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Dwarfmistletoe Removal and Reinvasion in Jeffrey and Ponderosa Pine, Northeastern California

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ABSTRACT: Nine years of removal of infections and prevention of seeding of dwarfmistletoe from a young mixed Jeffrey-ponderosa pine stand failed to eliminate the parasite. Spread of the parasite back into the experimental plot from infected trees outside averaged about 0.9 feet per year. One tree in 23 appeared to show some resistance to infection. Jeffrey pine had almost twice as many infections per tree as ponderosa pine.

Dwarfmistletoes, destructive plant parasites in the genus Arceuthobium, were early recognized as problems in the management of California's coniferous forests. Not enough was known about the biology of these parasites, however, to appraise satisfactorily the possibilities for control.

To learn more about the field biology of an important species of dwarfmistletoe on pines and other conifers in California--Arceuthobium campylopodum--an experimental plot (the Bunnel plot) was established in 1926. It was laid out in northeastern California near the eastern boundary of the Lassen National Forest in a young stand of Jeffrey and ponderosa pine infected by the parasite. The study had two objectives: (a) to remove the parasite from the plot, obtaining as complete a record as possible of the dwarfmistletoe infections found during removal, and (b) to determine the rate of spread of the parasite back into the plot from infected young trees outside its boundaries after removal was completed.

We anticipated that if infections were removed annually and no seed production by the parasite was permitted within the plot for a period of 5 to 6 years, the plot would be free of dwarfmistletoe originating from within it. Invasion by the parasite from outside the plot boundaries could then be followed.

Because of unexpected difficulties, observations on the plot were indefinitely suspended in 1939, but in 1964 the plot was revisited and a record made of the current status of dwarfmistletoe on numbered trees. The information supplements that of 1926-1939.

[1]L.H. Dougherty, Ernest Wright, and L.S. Gill took major parts in field work on the experimental plot between 1926 and 1935. D.R. Miller and H.R. Offord participated in the 1964 reexamination.

LOCALITY AND ENVIRONMENT

The area is in openly timbered country southeast of Goat Mountain, Lassen County. Sagebrush openings in the timber occur on some south slopes. The general drainage is southeast into the Susan River. The climate is interior in type, with warm daytime temperatures and cool nights during the growing season. Winter minimum temperatures occasionally drop as low as -20° F. Annual precipitation is about 16 inches, roughly 45 percent of which falls as snow. Rims and dikes of old lava rock appear as outcrops on ridges and along streams.

THE STAND

Before logging of the area in 1925, the forest consisted of a very open overstory of mature Jeffrey and ponderosa pines, interspersed with well-established advance growth of seedling to pole size of the same pine species. A few white firs grew on north or northeast slopes. Dwarfmistletoe was prevalent on part of the overstory trees and well-established on the pine advance growth around infected overstory pines. Logging removed most of the overstory without serious damage to the young stand.

THE PLOT

A rectangular plot 140 x 100 feet, about 0.34 acre, was laid out in moderately dense pine advance growth of uneven age, the dominants of which averaged 27 feet in height and 5 inches d.b.h. On parts of the plot almost every tree was infected with dwarfmistletoe, but on other parts many trees were free of the parasite. For the entire plot 32 percent of the trees were infected. No trees had been removed from the plot in logging, but a group of large pines had been logged from beyond the south boundary. Much of the dwarfmistletoe on the plot seemed to have come from a 36-in. d.b.h. Jeffrey pine on the southeast portion, felled as a snag several years before plot establishment. No mature overstory trees remained near the plot after logging.

Other plot information includes:

Pines present, 4-in. diam. class and larger	172
Pines under 3.6 in. d.b.h. (except seedlings)	232
Stand composition, Jeffrey vs. ponderosa pines	106/66
Stems per acre	1,188
Basal area per acre (sq. ft.)	97.56
Site class (5-site basis)	low III
Elevation	5,000 ft.
Exposure	Northeasterly
Slope	Gentle
Soil	Sandy loam

Considerable gnawing of bark over infections by small rodents was noticeable on the plot and had evidently hastened the death of a number of former infections. Most of the rodent chewing was old, and very little fresh work was noted after the plot was established. The kind of animal responsible for the gnawing was not positively determined.

PROCEDURES

Pines in the 4-in. d.b.h. class and over were numbered and tagged; those of lesser diameter were referenced by direction and distance to the closest numbered tree. Numbered trees were mapped. Each tree was examined limb by limb for dwarfmistletoe. Whenever crowns could not be inspected closely from the ground, trees were climbed or examined from a ladder. Infections found were recorded individually to show size, sex, and location within the crown or on the stem. In annual reexaminations a judgment was also recorded as to whether infections found were newly developed or had been overlooked in a previous inspection.

After recording, all infections on branches were pruned out, removing only as much branchwood as seemed necessary to eliminate the infections. In this way as much crown as possible was left to observe whether latent infections, already established but not yet visible, might later appear. For the same reason male infections, which cannot spread the parasite, were left when they occurred in the main stem. Well-developed female stem infections were removed by topping or cutting the affected tree. In a few cases, where a female infection was just entering the stem from a branch or was very young, an attempt was made to prevent its further development by removing invaded bark and also the surrounding bark for several inches beyond the apparent infection limits. This preserved the tree or crown for future observation.

