STATION PAPER NO. 62
AUGUST 1961





# SILVICULTURAL CONTROL OF dwarfmistletoe ON SOUTHWESTERN PONDEROSA PINE

A PROGRESS REPORT BY
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A Progress Report

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# SILVICULTURAL CONTROL OF DWARFMISTLETOE ON SOUTHWESTERN PONDEROSA PINE

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Dwarfmistletoe (Arceuthobium vaginatum forma cryptopodum (Engelm.) Gill) is widespread in the ponderosa pine (Pinus ponderosa Laws.) forests of Arizona and New Mexico. It is estimated that about 2-1/2 million acres of ponderosa pine sawtimber--more than one-third the commercial acreage--are infected (Andrews and Daniels, 1960). Forest productivity is substantially lowered because of reduced growth, untimely mortality, and lower quality resulting from deformities.

Dwarfmistletoe is one of the three main causes of ponderosa pine mortality in the Southwest, ranking about equal with wind and lightning. It accounts for about 20 percent of total mortality after partial cutting by improvement selection and causes as much as 35 percent reduction in increment (Pearson, 1950). Dwarfmistletoe takes a far heavier toll of ponderosa pine in Arizona and New Mexico than any other disease (Gill, 1958). Annual losses from mortality and growth reduction are estimated to be about 150 million board feet. Quality losses are considered to be even greater than growth and mortality losses.

The greatest spread of dwarfmistletoe is from overstory to understory trees (Gill and Hawksworth, 1954; Roth, 1953). Uneven-aged stands are therefore damaged more quickly and severely than even-aged ones. It is thought that selective harvest cuttings actually accelerate spread of infection in the understory reproduction (Kuijt, 1955). Dwarfmistletoe distribution is typically irregular; heavily diseased patches occur intermixed with healthy stands.

Dwarfmistletoe grows more rapidly after part of the stand has been cut, apparently because of improvement in light conditions and host vigor (Korstian and Long, 1922). Cutting also reduces the screening effect of foliage and limbs and thus increases the range of seed dispersal. Unless controlled, dwarfmistletoe will become increasingly more damaging with each cutting cycle.

Guides for controlling dwarfmistletoe in infected ponderosa pine stands are needed. Their development must be based on knowledge of dwarfmistletoe growth, seeding characteristics, and host damage. Several studies of dwarfmistletoe conducted in the pine forests of Arizona for many years suggested the possibility of control by management and silviculture (Gill, 1954; Gill and Hawksworth, 1954; Korstian and Long, 1922).

## THE STUDY

A pilot-plant study was begun in 1950 at the Fort Valley Experimental Forest, Arizona, to test dwarfmistletoe control measures suggested by other research. The virgin stand selected for study was fairly uniform in soils, exposure, site, condition class, and degree of dwarfmistletoe infection (table 1). Lightly to severely infected stands, representing all age classes were well distributed throughout the area.

Table 1. --Plot conditions before treatment

| Treatment | Volume per acre | Amount of infection | |
|---|---|---|---|
| | | Board foot volume | Stocked area |
| | Board feet | Percent | |
| Limited control | 11,670 | 43.9 | 50 |
| Unlimited control | 11,160 | 50.5 | 56 |
| Light improvement selection | 11,410 | 40.1 | 46 |

The study was designed to furnish answers to four questions:

1. Can dwarfmistletoe in heavily infected stands be controlled through such practical management measures as harvest cutting and stand improvement?

2. What is the influence of light improvement selection cutting on dwarf-mistletoe in heavily infected stands?

3. What are the relative costs and returns from practices that stress dwarf-mistletoe control? From light improvement selection cutting?

4. Is dwarfmistletoe control a sound management objective in heavily infected stands?

Three treatments, each replicated three times, were applied on nine 25-acre plots plus isolation strips. Three are being managed for "limited control," three for "unlimited control" or the greatest reduction of dwarf-mistletoe possible short of clearcutting the plots irrespective of costs, and three by light improvement selection cutting. The treatments were applied over a 4-year period from 1951 to 1954.

### LIMITED DWARFMISTLETOE CONTROL

The objective of limited dwarfmistletoe control is to reduce the intensity of infection to a level unimportant to timber production. Control measures were restricted to practices that can be financed and carried out by U. S. Forest Service National Forest Resource Administration under current allotments and regulations. Sustained yield was considered to be of secondary importance until reasonable control of dwarfmistletoe was accomplished.

