BMPMZ Management Guide

Management of Douglas-fir Infected with Dwarf Mistletoe in the Blue Mountains of Northeastern Oregon and Southeastern Washington

United States
Department of
Agriculture

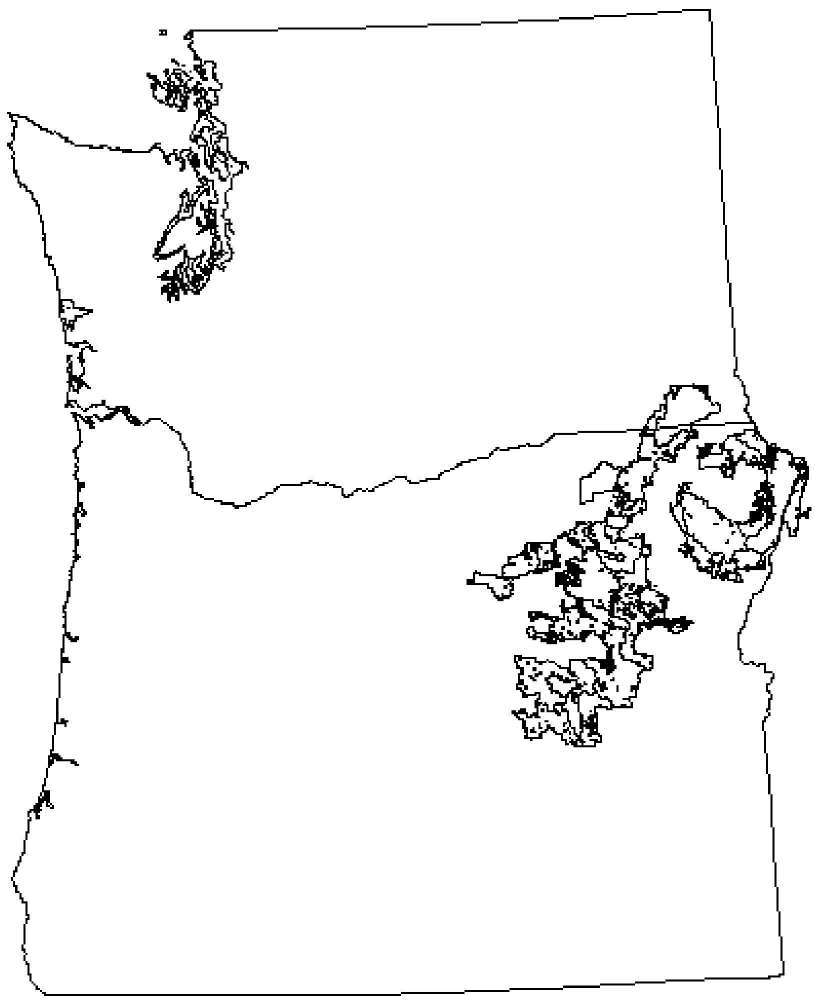
Forest Service

Pacific
Northwest
Region

**Blue Mountains Pest
Management Zone**

**Wallowa-Whitman
National Forest**

BMZ-97-2
March, 1997



Craig L. Schmitt
Zone Pathologist

Caring for the Land and Serving People

Table of Contents

BMZ-97-02

MANAGEMENT OF DOUGLAS-FIR INFECTED WITH DWARF MISTLETOE IN THE BLUE MOUNTAINS OF NORTHEASTERN OREGON AND SOUTHEASTERN WASHINGTON

Craig L. Schmitt, Zone Pathologist, Blue Mountains Pest Management Zone
Wallowa-Whitman NF, R-6
March, 1997

INTRODUCTION

Douglas-fir (*Pseudotsuga menziesii* [Mirb.] Franco, var. *glauca*) is an important conifer in the forests of the Blue Mountains of northeastern Oregon and southeastern Washington. This species is found throughout the Blue Mountains region, growing in pure and mixed stands over a wide range of aspects and elevations (VanHooser *et al.* 1991), and expressing a very broad ecological amplitude. Douglas-fir is a minor component in very dry communities such as the ponderosa pine/mountain-mahogany/Idaho fescue-bluebunch wheatgrass plant associations, but generally increases in composition on more mesic sites. Douglas-fir is present in some high elevation stands in subalpine fir/grouse huckleberry plant associations as an occasional seral component. The highest coverage and constancy occur in Douglas-fir and drier end grand fir series communities (Johnson and Clausnitzer 1992).

Douglas-fir has been harvested since the early days of pioneer settlement and mining in quantities second only to ponderosa pine (*Pinus ponderosa* Dougl. ex Laws.). Because of its structural strength and durability, Douglas-fir timbers and lumber have been preferred for use in mines and construction framing. In more recent years, harvest of fir has mostly been included in partial removals with pine, or in mixed conifer regeneration harvests. During or immediately following defoliator epidemics of Douglas-fir tussock moth (*Orgyia pseudotsugata* [McDunnough]) or more recently, western spruce budworm (*Choristoneura occidentalis* Freeman), substantial amounts of fir died as a result of defoliation stress coupled with other insects and diseases, drought, and excessive stocking. In recent years, this has prompted considerable salvage harvesting.

In addition to providing valuable wood products, Douglas-fir is an important ecosystem component, providing habitat for a variety of birds (Heji and Woods 1991), deer and elk (Skovlin and Vavra 1979), and small mammals (Thomas 1979). Douglas-fir inhabits a range of crucial riparian and big game cover sites, and maintains watershed and aesthetic values.

Douglas-fir dwarf mistletoe (*Arceuthobium douglasii* Engelmann) is a very common pathogen in the Blue Mountains. Dwarf mistletoe is probably the greatest threat to long-term successful management of Douglas-fir in the area. Bolsinger (1978) reported that 42 percent of the inland Douglas-fir type was infected. Forest Inventory data on the Wallowa Whitman NF indicates that 57 percent of the type is infected (Marsden *et al*. 1991). Stands in the Douglas-fir plant community series with dominant components of susceptible hosts from early through late successional stages will often have very high levels of infestation, with severe infection levels on individual trees (Wicker and Leaphart 1976). Stands in communities where Douglas-fir is a minor component or only becomes established late in succession, will usually have incidental or scattered light dwarf mistletoe infections.

Douglas-fir dwarf mistletoe causes large systemic witches' brooms to form as a result of profuse bud and branch stimulation (Fig. 1). These brooms serve as **nutrient sinks**[1] and limit the photosynthates and water available to the rest of the tree (Hull and Leonard 1964). Growth rates are reduced relative to the degree of infection. Hawksworth and Wiens (1996) report that diameter and height growth of severely infected trees averages 44 and 75 percent of uninfected trees, respectively. Mortality rates of severely infected Douglas-fir are substantial. Often, weakened trees are predisposed to Douglas-fir beetles (*Dendroctonus pseudotsugae* Hopkins).