Initial notes, pruning, and cutting of trees were completed in 1926. Reexamination and further pruning were conducted annually before seed ripening from 1927 through 1935, after which they were discontinued. Inspections of the plot were made in 1937 and 1939.

The reexamination in 1964 was from the ground with the aid of field glasses and covered only the 142 remaining numbered trees. No infections were pruned out.

RESULTS

INFECTIONS

Dwarfmistletoe infections found on the plot in the period from 1926 through 1935 totaled 2,601 (table 1), a rate of 7,645 per acre. However, this total does not include all infections present on the plot because it makes no allowance for infections established but not yet visible, termed latent infections, on 95 trees cut or topped on the plot to remove female stem infections. A conservative allotment to these cut or topped trees of 375 latent infections gives a total of 2,976 infections for the plot, or about 8,750 per acre. The allotment takes

Table 1. *Dwarfmistletoe infections tallied on the Bunnel plot, Lassen National Forest, 1926-1935 and 1964*

Year and type of infections found	On numbered or referenced trees		On seedlings		Total
	Number		*Number*		
1926	1,468		383		1,851
1927	62		10		72
New[1]		48		5	
Overlooked		14		5	
1928	79		14		93
New		69		12	
Overlooked		10		2	
1929	127		11		138
New		112		10	
Overlooked		15		1	
1930	106		14		120
New		97		14	
Overlooked		9		0	
1931	198		41		239
New		129		22	
Overlooked		69		19	
1932	25		2		27
New		18		1	
Overlooked		7		1	
1933	13		0		13
New		5		0	
Overlooked		8		0	
1934	27		0		27
New		12		0	
Overlooked		15		0	
1935	9		2		11
New		4		2	
Overlooked		5		0	
Total, 1926-35	2,124		477		2,601
1964	[2]309+		--		--

[1] ''New'' refers to infections that have become recognizable as such since the previous reworking of the plot. All had passed through a latent stage.

[2] On numbered trees only. For two trees the exact number of visible infections could not be counted. Numbers of infections tallied for them represent minimums.

into account the greater average number of recognizable infections per tree on the cut or topped trees in 1926 as compared with the number on infected trees not removed or topped: 7.08 vs. 3.68.

The number of additional infections appearing on the plot dropped off sharply after the fifth year, 1931, which was the sixth year after seed were last dispersed. This drop confirms the results of a seeding experiment carried out in the same general area, in which 3 to 6 years was found to elapse after seeding before resulting infections became recognizable.[2]

Debarking from and around limited female stem infections prevented shoot production for a few years, but in no case caused the death of an infection. All ultimately regenerated and fruited, but no fruiting occurred until after 1935.

A part of the 83 infections found from 1932 through 1935 unquestionably originated from seed dispersed from outside the plot. Sixty-two percent of the new infections found during this period were on trees within 20 feet of the plot border, usually on the sides of crowns facing the border. In 1935, the tenth year after annual removals were started, 3 of the 11 infections found were on interior parts of the plot beyond the limits of normal seed dispersal from external sources. The origin of these infections could not be definitely determined. The most likely explanation for their presence is that they represent cases of development to a visual state after an abnormally long period of latency. In the Southwest, Hawksworth[3] reports that 1 of 57 infections of a similar dwarfmistletoe, A. vaginatum f. cryptopodum, did not produce external shoots until 8 years after seeding. Field indications suggest that infections may occasionally persist in a latent state for even longer periods in A. campylopodum. If so, this could account for the late appearance of infections on interior parts of the Lassen plot.

RATE OF LATERAL SPREAD

The spread of dwarfmistletoe from overstory ponderosa pines into a young stand is usually more rapid than the rate of lateral spread from pine to pine through a young stand for two reasons: (a) the higher points of origin of the seeds of the parasite from overstory trees (Hawksworth[3]), and (b) the reduced chances of interception by surrounding tree crowns of seeds dispersed from an elevated seed source.

No infected overstory trees were present on, or near the Bunnel plot, and the limits of reinvasion from outside could not be exactly determined by 1964 because of infections from internal sources--in particular from the 12 debarked but regenerated female stem infections on the plot. However, the trees infected in 1964 were charted on a map, and inspection of the map indicated that spread into the plot

[2] Wagener, Willis W. Dwarfmistletoe incubation period on ponderosa and Jeffrey pines in California. Forest Sci. 8:16-20, 1962.

[3] Hawksworth, Frank G. Dwarfmistletoe of ponderosa pine in the southwest. U.S. Dept. Agr. Tech. Bul. 1246, 112 pp. 1961.

from external sources had not exceeded 20 feet by 1958, allowing 6 years for established latent infections to become visible by 1964. Significant amounts of the parasite were not found beyond 15 feet from the plot boundary. Twenty feet in 23 years is at an average yearly rate of advance of slightly less than 0.9 foot per year.