Initial harvest removed most of the infected sawtimber-sized overstory (fig. 1). Some lightly infected overstory trees were left where removal would have created large nonstocked openings. Guides for leaving infected sawtimber-sized trees where needed for stocking or for seed trees were:

1. Leave if all active infections were within 17 feet of the ground and could be pruned out during timber stand improvement following harvest cutting.

2. Leave if infections were in the lower bole or on a single declining branch anywhere in the crown and if they offered little threat of infection to understory reproduction.

3. Leave if multiple active infections were confined to the lower one-fourth of the crown and if there was no established noninfected reproduction within 60 feet of the tree.


Figure 1. --Partially infected sawtimber stand A, before and B, after "limited control." Trees remaining after control treatment are free of dwarfmistletoe.

All overstory trees in some groups were so severely infected that they would have jeopardized existing and subsequent reproduction. In such infections, the entire overstory was cut and large understocked openings were formed.

Improvement selection cutting in dwarfmistletoe-free sawtimber groups left well-spaced, good-quality trees. Poor-risk and poor-quality stems were cut (fig. 2).

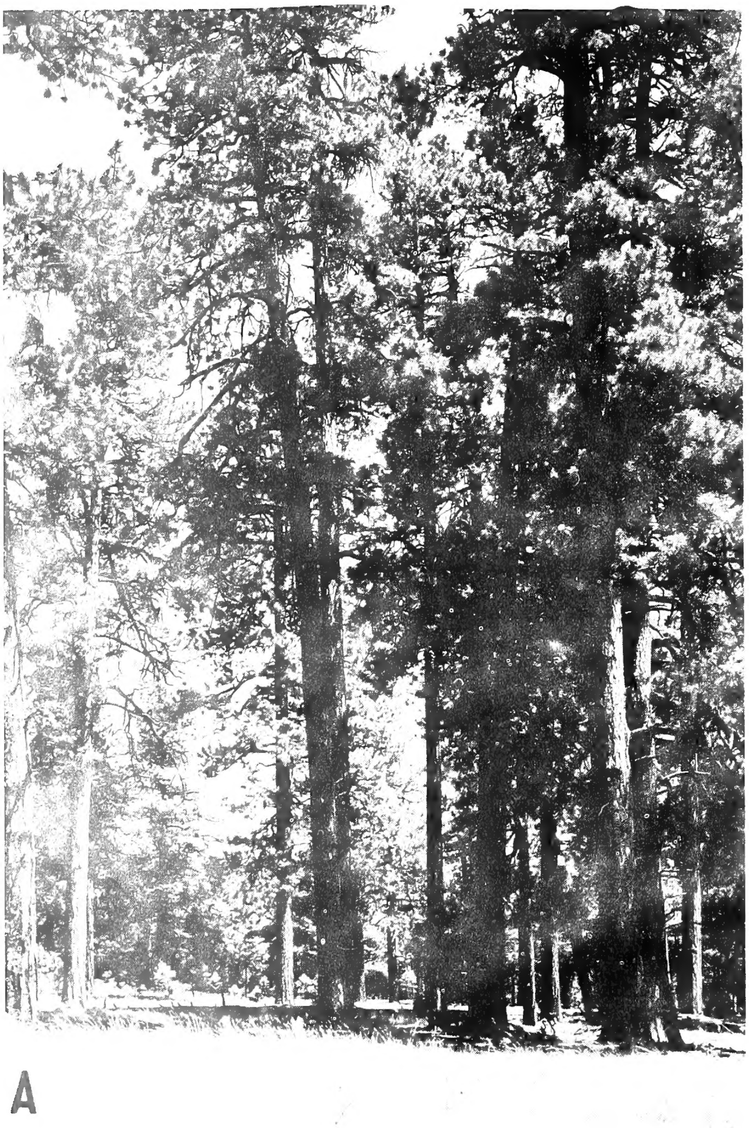



Figure 2. --Dwarfmistletoe-free sawtimber group A, before and B, after cutting by light improvement selection.

The first harvest cutting in 1951 removed 8,990 board feet or 77.0 percent of the original 11,670 board feet per acre. Infected volume was reduced from 43.9 to 10.4 percent (fig. 3). In addition to the sawtimber harvested, a number of smaller trees were accidentally removed during logging. Less than half of all the trees cut or destroyed were infected (fig. 4).

