic change occurs in the distribution of dwarf mistletoe infections (plants) in the crown of trees in even-age stands that are thinned and later release. The upper third of the crown quickly outgrows most infections while the number of infections in the mid and lower crown increases. The relative concentration of mistletoe plants continues to shift to the lower third of the crown. The accepted standard for rating or grading the level of infection on individual trees, the DMR or Hawksworth's Dwarf Mistletoe Rating system (Hawksworth 1977), discussed later in this paper, declines for a time, at least as trees are actively growing in height.

Barrett and Roth (1985) investigated response of a thinned stand of mistletoe-infected immature ponderosa pine that had recently had a removal of mature to overmature mistletoe-infected overstory. Comparisons with healthy, similarly thinned plots ten years later showed that trees responded in both infected and uninfected plots, and that there where no statistically significant differences. Another twelve years later, the infected plots were thinned again, and after eleven years, the average annual height increment was 1.4 feet per year, which was again similar to growth of healthy trees. It should be borne in mind when considering the results of this study that following the removal of the original overstory, this was an even-age stand.

Barrett and Roth (1985) investigated the response of a thinned stand of mistletoe-infected immature 40- to 70-year old ponderosa pine. Following thinning to 250 stems per acre, mistletoe-infected and healthy plots were established. Infected plots contained trees with DMR up to 4, while severely infected trees were removed, as were healthy trees where an acceptable infected tree could be left. Ten years after thinning, growth and mortality were compared between the two treatments, with both treatments responding to thinning and no significant differences found. Twelve years later, the infested plots were again thinned to an average 88 trees/acre. This time the best trees were reserved. Another eleven years later, the average annual height increment was 1.4 feet/year.

Conclusions of this study demonstrate that by regulating stand density, trees in even-age stands are able to tolerate light to medium levels of dwarf mistletoe and grow at or near rates of uninfected trees. Diameter increment of infected stands have been shown to respond favorably to thinning. Residuals with DMR of up to 4, show little or no differences from similarly thinned healthy trees. Severely infected trees (DMR 5 and 6) also release following thinning but diameter increment remains at 60 percent of healthy trees (Shea and Bulluschi 1965).

Pruning

Pruning may be done in cases where the objective is either: 1) to enhance tree survival or longevity, or 2) in lightly-infected stands, to remove all the source of infection to assure a sanitized stand. Very little quantitative data is available on pruning; none is available for ponderosa pine in the northwest. In California, Scharpf *et al* (1987) found that pruning of brooms on Jeffrey pine increased host vigor and reduced mortality. Pruning which reduced live crown ratio to 30 percent or less was found to offer little or no positive benefit and in some cases, was detrimental. Maffei (1992) recommends not pruning pine trees that will retain less than 50 percent live crown after removal of all infected branches. Because of costs, pruning is most likely to be seriously considered to restore vigor of high-value trees in special areas, like recreation and administrative sites.

Fire

Fire has long been considered to play a major role in naturally controlling or limiting spread and severity of dwarf mistletoe in pine stands simply by selecting against trees that are stunted or broomed due to dwarf mistletoe. Where fire has not recently occurred in heavily infected stands, excessive fuels will accumulate, including large fuels such as broken-off brooms and dead trees, resulting in increased heat and flame height during ground fires. Also, stunted infected understory and low persistent brooms with resin-impregnated branch wood and trapped dead needles both serve as fuel ladders, increasing the likelihood of ground fires crowning in mistletoe-infected portions of stands. Where fires crown and groups of trees are killed, the resulting openings may regenerate to relatively even-aged blocks of trees. Reinfection may occur if residual infected trees remain.

In an evaluation of effectiveness of fire in controlling western dwarf mistletoe on ponderosa pine in Oregon, Koonce and Roth (1980, 1985) concluded that young even-aged thinned and unthinned dwarf mistletoe-infected stands could be partially sanitized by prescribed underburning. They found that mistletoe-infected trees do not self-prune as well as healthy trees and with a given scorch height, a greater proportion of the crown length will be damaged.

Harrington and Hawksworth (1988) found that in an uneven-aged stand in Arizona following a prescribed underburn, average DMR dropped from 3.7 to 2.9 due to the disproportionate number of heavily-infected trees (average DMR 4.8) that were killed. They found that average crown scorch increased with DMR. They also found that with equal amounts of crown scorch in the 38 to 87 percent range, heavily infected trees have less than half the probability of survival. They concluded that use of controlled fire could be used to significantly reduce infection in lightly-infected stands but the amount of scorch required to effectively manage dwarf mistletoe in heavily infected stands would probably result in poor survival of residuals.

