Dwarfmistletoe on Red Fir and White Fir in California[1]

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Abstract. Stands of red fir and white fir in California are extensively infected with the fir dwarfmistletoe, and damage is heavy over much of the fir belt. Field observations and cross-inoculation studies show that there are two specialized forms of fir dwarfmistletoe, one attacking only red fir and one only white fir. In most fir stands, only one form is present in a given area. In such stands, reduction of mistletoe damage through stand conversion or through selective thinning of reproduction is suggested. Where both forms of mistletoe are present in the same stand, standard control procedures or interplanting with nonsusceptible species is suggested.

WHITE FIR (*Abies concolor* [Gord.] Engelm.) and red fir (*A. magnifica* A. Murr.) constitute nearly one-fourth of the timber volume in California's commercial forests (*1*) and about one seventh of the annual lumber production in that area (*6*). These species are therefore of considerable concern to timber managers. One of the major problems in fir management is the dwarfmistletoe, *Arceuthobium campylopodum* Engelm. Stands throughout the ranges of these fir species in California are heavily infected with this parasite and damage is extensive.

Many questions arise regarding the treatment of mistletoe-infected fir stands. General recommendations for control of dwarfmistletoes are available to guide forest managers, but information dealing specifically with fir problems is limited. Investigations of dwarfmistletoe on firs have been undertaken to help meet the need for additional information. Initial results of these investigations and their possible significance in the silvicultural treatment of fir stands are presented here.

Symptoms and Damage

Dwarfmistletoe attacks both the branches and main stems of fir. Branch infections cause localized, fusiform swellings from which the mistletoe shoots emerge. The length of these swellings varies from less than one inch to several feet, depending on the age of the infection and the size of the infected branch. Very old infections result in greatly swollen, gnarled branches, particularly in the lower crowns of open-grown trees (Fig. 1). Dormant buds are often activated in the infected area, causing abnormal proliferation of branches. This proliferation is not extensive, however, and witches'-brooms of the type frequently observed on infected pines are rare on firs. Branch dieback, resulting from secondary infection by canker fungi, is another characteristic symptom associated with branch infection. This dieback, commonly called flagging, is especially conspicuous on red fir, and the presence of numerous red or brown branches in the crowns of red firs is a nearly certain indication of mistletoe infection.

Mistletoe infections of the main stems are common in red fir and especially so in white fir. These infections cause swellings or "burls" that may be several feet long and nearly twice the diameter of the uninfected stem (Fig. 2). One to many such swellings may occur on a single stem at any height. In old infections, the bark sloughs from the central surface of the swelling, and insects and fungi enter the exposed wood. The wood then decays in the infected area and the tree often breaks at the swelling (Fig. 3), or the swelling and adjacent decayed wood must be culled during harvest.

Fir stands infected with dwarfmistletoe are readily recognized by the occurrence of the above symptoms. Overstory trees show extensive flagging, swollen, gnarled lower branches, and frequent stem swellings. Broken snags are often prevalent. Understory saplings usually show numerous branch infections and prominent flagging.

Accurate information on the amount of damage to fir stands caused by dwarfmistletoes is lacking. Reduction in growth, poor form, large branches, decayed stem infections, and mortality from breakage undoubtedly cause heavy losses and greatly reduce productivity. The frequency of breaks at stem infections and the size and weight of infected branches also create a hazard in recreational areas.

Spread and Intensification

Red fir and white fir form climax forests over extensive areas in California, red fir predominating at higher elevations and white fir at lower elevations within the fir belt (*3, 5*). Once dwarfmistletoe becomes established in a fir stand, perpetuation of fir as a climax stand appears to insure perpetuation of the mistletoe. As the old, overstory fir stand breaks up as a result of age and dwarfmistletoe activity, abundant fir reproduction is established. These young trees are readily infected by mistletoe seed produced in the declining overstory. The extensive, heavy infection over much of the fir type suggests that mistletoe has been present in these stands for many generations. Thus the dwarfmistletoe infestation apparently becomes permanent, or nearly so. Two factors that may affect this stable association have been observed; fire and host specialization.

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FIG. 1.—Pendant, swollen branches in the lower crown of a red fir infected with dwarfmistletoe.

FIG. 2.—An old, stem infection on white fir, showing swelling and sloughing of bark.

FIG. 3.—A white fir that has broken at an old, rotted mistletoe swelling. Broken trees of this kind are frequent in infected stands.

Fire.—Fires, while less frequent in the fir belt than at lower elevations, have destroyed large tracts of fir, thus removing the dwarfmistletoe with the stand. These large burns come back to manzanita, chinquapin, and similar plants that form dense brush fields. Firs are pioneer invaders of these brush fields, seeding in slowly from the margins or from islands of trees that survive the fire. Examination of areas where firs are advancing into brush fields indicates that, when stands at the margin or surviving islands of trees within the burn are infected, the advance of the mistletoe keeps pace with the advance of the fir. Thus the stand that eventually replaces the brush is often heavily infected. These observations suggest that while fire may temporarily destroy dwarfmistletoe by destroying infected stands, the ecological sequence leading to reforestation of burns in the fir belt tends ultimately to perpetuate extensive mistletoe infection.

