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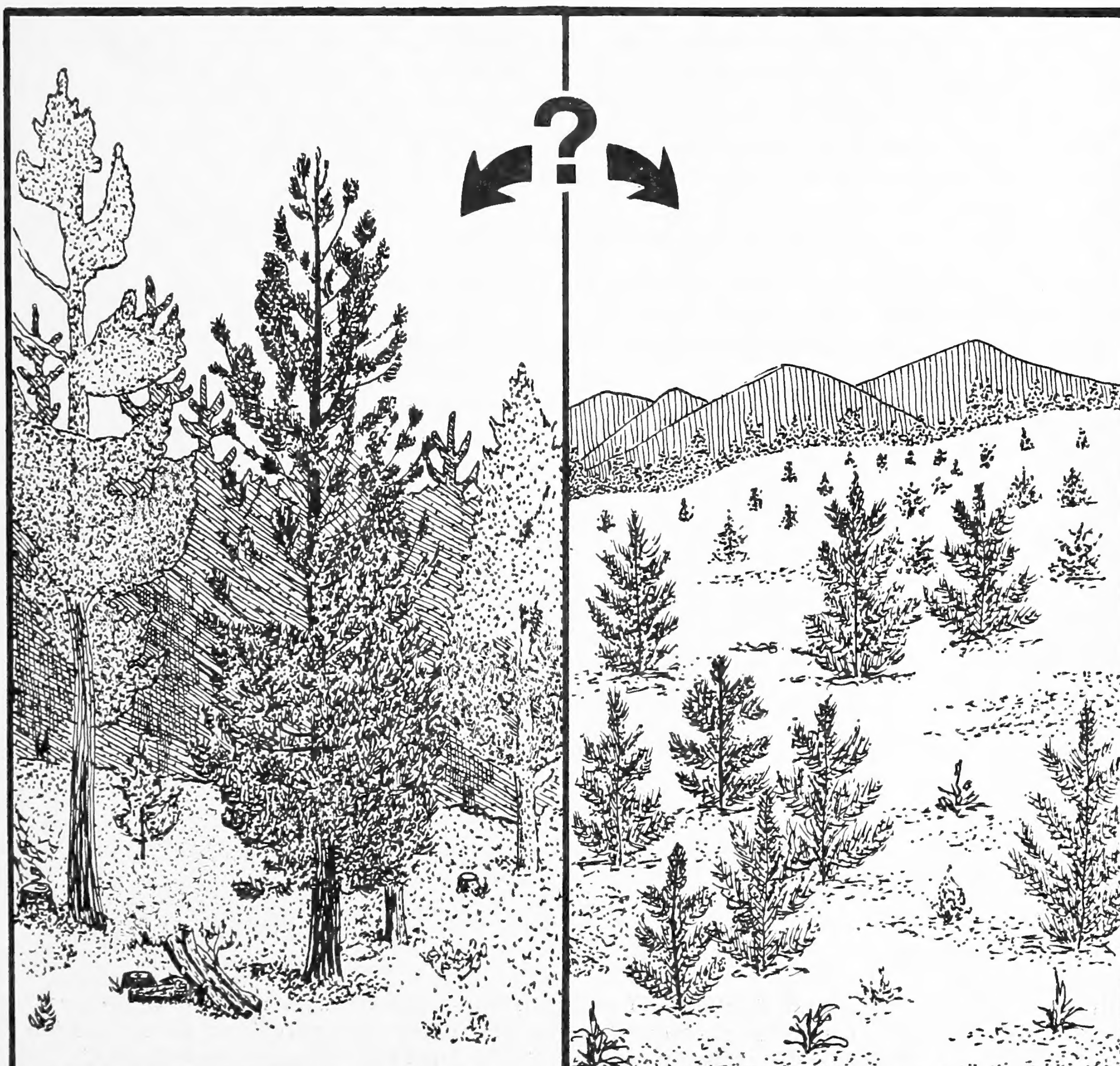
Response of Dwarf Mistletoe-Infested Ponderosa Pine to Thinning:

1. Sapling Growth

James W. Barrett and Lewis F. Roth



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Abstract

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Observations of thinned ponderosa pine infested with dwarf mistletoe over a 17-year period suggests that on average or better sites most infested stands can be managed to produce usable wood products in reasonable time, if trends found in juvenile stands continue.

Keywords: Thinning effects, western dwarf mistletoe, stand density, precommercial thinning, ponderosa pine, *Pinus ponderosa*.

Research Summary

No difference in rate of growth was found when plots of healthy ponderosa pine saplings thinned to 250 trees per acre were compared to similar plots parasitized by dwarf mistletoe. Abundance of mistletoe on individual trees increased progressively during the first 10 years of observation. After a second thinning and understory vegetation control on infested plots, height growth was good and dwarf mistletoe plants remained largely limited to lower portions of tree crowns.

Results indicate that parasitized ponderosa pine saplings can be managed by wide spacing that increases tree height growth in spite of abundant dwarf mistletoe. As long as rapid increase in height continues, this treatment will produce trees with healthy upper crowns and an acceptable rate of growth. Managing infested stands to complete the rotation may be a preferable alternative to clearcutting, site preparation, and planting.