Figure 1. Dwarf mistletoe-infected Douglas-fir with severe brooming.

BIOLOGY AND ECOLOGY OF DOUGLAS-FIR DWARF MISTLETOE

Hosts

In the Blue Mountains, *A. douglasii* primarily infects Douglas-fir. Other conifers including *Abies grandis* (Douglas ex D. Don) Lindley, *A. concolor* (Gordon and Glendinning) Hildebrand, *A. lasiocarpa* (Hooker) Nuttall var. *lasiocarpa*, and *Picea engelmanni*i are very rarely infected; not often enough to be considered secondary or even occasional hosts (Hawksworth and Weins 1996). Additionally, Douglas-fir will

[1] Terms displayed in bold type are defined in the Glossary.

rarely become infected by lodgepole pine dwarf mistletoe (*A. americanum* Nuttall ex Engelmann) (Hawksworth and Weins 1996). For management purposes, Douglas-fir can be considered the only host for *A. douglasii*, and no other dwarf mistletoe poses a threat to Douglas-fir in the Blue Mountains.

Life Cycle

Figure 2. Aerial shoots of a male (staminate) *Arceuthobium douglasii* plant on a Douglas-fir branch.

Arceuthobium douglasii has a life cycle similar to other dwarf mistletoes. Seeds of *A. douglasii* are produced singly within fruit **capsules** which develop on **aerial shoots** of the female plant. Seeds mature in late August to late September, having taken 17 to 18 months to develop (Hawksworth and Weins 1996). Mature fruits detach from the aerial shoots and the seeds are explosively discharged as the result of high **hydrostatic pressure** that develops within the capsule. Seeds have a viscous coating that causes them to adhere to almost anything they happen to hit. Seeds that stick to Douglas-fir needles will slide downward with gravity as moisture lubricates the viscous coating. Depending upon needle orientation, some seeds will fall to the ground while others will slide to the base of the needle and adhere there over winter. Snow melt will remove some of the seeds. Infection occurs only through tissue that is no more than a few years old. In the spring, seeds germinate, each producing a single radicle under which a **penetration wedge** grows into the cortex of the host and develops into **bark strands**. Bark strands grow through the cortex producing sinkers which penetrate the cambium and current year's xylem. Bark strands and sinkers are called haustorial strands; the network of these is known as the **endophytic system**. The endophytic system is perennial, remaining active as long as the host tissue is alive. Most species of *Arceuthobium* will remain localized at the point of infection and in immediately adjacent tissue, causing a swelling. *A. douglasii* is an exception. It becomes **systemic** in the host and will spread throughout the entire broomed host branch without causing host tissue to swell. New growth is infected after the endophytic system spreads into dormant buds and stimulates additional branching. The endophytic system grows systemically apace with new host growth and continues to infect new terminal buds. Aerial shoots of the parasite will form after branch tissue is 3 years old and will be found scattered along infected branches (Fig. 2). However, aerial shoot emergence may take longer on shaded branches. Aerial shoots elongate, mature, and produce either staminate or pistillate flowers, depending on whether the particular plant is male or female, between March and late June (Hawksworth and Weins 1996). In the autumn of the following year seed capsules mature, beginning the cycle again.

Spread

Distance of seed dispersal is usually 30 feet or less but in some cases may be as much as 50 feet. Due to the steep trajectory of **explosively discharged seeds**, the farthest spread occurs downslope from trees with infections high in crowns to nearby trees and from larger trees to susceptible understory. About 40 percent of seeds were found to be intercepted by trees in one study (Hawksworth 1965). Only a small proportion successfully initiate new infections. Most interception occurs within the same tree, resulting in spread throughout the crown and intensification of infection. Spread of expelled seeds to adjacent trees is the main mechanism for expansion of areas of infestation, although effectiveness is dependent upon stand structure and spacing. Wind has a minor effect on seed spread distance. In some cases, birds and small mammals will inadvertently carry seeds and spread infection. Birds are probably the principle long-distance vectors of the pathogen into areas sanitized by major disturbances, although avian and small mammal spread is probably insignificant within already-infected stands. Kuijt (1963) discovered several isolated pockets of Douglas-fir dwarf mistletoe in British Columbia that were about 50 miles from the nearest source of infection. Zilka and Tinnin (1976) found four species of birds, including Cassin's finch, mountain chickadee, red crossbill, and steller's jay; to be potential vectors of dwarf mistletoe seeds in eastern Oregon stands. Birds in this study apparently acquired seeds when roosting in dwarf mistletoe brooms at night. Since *Arceuthobium* seeds do not remain viable after passing through the birds digestive system (Hudler *et al.* 1979), there is no spread resulting from feeding. 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 distance of infection was 500 feet.

Occurrence

Considerable variability exists in Douglas-fir dwarf mistletoe infection intensity throughout the range of its host in the Blue Mountains. Some of this variation can be attributed to conditions favorable for infection and intensification maintained by certain plant communities. Stands that have a dominant Douglas-fir component from early seral through late succession will often host very high levels of *A. douglasii* (Wicker and Leaphart 1976). Examples of these communities are Douglas-fir/ninebark, Douglas-fir/snowberry, and Douglas-fir/oceanspray (Johnson and Clausnitzer 1992). Ridgetop stands, often in Douglas-fir/elk sedge or Douglas-fir/pinegrass communities, frequently have large scattered infected Douglas-fir (Fig. 3).

Figure 3. Ridgetop Douglas-fir/pinegrass plant community. Douglas-fir dwarf mistletoe is often common in large trees on such sites.

Stands in later successional stages will often have relatively high levels of dwarf mistletoe. Douglas-fir tends to increase as a stand component in later succession. Under natural historic conditions, prior to aggressive fire suppression, dry mixed conifer stands experienced fire at fairly frequent intervals, with varying burn intensities in different portions of the stands. Frequent fires maintained pine dominance and wide spacing. Douglas-fir regeneration was minor in pine-dominated stands and subordinate to pine in most Douglas-fir series plant communities. Douglas-fir that became established and developed low dwarf mistletoe brooms were more likely to be killed in fires due to the flammability of the broomed crown.

Due to the suppression of wildfires in the Blue Mountains, shade tolerant species, including Douglas-fir, have increased dramatically at the expense of the more fire tolerant pines and larches. In cases where Douglas-fir understories have increased under dwarf mistletoe infected overstories, stand infections levels have increased dramatically.

