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Management of Western Dwarf Mistletoe in Ponderosa and Jeffrey Pines in Forest Recreation Areas

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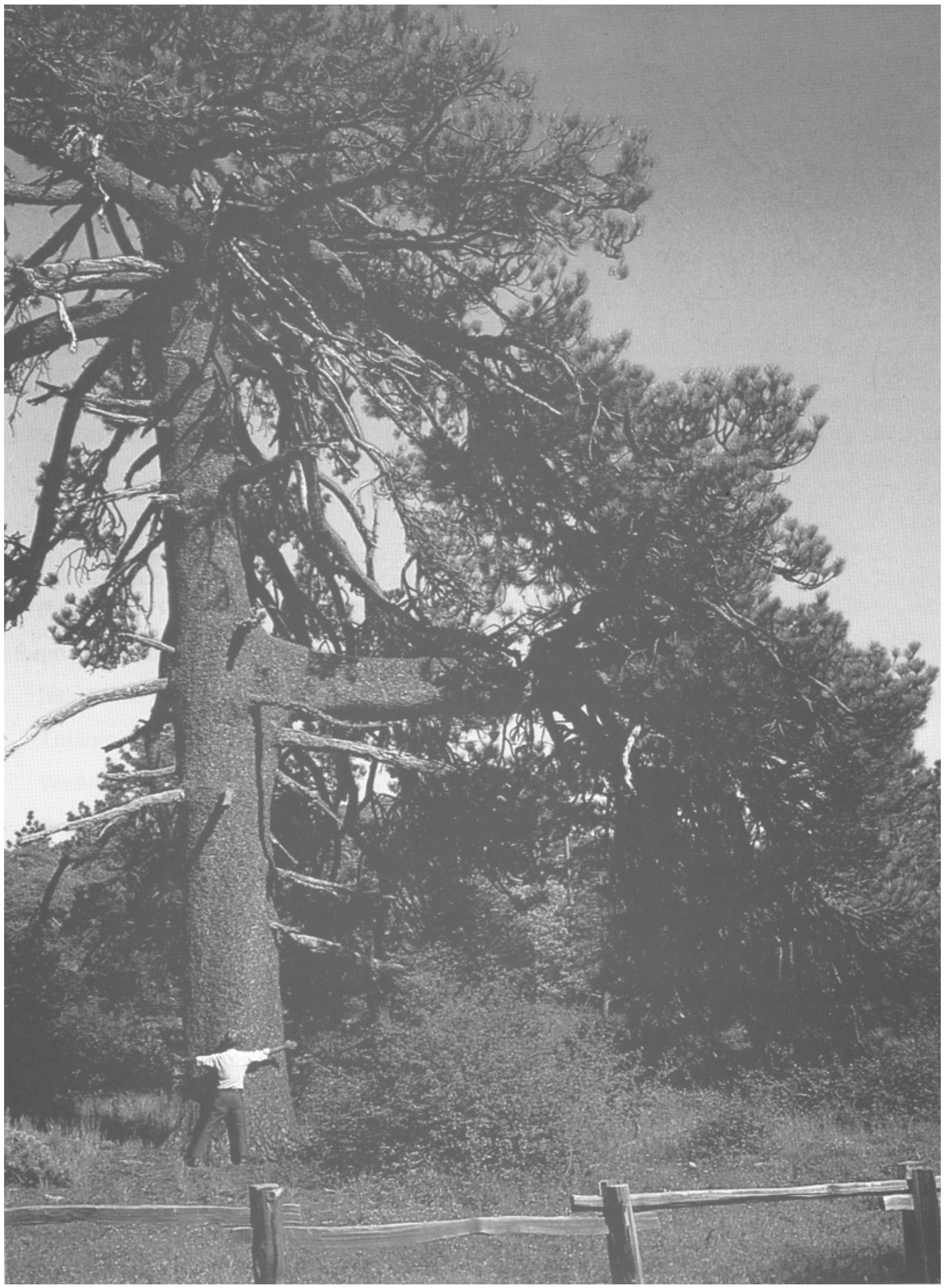

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Cover: This Jeffrey pine on Laguna Mountains, Cleveland National Forest, California is reputed to have the world's largest known "witches broom" caused by western dwarf mistletoe. The broomed tree, about 250 years old, is a major attraction on a self-guided nature trail.

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Western dwarf mistletoe (*Arceuthobium campylopodum* Engelm.) is a damaging parasite of pines in the Western United States. In high value campgrounds and recreational areas, dwarf mistletoe can be particularly damaging. Lowered life expectancy, increased hazard from defect, poor growth, and diminished esthetic or scenic values are some of the losses these parasitic plants cause in trees and forests.

Resource managers now realize that many such losses in western forests are caused not by single pests alone, but by the interaction of two or more pests including insects, diseases, and animals responding to specific environmental conditions. For example, insects and diseases together killed millions of trees in California weakened by a severe drought in 1976-77. Dwarf mistletoes were among the major pests associated with this drought-related mortality.

In addition, managers are increasingly aware that a single approach to control a given pest or pests is not always the best method of pest management. For instance, early attempts to eradicate dwarf mistletoes by pruning and thinning trees and stands have, for the most part, proven to be unsuccessful. The concept of "living with" dwarf mistletoe and keeping its population in check has become a more realistic approach to dealing with this disease problem. Also, the use of more than one method of managing pest complexes (more commonly known as integrated pest management) is becoming widely accepted as the best approach to managing most pest problems.

For dwarf mistletoes in high value recreational forests, integrated pest management is the necessary approach. First, the management goals for the recreational area must be defined before attempting any pest management activity. If, for example, the goals are to protect individual, high value trees, then the management options appropriate for that purpose are evaluated and used. If the goals are to protect stands or forests, then other management options are appropriate. Whatever the case may be, managers need to define goals before various alternatives to managing dwarf mistletoes can be intelligently selected and applied.