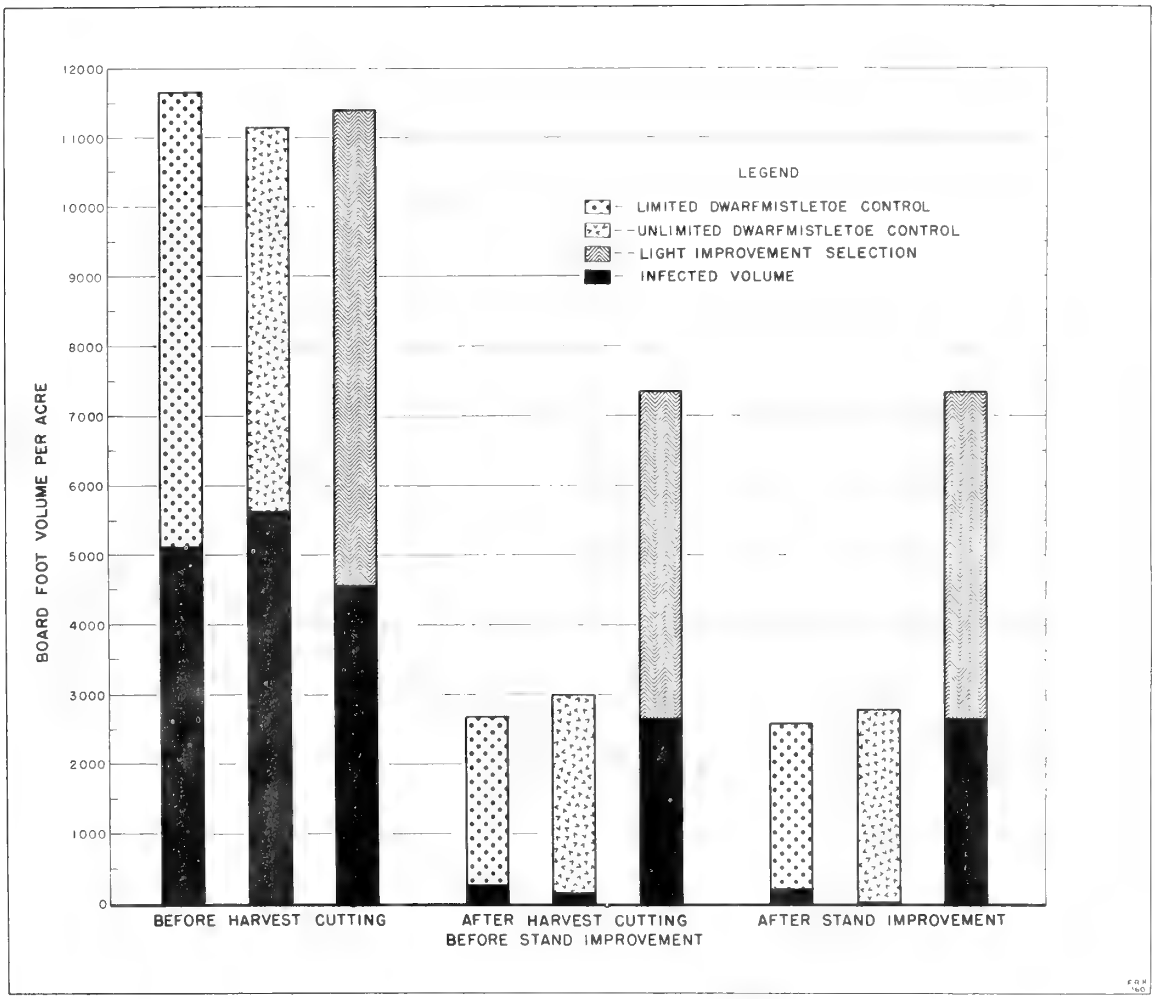


Figure 3. --Effect of three intensities of harvest cutting and stand improvement on infected and total volume of ponderosa pine sawtimber.

Following harvest cutting, additional infected trees larger than 2.6 inches d.b.h. or 10 feet tall were treated. Guides for removal or pruning were:

1. Noninfected groups. --No trees were removed or pruned.

2. Groups with occasional infected trees. --All infected poles and tall saplings were removed or poisoned except where this would have reduced stocking below a minimum level.[2] Where understocking would have resulted, treatment was as described in group 4.

3. Groups with infected fringe only. --All infected poles and tall saplings were removed except where the number of infected poles exceeded 10 percent of the total number of trees in the group. In such cases, treatment was as described in group 4.

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[2] Minimum stocking was defined as that resulting in a growing space of $43,560 \div (2D)^2$, where D equals average d.b.h. in inches.