Stand replacement fire might be considered an effective sanitation tool in severely-infected stands that are deemed non-viable.

Chemical Control

While most dwarf mistletoe control strategies have been cultural, considerable effort has been expended to develop a chemical-based control approach. Early work involved testing nearly 60 different chemicals, mostly various formulations of 2,4-D or 2,4,5-T. None of these were found effective in killing dwarf mistletoe plants without injuring the host. Also, none of these chemicals affected the mistletoe endophytic system within the host, so even if visible portions of plants are killed, aerial shoots would eventually reappear (Gill 1955). More recent work with a variety of herbicides and growth regulators have shown limited success by killing the aerial shoots and causing minimal host damage, but again, the endophytic system remains unaffected by all chemicals tested (Moinat 1988).

Most recent work has involved investigations on the use of ethophon (2-chloroethylphosphonic acid), a plant regulator that releases ethylene upon absorption by plant tissues. This chemical is used in the fruit and vegetable growing industry to promote ripening of cherries, apples, and tomatoes.

Numerous trials have been made to determine the effectiveness and potential use of ethophon for controlling dwarf mistletoes. Results of treatments on all species of mistletoes tested indicate that ethophon readily causes abscission of shoots older than one year for varying periods of time, but the endophytic system remains unaffected.

Trials in ponderosa pine in the Boise National Forest (Idaho), showed abscission rates of 60 to 100 percent at an application rate of 2400 ppm of ethophon (Ethrel[R]) with surfactant applied to run-off with a ground based hydraulic sprayer. New shoots began development within 2 months after treatment. After 1 year, most female and all male plants flowered. Seed production on the female plants resumed the second year after treatment (Parks and Hoffman 1991).

Lack of long-term effectiveness of ethophon greatly limits its potential use on an operational basis. Thus, it may be seriously considered only as a means of protecting developing understory in high value sites (recreational areas, administrative sites, or home sites) where host trees must be retained for seed sources or cover until regeneration becomes established after which the overstory trees could be removed. The expense and commitment of treating pine every two years needs to be carefully considered before embarking on use of this control.

### Resistance

Resistance to dwarf mistletoe infection by ponderosa pine has been demonstrated in field trials in central Oregon (Scharpf and Roth 1992). Scions selected from phenotypically resistant sources were grafted to rootstock and exposed to a high level of mistletoe infection from an overstory source for 20-22 years. Results indicated that both number of trees infected and infections per tree were significantly lower than controls. Tree size and crown characteristics were not related to infection intensity. While resistance was clearly shown, they were unable to identify the mechanisms of resistance or levels of inheritance, but concluded that resistance is not based on simple inheritance, but involves juvenile susceptibility and range of resistance in parents.

High levels of resistance exist in populations of central Oregon ponderosa pine and probably elsewhere in the inland west (Scharpf and Roth 1992). This resistance to infection is one of the ways trees resist disease and is part of the natural forest ecosystem.

## MANAGEMENT

### Recognition

The first step in managing dwarf mistletoe-infected stands is to recognize areas of infection in the stand examination or reconnaissance process. Sometimes light levels of dwarf mistletoe infections are missed by stand exam crews, especially if they are inexperienced or have not received training. There really is no excuse for missing moderate or severe levels of mistletoe.

Very commonly, other maladies or atypical host growth is misidentified as dwarf mistletoe infection. Elytroderma needle blight, caused by *Elytroderma deformans*, results in dense compact brooms that can be mistaken for similar appearing brooms caused by dwarf mistletoe. Close examination with binoculars if necessary should be made for the presence of spindle-shaped swellings on branches and aerial shoots of the mistletoe plants which will confirm presence of infection. In some localities, and especially on older trees, healthy branch form are somewhat broomed and resembles

Figure 8. Fallen segments of mistletoe plant aerial shoots on the forest floor help indicate presence of infection.

dwarf mistletoe brooms. These may be particularly difficult to assess, since they are often well above the ground.