IMPACTS

Vigor and Tree Growth

Dwarf mistletoe has long been known to reduce tree vigor. In an early study, Weir (1918) found that heavily-infected trees have smaller and fewer terminal buds than uninfected trees. Trees with large brooms are especially affected as these branches serve as nutrient sinks, with disproportionally high amounts of available nutrients allocated to them (Tinnin and Knutson 1980). The impacts are often particularly severe on Douglas-fir that are in or adjacent to openings or in sparsely-stocked or partially cut stands. These trees are often heavily broomed because *A. douglasii* propagation and spread is favored by high light intensities (Fig. 4).

Pierce (1960) found that basal area growth was impacted proportionate to the degree of *A. douglasii* stand infection. Reductions of 13.7, 41.0, and 68.5 percent from healthy stands were determined for stands having light, medium, and heavy infestations, respectively. Later work on growth and yield impacts, and mortality estimates were based on the 6-class Dwarf Mistletoe Rating (DMR) system of estimating tree and average stand infestation levels (Hawksworth 1977). Estimated diameter growth impacts from several data sets, most of which are from the Blue Mountains (Knutson and Tinnin 1986; Tinnin 1988), for DMR levels are as follows (Table 1):

Figure 4. Brooming is dramatic on trees adjacent to openings and exposed to sunlight.

Table 1. Douglas-fir diameter growth reduction based on severity of dwarf mistletoe infection.

DMR	**Diameter Growth** (% of healthy)
0	100
1	98
2	97
3	85
4	80
5	52
6	44

Source: Hawksworth and Weins (1996)

Filip *et al*. (1993) studied stands affected by both *A. douglasii* and western spruce budworm (*Choristoneura occidentalis* Freeman) and could find no significant interaction in growth loss although each contributed individually to this effect.

Impacts on height growth are similar to those on diameter growth in infected trees (Hawksworth and Wiens 1996) (Fig. 5). Quantifying impacts on height growth are more difficult than those on diameter growth and have received only limited investigation (Knutson and Tinnin 1986). Dwarf mistletoe will usually intensify on individual trees over time. Age at initial infection, stand structure, source of infection, and possibly tree growth will all influence the rate of infection intensification. Trees that are initially infected when pole-size or larger and growing under good conditions with a light overstory, will likely attain large size before infection becomes severe and growth is severely diminished. Trees that are infected when young having a long term source of infection from overtopping trees with reduced stocking that allows plenty of brooming will probably cease growth before large size is attained. Geils and Mathiasen (1990) found that small diameter severely-infected trees increased 2 DMR classes per decade while lightly-infected larger trees increased only 0.5 DMR classes. Other significant related factors included abundance of nearby infected overstory and stand density. No correlation was found with site quality.

Figure 5. Both height and radial growth have essentially stopped on these severely-infected Douglas-fir.

Mortality

Douglas-fir dwarf mistletoe readily kills its host as infection levels become severe. During drought conditions, infected trees are under increased stress and mortality levels can increase. Often, trees are sufficiently weakened that other agents will contribute to their demise. Stevens and Hawksworth (1984) found that the flatheaded fir borer (*Melanophila drummondi* [Kirby]) was commonly associated with mortality of dwarf mistletoe-infected trees. The Douglas-fir beetle has been reported attacking trees weakened by dwarf mistletoe (Weir 1916), although Furniss *et al.* (1981) did not find this relationship in the Rocky Mountains. The author has observed a strong correlation between severe dwarf mistletoe infection levels and Douglas-fir beetle attacks during the recent (late 1980's-mid 1990's) insect

Figure 6. The severely-infected tree in the foreground was attacked by Douglas-fir beetles the previous year and the crown is now fading.

epidemic in portions of the Blue Mountains (Fig. 6). Mortality rates have been estimated for the range of DMR levels from various pooled data from throughout the western United States (Table 2):

Table 2. Ten-year mortality of Douglas-fir associated with severity of dwarf mistletoe infection.

Stand Ave. **DMR**	**10-Year Mortality** (% dying in excess of similar healthy stands)
0	0
1	1
2	2
3	4
4	9
5	15
6	23

Source: Hawksworth and Weins (1996)

Wood Quality

There have been no studies that specifically investigated the effect of *A. douglasii* infection on wood quality, although such studies have been done for several other tree species. Generally, infections reduce structural strength of wood by shortening tracheids and increasing ray volume (Piirto *et al.* 1974); however there is not likely a significant impact on wood products as mostly branches are affected. Large knot size and related grade reduction is associated with logs from trees with large brooms. Weir (1916) mentions localized heavy pitch infiltration in mistletoe-infected western larch (*Larix occidentalis* Nutt.), Gill (1954) reports the same for southwestern ponderosa pine. Pitch pockets have been found by the author in heavily broomed Douglas-fir and are probably common in such trees. Infected branches within the shaded portions of crowns seen to live longer than uninfected branches because the mistletoe pulls nutrients and water into the branches. This results in larger knots and less clear wood.

Risks of Conflagration

Douglas-fir dwarf mistletoe tends to increase in the absence of periodic fire (Wicker and Leaphart 1976). Not only do shade tolerant host firs increase in prominence, but broomed trees which would likely be killed during ground fires proliferate. Decades of buildup of dwarf mistletoe-infected fir and related brooming characterize many Blue Mountains mixed conifer stands. Some stands have had cultural work, mainly thinning where firs are discriminated against, and fewer have been burned using prescribed fire. Stands that have not been treated and have an abundance of broomed trees are at grave risk of conflagration. Without periodic natural or managed fire or cultural work, brooms proliferate and remain alive, most commonly in the lower part of the crown. These brooms are especially flammable due to the dead material that accumulates within, the abundance of fine branches, and relatively high concentrations of resins. Brooms that break from trees add to the fuels around the base. Adding this to the down woody material that accumulates in the absence of fire, there is the probability of stand replacement fire occurring where frequent light ground fires were the normal historical events.

When fire does occur in high risk stands, temperatures are excessive with high flame heights due to the abundance of ground fuels. Flames easily reach the lower broomed branches of dwarf mistletoe-infected fir which burst into flames igniting the remainder of the crown. Individual crown ignition may quickly develop into a total stand crown fire if conditions allow. Other components, such as large ponderosa pine and western larch will likely be killed when the fire crowns throughout the stand. The aftermath of such an event may be complete conifer mortality and the problems associated with regenerating dry exposed sites.