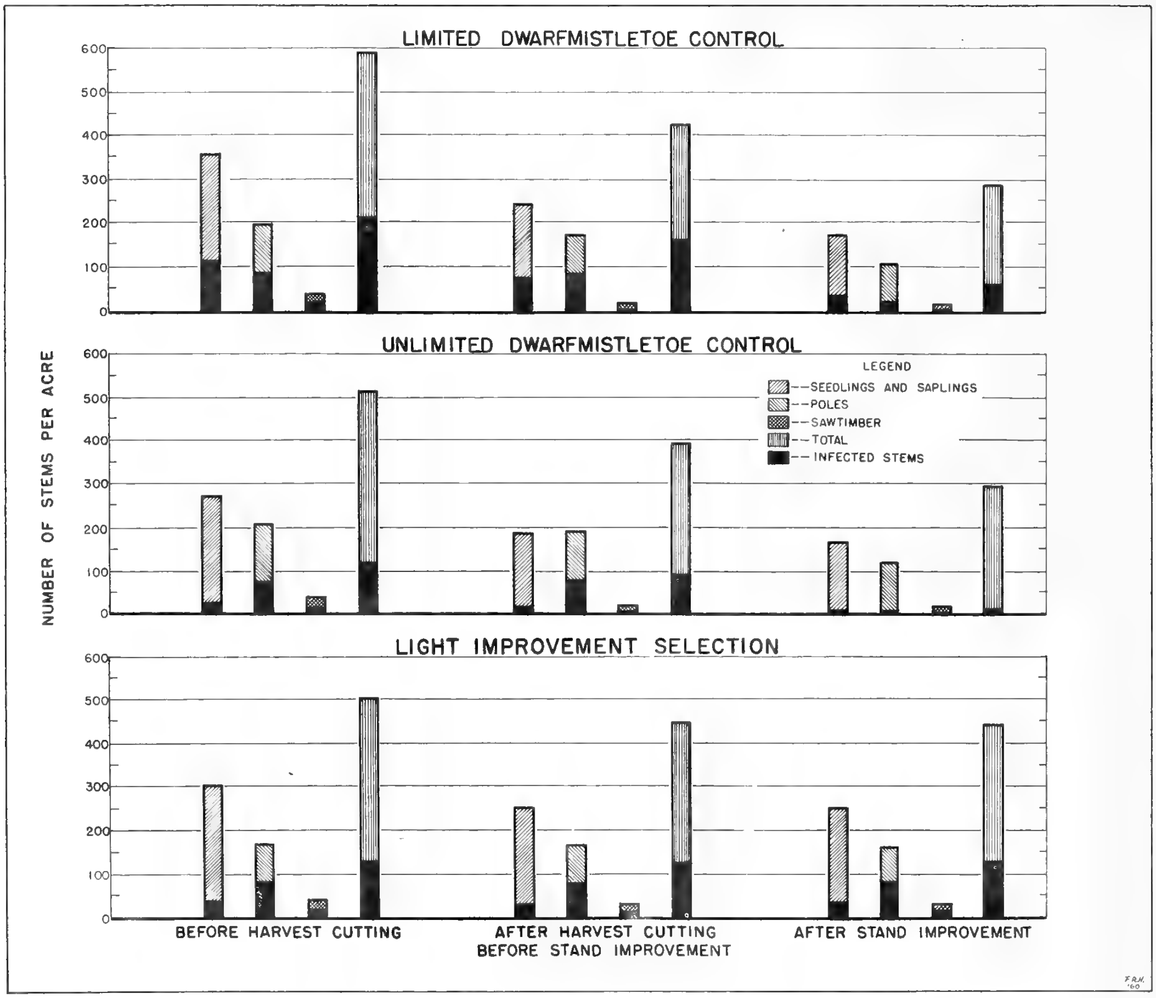


Figure 4. --Effect of three different intensities of harvest cutting and stand improvement on a stand of ponderosa pine infected with dwarfmistletoe.

4. Groups with all or nearly all trees infected. --Infected poles and saplings of desirable form were left to provide minimum stocking if the number of noninfected poles was inadequate (fig. 5). Trees with a prunable[3] infection or bole infection below the crown were left where available. Otherwise, poles with some nonprunable infections were left if total infection could be reduced to specified limits by pruning. These limits were (a) not more than two separate infections spaced no farther apart than one-third the live-crown length, or (b) three or more infections but all in the same one-third of the crown. Trees with infections exceeding these limits were not purposely left, regardless of reduction in stocking.

[3] A prunable infection was defined as one within 17 feet of the ground and with dwarfmistletoe shoots 12 inches or more from the tree bole.