Host specialization. — Recent studies have shown that in many stands, one or the other fir species is infected, but not both (*7*). These initial studies have been expanded to include observations over much of the northern Sierra Nevada. The evidence obtained indicates clearly that there are two specialized forms of dwarfmistletoe on fir, one infecting only red fir and one infecting only white fir. When both firs were found infected within the same stand, examination of the surrounding area generally disclosed that the two forms had converged from adjacent infection centers. Infection of both fir species in the same stand was encountered infrequently, however.

To confirm these observations experimentally, cross-inoculation studies were made in two areas of the northern Sierra Nevada: Latour State Forest (near Lassen National Park) and Pinecrest (about 250 miles south of Latour). In both areas, trees free of natural infection were used. At Pinecrest two red fir and two white fir saplings were inoculated by shaking detached clumps of fruiting mistletoe shoots so that numerous seeds were discharged into the crowns, giving tests of red fir mistletoe seed on one red and one white fir and white fir mistletoe seed on one red and one white fir. A count of seeds on sample branches indicated that several hundred seeds were deposited on each tree. At Latour, mistletoe seeds were placed individually on the branches of test trees at five seeds per branch. A group of six red fir saplings and a group of five white fir saplings were used, each group receiving 100 red fir and 100 white fir mistletoe seeds. Another experiment set up at the same time with seed from the same sources involved 200 red fir mistletoe seeds placed on 40 red fir seedlings (at five seeds per tree) and 425 white fir mistletoe seeds placed on 85 white fir seedlings (at five seeds per tree). All inoculations were made in the fall of 1958, and final results were recorded in the fall of 1961 (Table 1).

Mistletoe seed from red fir gave 39 infections on red fir and none on white fir. Mistletoe seed from white fir gave six infections on white fir and none on red fir. These data support the field evidence that dwarfmistletoes on red fir and white fir are physiologically distinct and are restricted to their respective host species. These data suggest also that white fir is somewhat resistant to infection, and that for a given level of inoculum, fewer infections develop on white fir than on red fir. The existence of two host-specific forms of dwarfmistletoes on firs has special taxonomy and management implications.

Discussion

Taxonomy.—Gill (*2*) divided *A. campylopodum* into formae based on available evidence for host spe-

TABLE 1.—RESULTS OF CROSS-INOCULATIONS WITH DWARFMISTLETOE SEEDS FROM RED FIR AND WHITE FIR

Source of dwarfmistletoe seed	Size of trees	Location and species inoculated			
		Latour State Forest[1]		Pinecrest[2]	
		Red fir	White fir	Red fir	White fir
Red fir	Saplings	29/100	0/100	5/–	0/–
Red fir	Seedlings	5/200	–	–	–
White fir	Saplings	0/100	0/100	0/–	3/–
White fir	Seedlings	–	3/425	–	–

[1]Number of infections over number of seeds.
[2]Number of seeds was not tallied. Sampling of selected branches indicated that several hundred seeds were deposited on each tree.

cialization. He stressed the provisional nature of this scheme and suggested that future revisions based on additional information would likely be necessary. The occurrence of two specialized forms of dwarfmistletoes on firs indicates that revision or modification of *A. campylopodum* f. *abietinum* (Engelm.) Gill is necessary. Without further knowledge of specialization on other fir species, the erection of new formae or the designation of races within the present forma would be premature, however. A thorough investigation of host specialization in *A. campylopodum* is clearly needed before any changes in the present scheme of classification are undertaken.

Management. — General procedures for controlling dwarfmistletoes in California timber stands have been outlined by Kimmey (*4*). Essentially three approaches are described: (1) sanitation by removal of merchantable trees and trees from which mistletoe cannot be pruned, followed by pruning to remove all infections in the residual stand, (2) clearcutting with removal of reproduction, followed by natural or artificial regeneration, or (3) conversion of mixed stands by removal of the infected species followed by natural regeneration of the uninfected species. With appropriate follow-up pruning where required and with the selection of natural barriers (roads, meadows, streams, etc.) or the erection of artificial barriers (cleared strips or strips of nonsusceptible trees) to prevent reinvasion, these procedures provide necessary control and should be considered whenever infected fir stands are harvested.

The existence of specialized forms of dwarfmistletoe on red fir and white fir makes stand conversion a particularly attractive control procedure in mixed fir stands in which only one species is infected. Since mistletoe damage to a stand is, in part, a function of the ratio of infected to uninfected trees, marking and cutting to promote maximum reproduction of the uninfected species is a sound procedure to reduce damage.

The above procedures involve harvest cuttings, and their application may not be practical in all stands. Many infected fir stands that have been selectively logged, partially burned, or that are naturally understocked or deteriorating because of age and dwarfmistletoe damage either contain insufficient volume to carry the cost of cutting and control or cannot be harvested until better stands have been worked. These open stands are filling in with a high percentage of infected reproduction, and losses in the future crop will be extensive unless steps are taken now to reduce the numbers of infected trees.

