

Management of Douglas-fir Dwarf Mistletoe in Forested Campgrounds and Other Developed Sites in Eastern Washington

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Introduction

Douglas-fir is one of the most common tree species in forested campgrounds in eastern Washington. Unfortunately, many campground Douglas-firs are infected by a disease-causing parasitic plant, Douglas-fir dwarf mistletoe. Douglas-fir dwarf mistletoe is native to eastern Washington and is very common. Douglas-fir is the principal and most common host of Douglas-fir dwarf mistletoe; subalpine firs and grand firs are rarely infected when growing in close association with infected Douglas-firs. At least 43 percent of the Douglas-fir stands in this area are infested. Douglas-fir dwarf mistletoe infection significantly reduces tree life expectancy, slows tree growth rates, alters the normal form and appearance of trees, and substantially increases the potential of branches and trees breaking.

The presence of Douglas-fir dwarf mistletoe in campgrounds and other developed recreation sites has different management implications than it does in forests where timber, wildlife, watersheds, and wilderness are management objectives. The disease, if left unchecked, can significantly increase the managing agencies' exposure to liability from damage claims and lawsuits from accidents involving infected trees. Federal agencies managing these sites have the responsibility to discover and correct unreasonably dangerous conditions to minimize the potential for injury to invited users or damage to their property. Responsibility to actively minimize hazards is roughly proportional to the degree of development of a recreation area. Highly developed sites, such as campgrounds, infer a greater degree of responsibility to provide safe conditions than less developed areas.

Campground Douglas-firs, especially those of moderate to large size, have high value. Considerable effort is warranted to retain such trees and keep them vigorous so they will remain in place and be safe for decades. Rapid replacement of large trees is impossible, and even establishment of large seedlings and saplings can be quite difficult to accomplish in frequently used campgrounds. Dwarf mistletoe management practices that may not be cost-effective in stands with timber and wildlife objectives are much more likely to be cost-effective in campgrounds.

Dwarf mistletoes and their effects on hosts have been studied for more than 90 years in western North America. Hundreds of papers have been published, so a great deal is known about these parasites. Control procedures have been developed, tested, implemented, and proven to be effective.

This paper provides advice on managing Douglas-fir dwarf mistletoe in forested campgrounds and other developed sites to reduce risk of accidents and associated liability; and to prolong the lives of Douglas-firs.

Biology

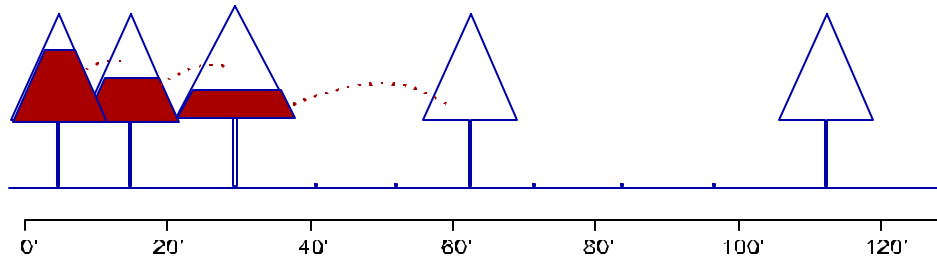
Douglas-fir dwarf mistletoe is a small, inconspicuous, seed-bearing parasitic plant. The slender, olive-green or light brown, leafless, perennial, aerial shoots are found on infected twigs and branches. Their average length is 0.75 inch, about the same as Douglas-fir needles (Figure 1). Aerial shoots are most commonly found on infected branch segments that are 3 to 7 years old, nestled among the fir needles. Although shoots contain chlorophyll they produce little food. The major function of the aerial shoots is reproduction. Shoots arise from a network of root-like strands in host tissues. This network, called the endophytic system, consists of strands growing within the living bark and sinkers embedded in the wood. The endophytic system absorbs nutrients and water from the host tree. The endophytic system lives as long as adjacent host tissues are alive.

Douglas-fir dwarf mistletoe causes a contagious tree disease. A Douglas-fir infected by mistletoe can serve as a source to infect other close-by Douglas-firs. The parasite spreads by sticky seeds produced on female plants. The seeds are forcibly discharged from the female shoots in the fall. Seeds may be shot out as far as 30 to 40 feet, but most land within 10-15 feet of the disseminating shoots. The seeds are slightly less than 0.1 inch long and are relatively heavy compared to fungus spores. Wind has little effect on seed spread. Seeds stick to objects they strike, especially foliage. They germinate in the spring, in a process during which thin bark is penetrated and the parasitic plant becomes established in the host. Approximately 3 years after infection, aerial shoots are produced and 2 years later a crop of seeds will be formed on the female plants. In the time from initial infection to the emergence of aerial shoots the infections cannot be seen and are called "latent". It takes about 5 to 6 years from the time of initial infection before aerial shoots are formed and seeds are disseminated in stands that are open and the trees are exposed to lots of light. Branch infections can remain latent for several years in dense stands where light exposure is limited.