Preface

Retarded growth and consequent prolonged timber harvest rotations are the most damaging effects of western dwarf mistletoe (*Arceuthobium campylopodum*) Engelm.) on ponderosa pine (*Pinus ponderosa* Laws.) forests in the Pacific Northwest. The seriousness of growth loss depends primarily on the abundance of dwarf mistletoe and its location in the crown, spacing of trees, the competition between trees and other vegetation for moisture, and site quality. These factors may act alone but usually interact.

Stands with heavy infestations of mistletoe on poor sites probably will not respond to silvicultural treatment, whereas lightly infected stands on good sites may need no treatment. Few stands fall into either category. The majority of stands, containing thousands of acres, have infestations that vary considerably in severity. The question is whether these stands are treatable, and, if they are, which stands should be treated, how, and when.

Most recent guidelines for mistletoe management of sapling and small-pole stands apply to dwarf mistletoes in general and do not provide the basis for critical decisions about a specific host species. Field observations over the last 25 years and results of long-term studies now provide realistic treatment possibilities in pure stands of ponderosa pine in the Pacific Northwest.

Dwarf mistletoes differ from most forest diseases in that the dispersal range of their seed—unlike that of fungal spores—is limited and predictable, and mature mistletoe plants are easy to see. Efforts to eradicate the pest have often proved unsuccessful because numerous large mistletoe plants appear within a few years of treatment, even though the stand work has been thorough. In thickets of slow growing pines, many invisible plants under the bark are missed at the time of treatment. Like their hosts, these hidden plants respond vigorously to thinning and develop fruitful aerial shoots. This habit of resurgent growth has discouraged dwarf mistletoe control in ponderosa pine in the Pacific Northwest.

Following an intensive evaluation of mistletoe in the varied natural stands in the Pringle Falls Experimental Forest on the Deschutes National Forest in central Oregon, Roth suggested that dwarf mistletoe in saplings and small poles could be tolerated through a rotation if stands could be silviculturally treated so as to maintain 10 inches or more of height growth each year.[1] Comprehensive study of mistletoe propagation by Roth and analysis by Strand and Roth (1976) disclosed that 10 inches did in fact approximate the lower theoretical level at which infested trees could maintain progress toward completion of a productive rotation without being overcome by mistletoe. This knowledge suggested that silvicultural maintenance of good height growth was an alternative to eradication of dwarf mistletoe.

Evidence was needed to determine (1) that the minimum growth of 10 inches could be achieved in infested stands, (2) that mistletoe, responding to increased tree vigor, would not offset the gain. This paper examines the effects of thinning on ponderosa pine saplings parasitized by western dwarf mistletoe. Data are from permanent sample plots. A companion paper (Roth and Barrett 1985) examines the effects of thinning on the dwarf mistletoe itself.

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[1] Roth, Lewis F. Unpublished data on file, Oregon State University, Department of Botany and Plant Pathology, Corvallis.

Contents

Introduction

Natural multistoried stands of ponderosa pine (*Pinus ponderosa* Laws.) in the Pacific Northwest are usually harvested and managed by (1) clearcutting and planting, (2) some form of selection cutting, or (3) removing the overstory and thinning the sapling or pole understory. The first method is used infrequently because of environmental and other constraints. The second and third methods cause disease and management problems in the many locations where western dwarf mistletoe (*Arceuthobium campylopodum* Engelm.) infects all but the smallest trees.

Frequently, dwarf mistletoe infests both the mature overstory and the understory in ponderosa pine stands. Harvest of the infested overstory to eliminate that source of the pest is generally accepted practice; however, the ability of the parasitized understory trees to respond positively to thinning has not been demonstrated.

A crop of dwarf mistletoe seed is usually disseminated each autumn by plants in the parasitized overstory trees. Many of these seeds shower down on needles of the understory. After light rain, the hygroscopic seeds slide down the needles and lodge on the fascicle sheath or the stem in the axil of the fascicle. Seeds germinate the following spring, and the primary "rootlet" penetrates the thin bark to form an absorption system in the tree tissues. In 4 to 6 years aerial shoots appear, flower, and produce seeds. Thus, a base is established for spread and proliferation of the parasite in the pine reproduction even after the overstory source of the parasite has been removed.

Some pine understories are infested more heavily than others, the extent depending largely on past seed production by dwarf mistletoe plants in the overstory trees.

Retarded growth is the most damaging influence of dwarf mistletoe, especially when plants are abundant. Tree growth also is greatly affected by stand density. Infested, unmanaged understories often grow poorly, while dwarf mistletoe in stands that have been thinned and sanitized may resurge so conspicuously as to cast doubt on the merits of silvicultural treatment.