Many of these stands contain numerous openings that could be planted to pines (or to the uninfected fir species in mixed stands where only one species is infected). Interplanting, or underplanting where stand conditions permit, would: (1) reduce the spread and intensification of mistletoe by providing patchwork barriers of nonsusceptible trees, (2) reduce natural regeneration of the infected fir species, and (3) provide groups of nonsusceptible trees around which future silvicultural mistletoe-control manipulations could be planned. In stands where both fir species are infected and harvest cutting must be deferred, interplanting or underplanting appear to be the only feasible means of reducing otherwise inevitable losses. Where only one fir species is infected, another approach is available.

Thinning of reproduction in many mixed fir stands appears advisable on silvicultural grounds. Where stand densities warrant thinning of reproduction, removal of a maximum number of trees of the infected species would increase the percentage of uninfected trees in the ensuing stand and at the same time decrease competition from infected trees. The resulting gain in numbers and growth of uninfected trees would insure a corresponding reduction in mistletoe damage. Where direct stand-improvement thinnings are not practical, partial control might be obtained by indirect means.

Both red and white firs are valuable as Christmas trees. Since dwarfmistletoe has little or no effect on the decorative value of most small firs and since susceptible trees in infected stands are unsatisfactory as crop trees, encouraging Christmas tree cutting in mixed fir stands appears to be a feasible procedure to reduce losses if cutting is restricted to the infected species. Christmas tree cutting might be carried out through commercial Christmas tree sales or through opening stands to supervised cutting by the public. This approach, while less effective than direct improvement thinning, would provide partial control at minimum cost.

Procedures to reduce or eliminate mistletoe damage vary in cost, complexity, and effectiveness. All involve some difficulty. However, the ecology of firs and of dwarf mistletoes is such that fir stands reproduce fir stands, and infected fir stands reproduce infected fir stands. Direct eradication of the parasites should be undertaken whenever feasible. Where eradication is not feasible, gradual reduction of losses through interplanting, selective thinning, or stand conversion is warranted. Such programs not only reduce what would otherwise be inevitable losses; they also provide stands better suited to future control manipulations.

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Reducing Trunk Malformation Caused by Injury to Eastern White Pine by the White Pine Weevil[1]

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Abstract. The value of eastern white pine (*Pinus strobus*) is often materially reduced because of trunk deformity resulting from attack of the white pine weevil which kills the terminal leader and causes a lateral branch (sometimes more than one) to assume the terminal position, producing a crook in the stem, and in some cases multiple stems. Purpose of this study was (1) to determine the extent to which subsequent trunk malformation is reduced by deliberately selecting the branch that will become the terminal shoot, removing all other competing laterals at that node, and (2) to investigate some factors involved. Weevil injury was simulated by excising the terminal leader on 120 sapling trees; all laterals but one in the top whorl were removed from certain trees; others were left untreated. Treatments were undertaken in May, June, and July. Recovery was consistently better on treated than untreated trees, greater and more rapid for early than late dates of treatment. On untreated trees, the successful competing lateral was one of the largest with its base in the upper part of the whorl. On treated trees, effect of branch size and position was less evident but data suggest that the lateral selected for retention should be of average size or smaller.

AT ITS BEST eastern white pine (*Pinus strobus*) is a valuable conifer for purposes of forest management, growing wood of high intrinsic value suitable for many uses, and producing per-acre yields that exceed the productivity of any other eastern species. But under less favorable circumstances, this pine is no more desirable than many of its associates, and less so than some. A major problem in the management of the species is concerned with factors that adversely affect tree form and lower both the volume, and especially the quality, of the lumber produced. Certain aspects of this problem will be considered in the discussion which follows.

A considerable share of the low quality found in run-of-the-mill eastern white pine can be attributed to agencies which damage the terminal leader on individual trees. When the leader is killed or otherwise rendered incapable of further terminal elongation, a lateral branch in the whorl below the point of injury asserts dominance over other laterals, curves upward, and becomes the new leader. In all cases, the lower part of this substitute leader is deformed to a greater or lesser degree. If this deformity is small, subsequent diameter growth of the stem usually overcomes the irregularity, and little significant loss in quality or value results. In many cases, however, the deformity is never completely corrected during an ordinary management rotation. Such malformation leads to loss in tree volume (*4*) and to the production of cross grain and reaction wood in the vicinity of the stem curvature (*2, 3*) which seriously degrades wood quality.

Of the three principal agents that damage or destroy the terminal leader on eastern white pine—the white pine weevil (*Pissodes strobi* Peck), birds, and glaze storms—attack by the weevil is the most widespread and serious (*1*). The minimal objective of pine management should be to produce at least a butt log free of serious weevil deformity, a goal accomplished either by control of the insect itself, or by reduction in the degree of malformity that results from the infestation.

The study being reported here concerns the latter approach to the treatment of the problem. For more than 30 years, young weevil-attacked trees in pine forests of central Massachusetts have been treated as described below to reduce stem deformity caused by weevil injury. Results were good in general, but no data have been available to provide a quantitative measure of the improvement to be anticipated. The objectives of these

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