Figure 5. --Partially infected sawtimber and pole stand A, before and B, after "limited control." Tagging: no tag--pole or small sawtimber tree not infected and not cut; one tag--infected pole; two tags--dead pole; vertical tag--dwarf-mistletoe-free small sawtimber tree marked for cutting; horizontal band--infected small sawtimber tree marked for cutting.

5. Scattered infected poles. --Infected poles of desirable form were left if needed for stocking and if the degree of infection did not exceed the limits described in group 4.

Stand-improvement work, pulpwood cutting, and additional cleanup of infected sawtimber decreased the proportion of infected stems 1 foot or more tall from 38.0 to 19.8 percent (see fig. 4). Postharvest cutting and poisoning of sawtimber-sized trees further reduced infected board foot volume from 10.4 to 7.9 percent (see fig. 3). Additional sawtimber-sized trees were killed only where stocking would not be adversely affected. Nearly 2.4 cords of pulpwood were produced per acre and 12 trees per acre were pruned.

Future cutting and cleanup in limited-control areas will be geared primarily to dwarfmistletoe reduction. Nonstocked and poorly stocked areas will be planted.

## UNLIMITED DWARFMISTLETOE CONTROL

The objective of unlimited control is to reduce infection to as near zero as possible as soon as possible without complete destruction of the stand. Dwarfmistletoe-free trees are to be saved. The only restriction on method of control is that it be a previously tested and effective procedure. Sustained yield is not an objective during the control phase.

All sawtimber-sized trees in which active dwarfmistletoe was seen were cut in unlimited control (fig. 6). Many of the smaller trees were accidentally killed during logging (see fig. 4). The first harvest cut removed 8,160 board feet or 73.1 percent of the original 11,160 board feet per acre. Infected volume was reduced from 50.5 to 5.5 percent (see fig. 3). Residual infected volume was primarily in large trees where dwarfmistletoe was not observed because the plants were small or new and inconspicuous. Extra care must be taken in searching for the parasite in overstory trees if the objective is total eradication in the overstory.

Unlimited control measures in sapling and pole-sized trees (2.6 inches d.b.h. or 10 feet tall, and larger) produced 3.4 cords of pulpwood per acre and 7 trees per acre were pruned. Poles and saplings with nonprunable infections were cut or poisoned with ammate crystals (Herman, 1954). Trees with prunable infections were left if needed for stocking; the formula for growing space $(43,560 \div (2D)^2)$ was used as a guide.

As a result of the pulpwood sale, stand-improvement work, and cleanup, the proportion of infected stems 1 foot or more tall was reduced from 23.5 to 3.3 percent (see fig. 4). Postharvest cutting and poisoning of sawtimber-sized trees further reduced the infected board foot volume from 5.5 to 0.6 percent (see fig. 3).

Future operations in unlimited-control areas will be aimed at controlling dwarfmistletoe and restocking the area in the shortest possible time, regardless of cost. Trees from which the infection cannot be pruned will be cut or poisoned. Pulpwood and timber stand improvement cuttings will be made periodically to reduce incidence of infection to as near zero as possible. Nonstocked areas (fig. 7) resulting from removal of dwarfmistletoe-infected trees will be planted.


Figure 6. --Severely infected sawtimber and pole stand A, before and B, after "unlimited control." Trees left after cutting were dwarfmistletoe-free. Much area is now in need of replanting.


Figure 7. --A, All trees in this two-storied stand contained dwarfmistletoe. B, Cutover area resulting from "limited control" needs replanting.

## LIGHT IMPROVEMENT SELECTION CUTTING

The objective of the light improvement selection treatment is to provide a standard for comparative purposes. With few exceptions, dwarfmistletoe reduction in practice has been limited to sanitation measures that did not reduce stocking and residual volumes below those recommended for noninfected stands (fig. 8). The primary objective of the first cutting in virgin stands was to reduce mortality losses by harvesting all merchantable trees that were dying or were expected to die during the following cutting cycle. This cut removed 30 to 40 percent of the total board foot volume.


Figure 8.--Sawtimber stand infected with dwarfmistletoe A, before and B, after cutting according to the light improvement selection treatment. Pole stand in background was lightly infected. Tagging: horizontal band--infected and cut; one tag--not infected and not cut; two tags--infected and not cut.

Marking guides specify that sawtimber ordinarily left in the reserve stand may be cut only if infected and near noninfected poles or reproduction. It is nearly impossible for an understory to be noninfected if near an infected overstory, so this guide is rarely used. Where the understory is already infected, the more seriously infected overstory trees are cut if their removal improves spacing.