One or more direct and indirect pest management treatments should be used to mitigate the damage caused by dwarf mistletoe and associated pests. Direct treatments include individual tree removal, thinning infected stands, pruning infected branches, pruning brooms only, installing buffer strips, and using resistant hosts. Direct management treatments are aimed mainly at lowering dwarf mistletoe populations, preventing spread and infection, and reducing hazard, but increased growth and vigor may also result from some of these treatments. Guidelines are included for direct treatments to suppress dwarf mistletoes in individual trees, even-aged stands, and all-aged or multistoried stands. Indirect management treatments include such measures as irrigation, fertilization, brush or weed control, and regulating human impact. Such treatments are applied primarily to alleviate environmental or physical stresses that weaken trees and make them more subject to pest impacts.

Intimate knowledge about the resource, establishing management goals, identifying the pest problems, and selecting the best methods to reduce damage from dwarf mistletoes and associated pests should result in longer lived, safer, healthier, more productive forests.

INTRODUCTION

Western dwarf mistletoe *(Arceuthobium campylopodum* Engelm.) causes widespread damage to pines in the coniferous forests of the Western United States. Not only does it contribute to growth reduction and mortality in commercial timber producing forests, it reduces forest recreational values as well. Lowered life expectancy, increased hazard from defective trees, poor growth; and diminished esthetic or scenic values are some of the losses caused by western dwarf mistletoe in high-value recreational forests.

With some exceptions, relatively little interest has been expressed or action taken to control dwarf mistletoes in high-value recreational forests. A notable exception is the cooperative effort of the National Park Service, U.S. Department of Interior, and Forest Service, U.S. Department of Agriculture, scientists to control dwarf mistletoe (*A. vaginatum* ssp. *cryptopodum* [Engelm.] Hawksworth and Wiens) on ponderosa pines (*Pinus ponderosa* Dougl. ex Laws.) at Grand Canyon National Park, Arizona (Lightle and Hawksworth 1973, Maffei 1984). This project, begun in 1949, involved poisoning, felling, or pruning infected trees, with emphasis on pruning. More than half the trees initially treated were pruned. Thousands of trees were killed or pruned with some pruned as many as four times, from 1949 to 1970, on about 2350 acres. Conclusions, based on a detailed examination of the control areas in 1970, were that the original goals--to reduce the level of dwarf mistletoe and to protect the ponderosa pine forest--were achieved. These results were accomplished "without undue alteration of, or disturbance to ponderosa pine stands within the treated area." In spite of the early success of this operation, questions still persist about how best to control other dwarf mistletoes elsewhere in the West.

In California, several efforts have been made to control dwarf mistletoes in recreational areas-in some as early as the late 1950's. The philosophy of control that prevailed at that time was one of eradication. Many managers and some scientists believed that in order to control dwarf mistletoes they had to be eradicated. Treatments usually included pruning and tree removal aimed at eliminating the parasite from the tree or stand. Although precise documentation is not available on most treatment sites, re-evaluation and subsequent research have shown that eradication by pruning is impossible or economically impractical. However, substantial suppression of dwarf mistletoe populations was achieved by these early treatments in many cases.

In the early 1950's, and at several intervals thereafter, chem.-icals were tested to control dwarf mistletoes on both timber producing and recreational areas (Quick 1964). Unfortunately, no successful chemical control of dwarf mistletoe was found. Recent tests in Minnesota indicate that ethephon may be an effective chemical to control eastern dwarf mistletoe (*A. pusillum* Peck) on black spruce (*Picea mariana* [Mill.] B.S.P.) on high value sites (Livingston and Brenner 1983).

Presently, the concept of "living with" dwarf mistletoes and keeping them in check has become a much more acceptable and realistic approach to dealing with the problem. For example, research on dwarf mistletoe of ponderosa pine in the southwest has shown that main stem infections in tree boles 5 inches (13 cm) or more in diameter pose little threat of spread, and contribute little to mortality (Mark and Hawksworth 1974).

However, living with some level of dwarf mistletoe in trees or stands is a concept that has made many managers uneasy and has raised questions about the efficacy of this approach. For example, how much dwarf mistletoe can we live with and still avoid unacceptable tree death or the development of hazardous trees? How rapidly does the level of dwarf mistletoe infection increase in a tree, and at what levels do we risk tree death under varying stand conditions? What methods should we use to reduce dwarf mistletoe infection levels? Answers to such questions are usually not available, but research and field testing have been undertaken to answer some of them.

This paper describes some approaches that can help reduce the damage from dwarf mistletoes on pines and includes some research and testing that has been done or that is in progress to provide answers on how best to manage dwarf mistletoes in high-value recreational forests and trees. It describes both direct and indirect management treatments that can be used.

MANAGEMENT GOALS

Before attempting any pest control activity, the resource manager must first establish a set of management goals for a recreational forest (Smith 1978). The nature of the recreational environment, e.g., wilderness versus developed campground, to a great extent determines the goals. For example, in high-value, developed recreational sites, emphasis is usually placed on protecting individual trees from damage by insects and diseases; and individual tree characteristics such as longevity, vigor, and visual features become important. On less intensively developed sites, protecting the general health and integrity of the forest and its overall utility may be the prime goal. Whatever the case may be, the manager needs to define the goals before the various alternatives of pest management can be intelligently selected and implemented.

In practice, pest management must go hand in hand with vegetation management. Attempts to mitigate the effects of pests in poorly managed stands often lead to failure. Therefore, silvicultural treatments such as thinning overstocked stands, removal of high risk or weakened trees, or other treatments that improve the vigor or growing conditions of individual trees or stands are a part of integrated pest management. Site selection and vegetation management are of particular importance in the development of new recreational areas. Knowledge about the composition and condition (including diseases, insects, and other pests) of the existing vegetation for a planned recreational area is essential before any development takes place. Often proper site selection and good vegetation management on new, and sometimes even existing recreational sites, preclude the need for any pest management activity.

