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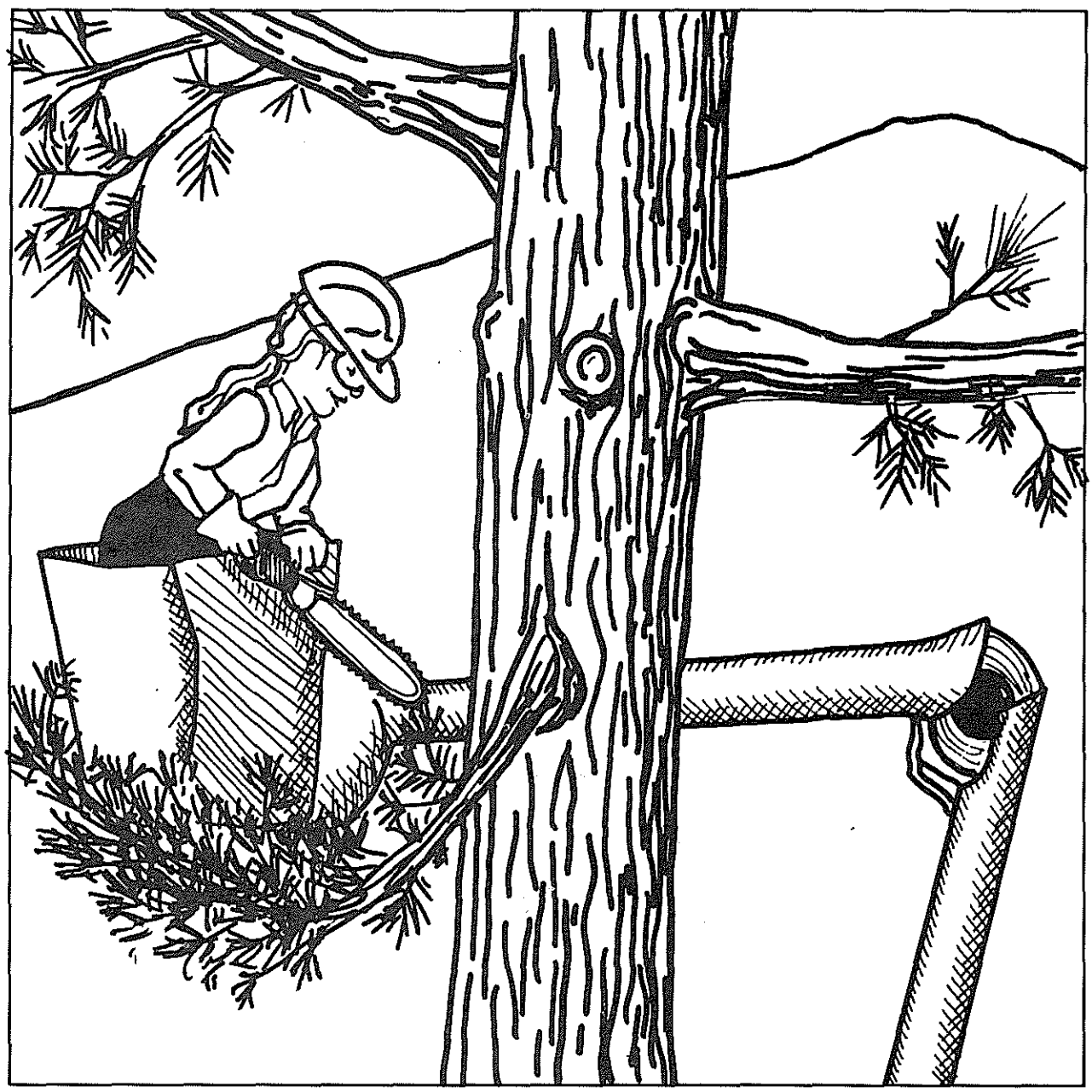
Pruning Dwarf Mistletoe Brooms Reduces Stress on Jeffrey Pines, Cleveland National Forest, California

Robert F. Scharpf Richard S. Smith Detlev Vogler



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IN BRIEF. . .

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Western dwarf mistletoe (*Arceuthobium campylopodum* Engelm.) has been recognized for years as a damaging disease organism of Jeffrey pine (*Pinus jeffreyi* Grev. & Balf.) in southern California. On Laguna Mountain, Cleveland National Forest, for example, heavy mortality associated with dwarf mistletoe and insects threatens high value recreational areas. In the southwestern United States, research has shown that pruning the brooms off dwarf mistletoe infected ponderosa pines (*P. ponderosa* Dougl. ex Laws.) increases vigor and reduces mortality considerably (Lightle and Hawksworth 1973).

We studied the effect of pruning brooms on vigor, growth, visual quality, and longevity of dwarf mistletoe infected Jeffrey pine on Laguna Mountain. For the study, we selected 757 Jeffrey pines 6 to 24 inches (15 to 61 cm) in diameter at breast height and with varying levels of dwarf mistletoe and live crowns. The pines chosen were considered to represent the type of trees that would be of high value on a recreational site. Trees were grouped by size and dwarf mistletoe rating. Half of each group were selected at random and pruned of brooms.

