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Robert L. Mathiasen
Northern Arizona University, Flagstaff

Frank G. Hawksworth
USDA Forest Service, Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colorado

Carleton B. Edminster
USDA Forest Service, Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colorado

EFFECTS OF DWARF MISTLETOE ON SPRUCE IN THE WHITE MOUNTAINS, ARIZONA

Robert L. Mathiasen[1], Frank G. Hawksworth[2], and Carleton B. Edminster[2]

ABSTRACT.—Mortality of spruce in mixed conifer stands moderately to heavily infested with western spruce dwarf mistletoe was two to five times greater than in healthy stands in the White Mountains, Arizona. Ten-year volume growth loss for heavily infected spruce trees ranged from 25% to 40%. Estimates of growth loss for spruce on a stand basis ranged from 10% to 20% in heavily infested stands. Because western spruce dwarf mistletoe is prevalent in the White Mountains and causes increased mortality and reduced growth, its control should be included in management of mixed conifer stands there.

Western spruce dwarf mistletoe (*Arceuthobium microcarpum* [Engelm.] Hawksw. & Wiens) is a damaging parasite of Engelmann spruce (*Picea engelmannii* Parry), blue spruce (*P. pungens* Engelm.), and bristlecone pine (*Pinus aristata* Engelm.) in the southwestern United States (Hawksworth and Wiens 1972, Mathiasen and Hawksworth 1980). The distribution of western spruce dwarf mistletoe is confined to Arizona (Pinaleno and White Mountains, San Francisco Peaks, Kendrick Peak, and the North Rim of Grand Canyon) and New Mexico (Mogollon and Sacramento Mountains) (Hawksworth and Wiens 1972, Mathiasen and Jones 1983). Western spruce dwarf mistletoe is most prevalent in the White Mountains, Arizona (Apache-Sitgreaves National Forest), where it has been reported to be in over 60% of the spruce type and is a primary factor associated with spruce mortality (Hawksworth and Graham 1963). It is more common in the lower mixed conifer forests than in spruce-fir forests, possibly because its distribution is restricted to below approximately 10,400 feet (Acciavatti and Weiss 1974, Mathiasen and Hawksworth 1980).

Gottfried and Embry (1977) reported blue spruce was more heavily infected than Engelmann spruce in a virgin mixed conifer stand in the White Mountains, Arizona, but overall infection of both species was relatively low (2% and 5% for Engelmann and blue spruce, respectively). However, Gottfried and Embry also reported that almost 20% of their sample points containing blue spruce had infected trees. Hawksworth and Graham (1963) reported 63%–70% of the spruce stands they surveyed in the White Mountains, Arizona, were infested with western spruce dwarf mistletoe. Our observations in the White Mountains also indicate blue spruce is heavily infected in many mixed conifer stands, particularly along drainages. Jones (1974), Gottfried and Embry (1977), and Ronco et al. (1984) proposed general recommendations for silvicultural management of mixed conifer forests that consider the dwarf mistletoe problem.

Although western spruce dwarf mistletoe represents the most damaging disease agent in southwestern mixed conifer forests dominated by Engelmann or blue spruce, little information is available regarding its effect on mortality and growth of its principal hosts. This study provides additional quantitative data on the mortality and growth loss caused by western spruce dwarf mistletoe in the White Mountains, Arizona.

METHODS

In 1981, 99 temporary rectangular plots ranging in size from 0.1 to 0.8 acre were placed in mixed conifer stands with various densities of Engelmann and/or blue spruce in the White Mountains, Arizona (Apache-Sitgreaves National Forest). Two-thirds of the plots were infested with various levels of western spruce dwarf mistletoe. Plots were selected in an attempt to maintain a homogeneous distribution of age classes, species

[1]School of Forestry, Northern Arizona University, Flagstaff, Arizona 86011.
[2]USDA Forest Service, Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colorado 80526.

composition, and dwarf mistletoe infection. Plots were only located in stands that had not been disturbed for at least 12 years prior to data collection.

The following data were recorded for each tree greater than 4.5 feet in height in each plot: species, diameter breast height (DBH) to the nearest 0.1 inch, dwarf mistletoe rating (six-class system, Hawksworth 1977)[3], crown class (dominant, co-dominant, intermediate, suppressed), tree condition (live or dead), and ten-year radial wood growth at DBH to the nearest 0.05 inch. Overstory $\overline{\text{DMR}}$ values were calculated using DMR for spruce trees only.

Height and age data were measured as follows: total height to the nearest 1.0 foot for two to three living or dead trees from each one-inch diameter class represented for each species in a plot; height to the base of the live crown to the nearest 1.0 foot for live trees measured for total height; distance from the ground to the tenth whorl from the top of live trees measured for total height; age at DBH for two live trees from each two-inch diameter class represented for each species in a plot. Height versus diameter curves were developed for each plot, and these curves were used to estimate present and past heights for trees with only measured diameters. Present volumes and past ten-year volumes were calculated from diameter and height data for Engelmann and blue spruce using the volume equations for Engelmann spruce developed by Hann and Bare (1978). Ten-year periodic annual volume increment (cubic feet/year) was calculated using present and past volumes for spruces greater than 6.0 inches at DBH.