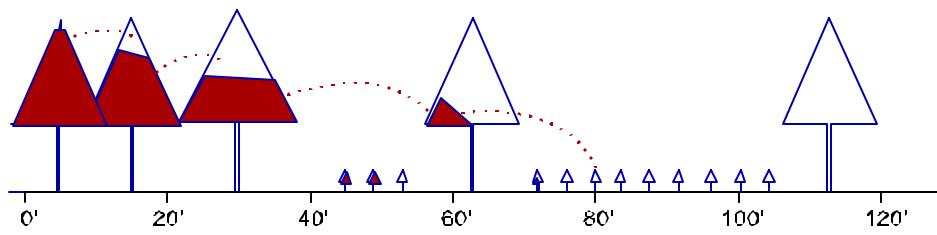
Dwarf mistletoe infection intensifies within a tree from seeds produced by aerial shoots already present, as well as from seeds coming from mistletoe plants in adjacent trees. Infections spread upwards in trees at an average rate of about 4 to 6 inches per year. Dwarf mistletoe infestations spread laterally through stands at an average rate of 1.5 feet per year. Douglas-fir dwarf mistletoe is responsive to sunlight. Infections on branches that are exposed to lots of light produce aerial shoots faster than shaded infections, and more seeds are probably produced by well-lighted plants. Spread is slower in dense stands than open stands.

The most severely infected stands typically have large infected Douglas-firs overtopping smaller Douglas-firs. Seeds from dwarf mistletoe plants in the tall trees drop down onto the small trees and cause infections. Figure 2 illustrates spread of dwarf mistletoe over 20 years in an infected Douglas-fir stand that had several trees removed.

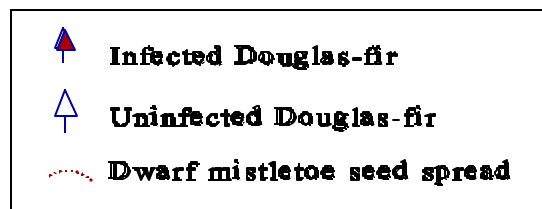
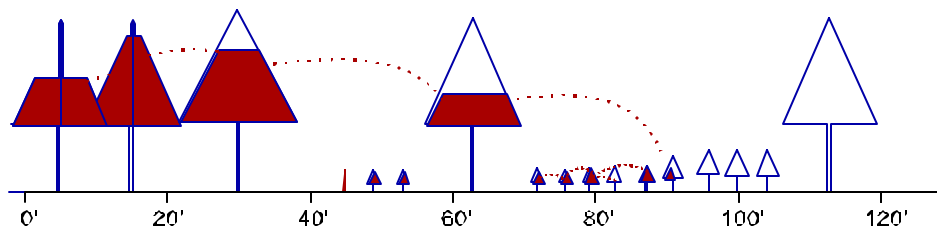
Year 0



Year 10



Year 20



Symptoms of Infection

The first symptom of dwarf mistletoe infection is a slight branch swelling at infection sites 1 to 2 years after host penetration. Initially, these can be difficult to see. As time passes and the endophytic system of the parasite becomes more extensive, the branch form of the host becomes distorted and infections can be readily detected. Douglas-fir dwarf mistletoe typically becomes systemic within the infected branch when the endophytic system invades tree buds at the infection site. Masses of invaded buds are stimulated to grow and develop long tree twigs, which eventually form witches' brooms. The mistletoe endophytic system grows apically at the same rate as the infected twigs and branches. Aerial shoots can be found on branch growth segments ranging from 2 to 7 years old.

The most striking symptom of dwarf mistletoe infection on Douglas-fir is the witches' brooms, which are easily noticeable within 10 years after infection takes place (Figures 3 and 4). Witches' brooms are abnormal proliferations of twigs. Broom shapes vary but start out as fan-shaped and eventually tend to become somewhat spherical. Twigs in witches' brooms may become long and droopy and attain lengths of 10 feet, but are typically only about one-quarter inch in diameter over their entire length. Branches with big witches' brooms develop large diameters at their junction with the main stem to support the weight, which can be several hundred pounds. Most extensive development of witches' brooms is usually in the lower half of tree crowns. Infected branches on trees exposed to lots of sunlight form large brooms that can eventually make up most of the crowns. Witches' brooms on low branches in dense stands develop slowly and tend to be small. These infected branches are kept alive while uninfected branches above are shaded out. Trees may have one to many witches' brooms. Branches with brooms are the last parts of infected trees to die. Severely infested Douglas-fir stands typically have many trees with stunted growth, witches' brooms, dying and dead tops, and dead trees (Figure 5).

The 6-class dwarf mistletoe rating (DMR) system is useful for quantifying intensity of infection in Douglas-fir trees and stands (Figure 6). DMR information can be used to prescribe treatments for trees. For this system, the live crown of a tree is visually divided into thirds and each third rated as: 0 = no visible infection, 1 = light infection (less than half of the branches in the third have witches' brooms), or 2 = heavy infection (more than half of the branches in the third have witches' brooms). The three crown third ratings are added to obtain a tree rating. The effects of infection on trees become greater as the DMR classes increase. It takes about 10 years to increase one DMR class in an individual tree. Mature Douglas-firs with DMRs ranging from 0 to 5 are illustrated in the Appendix.