The visual appearance of many trees was changed dramatically by pruning. Pruning removed a substantial proportion of the crown, particularly for larger trees with heavy dwarf mistletoe infection and full crowns. However, severe pruning did not appear to reduce vigor or kill trees unless the percentage of live crown fell below about 30 percent. On the contrary, pruning brooms appeared to increase vigor after 5 years and to reduce disease stress in many trees, even though the levels of dwarf mistletoe did not change markedly. Radial growth did not appear to be influenced by pruning, except growth after 5 years decreased in trees pruned to less than 30 percent live crown.

Mortality of pruned and unpruned trees from 1977 to 1986 was low and nearly the same each year except for October 1980 to September 1981 and October 1984 to September 1985, rain years of below-normal precipitation. In those years 21 of 28 trees that died were unpruned. Most dead trees were heavily infected with dwarf mistletoe and attacked by cambial feeding insects. Some dead trees were also infected by a root pathogen (*Fomes annosus* [Fr.] Cke.). Pruning brooms presumably relieved disease and moisture stress, thereby preventing successful attack by insects or damage by root diseases or both.

Managers should consider pruning brooms from high value Jeffrey pines in southern California to reduce disease stress during periods of below normal precipitation. Reducing this stress helps prevent mortality from damaging insects and root disease. Many trees have a substantial proportion of live crown removed by pruning, and some are reduced in visual quality. However, increased vigor from pruning will allow new live crown to develop over time, and pruning should enhance the longevity and recreational value of the treated trees.

INTRODUCTION

Diseases and insects have plagued the Cleveland National Forest in southern California for decades. Pines continue to be damaged and to die at an alarming rate (Trostle 1959, Swain 1972, Wood and others 1979), even though an active and expensive maintenance control program has been underway against western pine beetle (*Dendroctonus brevicomis* LeConte) and the California flathead borer (*Melanophila californica* Van Dyke) since the 1950's (Swain 1972). Reports suggest that mortality is the result of more than just insect activity and that climatic factors and diseases also play an important role (Trostle 1959, Swain 1972, Wood and others 1979, Vogler and Scharpf 1981).

Dwarf mistletoe (*Arceuthobium campylopodum* Engelm.) is one disease agent that is widespread on Jeffrey pine (*Pinus jeffreyi* Grev. & Balf.) in the area. Trostle (1959) suggested that the combination of this mistletoe and California flatheaded borers is the primary cause of damage, particularly for large-diameter trees—although some damage is due to flatheads or mistletoe alone. Other serious diseases found on the forest, such as annosus root rot (*Fomes annosus* [Fr.] Cke.) and armillaria root disease (*Armillaria mellea* Vahl. ex Fr.), also contribute to mortality of Jeffrey pines and other tree species (Wagener 1942). Wood and others (1979) attributed 90 percent of the mortality of Jeffrey pines to a combination of California flatheaded borer, dwarf mistletoe, and annosus root rot. Tree mortality due to pest interactions may best be reduced by integrated pest control. Control of dwarf mistletoe, which weakens trees and predisposes them to insect attack, is a logical adjunct to direct insect control.

In the Southwest, brooms caused by infection of ponderosa pines by *A. vaginatum* ssp. *cryptopodum* [Engelm.] Hawks. & Wiens reduced radial growth and, presumably, vigor more than that of infected pines without brooms. Even for heavily infected trees, radial growth rate of trees without brooms was reduced much less (14 pct) than for trees with brooms (59 pct) (Hawksworth 1961). More recent studies at Grand Canyon, Arizona, indicate that pruning infected branches of even heavily infected ponderosa pines will increase their vigor and prolong their life considerably (Lightle and Hawksworth 1973). These studies, however, did not include specific information on how pruning influenced dwarf mistletoe rating, amount of live crown removed, or tree longevity.

We undertook the study reported here to determine the effects of pruning brooms on dwarf mistletoe infected Jeffrey pines and to answer the following questions. Does pruning brooms increase tree vigor and longevity? Are dwarf mistletoe intensity and percentage of live crown markedly reduced by pruning? Are the visual and esthetic characteristics of trees adversely affected by pruning?

Our decision to study the effects of pruning only broomed branches from dwarf mistletoe infected Jeffrey pines was based on three assumptions. (1) We could not prune all the infected branches without weakening or killing many trees due to the removal of an excessive amount of live crown. (2) Much of the stress placed on the tree is the result of large old broomed branches, and removing this stress by pruning would aid in improving tree growth and aid in combating other agents that are associated with mortality. (3) Pruning only the broomed branches would be simpler and less costly and would leave trees in a more desirable condition from a recreational standpoint than would more thorough pruning.