A number of workers have reported the adverse effects of western dwarf mistletoe in unmanaged, mature, and overmature stands (Childs and Edgren 1967, Childs and Wilcox 1966, Weir 1916). Shea (1964) reported significant reduction in growth of small trees heavily parasitized by dwarf mistletoe but found growth reduction difficult to detect in moderately parasitized trees. Roth (1971) found that the amount of damage from dwarf mistletoe plants was strongly influenced by the amount of competing vegetation. He thought it reasonable to expect improvement in growth of a parasitized stand following thinning, not just because the amount of dwarf mistletoe was reduced but also because growing conditions for the remaining trees were improved.

The consistent increase in diameter growth of young, uninfected ponderosa pine after thinning of high density stands is repeatedly reported in the literature (Barrett 1970, 1972, 1982; Mowat 1953). Barrett (1982) also observed increased height growth of formerly suppressed, sapling-sized ponderosa pines with wide tree spacing.

There are few published data from the Pacific Northwest to evaluate management, after overstory removal, of infested, sapling-sized ponderosa pine to validate existing guidelines[2] for stand treatment, or to verify impressions of dwarf mistletoe occurrence and damage.

This paper compares growth data from thinned plots in a stand of trees parasitized by dwarf mistletoe and adjacent thinned plots of healthy trees. The results support the validity of existing guidelines for managing dwarf mistletoe in National Forests of the Pacific Northwest. In addition, the paper suggests ways to evaluate treatment success in thinned, dwarf mistletoe-infested ponderosa pine stands.

The Study

In 1957, six plots were established in an overmature stand of ponderosa pine with a sapling understory. Both overstory and understory were infected by dwarf mistletoe. Each plot was a rectangle 79.2 by 105.6 feet (0.192 acres) surrounded by a 33-foot buffer strip. Each inner plot contained 192 mil-acre subplots that were used for sampling sapling characteristics before thinning.

The overstory contained about 25 thousand board feet per acre of mature and overmature ponderosa pine. The understory consisted of 40- to 70-year-old ponderosa pine saplings. Site quality, according to Meyer (1961), was site IV, or 78 feet at 100 years of age.

Before overstory removal and thinning, the following characteristics of the sapling understory were sampled on 12 mil-acre subplots in each sample plot:

1. Tree density
2. Average diameter
3. Average height
4. Number of infested trees
5. Number of visible plants per tree
6. Number of visible plants in the top half of the crown
7. Number of plants on the bole.

The overstory was carefully harvested, then each plot was thinned to 250 trees per acre or 48 trees per plot. The half-chain buffer strips were thinned to a similar density. A system of ropes was used to give each plot a grid and provide for as uniform spacing of leave trees as possible. At each grid position a tree was marked as a leave tree. Trees chosen had to be within one-third of the spacing distance or 4.5 feet from a grid point. On the infested plots if there was a choice between a visibly infested tree and a noninfested tree, the infested tree was kept, although severely infested trees (class five and six, Hawksworth 1977) were not chosen. If there were not infested trees at a grid point, then an uninfested tree was kept.

Six plots adjacent to the infested area, but without dwarf mistletoe, were logged and the understory thinned exactly the same way. The best tree at each grid point was left.

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[2]From "Silvicultural Examination and Prescription Handbook", Pacific Northwest Region, Forest Service, U.S. Department of Agriculture, Portland, Oregon. 1979.

All 48 trees in each plot were tagged at breast height. Periodic measurements on all trees included d.b.h. to the nearest 0.1 inch and total height to the nearest 0.1 foot. Twelve trees on each plot were either climbed and measured or measured with a Barr and Stroud optical dendrometer for computing a volume equation of the form Volume $= a + b D^2 H$, where $D =$ diameter breast high (inches), $H =$ total height (feet). All trees from all plots were pooled to form one volume equation for each period. In addition, the following information was recorded for each of the 48 trees per plot during the 10-year period from 1959 to 1969:

1. Crown length
2. Crown density
3. Crown vigor
4. Number of visible plants in the top half of the crown
5. Total number of visible plants per tree
6. Total number of branches
7. Total number of branches bearing visible plants.

The principal objective at the time the study was established was to determine the magnitude of growth reduction caused by dwarf mistletoe in thinned, infested stands of ponderosa pine. In addition, we wanted to follow population trends of the parasite, over time, in individual trees and in the stand.

A second thinning was done to see if the remaining trees could be stimulated to grow in height faster than dwarf mistletoe moved up in the crown. Tree growth and dwarf mistletoe development were observed during 10 growing seasons from 1959 to 1969 at a density of 250 trees per acre. After analyzing growth of infested and uninfested plots during the 1959-to-1969 period, reviewing work by Strand (1973) and Strand and Roth (1976) on dwarf mistletoe population changes, and Barrett's (1970) observations of height growth in healthy stands, Roth suggested that the six infected plots be rethinned in the fall of 1971 to densities of about 90 trees per acre. In addition, pine manzanita (*Arctostaphylos patula* Greene), snowbrush (*Ceanothus velutinus* Dougl. ex Hook.), and bitterbrush (*Purshia tridentata* (Pursh) DC.) on the site were sprayed with herbicide to reduce brush competition and give the remaining trees further opportunity to grow. After the second thinning, growth and dwarf mistletoe development were observed for 11 growing seasons.

The uninfested plots were not thinned a second time because we wished to reserve trees at the 250-tree density for another purpose.