EFFECTS OF PESTS

Scientists and pest management specialists now generally agree that most pest-caused losses in western coniferous forests are caused not by single pests, but by the interaction of several pests including insects, diseases, and animals responding to specific environmental conditions. Results of these interactions were brought home quite clearly during and for a year or two after a severe drought in northern California in 1976-77, when insects and diseases together killed millions of drought weakened trees (Smith and others 1983). Dwarf mistletoe was only one of the more common disease organisms associated with the mortality-particularly in pine. Other agents, mainly root disease organisms and cambial feeding insects, were also involved. The extent to which the drought, insects, and diseases reduced vigor and growth of the surviving trees was not evaluated, however.

Although northern California's forests experienced the most widespread and severe drought-pest related damage in recent history, the high value forests of southern California have not escaped damage (DeNitto and Pierce 1983, Smith and Roettgering 1982, Wood and others 1979). And, in many cases they may be more subject to environmental and pest caused damages than other western forests. Forests in southern California are growing near the limits of the geographic range of their species, drought stress appears to be a common event in these arid areas, the sites are often heavily used for recreational purposes, and tree damage from air pollution has been well documented by scientists in southern California. The stresses caused by drought, marginal site, heavy use, and pollution in conjunction with those caused by insects and diseases can lead to decreased tree vigor and heavy mortality. Therefore, managers must keep in mind that insects and diseases seldom operate alone to damage and kill trees. Instead, they work in concert with other factors to overcome a tree's defenses-particularly during periods of unusual environmental stress. Additional stresses brought on by pollution or other human-related activities often accelerate damage and death.

Mortality

Reduced life expectancy of high value trees is of major concern to most recreational site managers. The extent to which dwarf mistletoe contributes to tree death is often unknown and sometimes variable. However, we do know that pines heavily infected with dwarf mistletoe are reduced in growth and vigor, and that dwarf mistletoe is intimately associated with weakened, dying, and dead trees.

How much mortality is associated with dwarf mistletoe infected pines, and what is the reduced life expectancy of the infected trees, are frequently asked questions. A 10-year study of ponderosa and Jeffrey pines (*P. jeffreyi* Grev. & Balf.) in campgrounds in California and Nevada showed that high levels of mortality have occurred among trees heavily infected by dwarf mistletoes (Vogler and Scharpf 1981). The following relationships were observed. (1) On all campgrounds mortality was greatest (about 35 pct) in trees with high levels of dwarf mistletoe and live crown ratios of 30 percent or less. Much lower mortality rates (less than 5 pct) occurred among trees with none to low levels of dwarf mistletoe and live crowns above 40 percent. Therefore, dwarf mistletoe intensity and the amount of living foliage on a tree are intimately related to tree mortality. (2) Mortality increased exponentially rather than arithmetically as levels of dwarf mistletoe increased. (3) Percent mortality varied markedly among the years studied, and increased in years of below normal precipitation. (4) Cambial feeding insects were involved in the death of nearly all trees. (5) Dwarf mistletoe built up noticeably in trees over time such that less severely infected ones became more heavily infected. Overall, 267 out of 3035 pines (9 pct) died in 10 years, ranging from 4 percent of the uninfected pines to 48 percent of the most severely infected pines.

This 10-year study was limited to only five widely separated campgrounds in California and western Nevada. But the variables and relationships involved in mortality were essentially the same on all the campgrounds studied, and we judge that these relationships would hold true for ponderosa and Jeffrey pines on other campgrounds or other recreation sites as well. Considering the values at stake in California alone, the potential losses from reduced tree longevity are of major concern. In addition, if losses in other tree species in the West from other dwarf mistletoes and associated pests even closely approach those in ponderosa and Jeffrey pines, the combined losses on forest recreation sites would be enormous.

Loss of Growth and Vigor

Although growth loss from dwarf mistletoe normally does not constitute a major effect in most developed recreation areas, it can cause management problems. If pine regeneration is being encouraged in an area, or if young understory trees are expected to replace or supplement the dominant tree cover on a recreational site, then stunting or growth loss by dwarf mistletoe compounds the management problem. In these situations, understory trees become infected by seed from the parasite growing in the surrounding overstory; and as a result, the infected small trees become deformed, stunted, and eventually die from suppression and other stress factors (Scharpf and Vogler 1986). Therefore, efforts to naturally regenerate pines, or expenditures of resources to plant susceptible trees under an infected overstory are poor practices from both a recreational and timber management standpoint.

Probably the greatest effect-reflected by growth losses from dwarf mistletoe-is in the larger more valuable trees on recreational sites. Growth loss can be equated to a loss of tree "vigor." Large, low vigor trees are much more subject to attack and damage by cambial feeding insects, and diseases. And during periods of adverse climatic conditions, such as drought, diseased trees are further weakened and die. Trees of all sizes on a given site that have been reduced in growth and vigor by dwarf mistletoes are much more apt to be killed by insects, other diseases, or adverse climatic conditions than are their healthy counterparts.

Hazard

Reduction of tree hazard on forest recreation sites is now recognized as both a moral and legal responsibility of public agencies. The extent of hazard caused by disease, and the level to which hazard is controlled are decisions that must be made by recreation land managers, however. Paine (1971) outlines some criteria that can be used in hazard rating and control decision making.

Dwarf mistletoe is one of several disease agents that can make trees hazardous. Premature death of dwarf mistletoe infected trees or large branches are cases in which hazard is increased in high-use recreation areas. Not all hazard is associated with dead trees or branches, however. Large, broomed branches are subject to breakage during high winds or heavy snow loads, and some trees with trunk infections, particularly those also invaded by bark beetles or decay fungi or both, pose a greater hazard from breakage than healthy trees. Occasionally dwarf mistletoe causes forking, dead tops and other deformities that can lead to weakening and failure of portions of a tree.

Therefore, managers should be aware that dwarf mistletoe, and other diseases as well, can increase hazard in infected trees and stands. As Paine (1971) points out, the extent to which hazard is reduced should be based on a number of factors. In general, the factors include the objectives of the recreational site, the ability to detect and appraise hazard, and management decisions to control the problem.