This paper reports on the response of dwarf mistletoe infected Jeffrey pines to pruning in southern California. Our criteria for determining the success of pruning were based on the following: (1) How many trees survived the first 8 years after pruning? (2) Did pruning appear to increase tree vigor and prolong the life of pruned trees? (3) Was the level of dwarf mistletoe infection reduced in pruned trees? (4) Was sufficient live crown left after pruning to justify the operation? Other questions that we addressed and that we will attempt to answer in cooperation with local managers are these: Did the pruning adversely affect the esthetic or recreational value of the trees? Was the treatment worth the expenditure of money and effort?

METHODS

The area chosen for study was Laguna Mountain on the Descanso District of the Cleveland National Forest. Laguna Mountain is part of the peninsular range in southern California and is about a 1-hour drive from San Diego, the second largest city in California. Because of its proximity to a large population center, Laguna Mountain is one of the most heavily visited recreational areas in the State—often receiving more than a million visitor-days of use annually. The lower elevations of the mountain support mainly brushy chaparral species, whereas, the higher portions support fine stands of Jeffrey pine, Coulter pine (*P. coulteri* D. Don), and black oak (*Quercus kelloggii* Newb.). Several thousand acres of Jeffrey pines and—to a lesser extent—Coulter pines are severely infested with western dwarf mistletoe.

In June 1977, we selected 757 Jeffrey pines for study. Trees were not selected at random but were chosen by the local

forest silviculturist to represent the type of trees that would be considered for control of dwarf mistletoe by pruning in a high-use recreational area. The trees ranged from about 6 to 24 inches in diameter and were infected to varying levels with dwarf mistletoe. Some pines were open growing, whereas, others were growing close to other trees. No trees judged to be suppressed by competition were chosen, however. Trees within or adjacent to known root-rot centers were also avoided.

At the time of selection, the trees were numbered with a metal tag and the following data were taken: diameter at breast height (d.b.h.) to the nearest 0.1 inch (0.25 cm); percentage live crown—the percentage of tree height in living crown, estimated to the nearest 10 percent; and dwarf mistletoe rating (DMR)—a rating of infection from 1 to 6 based on the intensity of dwarf mistletoe in the lower, middle, and upper portions of the living crown (Hawksworth 1977). Trees rated 1 to 2 were considered lightly infected, 3 to 4 moderately infected, and 5 to 6 heavily infected.

Trees were then paired by computer on the basis of their percentage live crown, DMR, and estimated percentage of live crown that would be left after pruning. One tree of each pair was then designated to be pruned and the other to remain unpruned as a control. Photo points were established and a black-and-white photograph taken of each tree before pruning.

Trees were pruned in November 1977 under contract with a local tree pruner. Only branches broomed by dwarf mistletoe were pruned, and they were selected and pointed out to the pruners by Forest Service personnel on the ground. Most trees were pruned with a chain saw from a "boom truck," although a few were pruned from the ground. Branches were pruned flush with the trunk.

Data recorded after pruning included percent live crown to the nearest 10 percent, DMR, number of brooms removed (determined by counting the number of fresh pruning scars), and tree condition (a few trees died or were dying between tree selection in June and pruning in November 1977). Shortly after pruning in 1977 and again in 1983 the pruned trees were rephotographed from the photo points.

From 1978 through 1986 tree condition was noted yearly, and if mortality occurred, the causes were determined. Several trees were rejected from the study because they were missing, cut when green, or not pruned. Also, sample size varied slightly in the analyses because we failed to take some data on a few trees.

Five years after pruning, 73 (10 pct) of the pruned and unpruned trees in each of two DMR groups (light 1-3, heavy 4-6), and four live crown ratio groups (10-20, 30-40, 50-60, and 70-80 pct) were sampled at random and measured for radial growth rate. One increment core containing at least 10 annual rings was taken at d.b.h. from each sample tree, and 5 years' radial growth before and after pruning were measured to the nearest millimeter.

A contingency test was used to ascertain if the variables of tree size, DMR, and percentage of live crown operated independently or interacted to determine number of brooms removed, reduction of DMR, and live crown after pruning.

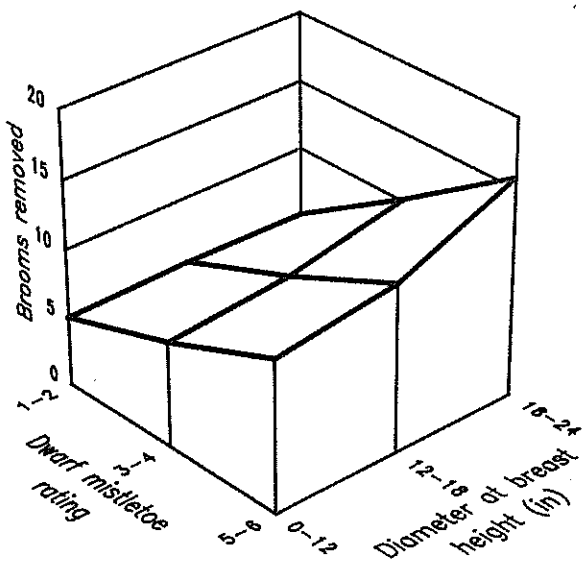
To determine the effect of pruning brooms on radial growth, an F-test based on SAS Type III mean squares (SAS Institute Inc. 1982) was performed using the variables of pruning or no pruning, live crown ratio, and DMR.