Effects of infection

Infection of Douglas-firs by dwarf mistletoe alters tree form, reduces vigor and growth rates, increases susceptibility to other damaging agents, and results in branch breakage, topkilling and tree death. These effects result from the parasite taking food and water from the host, thus reducing the amount of energy available for the tree's normal growth, reproductive, and protective processes. The effects of Douglas-fir dwarf mistletoe infection are progressive. Lightly infested trees do not differ much from healthy trees, however they become moderately, then severely infected with the passage of time, resulting in gradual tree and stand deterioration.

The large witches' brooms which are common on many infected campground Douglas-firs are especially debilitating. Dwarf mistletoe plants in the witches' brooms capture large amounts of water and food materials from the tree, including portions that are not infected. The tops of severely infected Douglas-



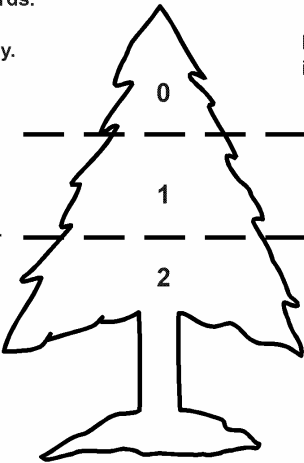


firs decline and ultimately die because the mistletoe tissues usurp so much water, minerals, and food materials from the trees.

The parasite is often a major factor contributing to tree death in campgrounds. Mortality of Douglas-fir in severely infested stands (stand ratings of DMR 4 or higher) is three to four times greater than that in comparable non-infested stands. Even stands with DMRs of 2 or 3 show increased mortality rates over uninfested or lightly infested (DMR 1) stands. Seedlings and saplings, especially those with main stem infections, readily succumb to the parasite. Douglas-firs infected when they are small are unlikely to attain large size. Trees weakened by numerous branch infections or large witches' brooms cannot compete successfully with surrounding trees and die.

The following information shows how DMRs relate to infection severity and tree effects:

Douglas-fir mistletoe rating	Infection severity	Tree effects
0	uninfected	none

INSTRUCTIONS	EXAMPLE
<p>STEP 1. Divide live crown into thirds.</p> <p>STEP 2. Rate each third separately. Each third should be given a rating of 0, 1 or 2 as described below.</p> <p>(0) No visible infections. (1) Light infection (1/2 or less of total number of branches in the third infected). (2) Heavy infection (more than 1/2 of total number of branches in the third infected).</p> <p>STEP 3. Finally, add ratings of thirds to obtain rating for total tree.</p>	<div style="display: flex; align-items: center; justify-content: center;">  <div style="margin-left: 20px;"> <p>If this third has no visible infections, its rating is (0).</p> <p>If this third is lightly infected, its rating is (1).</p> <p>If this third is heavily infected, its rating is (2).</p> <p>The tree in this example will receive a rating of $0 + 1 + 2 = 3$.</p> </div> </div>

1	light	slight growth reduction, few small witches' brooms
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2 and 3	moderate*	moderate growth reduction, top decline, some large witches' brooms
4 and 5	severe	severe growth reduction, topkill, large witches' brooms, some with dead twigs, some tree death
6	very severe	severe growth reduction, topkill, large witches' brooms with many dead twigs, tree death

* Trees with large brooms in the lower half of their crowns should be considered severely infected.

Other forest values are affected adversely by Douglas-fir dwarf mistletoe. Potential for wildfires is increased because dead twigs, small diameter living twigs, dead foliage, and lichens accumulate in witches' brooms in the lower portions of crowns. Increased tree mortality, and the accumulation of broken, dead witches' brooms around the bases of infected trees adds to the fuel loads in infested stands. Witches' brooms provide fuel ladders for ground fires to spread upward into tree crowns. Small diameter dead twigs in brooms ignite easily and can serve to spot fires as the burning embers are carried aloft. Mistletoe-infected trees are less likely to survive fires than healthy trees because they are already in a weakened condition. Severely infected trees are less capable of resisting attacks by other diseases and insects. Dead and dying trees may detract from visual quality.

Witches' brooms significantly increase the accident hazard potential in campgrounds because infected branches are more prone to breaking than healthy branches. The witches' brooms can collect large amounts of snow and ice during winter. An inventory of branches that broke from Douglas-firs in the winter of 1996-1997 in the Icicle Creek campgrounds on the Wenatchee National Forest revealed that 66% of broken branches at least 1.5 inches in diameter and at least 2 feet long were infected by dwarf mistletoe. Dwarf mistletoe infected broken branches averaged 30 pounds versus 18 pounds for uninfected branches. Some of the broken infected branches weighed almost 200 pounds. Severely infected trees may be broken or uprooted as snow and ice accumulate in the witches' brooms. Most branch breakage occurs in the winter but some failures happen during periods when the campgrounds are actively used. Branches that were cracked but did not fall during winter can fail at any time. Brooms present large surfaces areas for winds to blow against. Several infected branch failures have occurred during summer thunderstorms accompanied by strong winds.