Esthetics

An important value of trees on a recreational site is that they are esthetically pleasing as well as functional. People enjoy looking at trees and forests, and anything that detracts from a pleasant view diminishes the quality of the recreational experience. What constitutes a "pleasing visual experience" is difficult to evaluate, however. Beauty is in the eye of the beholder. Most people find live trees more pleasing to view than dead ones, and "healthy" trees are usually recognized as more pleasing than obviously sick or dying ones. But between these extremes is the majority of trees that are of little concern to recreationists as long as they appear more or less "normal." Also, people are willing to accept, and perhaps even find desirable, the occasional sick, dying, or dead tree over a large forest area or broad vista, whereas, sick or dying trees in a high-use campground would usually be considered unpleasant. How then should the manager deal with the esthetic value of diseased trees in a recreational area? First, as discussed earlier, the goals of the area need to be defined. Then the impact of disease, and the methods of control can be established.

Dwarf mistletoes are usually considered to do more harm than good but in a few instances the disease may enhance rather than diminish the esthetic value of a tree. Damage occurs in the form of dead tops, dead branches, sparse foliage, deformation, and excessive pitch exudation from stems and trunks. In a few cases, however, deformation or other unhealthy conditions result in the formation of "picturesque" trees of high scenic value. One example of this is a Jeffrey pine on Laguna Mountain, Cleveland National Forest that is reputed to have the "world's largest dwarf mistletoe broom." Whether the pine deserves this dubious distinction may be questioned. Nonetheless, the broom is a major attraction to visitors and is of considerable esthetic value.

Therefore, in the management of dwarf mistletoe on recreational sites, esthetic value should be one of the factors considered. Tree removal or severe pruning of brooms on high value trees merely to eliminate or reduce dwarf mistletoe is costly and may do more damage to recreational values than less severe treatments or no treatments at all.

SUPPRESSION AND PREVENTION

The main approach to dealing with pests and with improving tree and stand conditions in most forest recreational areas involves the use of one or more types of direct silvicultural treatment applied mainly to reduce pest effects and improve tree vigor. The treatments most often applied to dwarf mistletoe are individual tree removal, thinning, pruning, buffer strips, and use of resistant trees or non-host species.

Individual Tree Removal

Individual tree (or overstory) removal is best used in situations where large, heavily infected pines pose a threat to susceptible understory, and where management of the understory is of primary importance. Research has shown that it is not possible to develop a dwarf mistletoe-free understory within about 100 feet or so of large infected overstory ponderosa pine (Scharpf and Parmeter 1967, 1971; Parmeter and Scharpf 1972). In one study, about 15 percent of the understory pines became infected by the time they reached 5 feet (1.5 m) in height and 30 percent were infected before they were more than 10 feet (3.0 m) tall (Parmeter and Scharpf 1972). In another study, 77 percent of Jeffrey pine seedlings 1 inch (2.54 cm) in diameter at ground line growing under the drip line of infected overstory were infected by western dwarf mistletoe (Scharpf and Vogler 1986).

Occasionally individual tree removal is used to protect larger, adjacent trees from infection, but more often this is done by thinning stands.

Reduction of hazard is another reason to remove individual trees. As trees get older and larger they often become diseased and decayed and become serious hazards in a recreation area. All trees, particularly older ones, should be examined to determine if decay, disease, or other defect has created hazardous conditions.

Thinning

Thinning is a commonly used silvicultural method not only to improve growth and vigor of the residual trees in a stand by reducing competition for light, water, and nutrients but also to reduce pest populations, including dwarf mistletoes. Thinning can be one of the forester's best tools for both vegetation and pest management.

Timing of thinning or removal of dwarf mistletoe-infected trees is important in helping prevent spread of the disease. Cultural activities should begin before the fruit of dwarf mistletoe are ripe to prevent spread and infection of remaining trees.

One precaution must be taken in thinning or removing individual trees in high-value pine stands. A serious root disease fungus (*Heterobasidion annosum*) enters freshly cut stumps of pine and spreads to adjacent trees by root contact. Immediate treatment of stumps with powdered sodium borate is recommended as a method to prevent stump infection.

One advantage of thinning dwarf mistletoe infected stands is that the weakened trees or the most seriously diseased ones or both can be removed, preventing spread and intensification into the residual stand. Another advantage, where possible, is that susceptible host species can be removed leaving nonsusceptible hosts as preferred leave trees or barriers or both to limit spread and buildup of dwarf mistletoe. A third advantage is that weakened, suppressed, and diseased trees often act as focal points for attack and buildup of cambial feeding insects. Removal of these "high risk" trees may prevent insect attack of nearby trees and stands.

The main advantage of thinning, assuming that adequate stocking is present, is that a well thinned stand of trees, spaced at an optimum level for growth and development, will show increased vigor and greater resistance to other stresses and insect attack. For most forest management areas in general, and recreation sites in particular, a well established stand of properly spaced trees is highly desirable, even if some disease may be present. Reducing stocking of advanced regeneration below optimum levels just to "eradicate" or control all disease is not necessarily the best management alternative. Managers may need to consider "living with" some level of disease in order to achieve other management goals. For example, esthetic values need to be considered in thinning recreational sites. If stands are thinned too heavily, or improperly, the scenic or recreational value of the stand may be greatly impaired.

Therefore, in thinning stands for disease control on recreational sites, managers should also consider other objectives, like stocking levels, age distribution, species composition, and effect on esthetics that will result from thinning. Weighing these various factors, and keeping management goals in mind will result in selection of the best pest-vegetation management options.

Pruning

Pruning has been little used in the management of timber producing stands in the West, even though some increase in wood quality often results. Pruning is generally considered too costly and time consuming to justify the effort. However, for the management of some diseases, particularly dwarf mistletoes in recreation areas, pruning care be of value. And pruning can be used along with other silvicultural methods like thinning and individual tree removal to better manage diseased stands. For example, pruning was used in conjunction with poisoning and tree removal to control dwarf mistletoe at Grand Canyon National Park (Lightle and Hawksworth 1973, Maffei 1984). However, at Grand Canyon repeated pruning was apparently needed to control the parasite in some areas.