RESULTS AND DISCUSSION

Effects of Pruning on Trees and on Infection

Pruning broomed branches immediately affected many of the trees, particularly those from which numerous brooms were removed. Live crowns were reduced markedly, and the appearance of the trees was altered dramatically. Lightly pruned trees were less seriously affected.

An analysis of data from pruned trees indicated that the variables d.b.h., DMR, and percent live crown did not operate independently but interacted to affect the number of



DMR	D.b.h.	Standard error	Trees
1-2	0-12	2.4	10
1-2	12-18	3.0	8
1-2	18-24	4.0	4
3-4	0-12	1.1	65
3-4	12-18	1.4	44
3-4	18-24	1.7	24
5-6	0-12	0.8	101
5-6	12-18	1.0	83
5-6	18-24	1.5	27

Figure 1—The number of dwarf mistletoe brooms removed was directly related to both dwarf mistletoe rating (DMR) and tree diameter at breast height (d.b.h.).

brooms removed, the DMR, and percent live crown remaining after pruning.

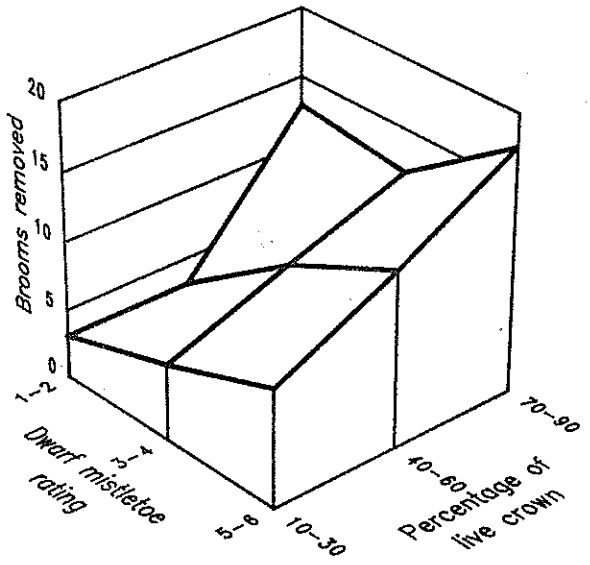
The average number of brooms removed was directly related to both tree d.b.h. and DMR *(fig. 1)*. As both d.b.h. and DMR increased, the mean number of brooms that were removed also increased significantly. A way to explain this relationship is that larger trees are generally older than smaller ones and have more branches that have become infected. Also, on older trees, infected branches have had a longer period of time to develop into brooms. Thus, tree size is related to age, which in turn is related to buildup of mistletoe and the number of brooms that develop.

DMR and percentage of live crown also interact to affect broom development *(fig. 2)*. Irrespective of size, trees with increasing levels of dwarf mistletoe and a high proportion of their height in living crown develop more brooms than do trees with small crowns or low levels of dwarf mistletoe infection. These results show that trees with large crowns and high DMR have more infected branches that can develop into brooms, and that heavy levels of dwarf mistletoe indicate longer periods of infection and greater opportunity for broom formation.

One question that needs to be answered before controlling dwarf mistletoe by pruning brooms is this: How much live crown can be removed by pruning? This information is important to managers because if too much crown is removed the tree may be seriously weakened, badly impaired in recreational value, or killed. Minimum percentages of live crown to leave after pruning to avoid mortality and loss of vigor are suggested below.

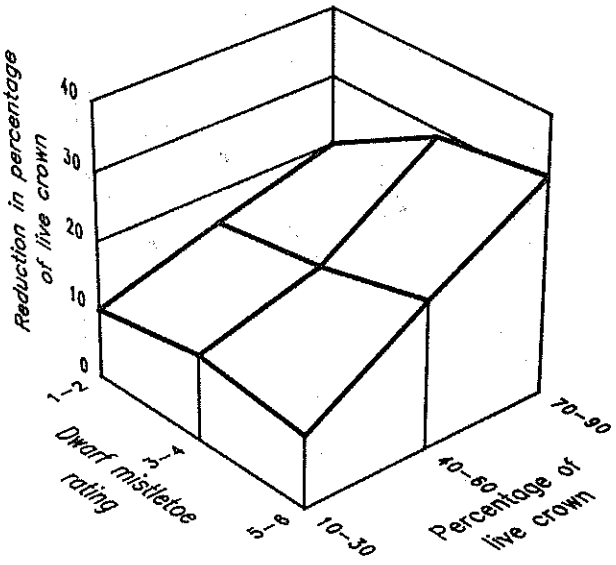
The amount of live crown removed by pruning brooms was directly related to both the DMR and the percentage of live crown before pruning *(fig. 3)*. For trees with live crowns smaller than 30 percent, the amount of crown reduced by pruning was about 10 percent or less regardless of the DMR. For trees with larger crowns the average reduction ranged from about 20 to 30 percent, depending on the DMR. With some exceptions, as will be reported in the section on mortality, most trees were successfully pruned without weakening them or destroying their recreational value.