Several benefits of Douglas-fir dwarf mistletoe have been recognized. The shoots and fruits are eaten by some birds, mammals, and insects. The large witches' brooms are used as thermal cover, foraging, hiding, and nesting sites by grouse, hawks, owls, martens, squirrels, porcupines, and other wildlife. Bird populations are likely to be more abundant and diverse in mistletoe- infected stands than mistletoe-free stands. Northern spotted owls, long-eared owls, and Cooper's hawks show an attraction to Douglas-fir witches' brooms as nest sites. Although the value of Douglas-fir dwarf mistletoe to several animal species is recognized, many times, the overriding consideration determining treatment in campgrounds is guided by the need to retain high value trees and to provide for public safety.

Control

General

Douglas-fir dwarf mistletoe should be controlled when it poses an unacceptable hazard and/or a threat to the survival of valuable trees in established campgrounds. Douglas-fir dwarf mistletoe is relatively easy to

control. The parasite is host specific; it only survives on living Douglas-fir. Infections are readily detectable because of the witches' brooms. The only practical control of Douglas-fir dwarf mistletoe is through cultural treatments. Pruning and tree removal are the basic control techniques available for use in campgrounds. No chemical or biological controls are available for treating dwarf mistletoes in infected Douglas-firs.

Dwarf mistletoe control in campgrounds should be a component of a comprehensive vegetation management plan and operation. A comprehensive management plan would evaluate all the vegetation concerns and opportunities present in the campgrounds, in addition to those attributable to dwarf mistletoe infection. It should develop an action plan that accomplishes long-term desired vegetation composition, structure, attractiveness, and safety.

Douglas-fir dwarf mistletoe control in campgrounds should be planned and conducted as multiple year, multiple treatment operations. A single treatment will reduce the number of infections and should remove the most damaging witches' brooms but in most situations will leave several infected trees that will need to be treated in the future. Eradication of Douglas-fir dwarf mistletoe is not a practical objective in most infested campgrounds. The goal of control should be to reduce the mistletoe population to levels that increase tree longevity and decrease risk of tree failures.

Surveys

Ability to detect and correctly identify dwarf mistletoe infections is essential for successful treatments. This holds true for all phases of the control operation from the initial assessment of campground sites to determine how much infection is present, to removal of the branches and brooms by workers doing the pruning and cutting. Infections are easy to detect with a small amount of training,. Dwarf mistletoe infections are most visible in tree crowns fully exposed to sunlight and become progressively more difficult to detect as crown shading increases. Not all witches' brooms in Douglas-fir are caused by dwarf mistletoe infection. Missed infections reduce the success of treatments and may necessitate more work in the future. Assistance in identifying infections and developing treatments is available from the forest pathologist at the Wenatchee National Forest forest insect and disease service center.

The first step in controlling Douglas-fir dwarf mistletoe in campgrounds is to determine where the infestation(s) are located. Ideally, every Douglas-fir larger than a seedling should be examined for witches' brooms caused by mistletoe infection. This can be done rather quickly because of the ease of identifying the brooms. Every Douglas-fir in the frequently used portions of campgrounds needs to be inspected. Each tree should be looked at carefully from at least two different sides; just looking at one side will tend to give inaccurate infection ratings. The witches' brooms can be detected most accurately on sunny days. An identifying number and DMR should be given to each infected tree. A preliminary assessment should be made as to whether the tree should be pruned, removed, or left untreated using criteria described later in this paper. A map should be made showing locations of Infected trees to help plan treatments. Infected trees should be tagged with a number in an inconspicuous spot to avoid removal of the tags.

A simple-to-make mistletoe -tree crown assessment gauge can aid in evaluating trees for infection and prunability. A transparent plexiglass strip about 1.5 inches by 18 inches is marked into three equal-length segments with a marker and marked again into tenths using a different color marker. The gauge is used to determine DMR by standing back and holding it so the base of the live crown is seen at the bottom and the tree top is at the top of the gauge. Each live crown third is then examined using the thirds markings to determine the DMR. The tenths markings on the gauge are used to help determine if infected trees can be pruned. The gauge is held so the top and bottom of the tree correspond to the top and bottom of the gauge;

starting at the top of the gauge count down in tenths until witches' brooms are seen. The number of top tenths without brooms represent the percentage of tree height apparently free of infection. Infected trees need to have at least 30 percent of their total height be infection free crown to be prunable.

Evaluating Sites for Potential Development

Forested sites being considered for development into campgrounds need to be carefully examined by a forest pathologist for the presence of dwarf mistletoes and other diseases as part of the site evaluation process. Douglas-fir stands that have widespread dwarf mistletoe infections are poor choices for development into campgrounds.

Control Treatments

Pruning

Pruning can be an effective method of controlling Douglas-fir dwarf mistletoe in campgrounds. Pruning off infected branches and witches' brooms provides a way to reduce, and in many instances eliminate the debilitating effects of the parasite, while saving valuable trees. Past experience with pruning dwarf mistletoe-infected Douglas-firs in eastern Washington shows that improvements in crown color and foliage quantity occur as quickly as two years after removal of large brooms. While pruning as a mistletoe control technique typically is not cost effective in stands where timber production is an objective, it is much more likely to be cost-effective in campgrounds due to the higher value of the trees.