In California, recent studies suggest that pruning alone may reduce mortality and increase vigor of dwarf mistletoe infected pines (Scharpf and others 1987). Removal of only dwarf mistletoe brooms from trees, irrespective of the rated level of dwarf mistletoe, increased tree vigor and reduced mortality. However, trees with less than about 30 percent of their total height in live crown after pruning generally did not benefit or were damaged more by pruning than by leaving broomed branches. Even trees with high levels of dwarf mistletoe after brooms were removed increased in vigor as long as more than about 30 percent of the live crown remained (*fig. 1*). On the other hand, vigor of unpruned trees generally remained unchanged or deteriorated from 1977 to 1983 (*fig. 2*). Although broom pruning was done mainly to relieve disease stress on the trees and increase resistance to insects, some reduction in spread and buildup of the parasite probably resulted also. In addition, pruning only brooms was considered to be less time consuming and more economical than pruning all infected branches.

Figure 1-Pruning brooms from a Jeffrey pine on the Cleveland National Forest, southern California, increased vigor and helped new crown development. The tree had 50 percent live crown and heavy dwarf mistletoe growth before pruning *(A)*; 20 broomed branches were removed *(B)* in fall 1977. A new crown had developed by May 1982 *(C)*.

Resistance

Most species of dwarf mistletoe in California are considered host specific (Hawksworth and Wiens 1972). *A. campylopodum* occurs mainly on ponderosa and Jeffrey pines but a few other pine species can serve as secondary or less susceptible hosts (Hawksworth and Wiens 1972). Jeffrey pine is considered to be more susceptible to infection by *A. campylopodum* than ponderosa pine (Wagener 1965). Other genera of conifers are immune to infection by this species of dwarf mistletoe.

On high-value sites where dwarf mistletoe is present and where non-hosts also occur, it may be advantageous to manage for the non-host species. A mixed species stand composition will not only insure a certain proportion of dwarf mistletoe free trees, but by having non-host trees among susceptible ones, some reduction of spread and buildup of the parasite will take place.

On some high value sites, only susceptible pine species are present. In these cases it is often difficult to prevent spread and damage from dwarf mistletoe. Planting of non-host trees is one way to alleviate the problem, but site conditions and

Figure 2--Jeffrey pine infected by dwarf mistletoe if left unpruned can suffer heavy loss of foliage. This pine was comparable in size to the one illustrated in *figure 1*, but with about 80 percent live crown and heavy dwarf mistletoe infection in fall 1977 *(A)*. By May 1983, crown decline and reduction in vigor as expressed by loss of foliage and shorter needles was noticeable *(B)*.

management constraints often preclude the planting of introduced tree species.

Planting genetically resistant members of a particular host species would be one way to aid in control of dwarf mistletoe. However, little is known about resistance to dwarf mistletoes within given tree species. Jeffrey pine and ponderosa pine are two species that have shown some resistance, and research is presently underway at the Pacific Southwest Forest and Range Experiment Station to test levels of resistance under both greenhouse and field conditions (Scharpf 1984). Resistant stock is not available for general outplanting at this time, however. Researchers are also searching for other conifer species in the West that show resistance to dwarf mistletoe.

Buffer Strips

Buffer strips or natural openings can be used to prevent spread of dwarf mistletoe from infected to non-infected trees or stands. Because dwarf mistletoes mechanically shoot their seeds, distance of dispersal is limited. The general rule of thumb is that the distance of dispersal is equal to about the height of the parasite within a tree crown. However, in areas with strong winds the distance of spread from tall trees could be somewhat further in the direction of the winds. In small trees, the horizontal distance of spread is usually considered to be a maximum of about 30 feet (10 m). Therefore, buffer strips or physical separation of trees can prevent spread--particularly among young trees.

Buffer strips can be open areas or they can consist of non-host species. If strips with large non-host species are used then the distance between infected and uninfected stands can be relatively short. The non-host trees will act as a physical barrier to spread. If open strips or strips with small non-host trees are used, then the rule of thumb stated above for spread should be applied.

Whatever strip method is applied, dwarf mistletoe can be excluded from an area by using cleared strips or natural openings or by using strips bearing non-host trees.

INDIRECT MANAGEMENT METHODS

In some cases it is not practical or possible to prevent spread or to suppress dwarf mistletoe populations in recreation areas. Therefore, indirect management measures must be taken to reduce disease stress. This practice can often be done by improving tree vigor by other means. Indirect methods of management that may be used in some situations to reduce impact from dwarf mistletoe are aimed at reducing other tree stresses. These include irrigation, fertilization, brush or weed control, and similar treatments that improve tree vigor. These methods are used to maintain or improve vigor of trees used in urban forestry or general arboriculture. Some of these methods should have application in many high value forest management areas, as well.

Irrigation

In many forests in the West, water is a limiting factor for tree growth and vigor. In years of normal or above normal precipitation, most native forest trees receive adequate water for growth and survival. During periods of drought, however, tree growth and vigor are reduced noticeably, and resistance to insect and disease damage is lowered markedly. It is often during these periods of drought that tree death and damage from insects and diseases takes place (Smith and others 1983, Smith and Roettgering 1982, Wood and others 1979).

On recreation sites, where water is available, irrigation during dry years could relieve moisture stress, thereby reduceing the probability of death from insects or diseases or both. Unfortunately, information is lacking on when and how much irrigation is needed to prevent moisture stress and associated pest damage in high value ponderosa and Jeffrey pine trees. In mountain residential areas in Colorado, irrigation has reduced the damaging effects of *A. vaginatum* on ponderosa pine and of *A. americanum* Nutt. ex Engelm. on lodgepole pine (*P. contorta* ssp. *latifolia* Engelm. [Critchfield]). However, until more specific information is available, only very general guidelines can be proposed:

- Large trees require more water than small ones.
- Timing of irrigation to coincide with the season (or months) of greatest stress is necessary.
- Trees more heavily infected have greater need for irrigation than lightly infected or uninfected ones in order to better cope with disease stress and ward off insect attack.

Until more information is available on when and how much to irrigate pines to prevent disease and insect damage, managers will have to use sound judgement and knowledge based on local conditions. On the basis of what is known, we conclude that irrigation during periods of moisture stress will not increase, and may even help prevent, insect and disease related mortality.