Another way to determine how pruning will reduce live crown is to estimate the number of brooms that need to be pruned. When more brooms are removed, the crown is reduced more *(fig. 4)*. DMR apparently has little influence on reduction of live crown because about the same amount of crown is removed when a given number of brooms are pruned, regardless of the DMR. Therefore, DMR alone cannot be used as a valid estimate of the number of brooms to be removed or of the proportion of the live crown that will be reduced as a result of pruning. The best approach to estimat-



DMR	PLC	Standard error	Trees
1-2	10-30	6.2	1
1-2	40-60	1.4	17
1-2	70-90	3.1	4
3-4	10-30	2.6	5
3-4	40-60	0.6	89
3-4	70-90	1.0	39
5-6	10-30	1.6	18
5-6	40-60	0.5	168
5-6	70-90	1.2	25

Figure 2—The number of dwarf mistletoe brooms removed was directly related to both dwarf mistletoe rating (DMR) and percentage of live crown (PLC).



DMR	PLC	Standard error	Trees
1-2	10-30	10.5	1
1-2	40-60	6.2	17
1-2	70-90	4.6	4
3-4	10-30	4.2	5
3-4	40-60	1.6	89
3-4	70-90	1.8	39
5-6	10-30	2.2	18
5-6	40-60	0.8	168
5-6	70-90	1.7	25

Figure 3—Reduction in percentage of live crown by broom pruning was directly related to the dwarf mistletoe rating (DMR) and percentage of live crown (PLC) before pruning.

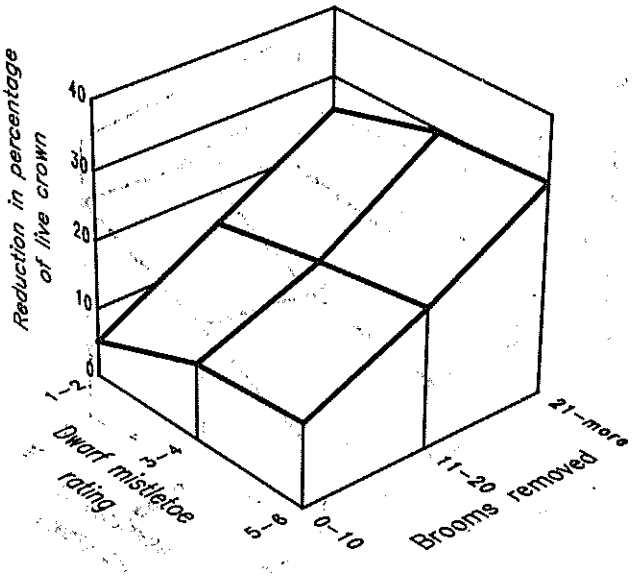
ing the amount of live crown that will be reduced by pruning is to count or estimate the number of brooms that will be removed.

Another critical question asked by managers is this: How much is the level of dwarf mistletoe reduced in a tree as a result of broom pruning? Knowledge about the residual levels of dwarf mistletoe after pruning is needed to judge how rapidly the parasite will intensify in pruned trees. The value of broom pruning may in part be based on how much the levels of dwarf mistletoe are reduced. In general, the average DMR was reduced by broom pruning only about 0.2 to 1.0 on trees of all rated levels of infection irrespective of the number of brooms pruned *(fig. 5)*. Although some dwarf mistletoe is removed by broom pruning, sufficient infection is left on nonbroomed branches so that the DMR as determined by the Hawksworth (1977) rating system does not change markedly. Therefore, lowering DMR alone cannot be used as justification for broom pruning. Also, further research is needed to determine how rapidly brooms develop from remaining dwarf mistletoe in pruned trees.

Pruning apparently did not affect 5-year radial growth rate, in a 10 percent sample of the study trees. Growth rates before and after pruning were highly variable among the trees sampled, and no significant differences could be shown for pruned and unpruned trees before or after pruning with different live crown ratios or different levels of dwarf mistletoe. The only relationship that showed a statistically significant difference ($P<.05$) was that trees with live crown ratios of 10-20 percent grew slower both before and after pruning than did trees with live crown ratios of 30 percent or greater. Radial growth of trees with 10-20 percent live crown ratios was on the average about 1 mm per year, or about half as much as trees with greater live crown ratios. Increasing the sample size and measuring growth 10 years rather than 5 years after pruning may provide a better understanding of the effects of broom pruning, live crown ratio, and dwarf mistletoe on radial growth.