A dwarf mistletoe-infected Douglas-fir should be considered a good candidate for pruning if it has all of the following characteristics:

- There are no visible mistletoe infections in the top 1/3 of the living crown.
- The tree is at least 40 feet away from the crown edges of overtopping dwarf mistletoe infected Douglas-firs that will be retained and not pruned. (Trees closer than 40 feet are likely to be exposed to dwarf mistletoe seeds almost every year.)
- The tree has a DMR of 3 or less.
- Removal of visibly infected branches would leave a minimum of 30 percent of the total tree height with live, apparently infection-free crown.
- The tree is free of other defects that pose a high risk of failure.

Dwarf mistletoe pruning recommendations change as the size of the tree increase.

Seedling size trees, DBH less than 1 inch: Pruning is not recommended for Douglas-fir seedlings. Trees infected as seedlings have a high probability of being killed by mistletoe; they should be cut and replaced with another tree species, if needed. Most infections on seedlings will be latent and impossible to detect. Douglas-fir seedlings less than 3 feet tall have low rates of infection.

Sapling size trees, DBH less than 5 inches: All visibly infected branches should be removed from saplings. Infections on the typical tree will be in the lower one-half of the crown. Infections less than 10 years old are

likely to have flat fan-shaped witches' brooms rather than the spherical brooms seen with older infections. Trees with visible infections in the top 1/3 of the crown are poor choices for pruning. Sufficient live crown should be retained following pruning to enable the tree to average at least 12 inches of height growth annually for at least 20 years. No more than 50 percent of the live crown length should be removed and the tree should have at least a 40 percent live crown ratio following pruning. Dwarf mistletoe infected saplings growing within 40 feet of overtopping mistletoe infected firs are poor candidates for pruning if the overtopping trees are to be retained and not have their infections removed. Dwarf mistletoe plants in the overtopping trees will continue to produce seeds that will shower down onto the smaller trees resulting in numerous infections. If there is a strong commitment to do follow-up treatment then pruning can be limited to removing the obviously infected branches, recognizing that some branches have latent infections and will need to be removed within 4 to 5 years. If there is not a strong commitment to do follow-up treatments in 4 to 5 years, prune all living branches below the visibly infected branches, the whorls with infections, and two whorls above the uppermost visibly infected branch.

Pole size trees, DBH 5 to 10 inches: Dwarf mistletoe infections in pole size trees typically should be more visible than on smaller trees because many will be older and have larger witches' brooms. Some tree climbing or use of lift trucks may be needed to prune these trees. Trees with infections in the top 1/3 of the crown are poor choices for pruning. Sufficient live crown should be retained following pruning to enable the tree to average at least 12 inches of height growth annually for at least 20 years. No more than 40 percent of the live crown length should be removed and the tree should have at least a 40 percent live crown ratio following pruning. If there is a strong commitment to do follow-up treatments then pruning can be limited to removing the obviously infected branches, recognizing that some branches will have latent infections and will need to be removed in 4 to 5 years. The large witches' brooms must be removed. Branches with large witches' brooms are more likely to break than those with small brooms and large brooms cause more stress on trees than small brooms. Branches with small brooms could be left for 3 to 4 years with the realization that additional infections are likely from seeds produced by aerial shoots in them. Pruning of only the visibly infected branches is likely to speed up emergence of aerial shoots from latent infections on adjacent branches as a result of increased exposure to sunlight. If there is not a strong commitment to do follow-up treatments, prune all branches below the visibly infected branches, the whorls with infections, and two whorls above the uppermost visibly infected branch.

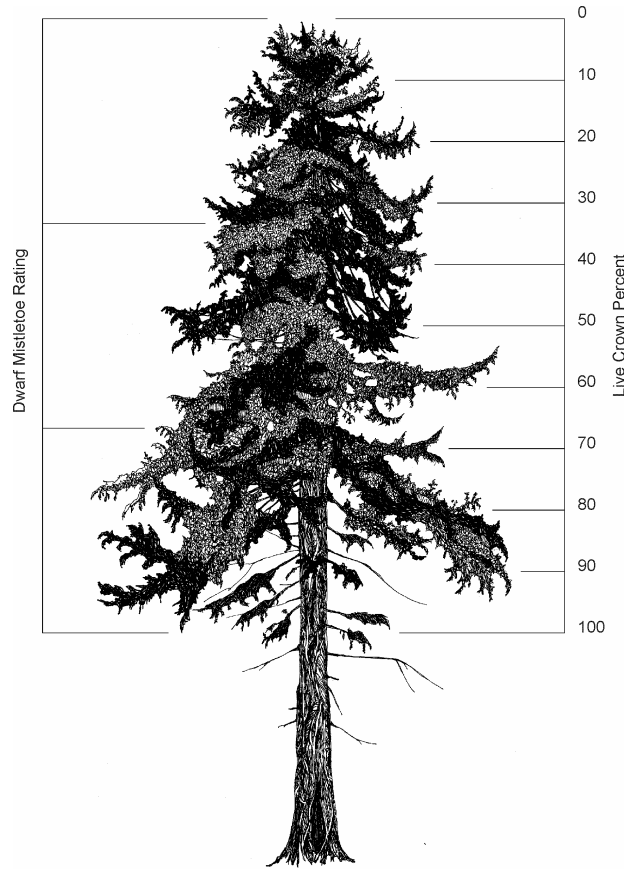
Large trees, DBH greater than 10 inches: Most dwarf mistletoe infections on large Douglas-firs in campgrounds typically appear as big, spherical witches' brooms. These trees generally, but not always, have been exposed to full sunlight on at least one side for many years. The infections, especially near the bases of the trees, are old and have formed large brooms. Severely infected trees with DMR ratings of 4 to 6 are poor candidates for pruning. They should either be left unpruned and facilities moved from underneath them or the trees should be removed. All branches below visibly infected branches on mature firs are probably infected and should be pruned along with those visibly infected. Branches with large witches' brooms are more likely to break than those with small brooms. Large brooms cause more stress on trees than small brooms, so it is most important to remove them. Branches with small brooms could be left for 3 to 4 years with the realization that additional infections may result from seeds produced by plants in the remaining brooms. At least 30 percent of the total tree height should be live, apparently healthy crown. Climbing will almost always be required to prune mature Douglas-firs.