Fertilization

In some forest stands, the addition of nutrients, nitrogen in particular, has noticeably increased tree growth (Cochran 1973, Graham and Tonn 1979). But the effect of fertilizing forest trees in order to prevent death and damage from insects and diseases is only partly known (Peters and Parmeter 1982). In a few cases fertilization has aggravated an insect or disease problem, and in other instances it mitigated it. Peters and Parmeter (1982) conclude from their review of the effects of forest fertilization on insects and diseases that there is little direct or indirect evidence that fertilizing would affect most insect or disease activity.

Dwarf mistletoe is one exception, however. Knutson (1973) found that healthy and dwarf mistletoe infected greenhouse-grown ponderosa pine seedlings fertilized with nitrogen grew considerably taller than did unfertilized healthy and infected seedlings. Increasing growth of trees in the field by the use of fertilizers is one way to mitigate damage from dwarf mistletoe. For example, Scharpf and Parmeter (1976) have shown that in the absence of overstory dwarf mistletoe, young firs growing well in height (1 foot or more per year) can outgrow the vertical spread of dwarf mistletoe within the tree. Although not yet demonstrated, the same phenomenon may occur in pines. If the addition of nutrients to young, high value pines enables them to outgrow the upward spread of dwarf mistletoe, then fertilization may be another method to aid in control of these pathogens. In addition, increased vigor of fertilized trees may enable them to better resist the effects of insect attack or drought.

Brush or Weed Control

Unwanted weeds, brush, and small understory trees can exert a good deal of stress on forest trees. Unwanted vegetation competes for water, nutrients, and sunlight. Small trees are particularly subject to stunting and even death as a result of severe competitive stress. Even large trees can suffer moisture stress and growth reduction from weed competition (Oliver 1984).

On high value sites where soil moisture is limited, vegetation control likely can aid in reducing mortality from bark beetle attack of dwarf mistletoe infected trees, particularly during periods of drought. If it is desirable to maintain the understory vegetation in certain high value recreational areas where soil moisture is limited, irrigation should be considered as a possible method to relieve stress in dwarf mistletoe infected trees.

Regulate Human Impact

The recreational site user often exerts a direct effect on the forest vegetation, and this effect on trees already weakened by other stresses can lead to increased disease and insect activity, accelerated mortality, increased hazard, and general deterioration of the forest recreational environment. Soil compacttion and physical damage to trunks and roots by vehicles, malicious damage by persons wielding axes, knives, and saws, and burning of trunks and foliage by misplaced campfires are just some examples of human activities that can damage and further stress trees. Many of these adverse effects can be prevented by educational programs, proper campground design, and enforcement of appropriate regulations governing campground use. Nonetheless, even in the best designed and managed campgrounds, vegetation will probably suffer some effects from recreational development and human activeities. Management agencies need to recognize that human activities can further weaken or injure trees and take whatever steps are reasonable to keep them to a minimum.

MANAGEMENT STRATEGY

Managers have a number of factors to consider in the care and maintenance of high value, recreational forests. Mitigating damage caused by dwarf mistletoe may be only one consideration. Where dwarf mistletoe is a problem and where decisions need to be made on how best to suppress it, a variety of factors should be considered in selecting the best management strategies.

For reducing damage from dwarf mistletoe in high value ponderosa and Jeffrey pines we suggest this approach:

- List goals and constraints to management.
- Keep in mind the values to be protected.
- Evaluate and select the most useful dwarf mistletoe suppression options based on the resource to be managed.

We have developed flow charts that can help managers decide on the steps aimed at suppressing and preventing the growth and spread of western dwarf mistletoe on pines in forest recreation areas (*figs. 3-5*). The charts are not intended to provide definitive answers to dwarf mistletoe problems. Rather, they are intended as guidelines to suppressing and preventing western dwarf mistletoe in (a) individual trees, (b) even-aged stands, and (c) all-aged or multistoried stands.

Conditions and management objectives vary markedly, therefore not all elements of these guides may apply to all forest recreation situations. However, they should assist managers in developing and implementing tree or stand management plans for mitigating damage and losses from dwarf mistletoes and associated pests in many forest recreational areas.

In addition to the information presented in these charts, managers should also consider indirect management methods described earlier.

Terms used in the charts are defined as follows:

- Bole infection: a dwarf mistletoe infection of the trunk that originated either as a direct infection of the trunk or entered the trunk through an infected branch. Branch infections with shoots or swollen branch tissue within 3 inches (8 cm) of the trunk are considered bole infections.
- Branch and/or broom prune: removal of an infected branch or broom where it enters the tree trunk.
- Broom: a branch, usually infected by dwarf mistletoe for several years, that has developed into an abnormally dense growth caused by the proliferation of lateral branches and twigs.
- Percent live crown: an estimate of the trees total height that consists of live branches and foliage. Openings and missing portions of the crown are deducted from the total live crown estimate.
- Dwarf mistletoe rating: to rate the intensity of dwarf mistletoe in a tree, the level of infection is visually estimated in the lower, mid, and upper crown. For each crown portion, no infection=0; less than half the branches infected= 1; and more than half the branches infected=2 (any portion of the crown with a broom=2). Level of infection in the tree equals the sum of the numbers, O=no infection; 1 to 3=light infection; and 4 to 6=heavy infection.

CONCLUSIONS

Proper management of dwarf mistletoe infected, high value pine stands can be an expensive and time consuming task. But protection of the values at stake are often worth the time and effort. Managers need to develop a long term plan of management that includes the resource values, costs of management, and alternatives available to best reduce mortality and damage from dwarf mistletoe and associated pests. Because site, disease, insect, and management conditions vary from forest to forest no one approach to management will apply everywhere. Each manager needs to consider what method or combination of methods should be used to best manage the area. Considering all approaches to pest management includeing dwarf mistletoe suppression, increasing tree health and vigor, vegetation management, and regulation of human impacts should result in healthier, safer, more esthetically pleasing, long lived recreational forests.