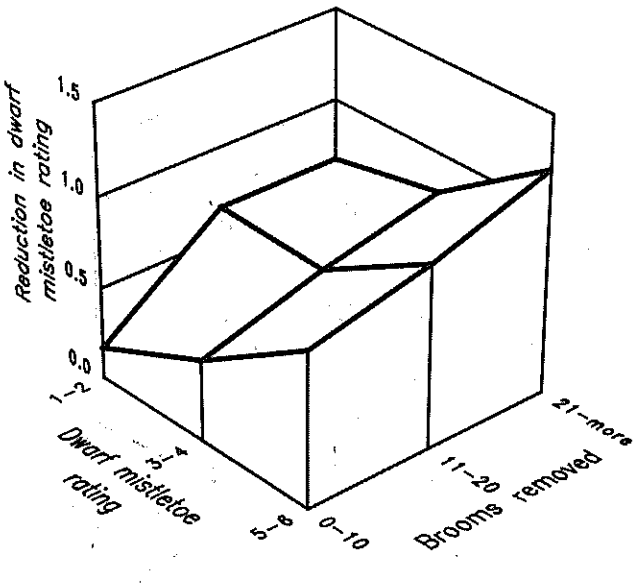
Tree Mortality and Vigor

Sixty-nine test trees died from November 1977 to May 1986. The proportion of pruned and unpruned trees that died each year was inconsistent, however *(table 1)*. No test trees died between November 1977 and April 1978, 5 months after pruning. One and two years later, more pruned than unpruned trees died. Most of the pruned trees that died had little live crown remaining after pruning, and some also had a high remaining DMR. We did not expect severely pruned trees to survive very long. In addition, trees with low percentage live crown are of questionable esthetic and recreational value even if they do survive. We believe that the combination



DMR	Brooms	Standard error	Trees
1-2	0-10	3.6	20
1-2	11-20	10.1	1
1-2	≥21	10.1	1
3-4	0-10	1.5	93
3-4	11-20	2.0	35
3-4	≥21	4.1	5
5-6	0-10	1.1	101
5-6	11-20	1.2	88
5-6	≥21	2.0	22

Figure 4—Reduction in percentage of live crown was directly related to the number of brooms removed and was not influenced significantly by dwarf mistletoe rating (DMR).



DMR	Brooms	Standard error	Trees
1-2	0-10	0.39	20
1-2	11-20	1.08	1
1-2	≥ 21	1.08	1
3-4	0-10	0.16	93
3-4	11-20	0.21	35
3-4	≥ 21	0.44	5
5-6	0-10	0.12	101
5-6	11-20	0.13	88
5-6	≥ 21	0.21	22

Figure 5—Reduction in dwarf mistletoe rating (DMR) by broom pruning was directly related to number of brooms pruned and to a lesser degree by the DMR before pruning.

of low percentage live crown and high remaining DMR were the primary causes of death among some of the pruned trees during the 2 years after pruning. Except for 1981-82 and 1984-85, mortality was relatively low. During 1981-82, mortality was greater than in any other year and occurred almost entirely among unpruned trees, whereas during 1984-85 mortality occurred about equally among pruned and unpruned trees.

Not all heavily pruned trees died. Many survived, even with live crown percentages as low as 20 percent, and some even appear to be increasing in growth and vigor. For example, a tree with 70 percent live crown and DMR 6 that was pruned to 30 percent live crown and DMR 4 survived and was noticeably improved in growth and vigor 6 years later *(fig. 6)*. Little mortality occurred and crown growth improved among nearly all the other heavily pruned trees with high DMR.

Only a few lightly infected trees (DMR 2 or less) died during the test period, and annosus root disease was a contributing factor to mortality. Except for the lightly infected pruned trees, the rate of mortality increased with an increase in DMR of both pruned and unpruned trees *(table 2)*. Therefore, mortality of Jeffrey pines on Laguna Mt. appeared closely related to degree of dwarf mistletoe infection particularly when pines are grouped into light, moderate, or heavy infection classes using the Hawksworth rating system. We did not include any noninfected trees in our study so we do not know the mortality rate of trees without dwarf mistletoe. We believe, however, that it is similar to that of lightly infected trees.

Other factors besides severe pruning and high levels of dwarf mistletoe appeared to be involved in tree death. Flat-

Table 1—*Pruned and unpruned test trees that died from 1977 to 1985, Cleveland National Forest, California*

Dates	Interval	Live Trees	Dead trees		
			Pruned	Unpruned	Total
	Months				
Nov. 1977 to Apr. 1978	5	741	0	0	0
Apr. 1978 to Apr. 1979	12	741	6	3	9
Apr. 1979 to May 1980	13	732	4	2	6
May 1980 to May 1981	12	726	3	3	6
May 1981 to May 1982	12	720	1	14	15
May 1982 to May 1983	12	705	6	4	10
May 1983 to May 1984	12	695	3	3	6
May 1984 to May 1985	12	689	2	2	4
May 1985 to May 1986	12	676	6	7	13
Totals			31	38	69

a b c

Figure 6—Broom pruning of this Jeffrey pine *(a)* reduced the percentage of live crown from 70 to 30 percent, and the dwarf mistletoe rating from 6 to 4 in 1977 *(b)*. By 1983, this tree had improved noticeably in growth and vigor *(c)*.