Results

Stand Characteristics Before the First Thinning

Before thinning, the plots contained about 8,000 saplings per acre. Trees averaged 0.7 inch d.b.h. and 7.5 feet high, with an average crown length of 3.0 feet, or a 40-percent crown ratio. An average of 2,600 trees per acre (32 percent) were visibly parasitized by dwarf mistletoe on the six infested plots. Twenty-two percent of these had visible infestations on the bole, and 20 percent had dwarf mistletoe in the top half of the crown.

Stand Characteristics After the First Thinning and 10 Years Later

Visibly parasitized trees increased from 74 to 89 percent in the 10-year period after the first thinning (table 1). Most plants that later appeared on "unparasitized" trees probably were present prior to 1959 (Roth and Barrett 1985). These latent infestations became visible 3 to 5 years after overstory removal and thinning. The average number of visible plants per parasitized tree increased dramatically from only four in 1959 to 36 in 1969.

Table 1—Average tree and stand characteristics of 6 uninfested plots and 6 infested plots of ponderosa pine saplings directly after thinning in 1959 and 10 growing seasons later

Stand and year	Trees per acre	Diameter at breast height	Height	Volume	Trees with mistletoe	Trees with plants on stem[1]	Trees with plants in the top half of the crown
		Inches	Feet	Cubic feet	Percent		
Uninfested:							
1959	250	1.8	10.3	33.6	--	--	--
1969	249	4.3	15.1	210.6	--	--	--
Infested:							
1959	250	1.9	11.4	37.7	74	56	38
1960	244	4.6	16.3	243.3	89	61	47

1/Plants on branches within 4 inches of the main stem were considered as potentially on the stem.

Average dimensions of trees in the infested and uninfested stands were similar in 1959 (table 1), although trees in the infested plots averaged slightly larger. Diameter growth during the first decade of observation averaged 2.5 inches for trees in the uninfested plots and 2.7 inches for the infested plots (fig. 1). Tree height growth averaged 4.8 feet for the uninfested plots and 4.9 feet for the infested plots during the decade (fig. 2). As might be expected from figures for diameter and height growth, volume increment averaged slightly higher on the infested plots (fig. 3). There was considerable variation from plot to plot (figs. 1, 2, and 3) and, although averages are larger on the infested plots, an analysis of variance indicated no statistical difference between diameter, height, and volume increment on the respective plots. Trees on infested plots were slightly higher initially. Therefore, a separate covariance analyses was done for each 1959 variable: diameter, height, and volume. A nonsignificant portion of the growth variance was accounted for by these covariants.

Only six trees died out of 288 on the six infested plots. None of the trees that died was heavily parasitized by dwarf mistletoe, but trees that died were below average height and diameter and had short, low-density crowns. This loss amounted to only about 3 percent of gross increment. Only one tree on the uninfested plots died and it was low in vigor.

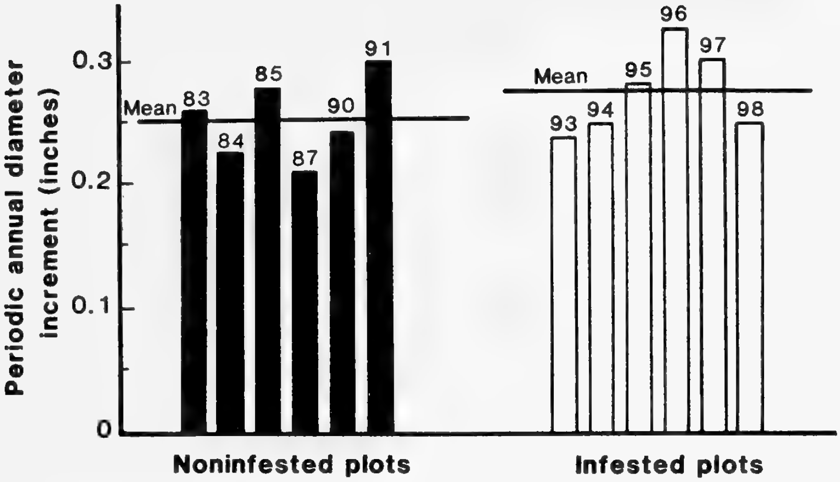

Figure 1.—Periodic annual diameter increment of plots from 1959 to 1969, when stand density was 250 trees per acre.

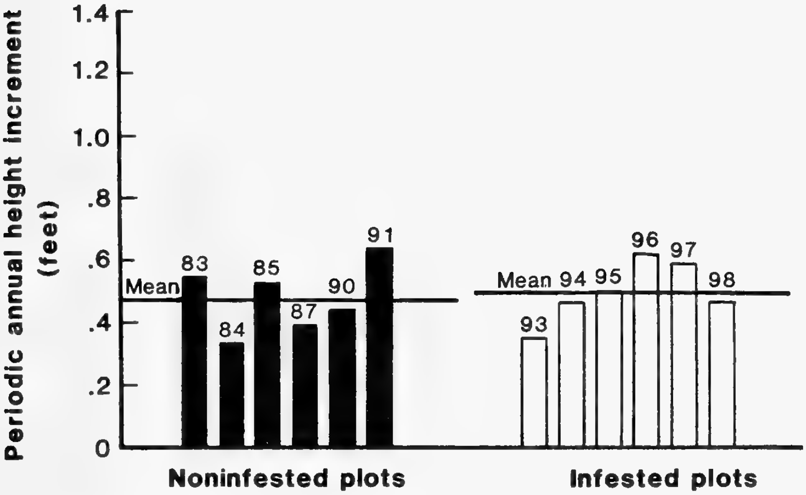

Figure 2.—Periodic annual height increment of plots from 1959 to 1969, when stand density was 250 trees per acre.