Pruning large numbers of dwarf mistletoe-infected branches from big Douglas-firs in campgrounds should be done from July to the end of January to avoid attracting Douglas-fir beetles. The peak flight period of Douglas-fir beetles is from April to mid-June. The beetles may be attracted by resin flowing from large, fresh

pruning cuts and kill not attracted to old against Douglas-fir deploying the pheromone MCH near Removal of big in large cuts on some from the large cuts has problem. Examples of large Douglas-firs are through 12.

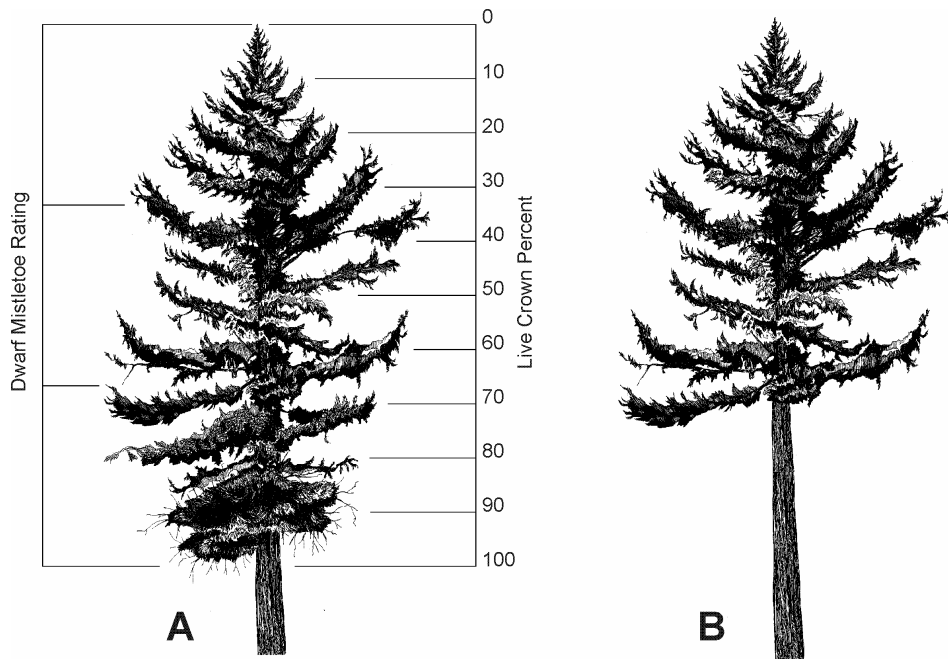
Retreatment: treatments will almost additional infections takes about 3 years Douglas-fir dwarf appear, even then About 2 years after a more light by pruning it will produce aerial witches' broom Infections that are pruning will most only visibly infected infections should be observations 3 to 4 pruning. Trees should be examined within 4 years of the initial pruning and any visibly infected branches should be pruned to prevent more infections from seeds produced by the newly emerged female plants. Retreatments almost always involve much less individual tree work than the initial treatment.

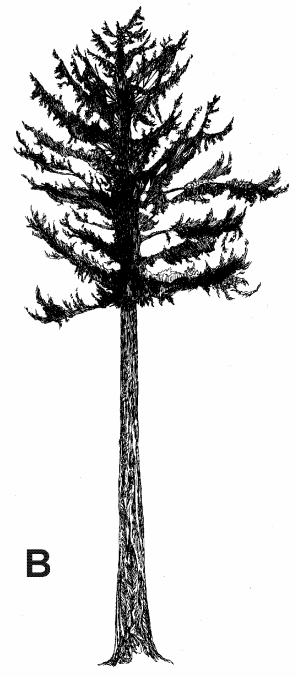
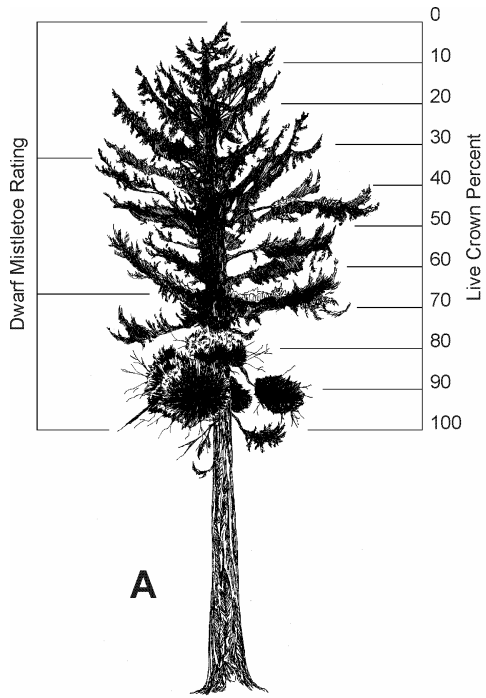
Pruning practices: Infected trees should not be "over-pruned". Severe pruning can degrade tree aesthetics and may kill the trees. Douglas-firs can tolerate removal of substantial numbers of live branches. Generally, saplings and pole-size trees should have no more than 50 percent of their live crown lengths removed in one pruning and they should have at least 40 percent of the total height in live crown following pruning. Growth rates of trees pruned to this degree will be slowed for a few years but the trees are unlikely to be killed.