USE BY WILDLIFE

Douglas-fir dwarf mistletoe brooms are often used by birds and small mammals for hiding and nesting cover (Smith 1982; Martinka 1972; Stauffer and Peterson 1986). Bull and Henjum (1990) reported that 20 percent of the great gray owls in their studies used Douglas-fir dwarf mistletoe brooms as nesting platforms. On the Wallowa-Whitman National Forest, Moore and Henny (1983) found that 64.5 percent of Cooper's hawk nests located were in Douglas-fir dwarf mistletoe brooms. Somewhat lesser usage of Douglas-fir brooms was found for sharp-shinned hawks and goshawks, 20.0 and 14.7 percent, respectively. As broom use by birds is well documented in the Blue Mountains, it is likely that various species of birds benefit from fir stands with abundant broomed trees. Douglas-fir brooms are also used by grouse for roosting cover (Martinka 1972; Stauffer and Peterson 1986; Weir 1916). In a Colorado study, Bennetts and Hawksworth (1992) found that severely mistletoe-infected stands of ponderosa pine supported increased bird species diversity and density. Similar effects might be expected with mistletoe-infected Douglas-fir stands . Douglas-fir brooms are reportedly used by porcupines for winter protection from snow and wind (Smith 1982).

In Arizona, Severson (1986) reports that Douglas-fir dwarf mistletoe seeds make up 2 to 8 percent of the fall diet of the blue grouse. Crawford *et al*. (1986) documented that in a fall diet survey of hunter-killed blue grouse in Wallowa County, 5 percent of examined birds had consumed portions of entire *Arceuthobium* spp. plants (probably *A. douglasii*). Mistletoe plants represented 4 percent of the total dried weight of the sample. Various mammals have been found to use *Arceuthobium* species for occasional food (Shaw and Hennon 1991; Broadbooks 1958, Baranyay 1968), but it is suspected that compared to other local dwarf mistletoes all of which have substantially larger size aerial shoots and occur in clumps, use of *A. douglasii* for food by most mammals is incidental.

METHODS OF CONTROL

Considerable effort has been expended developing and implementing effective disease control. While **biological controls** have not shown promise and **chemical controls** have limited potential, **cultural control** has been quite effective. Genetic resistance to *Arceuthobium* infection has been shown for some conifer species. However, as yet there is no reported evidence of Douglas-fir resistant to *A. douglasii* .

Chemical Control

Researchers, primarily in the late 1940's and 1950's, screened a wide range of herbicides, especially various isomers of 2,4-D and 2,4,5-T, in an attempt to identify any selective for *Arceuthobium*. None have been identified that would kill the dwarf mistletoe plant without killing or seriously injuring the host. Quick (1964) did claim that an isooctyl ester of 2,4,5-T showed more promise than other tested herbicides, although this chemical is now banned. More recent investigations show that the ethylene-releasing growth regulator ethephon (2-chloroethyl phosphoric acid) readily causes dwarf mistletoe aerial shoot abscission although the endophytic system remains unaffected and new aerial shoots will reappear in a year or two. This ethephon formulation is registered by EPA and marketed as Florel for use on conifers. Ethophon may slow dwarf mistletoe spread and help protect an understory when there is an overstory source of infection, but it will not kill the mistletoe plants in already-infected trees. Most of the studies regarding this type of control have been with pines and larch, and in a few cases ethophon has been used to help protect understory becoming established on certain high value sites. Mistletoe shoot abscission by ethophon is unlikely to provide significant benefits to stands of infected Douglas-fir.

Cultural Control

Most historical dwarf mistletoe control has involved removing infected trees from stands, modifying stand structure to minimize spread, and managing other tree species which are not susceptible to damage. In many cases such treatments have been quite effective. Some of these techniques will be further described in this paper. Future management emphasis will likely be based on designing effective treatments while protecting other resources and resource concerns. For a variety of reasons, Douglas-fir dwarf mistletoe can be quite effectively controlled using applied silviculture. These are:

Dwarf mistletoes infections die when the infected host is killed.

Species of *Arceuthobium* are obligate parasites that require a living host to remain alive and complete their lifecycle. Dwarf mistletoe plants on trees will die within a year of the death of the host. While killing, but leaving standing, infected trees is desirable where snags are deficient, girdled trees will often retain a live crown for years following this treatment. As long as the crown remains alive on such trees, the dwarf mistletoe will also survive.

Infected portions of trees (brooms) may be successfully pruned.

Intensification of Douglas-fir dwarf mistletoe is relatively slow.

*Douglas-fir dwarf mistletoe infection is restricted to Douglas-fir. Other tree species may be safely managed near and under retained infected fir. This technique is called **species manipulation**.*

Stands recently disturbed by wildfires usually have low tree densities, and seral lodgepole and ponderosa pines and western larch can be introduced or selected and managed under infected overstory Douglas-firs. Without disturbance, heavy stocking of shade-tolerant understory trees (often susceptible Douglas-fir) makes successful management of early seral species impossible.

Managed fire may be used to help reduce Douglas-fir dwarf mistletoe infestations.

Dwarf mistletoes almost always spread by forcibly expelled seeds and very infrequently by birds carrying already expelled seeds. Range of ejected seeds is rather short, less than 50 feet.

Expelled seeds are important for most spread within stands. Bird spread of seeds is the main mechanism for spread into uninfected areas. Along with complete sanitation, geographic features and created buffer strips can be used to isolate treated and/or uninfected potions of stands from nearby infected areas since seed spread is less than 50 feet.

Dwarf mistletoe can be effectively removed from infested areas by removing or killing infected individuals.

Evenage stand structure will minimize spread and intensification.

Dwarf mistletoes spread most effectively from overstory sources of infection to understory trees. Due to the trajectory of expelled seeds, spread between trees in evenage conditions is slow and irregular. However, unevenage structure will greatly facilitate spread.

The life cycle of dwarf mistletoe takes a minimum of five years to complete and contributes to its relatively slow propagation and spread.

Dwarf mistletoe infected overstory Douglas-fir can be treated since they are readily identifiable.

While many conifer diseases require root excavations and close examinations of the host and/or the pathogen, Douglas-fir dwarf mistletoe produces unique and readily-identifiable brooms on trees that are spaced and exposed to light. Field crews can easily identify infected stands and most infected trees with little training. Problems are encountered in identifying all infected trees in fully-stocked stands, especially understory trees. Infected but unbroomed branches and recent undeveloped (latent) infections, cannot be identified in the field.

Dwarf mistletoe spread and intensification can be limited by maintaining high stand density.

Brooming, production of aerial shoots and seeds, and resultant spread are minimized in dense stands. Thinning of infected stands, leaving infected Douglas-fir residuals, will result in rapid intensification and proliferation of infection.