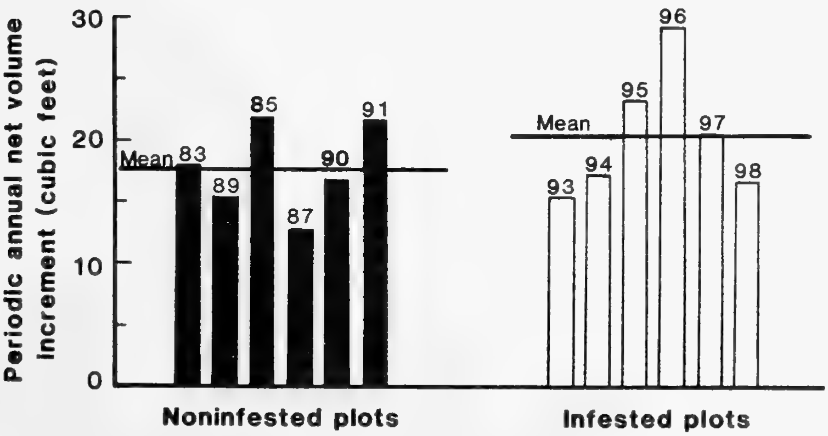

Figure 3.—Periodic annual net volume increment of plots from 1959 to 1969, when stand density was 250 trees per acre.

Stand Characteristics After the Second Thinning

In the fall of 1971, the six infested plots were further thinned to an average of 88 trees per acre.

When infested plots were thinned the second time, the best trees were left, regardless of the amount of dwarf mistletoe they bore. Competing brush was suppressed with herbicides to give the remaining trees further opportunity to grow well. Growth on these trees was observed during eleven growing seasons from spring 1972 through fall 1982 (table 2).

Table 2—Stand characteristics of the 6 plots infested with dwarf mistletoe after the second thinning in 1972 and 11 growing seasons later in the fall of 1982

Plot number	Trees per acre	Diameter at breast height		Height		Volume 1/	
		1972	1982	1972	1982	1972	1982
		Inches		Feet		Cubic feet	
93	89	5.71	8.69	20.2	31.4	149.0	426.0
94	89	5.96	10.12	21.2	37.2	155.0	630.6
95	94	6.49	10.12	23.9	38.3	199.8	709.7
96	99	6.96	10.67	24.6	38.9	265.8	765.5
97	78	6.35	10.23	22.6	37.2	150.8	567.9
98	78	5.80	9.52	20.9	34.0	126.8	482.0
Average	88	6.2	9.9	22.2	36.2	174.5	597

1/Total volume from ground to tip of tree.

Diameter growth rate on trees left after the second thinning remained surprisingly similar to that observed on the same trees during the first decade while they were part of the 250-trees-per-acre stand (fig. 4). Rate of height growth, on the other hand, increased after the second thinning, and these same trees grew an average 1-1/4 feet each year on five of the plots and 1 foot on one plot (fig. 5). The same trees grew only an average of 0.7 foot from 1959 to 1969 after the first thinning. Annual height growth on the uninfested plots, however, also increased about 0.9 foot from 1972 to 1982. We can attribute a portion of this increased rate of height growth after the second thinning to additional release both from trees and brush, but it is also substantially a function of greater time since the first thinning (Barrett 1973). This increase in rate of height growth played an important part in the volume increment that accumulated after the second thinning (fig. 6). Although this appears to be a notable increase in volume increment from one period to another, it should be kept in mind that current annual volume increment in a released young stand such as this rises rapidly in the first several decades after treatment. The uninfested plots that still maintained 250 trees per acre during this 11-year period grew about 60 cubic feet per acre per year because of the additional time at the higher density and thus a greater growing stock base, while the rethinned infected plots grew about 38 cubic feet per acre per year. This is not a totally legitimate comparison, however, because we did not rethin the uninfected plots, but it helps compare growth in the two stands.