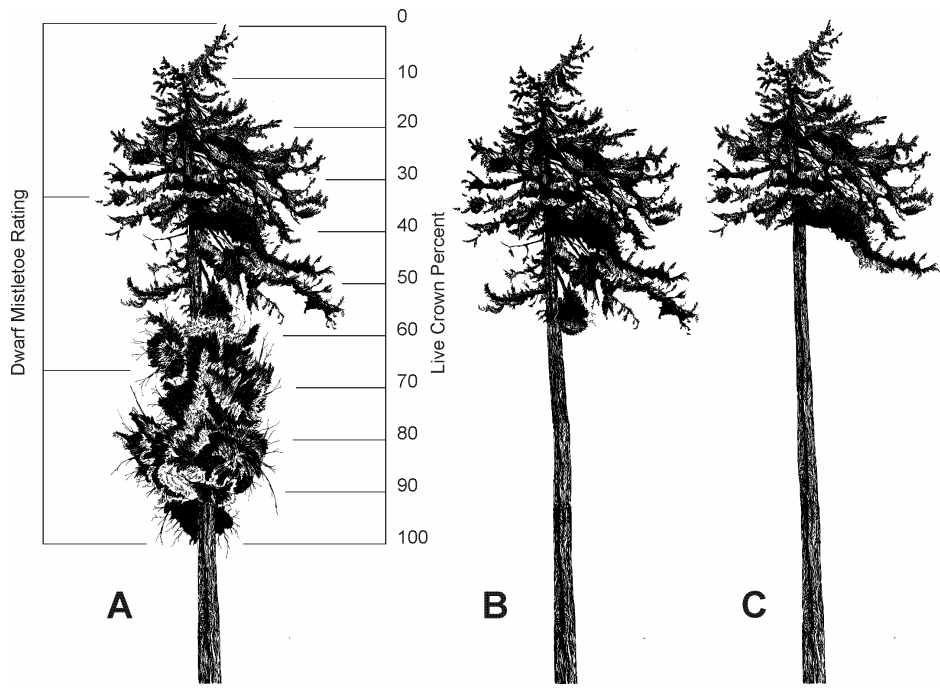


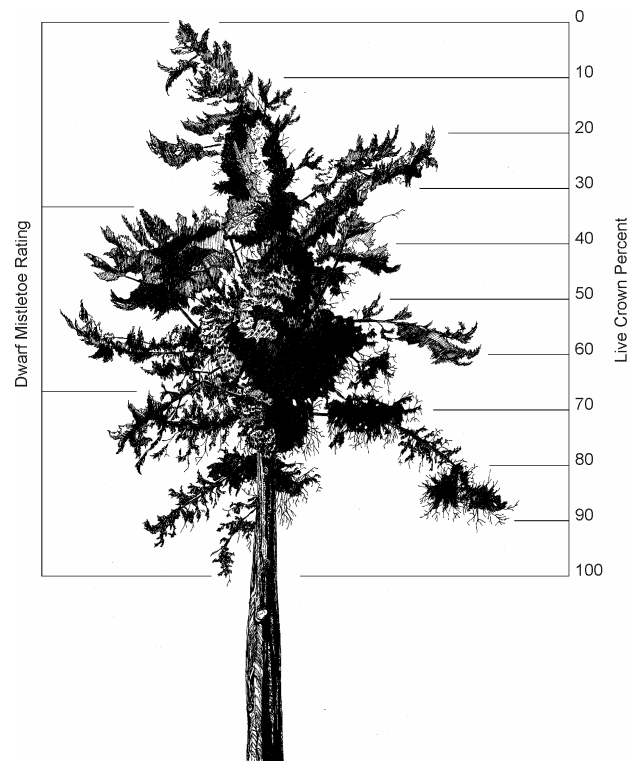
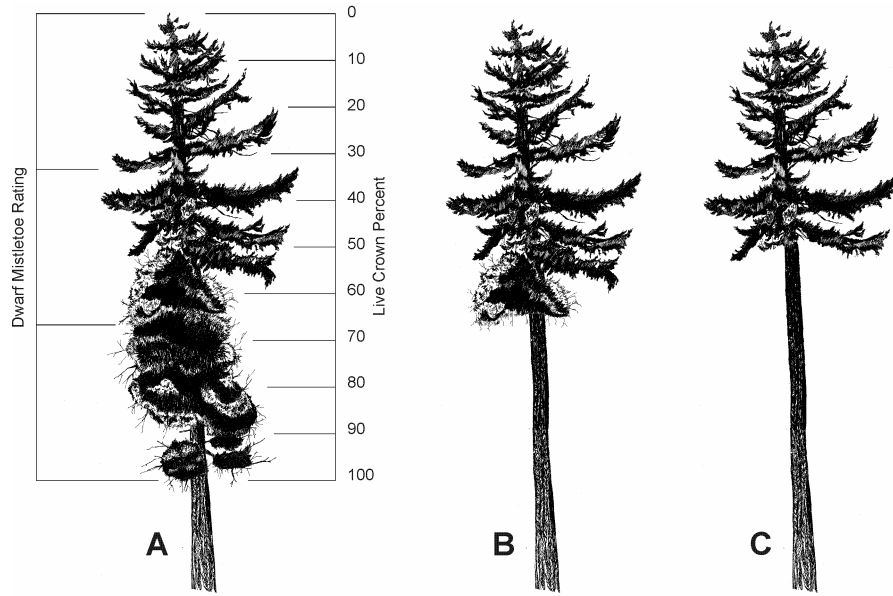
the trees. The beetles are resin. Additional protection beetle can be obtained by antiaggregating beetle freshly pruned trees. witches' brooms will result trees. Excessive resin flow not been a recurring pruning prescriptions for illustrated in Figures 7