LOCATION OF INFECTIONS IN 1964

When tallied by location, 52 percent of the visible infections found in 1964 were in a 20-foot wide peripheral zone inside the plot boundary, 41 percent were in the vicinity of regenerated female infections within the plot, and 7 percent on other parts of the plot. These percentages are not exact. For example, some infections within the peripheral zone were also close to one of the 12 regenerated female stem infections. In that case the later established infections were assigned to whichever source appeared to be the most important, based on the general infection pattern in the vicinity. The percentages do indicate, however, that infections from exterior seed sources and from regenerated female plants accounted for nearly all infections on the plot in 1964.

HOST RESISTANCE

Seventeen out of the 172 numbered trees originally on the plot were free of dwarfmistletoe in 1926, including an absence of signs of old dead infections, and have remained free since then. Five of the 17 were Jeffrey pines and 12 ponderosa pines. Seven of the 17 were dominant trees in the stand. Of the 17, 9 were in portions of the plot where infection was light and thus could have escaped infection. The remaining eight trees, of which six were ponderosa and two Jeffrey pines, undoubtedly embody some resistance to the parasite.

EFFECT OF PRUNING

Seventy-five trees--more than half of the 142 numbered trees remaining on the plot in 1964--were free of visible dwarfmistletoe infections in 1964. Of these 75 trees, 56, or about three-fourths, had previously been infected. The absence of reinfections on these trees is undoubtedly owing to the effect of pruning out of infections on the plot, or, in a few cases, to the death of twig infections before pruning.

COMPARATIVE SUSCEPTIBILITY OF HOST SPECIES

A comparison of the average number of infections per tree for the two pines gave 7.73 dwarfmistletoe infections for the average Jeffrey pine and 4.61 infections for ponderosa pine. These numbers were for the total infections per tree for the 10-year period, 1926-1935, on trees in the 4-inch-and-over d.b.h.-classes. The results support those from a dwarfmistletoe seeding experiment (Wagener[2]) in the same general area, in which 3 to 4 times as many infections became established on Jeffrey as on ponderosa pines in a mixed young stand. Jeffrey pine predominated in the stand but at less than a 2:1

ratio. Results in both cases indicate that in this eastern Lassen area, Jeffrey pine is more susceptible to infection by dwarfmistletoe than ponderosa pine.

DISCUSSION

Nine years of annual removal of dwarfmistletoe and prevention of seed production failed to eliminate the parasite from interior parts of the plot remote from external infected trees. This finding is supported by unreported similar results obtained on a plot in pure ponderosa pine on the Plumas National Forest. It emphasizes the difficulty in eradicating the parasite from a young stand by pruning and cutting infected trees.

In the 29 years since the removal of infections was discontinued, however, the parasite showed little increase within the plot. This result suggests that once the incidence of dwarfmistletoe is reduced to a low level, its increase will be slow. In this condition the parasite should have little effect on the growth of the stand. Similar results have been noted after 23 years of observations following control operations against A. vaginatum f. cryptopodum on ponderosa pine in Arizona[4].

The relatively slow rate of lateral spread of the parasite into the plot from outside, about 0.9 foot per year, agrees closely with the 0.9 foot per year average rate reported by Hawksworth[3] for lateral spread of A. vaginatum f. cryptopodum in young ponderosa pine in the Southwest.

Spread on the Bunnel plot took place through a well-stocked stand. In a very open stand a faster rate of progress can be expected because the chances for interception close to the place of origin of the explosively propelled seeds will be greater in a close stand than in an open one.

On the Bunnel plot almost all infections that appeared to originate from seed from outside the plot became established on branches of lower or midcrowns. Here their presence had little effect on the host tree, in contrast to infections from overstory sources. Many of the latter become established in upper crowns or upper main stems where they can be much more damaging. This difference can be important in estimating damage potentials of dwarfmistletoe in young-growth pine. Most cases of the parasite that attract attention in young pine stands have arisen from overstory sources. It is not safe to use such stands as guides for estimating damage from dwarfmistletoe progressing by lateral spread in a young native stand or a plantation.

SIGNIFICANCE FOR CONTROL

Although the study was not designed as a field test of dwarfmistletoe control by pruning or cutting infected trees, the results obtained have some significance for control of the parasite. They indicate that:

[4]Hawksworth, F. G. Personal communication, February 15, 1965.

--Complete elimination of dwarfmistletoe, although silviculturally desirable, is not practical to achieve by pruning or removing infected trees.

--Dwarfmistletoe builds up slowly after reduction to a low level in a stand containing no overstory trees and is not likely to cause serious damage to the stand.

--Lateral extension of dwarfmistletoe from infected to noninfected parts of a relatively even-aged, well-stocked stand, natural or planted, will average less than 1 foot per year.

--Dwarfmistletoe infection from an overstory source is not a safe guide for estimating the damage potential of the parasite when extending laterally through a relatively even-aged stand.

Because environmental conditions considerably influence dwarfmistletoe (Wagener[2]), the results obtained on the Bunnel plot cannot be expected to apply without modification in environments differing widely from those of the plot.

The Author. . .

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