Small trees (less than 3 feet tall) are likely to remain uninfected even if near an infected overstory.

Small crowns on short trees make small targets to intercept dwarf mistletoe seeds. Such trees may be successfully managed if the overstory infection source is removed before the understory exceeds 3 feet in height. Maintaining understory trees as they become larger when they occur under an infected overstory will result in rapid increases in infection rates.

Managed fire

Space infected understory firs are readily killed by ground fire. Thin bark on small Douglas-fir, accumulated litter and flammable brooms tend to predispose these trees to mortality during fire events. However, if fuels are excessive, fires may become intense enough to kill other overstory trees, including fire resistant species. Frequent ground fires historically burned under conditions of light fine fuels, while removing most of the understory regeneration without damaging the overstory. Koonce and Roth (1980) investigated the effects of prescribed fire on mistletoe-infected ponderosa pine in central Oregon and found that dwarf mistletoe can be partially sanitized. The effects in stands of Douglas-fir *could* be similar, although the conditions of a densely-stocked understory of fir would most likely permit a crown fire to develop. Additionally, firs are more susceptible to mortality following crown scorch. It is likely that under relatively open spaced stand conditions, a controlled ground fire would yield desirable reduction in average dwarf mistletoe levels since individual broomed trees would be more apt to be killed by crown fire. Also, stress induced by fire may compound already stressed diseased trees, rendering them susceptible to secondary agents. Harrington and Hawksworth (1990) found that given the same amount of crown scorch, survival of mistletoe-infected ponderosa pine in Grand Canyon National Park were less than one-half that of healthy trees when scorch was in the 40 to 90 percent range. Managed fire in Douglas-fir communities would undoubtedly be best applied with the intent of removing most advanced fir regeneration, with or without retaining the overstory (including some desirable large broomed fir).

Wicker and Leaphart (1976) concluded that most relationships between fire and dwarf mistletoes are indirect, in that most effects of fire are on the ecology of the host and the successional status of the stand. Rather than fire having a direct impact on dwarf mistletoe plants or infections, the effect is one of limiting stocking, reducing the shade-tolerant host component, and minimizing mixed canopy layers, all of which discriminate against dwarf mistletoe intensification. The direct effect is that infected trees are killed, or that fire behavior becomes more extreme.

Pruning

Removal of brooms can reduce stress and improve longevity of trees as long as a viable crown can be left (Lightle and Hawksworth 1973). Candidate trees for pruning should have infections restricted to the lower one-half of the crown, rate as a DMR 3 or less, and not have main stem infections (Hawksworth and Weins 1996). Pruning can be used to eliminate infestations on trees where brooms are well out from the bole or simply to reduce the nutrient sink of the broom.

Pruning of brooms has been done to reduce the hazard potential of infected trees in recreation sites. Pruning is also a viable option where particularly valuable trees need to be retained. Pruning is not an economically viable option for general forests.

Sanitation

With most dwarf mistletoe-infected conifers, the removal of infected individuals and a 6 to 10 year follow-up will effectively control the disease. This includes the removal of infected understory and overstory, or simply the infected component in a mixed conifer stand. Such a procedure seldom is successful with Douglas-fir. Infected trees that are in the main canopy layer of fully stocked stands will often be difficult or impossible to detect. *A. douglasii* plants are so small they can not be seen from more than a few feet away, in many instances very few plants are produced, and infected trees do not form brooms in fully shaded conditions. Sanitation of infected Douglas-fir stands require removal of infected overstory individuals (where a susceptible understory will be established) and the removal of all Douglas-fir understory trees within 35 to 50 feet (horizontal distance) from the base of large infected overstory trees (retained or cut) and 25' from identifiable infected trees of the same or smaller size class. Retention of infected advanced regeneration 10 to 15 years following a partial removal will result in severe brooming and associated impacts on those trees (Figure 7).

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 are missed by stand exam crews, especially if they are inexperienced or have not received training. Stands that have recently had an overstory removal may not show much evidence of infection in the understory if the stand had been fully stocked. Given five or more years after harvest, brooming should become noticeable. Often, lopped broomed branches from the infected and harvested overstory will remain on site and substantiate infestation. In almost all infected stands there will be individuals in or adjacent to openings or in the overstory with distinctive brooms. Mistletoe typically has spread to many adjacent firs even though the infections may be difficult to see. Living branches well below the average living lower crown are good indicators or infection, even though such branches may not be broomed. The mistletoe plants themselves are most common and most easily seen on prolific brooms exposed to sunlight. Even then, plants of *A. douglasii* are usually not much longer than the needles and can only be seen upon close inspection.

Figure 7. The aftermath of an overstory removal about 10 years ago. Understory Douglas-fir were heavily infected with dwarf mistletoe, although brooming was not likely readily apparent.

Rating Infection Severity

Severity of dwarf mistletoe infection has been characterized by a standardized 6-class rating system known as the Dwarf Mistletoe Rating (DMR) which is easily learned and can be applied to individual trees and averaged for stands (Hawksworth 1977). 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.

While this rating system is used for Douglas-fir, it sometimes does not adequately measure the severity of infection on some trees. An example would be a tree with a large broom in the lower crown that offers no sign of infections in the upper two-thirds of the crown. While such a tree would rate a "2", it would likely be considered severely infected (Fig. 8). A rating system based on percent crown broomed has been proposed for Douglas-fir which may more accurately quantify the severity of infection, however DMR continues to be the standard, perhaps to remain consistent across all hosts.

Figure 8. This tree has a large broom in the lower crown and the upper portion of the crown is free of infection. This tree would rate a DMR of "2" although it would be considered severely infected.

Detection Surveys

An important step in formulating management decisions regarding Douglas-fir stands requires information on occurrence and severity of dwarf mistletoe. Such information is essential for determining the appropriate silvicultural treatment and priority. Mistletoe 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, but 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, planning 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. The presence of dwarf mistletoe can be beneficial for some objectives and detrimental to others. As mentioned previously, broomed trees provide habitat for some birds and small mammals, and plants are a minor 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. In some situations, even very minor amounts of infection could be detrimental. 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.

A preliminary step in any treatment for dwarf mistletoe is to determine location and severity of infection. Where portions of the stand are determined to be manageable, delineation will need to be carefully done by field crews or layout personnel.

Recreation Sites

Recreation sites with dwarf mistletoe-infected Douglas-fir will have at least two major issues associated with this infestation: reducing the hazard of infected trees and brooms, and maintaining tree vigor. Additionally, minimizing spread to uninfected areas may be a concern.