The light improvement selection treatment removed 4,040 board feet or 35.4 percent of the original 11,410 board feet per acre. Infected volume was reduced from 40.1 to 36.3 percent by harvest cutting and stand improvement (see fig. 3). Marking for harvest cutting and stand improvement followed U. S. Forest Service Region 3 Timber Management Handbook guides.

Stand improvement measures after harvest cutting were:

1. Pruning and release of pruned trees were usually restricted to noninfected pole groups at least 50 feet from an infected overstory.

2. Where there were no noninfected groups, pruning and release were limited to lightly infected groups. In such groups, crop trees free of infection were selected where available. Otherwise, trees containing prunable infections were pruned and released.

3. Poles in groups severely infected with dwarfmistletoe or less than 50 feet from an infected overstory were not to be pruned or released (fig. 9). However, some pruning was done within 50 feet of infected overstory trees, apparently because dwarfmistletoe was overlooked.

About 23 trees per acre were pruned, some of which contained dwarfmistletoe or were adjacent to infected stems.

The proportion of infected poles was actually somewhat higher following harvest cutting and timber stand improvement than before (see fig. 4). The increase probably represented trees on which infection became apparent during the 4-year period of treatment, infection overlooked at the beginning of the period, and loss of noninfected poles during logging.

Additional harvests will be made at 10- to 20-year intervals. Only dwarfmistletoe-control procedures in common use on the southwestern national forests at the time of each cutting will be used. Stand-improvement practices will also be those in effect on the national forests at time of cutting.

## TREATMENT EFFECT ON STOCKING

The light improvement selection treatment reduced total stocking only 8 percent (fig. 10) but did not reduce the stocking of dwarfmistletoe-infected trees. Twenty percent of the area was left nonstocked. Forty percent of the total area was still stocked with infected trees, just as before harvest and stand-improvement cutting. Degree of stocking was determined by using a point-stocking system developed on the Fort Valley Experimental Forest (U. S. Forest Service, 1951).

Limited and unlimited control left 44 and 47 percent, respectively, of the areas nonstocked. Only 4 percent of the limited-control area and 3 percent of the unlimited-control area remained stocked with dwarfmistletoe-infected trees.

Figure 9. --Severely infected pole stand A, before and B, after light improvement selection cutting. All tagged trees contained dwarfmistletoe. Treatment had little effect on this stand.