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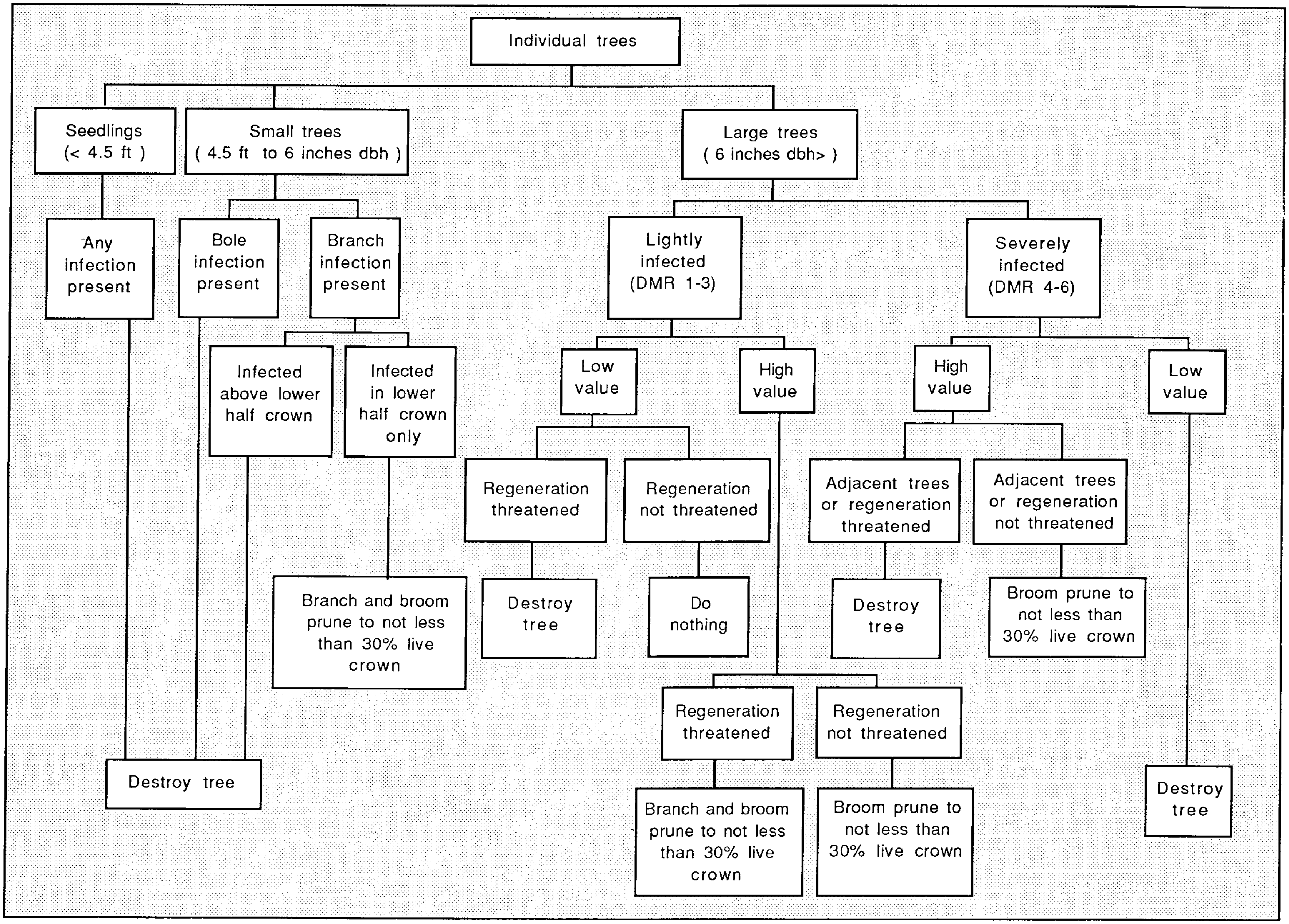

Figure 3—Flow chart for deciding on management of individual ponderosa and Jeffrey pines.