Pruning has already been discussed and probably has its most applicability in developed recreation sites. Trees with large brooms, especially those which are near sites with structures or places where people or their property are likely to be, are good candidates for treatment. These heavy branches may eventually fail, posing a potential for damage and/or injury. Pruning will reduce hazards associated with a broom while retaining the tree. Often, large distinctive trees in recreation sites are particularly valuable and steps taken to assure their longevity are warranted. The vigor and likelihood of survival of dwarf mistletoe-infected trees can be improved by careful pruning of brooms. Such action may also remove a source of infection threatening advanced regeneration and reduce disease spread.

Perhaps the best long-term strategy for dwarf mistletoe-infected recreation sites is to assure that diversity of vegetation is maintained or achieved to limit the host component.

Severely-infected stands

Stands that are heavily infected probably do not have a viable Douglas-fir component that is worth saving other than that needed for wildlife.

Mixed Conifer Stands

Mixed conifer stands will contain a component of species unaffected by *A. douglasii*, although the viability of those trees may be limited by other insects and diseases. Generally, the earlier seral component will offer the most resilience in terms of insect and disease risk. Silvicultural options which favor the establishment of early serals via group selection, shelterwood, patch- or clearcuts, retaining residual serals for seed, while removing the bulk of the infected and susceptible fir component, are likely to offer the best results in disease control (Fig. 9). Other resource considerations may limit the scale of treatment and may modify the actual prescription.

Douglas-fir Dominated Stands

Stands with a heavy component of Douglas-fir that are severely infected are a challenge to treat and make attainment of resource objectives unlikely. A common situation occurs in stands that were once stocked with a mix of Douglas-fir and ponderosa pine. Partial cutting and mortality of the pine component has essentially eliminated this species in the overstory and heavy stocking of firs in the understory has not allowed pine to regenerate. Dwarf mistletoe will quickly intensify under these conditions (Fig.10). Removal of almost all fir and reestablishment of pine is probably the only viable control option in these situations. Use of regeneration silviculture techniques are required to establish shade intolerant pine. The size and scale of the treatment is about all that can be manipulated.

Figure 9. This mixed conifer stand has a healthy ponderosa pine overstory and a dwarf mistletoe-infected understory. By retaining the pine component and removing the infected and excess fir, these pine will survive for many more years.

Young Stands

Young stands of Douglas-fir can be successfully managed as long as most of the infected component is removed when stands are opened or spaced. Trees that are within about 30' of obviously infected overstory sources of infection should be considered infected regardless of evidence of brooming. The results of such sanitation treatment will be scattered openings where Douglas-fir have been removed and alternative species already occur or can be planted along with fir.

Figure 10. This stand is no longer viable. The ponderosa pine component was removed in the last entry and the Douglas-fir are severely infected with dwarf mistletoe.

Mature Stands

In mixed conifer stands, infected Douglas-fir can be discriminated against (removed) in intermediate or reserve tree harvests. Where Douglas-fir is dominant, some infected individuals will probably need to be retained among reserved trees. Regeneration prescriptions including shelterwood and seed tree cuts can be successful if retained seed trees have relatively low levels on infection and those trees are killed or removed where and when they threaten a newly-established Douglas-fir understory. Young Douglas-fir is not readily infected until it is about 20 years old or reaches 3 feet tall. Excessive dwarf mistletoe and absence of alternative species may require clearcut harvesting to remove infected overstory and advanced regeneration.

Retaining Infected Trees

To meet wildlife objectives there may be a need to retain some infected trees within treatment blocks. This should be designed in a manner which minimizes potential for spread to healthy trees and uninfected portions of the stand. The recommended procedure for meeting this objective is to isolate selected infected reserve trees in small discrete groups or clumps. Use of non-host or unstocked buffers of at least 50' between infected trees and treatment areas or uninfected residuals can be used. For example, desirable blue grouse habitat of broomed infected ridgetop trees can be retained in groups and buffered from nearby healthy trees by buffers of ponderosa pine on dry aspects and western larch and grand fir on moist aspects. Clumps can also be safely retained in draw bottoms by similarly isolating clumps of infected trees. This will reduce the risk of stand replacement fire and the eventual large scale mortality effects of infection.

ACKNOWLEDGEMENTS

Jim Hadfield, Don Goheen, and Katy Marshall reviewed earlier drafts of this document and provided suggestions which improved the final paper.

Literature Cited

Baranyay, J.A. 1968. *Squirrel feeding on dwarf mistletoe infections*. Bi-Monthly Progress Report. [Ottawa: Canada Department of Forestry 24(5): 41-42.

Bennetts, R.E., and F.G. Hawksworth. 1992. *The indirect effects of dwarf mistletoe on bird communities in Colorado ponderosa pine forests.* In: Muir, J.A., comp. Proceedings, 39th Annual Western International Forest Disease Work Conference; 1991 August 5-9; Vernon, B.C. Victoria: British Columbia Ministry of Forests, Silviculture Branch: 14-17.

Bolsinger C.L. 1978. *The extent of dwarf mistletoe in six principal softwoods in California, Oregon, and Washington, as determined from forest survey records.* In: Scharpf, R.F., and J.R. Parmeter, Jr. comp. Proceedings of the symposium on dwarf mistletoe control through forest management, April 11-13, Berkeley CA. General Technical Report PSW-31, Berkeley, CA: USDA Forest Service, Pacific Southwest Forest and Range Experiment Station, p. 45-64.

Broadbooks, H.E. 1958. *Life history and ecology of the chipmunk, Eutamias amdenus, in eastern Washington.* Miscellaneous Publication 103. Ann Arbor, MI: University of Michigan Museum of Zoology. 42p.

Bull, E.L.; R.S. Holthausen; and M.G. Henjum. 1992. *Roost trees used by pileated woodpeckers in northeastern Oregon.* Journal of Wildlife Management. 56(4):786-793.

Bull, E.L.; J.W. Thomas; and K. Horn. 1986. *Snag management on National Forest in the Pacific Northwest-1984.* Western Journal of Applied Forestry 1:41-43.

Bull, E.L., and M.G. Henjum. 1990. *Ecology of the great gray owl.* General Technical Report PNW-GTR-265. Portland, OR: USDA Forest Service, Pacific Northwest Research Station: 39p.

Crawford, J.A; W. Van Dyke; S.M. Meyers, and J. F. Haensly. 1986. *Fall diet of blue grouse in Oregon.* Great Basin Naturalist 46:123-127.