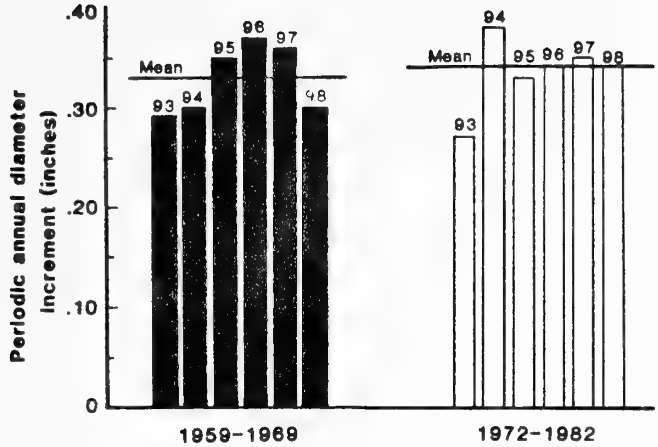

Figure 4.—Periodic annual diameter growth of trees in infested plots kept through both thinnings; during the first decade at a stand density of 250 trees per acre and during the second period at 88 trees per acre.

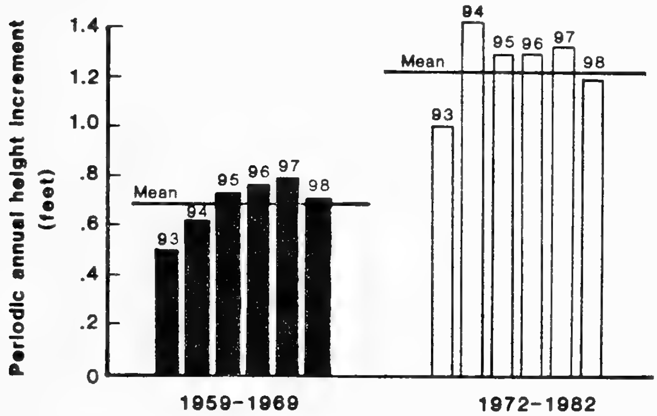

Figure 5.—Periodic annual height growth of trees in infested plots kept through both thinnings; during the first decade at a stand density of 250 trees per acre and during the second period at 88 trees per acre.

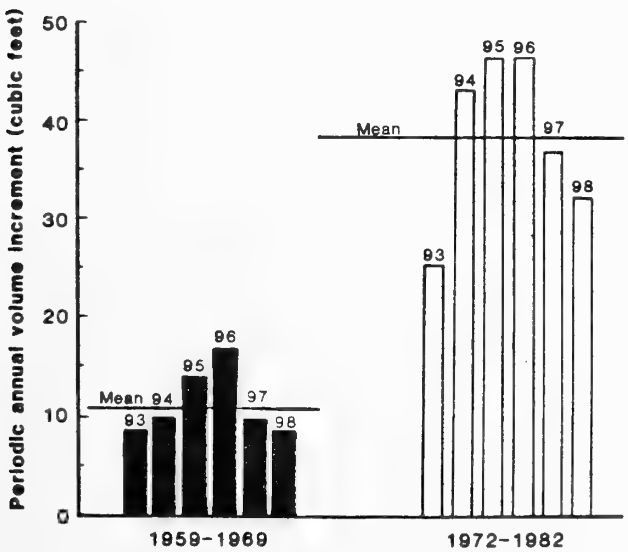

Figure 6.—Periodic annual volume growth of trees in infested plots kept through both thinnings; during the first decade at a stand density of 250 trees per acre and during the second period at 88 trees per acre.

Discussion and Application

This study indicates that, for at least a decade, moderately infested stands of sapling-sized ponderosa pine thinned to 250 trees per acre will produce as much wood as healthy stands thinned to the same density. This is not a new idea, because Shea (1964) and Belluschi (Shea and Belluschi 1965), working with individual tree growth rather than per acre wood production, found significant reductions in diameter growth only in "severely" infested trees.

This study and other work (Barrett 1973) shows that height growth of individual trees, whether parasitized by dwarf mistletoe or not, may be increased by regulating stand density and further augmented by controlling understory vegetation. General observation of the study area 11 years after the second thinning shows trees to be growing well over 10 inches in height per year in spite of heavily parasitized lower branches (fig. 7). The appearance of abundant mistletoe in the lower crowns is disturbing to forest managers until they look closely at the growth in height and diameter that is taking place (figs. 8 and 9). One must conclude from the performance of these trees that good height and diameter growth can be maintained for several decades and that considerable dwarf mistletoe may be tolerated in a managed stand.

Figure 7.—General view of a twice-thinned infested stand in 1983.

Figure 8.--Although these trees have heavily parasitized lower crowns they are growing more than 1 foot in height annually.

Figure 9.—The lower crown of this tree is heavily parasitized, yet height and growth diameter are good.

If sustained good height growth is a primary mitigator of dwarf mistletoe damage, fertilization—an additional management choice—may be available to limit loss in parasitized thinned stands. Cochran (1979) reports a 50-percent increase in height growth in thinned fertilized plots as compared with unfertilized plots. He fertilized a thinned stand of small poles at rates equivalent to 200 pounds of nitrogen, 100 pounds of phosphorus, and 33 pounds of sulfur per acre. These elements were applied in the form of ammonium sulphate, urea, and triple super phosphate. The time over which this treatment will be effective is not yet known. The effect of fertilization on the mistletoe also is unknown. We would expect plants to become more fruitful but would not expect this increase to offset benefits from improved growth in tree height. Fertilization of infested stands should be undertaken with discretion. It might be highly appropriate for special use areas such as campgrounds.