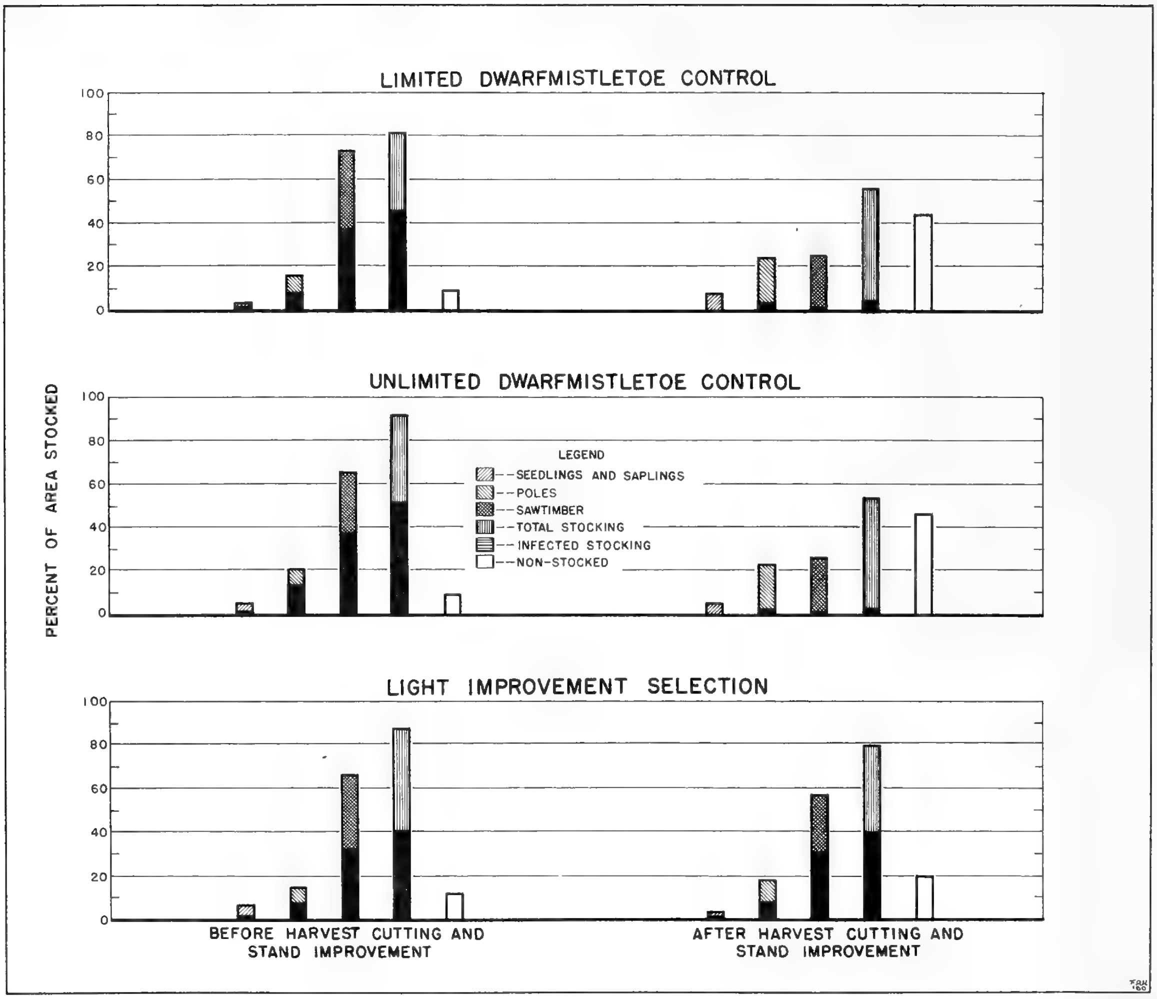


Figure 10. --Effect of three intensities of harvest cutting and stand improvement on infected and total stocking of a stand infected with dwarfmistletoe.

Thus, from a reinfection standpoint, there may be little difference between the two treatments until further cutting is made in the unlimited-control area.

The average number of infections on infected trees was highest in the light improvement selection areas and lowest in unlimited-control areas. Little attention was given to reducing the degree of infection in the light improvement selection areas. Light infections were deliberately left under limited control if the host trees were needed for stocking (fig. 11). Infections were accidentally left under unlimited control (fig. 12) if inconspicuous or latent at time of cutting. Subsequent increases in spread of infection are expected to be more rapid with light improvement selection cutting than with the control treatments. Thus, future amount and quality of stocking may ultimately be lower where light improvement selection cutting was applied.


Figure 11. --Pole and sapling stand under severely infected 27-inch d. b. h. ponderosa pine A, before and B, after "limited control." After control, the area was partially stocked with lightly infected poles, saplings, and seedlings. Tagging: no tag--no visible active infection; one tag--infected; two tags--dead.


Figure 12. --Partially infected poles and saplings beneath a formerly infected (A) sawtimber-sized overstory that no longer contains (B) active dwarfmistletoe. This group was treated according to "limited control." Tagging: no visible active infection; one tag--infected; two tags--dead.

## COSTS AND RETURNS

Nearly twice as much time was spent treating the limited- and unlimited-control areas as was spent in the light improvement selection treatment areas (table 2). Unlimited control required the greatest time, primarily for stand-improvement and control measures.

Table 2. --Comparison of time expended during initial timber harvesting and stand improvement of dwarfmistletoe-infected ponderosa pine

| Treatment | Year | Acres[1] | Man-hours Total | Man-hours Per acre |
|---|---|---|---|---|
| | | Marking | | |
| Limited control | 1951 | 149 | 179.0 | 1.20 |
| Unlimited control | 1951 | 119 | 145.0 | 1.22 |
| Light improvement selection | 1951 | 157 | 35.0 | 0.22 |
| | | Administration of timber sale[2] | | |
| Limited control | 1951 | 149 | 255.6 | 1.72 |
| Unlimited control | 1951 | 119 | 186.3 | 1.56 |
| Light improvement selection | 1951 | 157 | 113.3 | 0.72 |
| | | Stand improvement and control measures | | |
| Limited control | 1953-54 | 114 | 795.0 | 6.97 |
| Unlimited control | 1953-54 | 119 | 891.5 | 7.49 |
| Light improvement selection | 1953-54 | 157 | 732.0 | 4.66 |
| | | Total time, not including slash disposal | | |
| Limited control | 1951-54 | [3] 149 | 1,229.6 | 9.89 |
| Unlimited control | 1951-54 | 119 | 1,222.8 | 10.27 |
| Light improvement selection | 1951-54 | 157 | 880.3 | 5.60 |

[1] Includes isolation strips.