Filip, G.M., J.J. Colbert; C.G. Shaw III; P.F. Hessburg; and K.P. Hosman. 1993. *Influence of dwarf mistletoe and western spruce budworm on growth and mortality of Douglas-fir in unmanaged stands*. Forest Science. 39(3): 465-477.

Furniss, M.M.; R.L. Livingston; and M.D. McGregor 1981. *Development of a stand susceptibility classification for Douglas-fir beetle.* In: Hedden, R.L.; S.J. Barras; and J.E. Coster, tech. eds. Hazard-rating systems in forest insect pest management. General Technical Report WO-27. Washington, DC: USDA Forest Service: p. 115-128.

Geils, B.W.; and R.L. Mathiasen. 1990. *Intensification of dwarf mistletoe on southwestern Douglas-fir.* For. Sci. 36(4):955-969.

Gill, L.S. 1954. *Dwarf mistletoe of ponderosa pine in the southwest.* USDA Forest Service Rocky Mountain Forest and Range Experiment Station. Station Paper 14. 9p.

Harrington, M.G.; and F.G. Hawksworth. 1990. *Interactions of fire and dwarf mistletoe on mortality of southwestern ponderosa pine.* Effects of Fire Management of Southwestern Natural Resources: proceedings of the symposium, November 15-17, 1988, Tucson AZ. p. 234-240, Gen. Tech. Rep. RM-191. USDA Forest Service, Rocky Mnt. For. and Range Exp. Stn., Ft. Collins, CO.

Hawksworth, F.G. 1965. *Life tables for two species of dwarfmistletoe.* 1. Seed dispersal, interception, and movement. Forest Science. 11:142-151.

Hawksworth, F.G. 1977. *The 6-class dwarf mistletoe rating system.* Gen. Tech. Rep. RM-48. USDA Forest Service, Rocky Mnt. For. and Range Exp. Stn. Ft. Collins, CO. 7p.

Hawksworth, F.G.; and D. Weins. 1996. *Dwarf mistletoes: biology, pathology, and systematics.* Agriculture Handbook 709. USDA Forest Service. Washington, DC. 410p.

Heji, S.J.; R.E. Woods. 1991. *Bird assemblages in old-growth and rotation-aged Douglas-fir/ponderosa pine stands in the northern Rocky Mountains: a preliminary assessment.* In: Baumgartner, D.M.; J.E. Lotan, comp. and eds.; symposium proceedings: Interior Douglas-fir, the species and its management. February 27-March 1, 1990. Cooperative Extension, Washington State University, Pullman, WA. p. 93-100.

Hudler, G.W.; N. Oshima, and F.G. Hawksworth. 1979. *Bird dissemination of dwarf mistletoe on ponderosa pine in Colorado.* American Midland Naturalist 102:273-280.

Hull, R.; O. Leonard. 1964. *Physiological aspects of parasitism in mistletoes (Arceuthobium and Phoradendron) 1. The carbohydrate nutrition of mistletoe.* Plant Physiol. 39:996-1007.

Johnson, Jr. C.G., and R.R. Clausnitzer. 1992. *Plant Associations of the Blue and Ochoco Mountains.* R6-ERW-TP-036-92. USDA Forest Service, Pacific Northwest Region, Wallowa-Whitman National Forest, Baker City, OR 164p. w/appendices.

Knutson, D.; R. Tinnin. 1986. *Effects of dwarf mistletoe on the response of young Douglas-fir to thinning.* Canadian Journal of Forest Resources:16:30-35.

Koonce, A.L., and L.F. Roth. 1980 *The effects of prescribed burning on dwarf mistletoe in ponderosa pine.* Proc.: Sixth Conf. on Fire and and For. Meteor., Seattle, WA. April 22-24, 1980.

Kuijt, J. 1963. *Distribution of dwarf mistletoes and their fungus hyperparasites in western Canada.* National Museum of Canada Bulletin. 186:134-148

Lemons, D.E. 1978. *Small mammal dissemination of dwarf mistletoe seeds.* M. S. Thesis, Portland State University, Portland, OR. 38p.

Lightle, P.C.; and F.G. Hawksworth 1973. *Control of dwarf mistletoe in a heavily used ponderosa pine recreation forest: Grand Canyon, Arizona.* Research Paper RM-106. Fort Collins, CO: USDA Forest Service, Rocky Mountain Forest and Range Experiment Station. 22p.

Maffei, H.M., J.V. Arena. 1993. *Forest insect and disease risk and occurrence maps in GIS: application to integrated resource analysis.* In: Proceedings: Spatial Analysis and Forest Pest Management. A.M. Liebhold and H.R. Barrett, eds. USDA Forest Service, Northeast Forest Experiment Station. General Technical Report NE-175. p.8-14.

Marsden, M.A.; G.M. Filip; and P.F. Hessburg. 1991. *Using the forest timber inventory for sampling the occurrence of pests on interior Douglas-fir.* In: Baumgartner, D.M.; J.E. Lotan, comp. and eds.; symposium proceedings: Interior Douglas-fir, the species and its management. February 27-March 1, 1990. Cooperative Extension, Washington State University, Pullman, WA. p. 109-113.

Martinka, R.R. 1972. *Structural characteristics of blue grouse territories in southwest Montana.* Journal of Wildlife Management. 36:498-510.

Moore, K.R.; C.J. Henny. 1983. *Nest site characteristics of three coexisting accipiter hawks in northeastern Oregon.* Journal of Raptor Research. 17:65-76

Pierce, W.R., 1960. *Dwarf mistletoe and its effect upon the larch and Douglas-fir of western Montana*. Bulletin 10. Bozeman, MT: Montana State University, School of Forestry. 38p.

Piirto, D.D., D.L. Crews, and H.E. Troxell. 1974. *The effects of dwarf mistletoe on the wood properties of lodgepole pine*. Wood Fiber 6:26-35

Quick, C.R. 1964. *Experimental herbicidal control of dwarfmistletoe on some California conifers.* Research Note PSW-47, Berkeley, CA: USDA Forest Service, Pacific Southwest Forest and Range Experiment Station. 9p.

Severson, K.E., 1986. *Spring and early summer habitats and foods of male blue grouse in Arizona.* Journal of the Arizona-Nevada Academy of Science. 21:13-18.

Shaw, C.G.,III.; P.E. Hennon. 1991. *Spread, intensification, and upward advance of dwarf mistletoe in thinned, young stands of western hemlock in southeast Alaska.* Plant Disease. 75:363-367.

Skovlin, J.; M. Vavra. 1979. *Winter diets of elk and deer in the Blue Mountains, Oregon.* Research Paper PNW-260, Portland, OR: USDA Forest Service, Pacific Northwest Forest and Range Experiment Statio

n.
21p.