Infections in overstory trees can usually be confirmed by looking for plants on understory host trees close to suspect overstory. Old broken segments of mistletoe plants can also be found under infected trees (Fig. 8). Finally, remnant basal cups, the point-of-attachment of the shoot to the host, can usually be found on live as well as fallen dead branches, usually towards the edges of spindle-shaped swellings (Fig. 9).

Rating Infection Severity

Severity of dwarf mistletoe infection has been characterized by a standardized 6-class rating system that works especially well with western dwarf mistletoe on ponderosa pine. The Dwarf Mistletoe Rating (DMR) is easily learned and can be applied to individual trees and averaged for stands (Hawksworth 1977).

Figure 9. Basal cups remain visible long after branches die, helping verify infection when mistletoe shoots are no longer present.

Infected trees are rated as follows:

1) Visually divide the live crown into thirds (top, middle, and bottom).

2) Rate each third separately as--

0= no visible infection

1= light infection; one-half or less of the branches have infections

2= heavy infection; more than one-half of the branches have infections

3) Add the ratings for each crown third to obtain the rating for the tree. Trees rated 1 or 2 are considered lightly infected; 3 or 4 moderately infected; 5 and 6 severely infected.

Detection Surveys

An important step in formulating management decisions regarding ponderosa pine stands requires information relating to occurrence and severity of dwarf mistletoe. Such information is essential for determining the appropriate silvicultural treatment and priority. Surveys can be part of the stand examination process. Data obtained includes the DMR of trees in plots as well as distribution of infection. Standard stand exam data including infection and DMR properly coded in the Damage and Severity fields is adequate to drive the mortality and diameter growth reduction equations in the current Blue Mountain Variant of FVS stand simulation model (PROGNOSIS) (Wykoff *et al.* 1982; Johnson 1990). If sampling intensity is good, and the entire block is covered with a systematic grid, resulting data can be used to construct a map showing areas of infection and intensity. Road-side surveys have been successfully done in other Regions, and are best used to document large-scale occurrence of infection, rather than stand level distribution.

Field reconnaissance using a systematic grid approach can be used to survey and map areas in proposed treatment areas. This type of survey is also best for setting treatment priorities, suppression work such as girdling or falling of infected overstory residuals, whip-falling or sanitation thinning. Surveys are best done in the summer or fall when aerial shoots are well-developed and visible. Maffei and Arena (1993) describe a survey that is done using visual reconnaissance points placed on a 5 X 5 chain grid over a project area. Stand structure and mistletoe infection incidence and severity information is collected and incorporated into a Geographic Information System (GIS). Dwarf mistletoe infection levels can be displayed in a landscape view and be used along with other resource information for treatment planning.

Silviculture Treatment and Recommendations

Stand treatment options and priority are determined not only by condition, but by management objectives as presented in the Forest Plans. The scale of treatment considered in some Management Allocations may be greater than others. These decisions should be made in an interdisciplinary forum where all resource values are considered. Stands with an endemic level of dwarf mistletoe should be considered healthy. As mentioned previously, broomed trees provide habitat for some birds and small mammals, and plants are a supplementary food source for others. The point does need to be made that maintenance of healthy stands is desired in all Management Allocations, and is expressed as the desired future condition, and that stands are no longer healthy when dwarf mistletoe levels become excessive and impacts occur. The hazards of stand replacement fire and the role that dwarf mistletoe can play in predisposing stands to these events also needs to be considered. For these reasons, this document will present management alternatives as silvicultural strategies, realizing that in different Management Allocations they can be applied differently in terms of scale and intensity.

Since resistance to dwarf mistletoe infection occurs and some level of inheritability of this resistance exists, efforts should be made to maintain trees exhibiting resistance (Scharpf and Roth 1992). Whether this genetic material is propagated in seed orchards or allowed to be perpetuated as selected residuals following thinnings, these trees should remain an important part of healthy pine ecosystems.

<u>All Age Stands</u>

Multiple age and size class stands have developed naturally on some sites, and have also been favored by selective harvesting. Dwarf mistletoe is most apt to spread, intensify and cause damage under unevenage conditions. While most, if not all Forest Plans direct that unevenage management strategies will be used in the pure pine type, the presence of mistletoe will make successful stand management in an unevenaged structure much more difficult. Direction to retain most or all large diameter trees (>21" dbh) regardless of dwarf mistletoe infection is current policy on Eastside Forests. Large infected trees will perpetuate infection and reduce success of sanitation attempts. Regenerating trees that soon become infected, then mature under a canopy of infected overstory trees, will likely not contribute to LOS (late and old structure) of large diameter trees. For this reason, stand conditions of heavy infection in an overstory component with most understory being exposed to seed dissemination, warrants review of the management direction to allow cultural work for successful development of some large reasonably healthy trees.