It should be recognized that acceleration of height growth in thinned suppressed sapling stands was not immediate. Response of well chosen trees on good to average sites is delayed 3 to 5 years after thinning. Growth peaks in 8 to 12 years (Roth and Barrett 1985). The magnitude of the growth response is related to stand density. As shown in figure 10, height growth in a healthy stand of 125 trees per acre does not exceed 10 inches per year until 8 to 12 years after thinning. If understory vegetation is controlled, making more soil moisture available to the trees, this desirable rate of height growth may be achieved sooner. Trees under intensive management should maintain the desired increment rate for a substantial portion of present day rotations (Barrett 1978).

A companion paper (Roth and Barrett 1985) shows that height growth has a notable effect on the distribution of dwarf mistletoe within the tree. A review of what was done in that study shows how infected stands can benefit from thinning. First, 250 trees per acre were left after overstory removal and the first thinning. This is more than are usually left when the sawlog market is the target for the first commercial entry. This is also a high stocking level that can lead to spread of dwarf mistletoe (Strand and Roth 1976). Second, trees parasitized by dwarf mistletoe were deliberately left in the first thinning. Consequently, in the first thinning we created a less desirable management situation than if we had left fewer trees and had discriminated against trees parasitized by dwarf mistletoe. Even so, growth was not reduced by dwarf mistletoe during the decade after thinning. In the second thinning we regulated density so that trees were widely spaced but the number per acre that had average diameters was above the minimum stocking-level curve (Barrett 1979) on all plots (table 2).

If density had been reduced in the first thinning to between 100 and 140 trees per acre that appeared free of dwarf mistletoe or were only moderately parasitized, and then if the undesirable trees had been harvested a decade later, would we have created a stand that would produce volume comparable to that of uninfested stands?

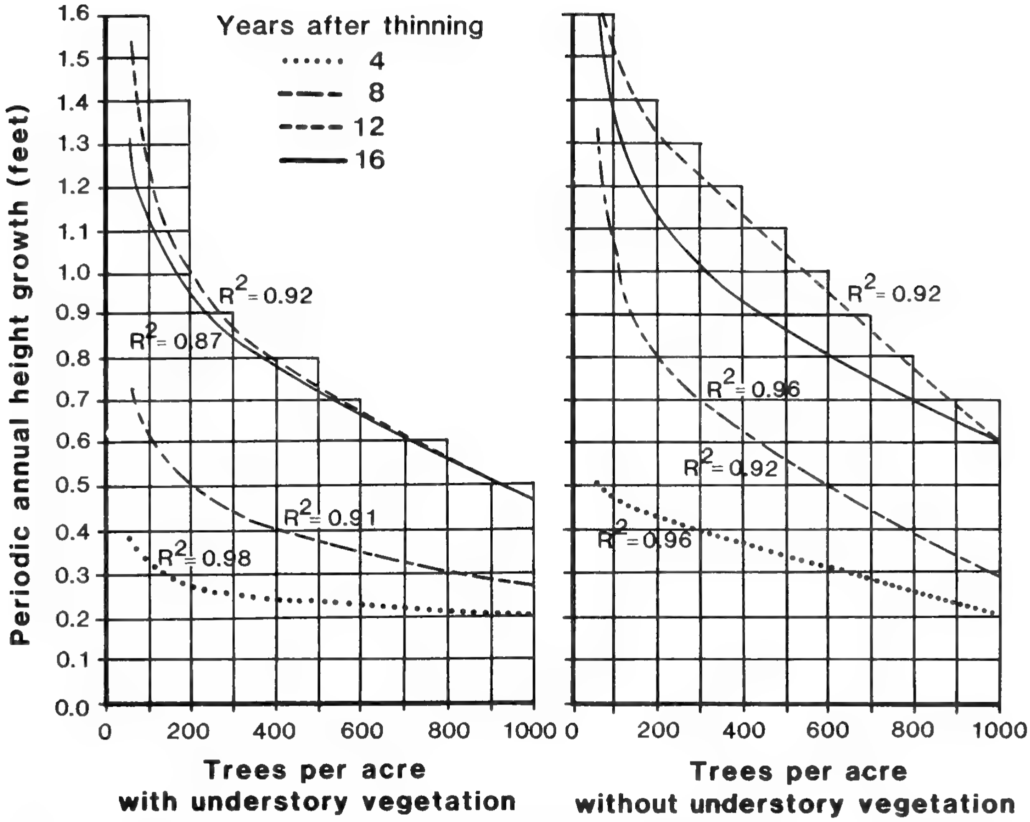

Figure 10.--Periodic annual height growth of thinned healthy ponderosa pine saplings (Barrett 1973). Brush was allowed to develop naturally on half the plots and was controlled on the other half.

Conclusion

Foresters should not be discouraged by the occasional resurgence of dwarf mistletoe in thinned, second-growth ponderosa pine because continued rapid height growth will produce healthy upper crowns free of mistletoe. The following field exercise is recommended to evaluate the growth of thinned sapling or small-pole stands infected by dwarf mistletoe.