Smith, G.W. 1982. *Habitat use by porcupines in a ponderosa pine/Douglas-fir forest in northeastern Oregon.* Northwest Science. 56:236-240.

Stauffer, D.F.; S.R. Peterson. 1986. *Seasonal microhabitat relationships of blue grouse in southeastern Idaho.* Great Basin Naturalist. 46:117-122.

Stevens, R.E.; F.G. Hawksworth. 1984. *Insect-dwarf mistletoe associations: An update.* In: Hawksworth, F.G.; R.F. Scharpf, tech. coords. Biology of dwarf mistletoes: Proceedings of the symposium; 1984 August 8; Fort Collins, CO. General Technical Report RM-111. Fort Collins, CO: USDA Forest Service, Rocky Mountain Forest and Range Experiment Station: 94-101.

Thomas, J. 1979. *Appendices*. In: Wildlife habitats of Oregon and Washington. USDA Handbook No. 553. US Gov. Print. Off., Washington DC 1979.

Tinnin, R.O. 1988. *Responses of dwarf mistletoe and host following thinning in immature stands of Douglas-fir on the Malheur National Forest., Oregon: final report.* Rocky Mountain Forest and Range Experiment Station, Fort Collins, CO.

Tinnin, R.O.; D.M. Knutson. 1980. *Growth characteristics of the brooms on Douglas-fir caused by Arceuthobium douglasii*. Forest Science 26:149-158.

Van Hooser, D.D.; K.L. Waddell; J.R. Mills; and R.P. Tymcio. 1991. *The interior Douglas-fir resource: current status and projections to the year 2040.* In: Baumgartner, D.M.; J.E. Lotan, comp. and eds.; symposium proceedings: Interior Douglas-fir, the species and its management. February 27-March 1, 1990. Cooperative Extension, Washington State University, Pullman, WA. p. 9-14.

Weir, J.R. 1916. *Mistletoe injury to conifers in the Northwest.* US Dept. Agri. Bull. 360. 39p.

Weir, J.R. 1918. *Experimental investigations on the genus Razoumofskya.* Botanical Gazette. 56:1-31

Wicker, E.F.; C.D. Leaphart. 1976. *Fire and dwarf mistletoe (Arceuthobium spp.)*

relationships in the northern Rocky Mountains. In: Proceedings, Tall Timbers Fire Ecology Conference; Fire and Land Management Symposium; 1974 October 8-10; Missoula, MT. Tallahassee, FL: Tall Timbers Research Station: 279-298.

Wykoff, W.R., N.L. Crookston, and A.R. Stage. 1982. *User's guide to the Stand Prognosis Model.* Gen. Tech. Rept. INT-133. USDA Forest Service, Intermountain For. and Range Exp. Stn. Ogden, UT 112p.

Zilka, P.J., and R.O.Tinnin. 1976. *Potential avian influence in the distribution of dwarf mistletoe*. Northwest Science (50) 1: 8-16.

Glossary

AERIAL SHOOTS-- Aerial shoots are the portion of the dwarf mistletoe plant on the exterior of the host. These are the first signs of infection, produced 2-3 years after infection and usually produced until the host branch dies.

BARK STRANDS-- The portion of the dwarf mistletoe plant that grows throughout the inner bark of the host, giving rise to shoots and sinkers.

BIOLOGICAL CONTROL-- Various birds, mammals, insects, spiders, mites and fungi feed on or parasitize dwarf mistletoe shoots, flowers, and fruits. These tend to help maintain a natural endemic level of the dwarf mistletoe within the realm of other ecosystem components. Attempt to propagate or favor one or more of these agents to become artificially active and thus, suppress or eliminate dwarf mistletoe infestation have not been successful.

CAPSULES-- The fruits or capsules produced by the female dwarf mistletoe plants are attached to the aerial shoots by the pedicel. The interior of the pericarp contains the seed, complete with embryo and endosperm. The pericarp also contains fluid under pressure that ejects the seed at the moment the fruit detaches from the pedicel.

CHEMICAL CONTROL-- Artificial control of dwarf mistletoe plants through application to the plant or the host of a herbicide or related chemical has been meet with limited success. Chemicals that kill the entire plant are also injurious to the host. Ethophon, which does not injure the conifer host, will cause aerial shoot abscission, but the endophytic system remains unaffected.

CULTURAL CONTROL-- Use of established silvicultural techniques are commonly used to control dwarf mistletoe infection levels. These include tree-cutting techniques of sanitation, species manipulation, infected portions of trees removed (pruning), and managed fire.

ENDOPHYTIC SYSTEM-- The portion of the dwarf mistletoe plant that is within the host tissues. This is analogous to a root system, and includes bark strands in the phloem and sinkers that extend downward into the xylem. The year tissues became infected can be determined by the age on the inner most xylem ring with swelling.

EXPLODING DISCHARGED SEEDS-- Seeds are ejected from the fruit or capsule by hydrostatic (fluid) pressure at the moment the capsule detaches from the pedicel. The seed ejects at about 90 ft. per second and for a horizontal distance of up to 50 feet. A viscous coating allows the seed to adhere to whatever it hits.

HYDROSTATIC PRESSURE-- The fluid inside the pericarp of the capsule is under pressure that increases as the fruit matures. This fluid forces out the seed at high velocity the moment the capsule detaches from the pedicel.

NUTRIENT SINKS-- Relatively high transpirtation rates of the dwarf mistletoe (and infected host tissues) increases mineral acquisition at the expense of the host. Organic nutrients used by dwarf mistletoes are derived from the host. Chlorophyll content of dwarf mistletoes is relatively small compared with host foliage and phytosynthates used by the parasite are produced mainly by the host. Cytokinins (growth hormones) are concentrated in dwarf mistletoe plants and result in accumulation of minerals and nutrients derived from the host.

PENETRATION WEDGE-- The dwarf mistletoe structure that initially penetrates host cortex tissue and results in infection.

SYSTEMIC INFECTION-- A less common type of infection among the species of *Arceuthobium* (but characteristic of *A. douglasii*) where the endophytic system grows along with that of the host branch. The result is a continuous endophytic system throughout the host infected branch tissue.

VISCOUS COATING-- Dwarf mistletoe seeds are covered with a coating that is extremely sticky at the time seeds are expelled and causes them to adhere to whatever they happen to contact. This coating will dry with lowered humidity. When wetted, the coating will serve as a lubricant and cause the seed to slide down the foliage needle, allowing it to contact the branchlet at the base of the needle where infection can occur.