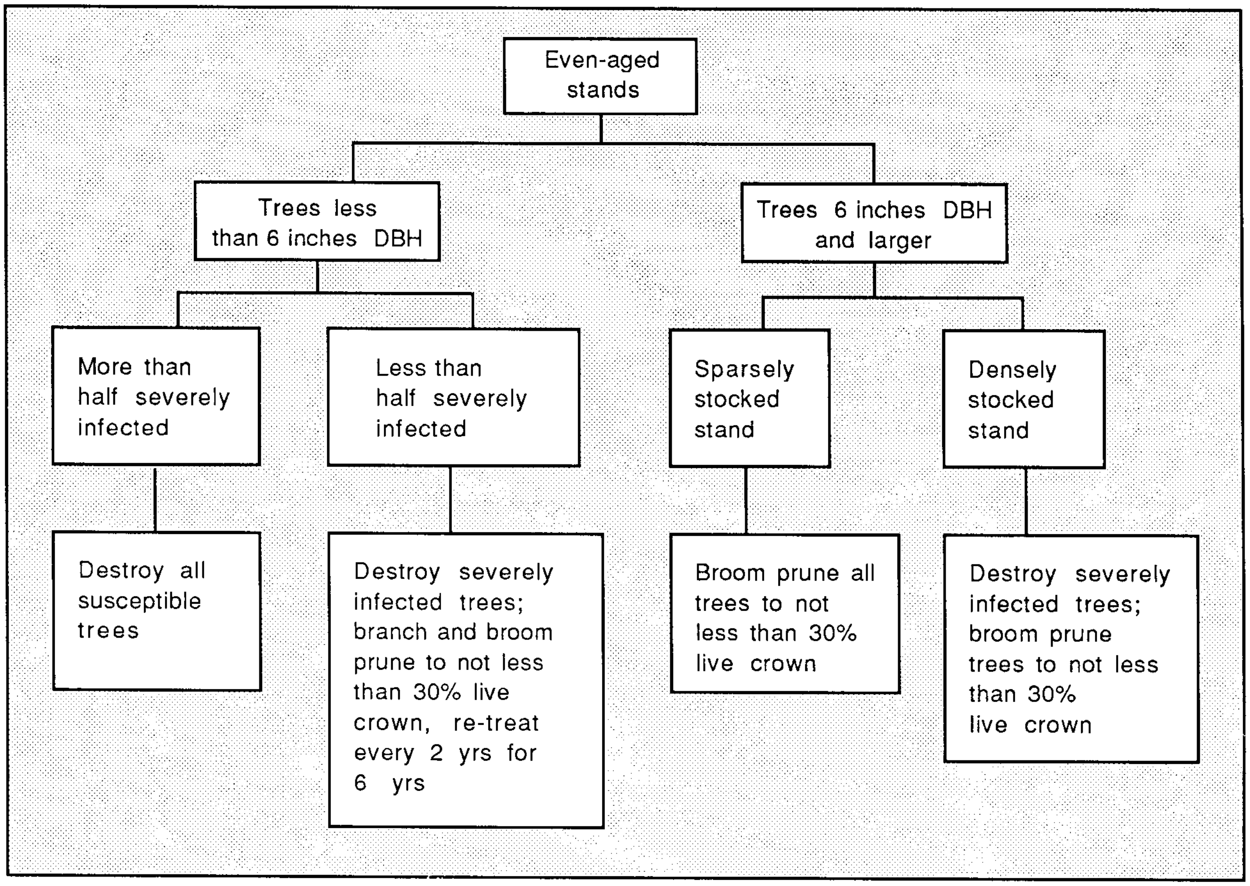

Figure 4-Flow chart for deciding on management of ponderosa and Jeffrey pines in even-aged stands.

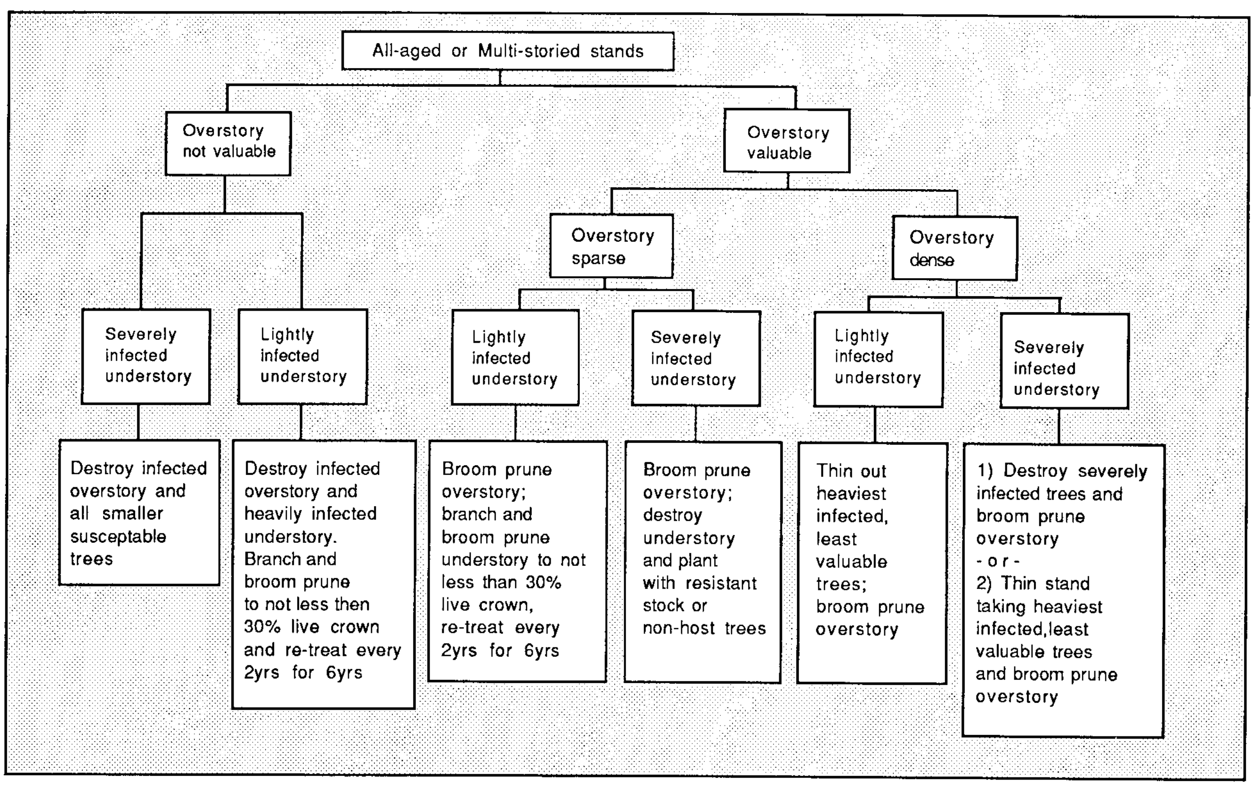

Figure 5-Flow chart for deciding on management of ponderosa and Jeffrey pines in all-aged or multistoried stands.

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Pines on many high value recreational sites in the Western United States suffer damage and death from western dwarf mistletoe (*Arceuthobium campylopodum* Engelm.). Dwarf mistletoe alone, however, is not solely responsible. Other pests and environmental conditions interact with dwarf mistletoe to damage and kill trees. An integrated pest management approach can help solve dwarf mistletoe-pest related problems. The approach includes setting management goals, considering the combined effect of all other pests and environmental impacts, and using direct treatments aimed at lowering pest populations, preventing spread and infection, and reducing hazard. These direct treatment methods include individual tree removal, thinning, pruning, buffer strips, and use of resistant trees or non-host species. Indirect treatments such as irrigation, fertilization, vegetation management, and regulating human impacts can also be used to help alleviate environmental or physical stresses that weaken trees and make them more subject to pest impacts.

Retrieval Terms: western dwarf mistletoe, *Arceuthobium campylopodum,* integrated pest management, pest damage, control, forest recreational areas, *Pinus ponderosa, P. jeffreyi*