1. Locate an adequate number (at least one per acre) of 1/20-acre circular plots (radius = 26.3 feet) within the stand.
2. Extract from each tree on the plot an increment core that includes as many rings before thinning as after thinning.
3. Measure and calculate growth rate per decade after thinning.
4. If time since thinning is less than 10 years, calculate a decadal rate. For example, if an increment core shows seven growing seasons since thinning and radial growth was 0.9 inch, decadal rate may be calculated as follows:

   $$\frac{0.9 \text{ inch}}{7 \text{ years}} = \frac{x}{10 \text{ years}},$$

   $7\,x = 9.0,$

   $x = 1.29$ inches radial growth per decade,

   $1.29 \times 2 = 2.58$ inches diameter growth per decade.
5. Calculate an average decadal growth rate per plot and compare this rate to that shown in figure 11. Growth rates should be at least 80 percent of the rate for the density indicated. Stands thinned 6 years or less should not be evaluated. Diameter growth rate can be useful in estimating the time needed before a commercial entry may be made and any badly infested trees harvested.
6. Adequate height growth—not diameter growth—is the key to productive growth in infested stands. In sampling growth of an infested stand, the most important fact to determine is whether or not most trees are attaining 10 inches or more of height growth annually.

If the sample plots reveal that stands are not growing at acceptable rates, and if numerous dwarf mistletoe plants appear in the upper one-fourth of the crowns on most of the trees, then serious consideration should be given to clearing the site and planting.

On the other hand, if growth rates approximate those in a healthy stand, the infested stand should be carried at least to a minimum merchantable size, at which time growth characteristics should be assessed again. If the stand, as a whole, continues to grow at acceptable rates, a commercial thinning could be made at merchantable age and the better trees retained to accumulate more volume and possibly act as a shelterwood for a new stand.

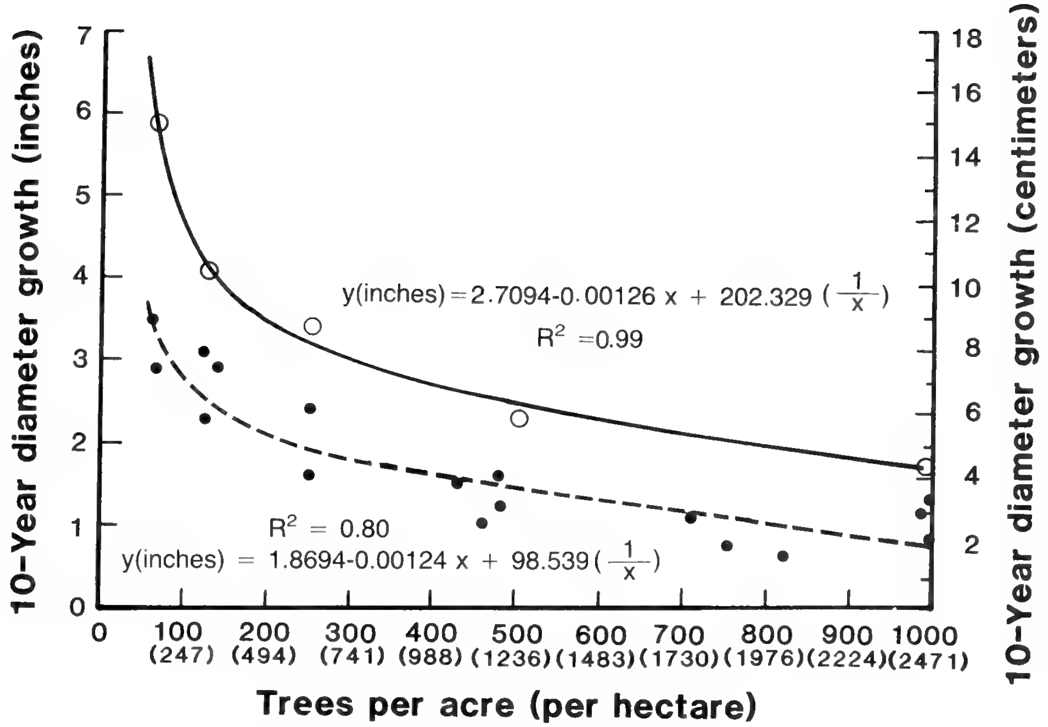

Figure 11.—Relation of diameter growth to density in suppressed, sapling-size ponderosa pine after thinning (Barrett 1979), with understory vegetation controlled, (solid line) and with understory vegetation allowed to develop naturally.

Metric Equivalents

1 inch = 2.54 centimeters
1 foot = 0.3048 meter
1 acre = 0.405 hectare
1 square foot/acre = 0.2296 square meter/hectare
1 cubic foot/acre = 0.06997 cubic meter/hectare
1 tree/acre = 2.471 trees/hectare

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Observations of thinned ponderosa pine infested with dwarf mistletoe over a 17-year period suggests that on average or better sites most infested stands can be managed to produce usable wood products in reasonable time, if trends found in juvenile stands continue.

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