In unevenaged stands with numerous scattered infections, conditions will undoubtedly deteriorate over time. Such stands should be scheduled for treatment while a vigorous seed source still exists. Recommended treatment includes carefully selecting 10 to 18 trees per acre of the healthiest seed trees in the intermediate to dominant components of the overstory; slash the understory, retaining any significant blocks of uninfected trees that exist. Do not attempt to select individual uninfected trees among infected individuals. Prepare the seed bed and monitor for natural regeneration. Following establishment of regeneration, inspect the overstory for trees that are uninfected; these should be retained. Infected trees should be removed or killed and used as snags.

In unevenage stands with few scattered blocks of infection, the opportunity exists to retain portions of the stand intact. Following a careful survey where infestations are marked, delineate blocks within the unit for treatment. Treatment blocks should include groups of infected trees and a buffer of 100 feet beyond visibly infected trees. Larger treatment blocks could be treated as a small regeneration unit using a shelterwood or seed tree approach. Following establishment of understory trees, the overstory could than be killed or removed (Fig. 10).

Figure 10. An infected overstory residual and susceptible understory.

The historical concept of unevenage structure in most pine communities was likely one of a mosaic or patchwork of mostly single story stands with pockets of younger age classes interspersed among large widely scattered old pine. This is not the same unevenage mixed canopy structure that is often advocated for wildlife screening qualities. Mosaics of mostly single story age groups can be more successfully managed when at risk to moderate to heavy mistletoe occurrence with regard to the development of large diameter trees.

Two-Storied Stands

In typical two-storied stands, an overstory of mature to overmature trees occurs above an understory of smaller pine that became established due to disturbance that reduced stocking of the overstory (beetle-kills, selective logging, etc.) or due to lack of periodic ground fire from the system that had played a thinning function.

Understory age and infection levels in the overstory will dictate the amount of infection in the understory. If the understory has good crown ratios and form, they are probably manageable. Removal of the overstory and subsequent thinning to appropriate stocking levels based on site quality would release the understory creating an uneven-aged stand. Best formed and least-infected trees should be retained. Trees that respond will to release tend to out-grow mistletoe infections by adding height faster than upward spread of infection. Such trees will soon be

Figure 12. The severely infected tree on the left is not viable and did not respond to thinning.

Figure 11. Thinned trees with infections restricted to the lower crown. Growth rates are similar to uninfected trees.

growing at or near rates of uninfected healthy trees (Fig. 11).

If understory trees have been suppressed for years and have poor crown ratios, they probably also have excessive mistletoe infection levels and may not be viable (Fig. 12). Such trees are best destroyed. Use of mistletoe infected overstories for seed trees is allowable, provided trees are considered capable of producing seed. Infected trees need to be removed or killed by the time regeneration is well-established. Ten years old or three feet tall are recommended guidelines.

Evenaged Stands

Thinning mistletoe infected stands is recommended unless site quality is very poor or dwarf mistletoe levels are very severe. Site quality can be approximated using Hall (1973) or Cochran *et al.* (1994) using Stand Density Index and stocking level guidelines. If healthy stands on comparable sites are able to respond after a 5- to 6-year lag with at least a 10 inch annual terminal growth response, Roth and Barrett (1985) predict all but the most severely infected stands will favorably respond to thinning. Control is not the objective, response upon release is. All but the most severely infected stands are considered manageable; full stocking of acceptable crop trees should exist in most infected stands. Leave trees should include (modified from Roth and Barrett (1985) in declining order:

1. Healthy dominants (Dom) and codominants (Codom).

2. Dom and Codom with Dwarf Mistletoe Ratings (DMR) 1 or 2

3. Dom and Codom with DMR 3

4. Dom and Codom with DMR 4

5. Healthy intermediates (Int)

6. Int with DMR 1, 2, or 3

7. Healthy appearing trees below the general canopy with good crowns. No crop trees should have bole infections or branch infections within 8 inches of the bole. Crop trees should exhibit good terminal growth over the last 5 years.

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