Subsequent pruning always be needed to remove from individual trees. It after initial infection by mistletoe for symptoms to detection can be difficult. latent infection is exposed to or removal of adjacent trees shoots and the process of formation will accelerate. latent at the time of the initial likely be missed, especially if branches are cut. Such visible with careful years after the initial









For larger trees, pruning should not remove more than 40 percent of the live crown length in one pruning and they should have at least 30 percent of the total height in live crown following pruning. In some cases involving trees that need to have many branches pruned, there should be two separate prunings separated by at least four years. This would allow the trees to recover from the first pruning and be able to tolerate an additional light pruning. Do not flush cut branches when pruning; cut up to the branch collar, the slightly swollen tissues right at the junction of the branch to stem. Flush cutting cannot be avoided when large diameter branches need to be removed. Do not leave stubs more than 1/2 inch long because they slow closure of the cuts. Do not use any tree wound paints or dressings. Make undercuts on the large diameter branches to avoid tearing bark from the stems. Do not attempt to save apparently uninfected parts of infected branches; prune the entire branch.

CAUTION: Some campgrounds have lines carrying electricity, check for power lines before using pole saws and lift trucks to prune trees and avoid contact with the lines.

Tree Removal

Some trees will be too severely infected to prune. A dwarf mistletoe infected Douglas-fir should be considered for removal from a campground if it has all the following characteristics:

- The tree has a DMR of 4 or more, or there are visible infections in the top 1/3 of the living crown.
- Removal of visibly infected branches would leave a tree with less than 30 percent of the total height with live crown.
- The tree is an infection threat to adjacent Douglas-firs and/or the witches' brooms present an unacceptable hazard to users and facilities.

In addition, infected trees should be considered for removal if they are within 40 feet of taller, infected Douglas-firs that will not be treated. If understory Douglas-firs are left within 40 feet of infected taller firs they have a high probability of being continuously infected from mistletoe seeds disseminated from the overstory trees.

Infected trees can be cut at any time of year, but there is a risk of attracting Douglas-fir beetles when trees larger than 11 inches DBH are cut in January to the end of June and left on site. If cut trees are to be left on

the site they should be cut into firewood lengths and campground users should be encouraged to burn it, otherwise the stems should be removed before the next April. Removal of bark from large diameter, freshly cut trees, although labor intensive and expensive, would prevent brood production by Douglas-fir beetles.

Tree Species Manipulation

The spread of Douglas-fir dwarf mistletoe from tree-to tree can be controlled by favoring tree species other than Douglas-fir in infested campgrounds. The other tree species will serve as screens to block seed spread and will not become infected by Douglas-fir dwarf mistletoe. A band 50 feet wide of tree species other than Douglas-fir is effective in containing Douglas-fir dwarf mistletoe. Even stands with a mix of Douglas-fir and other tree species will have a lower rate of Douglas-fir dwarf mistletoe spread than pure stands of Douglas-fir (Figure 13). Care should be taken to determine if these other species of trees are infected by other species of dwarf mistletoes. Hardwoods and shrubs may be desirable in dwarf mistletoe-infested campgrounds because

they are immune to all species of dwarf mistletoes found in eastern Washington. However, many hardwood species are relatively short-lived in comparison to Douglas-fir.

Barriers to Spread

Almost all Douglas-fir dwarf mistletoe seeds are spread less than 50 feet from the crown edges of infected host trees. Buffers free of Douglas-firs can be used to confine spread of the parasite. They should be at least 50 feet wide and may be free of trees or contain any tree species other than Douglas-fir. Roads, wide streams, meadows, and other openings, either natural or manmade, can serve as effective obstacles to dwarf mistletoe spread (Figure 14). Barriers may need to be periodically cleaned of Douglas-fir seedlings.