Table 2—*Mortality of pruned and unpruned Jeffrey pines in 1985, 8 years after pruning, by dwarf mistletoe rating, Cleveland National Forest, California*

DMR[1]	Pruned			Unpruned		
	Trees	Dead	Pct	Trees	Dead	Pct
1-2	[2]65	3	5	19	0	0
3-4	194	8	4	134	7	5
5-6	108	[3]20	19	221	31	14
Total	367	31	8	374	38	10

[1]Dwarf mistletoe rating immediately after pruning in 1977.
[2]Includes seven trees with no visible dwarf mistletoe after pruning.
[3]Most mortality resulted from excess pruning.

headed borers, annosus root disease, and moisture stress caused by below-normal precipitation in 1980-81 and 1984-85 were also associated with and probably contributed to mortality. In 51 of the 69 dead trees, we found trunks extensively colonized by the California flatheaded borer, or roots with annosus root disease, or both. Eleven trees died from dwarf mistletoe and flatheaded borers only, and one dead tree was colonized by both flatheaded borers and the California five-spined engraver (*Ips confusus* [Lec.]). For the remaining six trees, we were not able to determine precisely the causes of death. We believe that moisture stress brought on by below-normal precipitation is closely related to tree mortality.

In general, most of the pruned and unpruned trees at Laguna Mountain appeared to show improved vigor over the 8-year test period. This improvement can probably be attributed as much to above-normal annual precipitation as to increased vigor from pruning. Weather data are not available for Laguna Mountain but are recorded at nearby Cuyamaca State Park (elev. 4640 ft. [1414 m]). Except for rain years 1980-81 and 1984-85, precipitation for the period 1977-85 was above normal at Cuyamaca weather station *(fig. 7)* and undoubtedly at Laguna Mountain. A rain year is October through September and better represents precipitation that affects tree moisture stress and growth than does precipitation measured on a calendar year. Excluding the Jeffrey pines that apparently died because of excessive pruning, mortality was low among the test trees during these years of above-normal precipitation *(fig. 7)*.

In rain year 1980-81, precipitation was well below normal, and nearly twice as many unpruned trees died than had died during the previous 3 years combined. In May 1981 about 22 percent of the total mortality was recorded *(table 1, fig. 7)*. In 1984-85, a year when precipitation was slightly below normal, the second heaviest mortality (19 pct) occurred. Thus, 41 percent of the tree death occurred during the 2 years of below-normal precipitation. These findings generally agree with those of Schultz and Allison (1982), who reported that the underlying factor common in recent pine mortality was below-normal precipitation from mid 1980 through late 1981. In addition they reported low mortality during 1978 through early 1980, years of above-normal precipitation. They also suggested that mortality from insect and disease attack will not subside until precipitation returns to normal. However, we found that trees pruned of dwarf mistletoe brooms suffered little mortality during the drought of 1980-81. We believe that pruning brooms from dwarf mistletoe infected trees, except when done to excess, relieves the trees of disease stress and allows them to better survive moisture stress brought on by below-normal precipitation. However, mortality was still somewhat greater among trees with high DMR after pruning than among less heavily infected trees *(table 2)*. Broom pruning did not entirely relieve trees of disease stress, and did not affect tree survival during periods of above-normal precipitation. Whether pruning will allow trees to survive two or more successive years of drought, however, is not known.

In summary, for the first 2 years, pruned trees apparently died primarily from overpruning alone or from excessive pruning and high residual dwarf mistletoe that weakened