[2] Includes road layout and survey.

[3] For "Stand improvement and control measures" activity was restricted to 114 acres.

The two control treatments cost almost three times as much per acre as cutting by light improvement selection (table 3). Limited control cost the most because of efforts to maintain reasonable stocking through retention of infected trees. This treatment took less time than unlimited control (see table 2) but required somewhat more costly skills for administration of the timber sale. In limited-control areas, marking of timber for cutting was more difficult than in the other areas. All infections on sawtimber-sized trees needed for stocking were carefully scrutinized to determine whether the tree had less than maximum allowable infection and could be left.

Table 3. --Comparison of actual costs and returns from 1951 harvest cut and 1953-54 pulpwood sales

| Treatment | Cut per acre | | Stumpage charges per M bd. ft. | | Gross returns per acre | | | Manage-ment costs | Net returns per acre |
|---|---|---|---|---|---|---|---|---|---|
| | Sawtimber | Pulpwood | Sawtimber[1] | Pulpwood[2] | Sawtimber | Pulpwood | Total | | |
| | Bd. ft. | Cords | - - - - - - - | - - - - - - - | Dollars | - - - - - - - | - - - - - - - | - - - - - - - | - - - - - - - |
| Limited control | 8,990 | 2.37 | 13.40 | 0.90 | 120.47 | 2.13 | 122.60 | 20.97 | 101.63 |
| Unlimited control | 8,160 | 3.36 | 13.40 | .90 | 109.34 | 3.02 | 112.36 | 20.12 | 92.24 |
| Light improvement selection | 4,040 | 0 | 13.40 | 0 | 54.14 | 0 | 54.14 | 7.23 | 46.91 |

[1] Includes stumpage charge of $8.40 per M b.m., plus K-V deposit, 1951.
[2] 1958 stumpage prices.

Man-hours expended and actual costs are expected to vary with stand, infection, and topographic and economic conditions. However, the relative relationships shown here are expected to remain similar.

## DISCUSSION AND SUMMARY

A pilot-plant study was begun in 1950 at the Fort Valley Experimental Forest, Arizona, to test silvicultural control of dwarfmistletoe. Three groups of three 25-acre plots each were treated according to these objectives:

1. Limited dwarfmistletoe control by using harvest and stand-improvement cuttings to reduce infection to levels unimportant to timber production. The practices could be applied on national forests under existing allotments and regulations.

2. Unlimited dwarfmistletoe control to reduce the level of infection to as near zero as possible.

3. Light improvement selection treatment to provide a standard for comparative purposes.

Silvicultural control of dwarfmistletoe is directed toward restricting spread by removing the seed source. First, the infected sawtimber overstory is removed in a harvest cutting. Then, infections in understory poles and saplings are removed by sanitation cuttings and pruning.

Dwarfmistletoe can be controlled in lightly infected stands with only minor modifications of current harvest-cutting and stand-improvement practices. In such stands, the parasite should be controlled early to arrest its spread. Incidence of infection and size of infected area increase at an accelerated rate with increase in age of infection. Infection levels not serious today will be so in a few years; heavy infections will become worse.

In severely diseased stands, such as those described here, little will be accomplished without heavier than normal cutting and substantial investment in direct control. Often severely infected stands cover only 5 to 10 acres, so by drastically reducing the infection level, larger noninfected areas can be protected (Andrews, 1957). Proved regeneration measures should be undertaken soon after secondary control where stocking is reduced below acceptable levels.

A second round of control measures should be applied from 3 to 7 years after the initial operation (Gill, 1954; Gill and Hawksworth, 1954). Visible shoots are not produced by dwarfmistletoe for several years after seeds germinate. About 60 percent of these latent infections appear within 5 years after the original control operations and 80 percent within 7 years. A third operation may not be needed for 20 years or longer (Gill, 1954; U. S. Forest Service, 1957). For unlimited control, more than three reduction operations may be needed.

The study will be continued to further test the practices described and to test new control techniques. The latter may include both new silvicultural control methods and direct control by chemicals and biological agents. Periodic measurements will be made to determine the effect of the treatments on stocking, net growth, and timber quality. Records will be kept of the costs of control and the returns through sales of stumpage.

As control techniques are developed and their costs determined, improved guides for managing southwestern ponderosa pine will become available. More growth, mortality, and quality losses from dwarfmistletoe can be avoided and a positive step will be taken toward maximum volume and quality production.

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