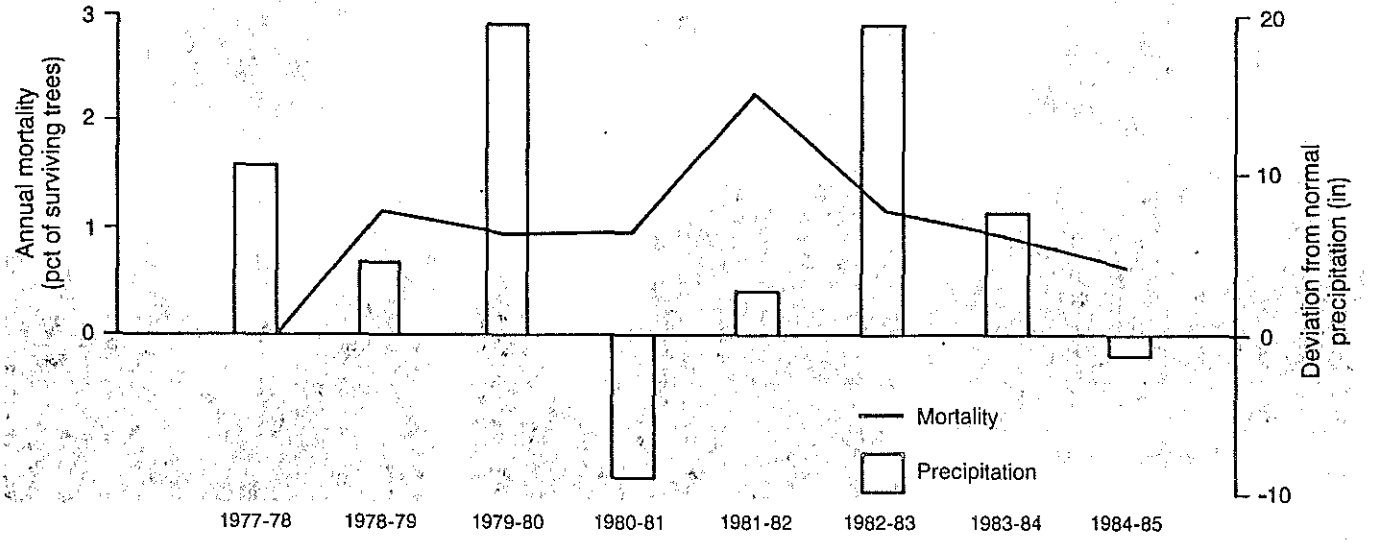


Figure 7—Annual mortality of all test Jeffrey pines at Laguna Mountain was related to annual precipitation recorded at Cuyamaca weather station.

them and made them more subject to insect attack and damage from other diseases. Thereafter, unpruned and—to a lesser extent—pruned trees appeared to be killed mainly by a combination of moisture stress, heavy dwarf mistletoe infection, insects, and diseases.

CONCLUSIONS AND RECOMMENDATIONS

The change in the visual appearance of pruned trees will probably be a main concern of recreational site managers. If pruning dwarf mistletoe destroys or seriously impairs the recreational value of a tree, then this disease control approach may be of little use irrespective of any benefits pruning may offer.

Managers should be aware of some of the longer term beneficial effects of pruning that are not immediately apparent, however. Perhaps the most important is that many trees, even those pruned heavily and of marginal visual quality or immediate recreational value improve in vigor and appearance over time. Within just the 8-year span of this study, we observed remarkable improvement in growth and visual appearance of many heavily pruned trees that may have been considered of limited value by managers. These observations agree with those of Lightle and Hawksworth (1973). They reported improved growth and vigor of pruned, dwarf mistletoe infected ponderosa pines in the Southwest. One caution should be heeded. Any benefits of pruning can be offset if pruning is carried to the extreme. Besides the adverse visual effects, trees pruned too heavily are weakened and often die or are attacked and killed by other agents within a year or two after pruning. Therefore, managers must use care in selecting trees that will have sufficient live crown remaining after broom pruning.

The effect that pruning a given number of brooms has on tree growth and survival cannot yet be determined. Brooms varied greatly in size and number per tree, and the effect of pruning brooms appears to be mainly a function of the amount of live crown remaining after pruning. Managers probably should not prune beyond about 30 percent remaining live crown in most instances, regardless of how many brooms need to be removed. Broom pruning did not eradicate dwarf mistletoe from most infected trees, but the intensity of infection was usually lowered. However, in time, the level of dwarf mistletoe will no doubt increase and new brooms will develop. On the other hand, continued height growth of the tree will allow new crown to develop at a rate that may be more rapid than the dwarf mistletoe is able to spread (Scharpf and Parmeter 1976). Further study is needed to determine the rate of dwarf mistletoe buildup and broom formation, and whether additional broom pruning will be necessary.

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Western dwarf mistletoe *(Arceuthobium campylopodum)* is a damaging parasite of Jeffrey pines *(Pinus jeffreyi)* in southern California. Infected branches that develop into brooms are believed to reduce tree vigor and increase mortality. Brooms were pruned from Jeffrey pines with varying levels of dwarf mistletoe infection and live crown. Many of the trees showed an increase in crown vigor when compared with unpruned trees after 5 years. Mortality was not reduced by pruning brooms, except during years of below-normal precipitation. Of the trees that died, most had little live crown, heavy dwarf mistletoe infection, and were also attacked by root diseases or insects or both. Reducing the stress of dwarf mistletoe by broom pruning to no less than 30 percent live crown helps to prevent mortality due to root disease and insect attack during years of below-normal precipitation.

Retrieval Terms: dwarf mistletoe, *Arceuthobium campylopodum,* Jeffrey pine, *Pinus jeffreyi,* disease stress, insect damage, control, forest recreational areas