RESULTS

THE SAMPLE.—Of the 99 plots sampled, 34 were predominantly Engelmann spruce, 42 were predominantly blue spruce, and 23 had approximately equal representation of Engelmann and blue spruce based on stems/acre. Basal areas (square feet/acre) ranged from 10 to 134 for blue spruce and from 6 to 156 for Engelmann spruce. However, approximately one-third of the plots sampled had Engelmann or blue spruce basal areas of less than 50 square feet/acre:

Basal area (square feet/acre)	Number of plots Engelmann spruce	Blue spruce
< 50	31	37
51–100	6	8
>100	5	12

The majority of the plots sampled had spruce densities (stems/acre) of less than 200:

Stems/acre	Number of plots Engelmann spruce	Blue spruce
<100	17	19
101–200	13	21
201–300	5	5
>300	7	12

One-third of the plots had no western spruce dwarf mistletoe infection and the remainder ranged from light to heavy:

$\overline{\text{DMR}}$	Number of plots
0	33
0.1–1.0	27
1.1–2.0	20
2.1–3.0	10
>3.0	9

MORTALITY.—Percent mortality was determined for the following size classes: small saplings (DBH 0.1–1.0 inches), large saplings (DBH 1.1–5.0 inches), poles (DBH 5.1–10.0 inches), small sawtimber (DBH 10.1–16.0), and large sawtimber (DBH greater than 16.0 inches) by 1.0 $\overline{\text{DMR}}$ classes (Table 1). Mortality of small and large saplings was approximately the same for healthy plots ($\overline{\text{DMR}}$ 0) and for plots with a $\overline{\text{DMR}}$ less than 2.0. However, percent mortality for these size classes was approximately two and four times greater than in healthy plots for $\overline{\text{DMR}}$ classes 2.1–3.0 and greater than 3.0, respectively. Mortality of pole size spruce increased rapidly as $\overline{\text{DMR}}$ increased. Mortality of pole-sized Engelmann spruce was higher than for blue spruce in the higher $\overline{\text{DMR}}$ classes ($\overline{\text{DMR}}$ greater than 2.0). This trend was reversed in the small and large sawtimber size classes,

[3]The six-class dwarf mistletoe rating system divides the live crown of a tree into thirds, and each third is rated separately as: 0, no infected live branches; 1, less than 50% of the live branches infected; 2, more than 50% of the live branches infected. The ratings for each third are totaled to obtain a dwarf mistletoe rating (DMR) for the tree. Adding the DMRs for all live trees in a stand and dividing the total by the number of trees is the average stand dwarf mistletoe rating ($\overline{\text{DMR}}$). The six-class system is a standard method for quantifying the intensity of mistletoe infection for individual trees or stands.

TABLE 1. Percent mortality of Engelmann and blue spruce by 1.0 $\overline{\text{DMR}}$ classes and size classes.

$\overline{\text{DMR}}$ Class	Small sapling (0.1–1.0)		Large sapling (1.1–5.0)		Poles (5.1–10.0)		Small sawtimber (10.1–16.0)		Large sawtimber (>16.0)		All trees	
	E[1]	B[2]	E	B	E	B	E	B	E	B	E	B
0	5	4	7	9	7	4	9	5	6	4	6	6
0.1–1.0	7	1	5	6	17	10	11	3	2	0	8	4
1.1–2.0	2	3	7	6	18	18	12	23	10	10	10	14
2.1–3.0	10	9	12	16	20	15	17	27	11	20	16	17
>3.0	20	17	32	25	34	24	20	33	19	33	23	28

Size class (Inches)

[1]Engelmann spruce
[2]Blue spruce

TABLE 2. Percentage of dead trees with DMR 2–6 by size class.[1]

Size class (Inches)	Total trees	Dwarf Mistletoe Rating[2] 2	3	4	5	6
		(Percent)				
Small sapling (0.1–1.0)	20	5	10	20	30	35
Large sapling (1.1–5.0)	63	8	11	14	27	40
Poles (5.1–10.0)	29	0	0	14	28	58
Small sawtimber (10.1–16.0)	33	0	0	6	36	58
Large sawtimber (>16.0)	14	0	0	14	28	58
Total	159	4	6	13	30	47

[1]Includes both Engelmann and blue spruce
[2]Includes only dead trees that could be assigned an accurate DMR

TABLE 3. Mean ten-year periodic annual volume increment for Engelmann and blue spruce greater than 6.0 inches DBH by DMR class.

DMR class	N	Mean ten-year periodic annual volume increment (cubic feet/year)	Percent difference from DMR 0
0	620	0.32 A[1]	—
1	48	0.34 A	+6
2	94	0.31 A	−3
3	127	0.30 A	−6
4	100	0.28 B	−12
5	128	0.24 C	−25
6	107	0.20 D	−38

[1]Numbers followed by different letters are significantly different. Oneway AOV, $\alpha = 0.05$, Student-Newman-Kuels.

where blue spruce had a more rapid increase in mortality as $\overline{\text{DMR}}$ increased. Mortality of small sawtimber was from two to five times greater in the most heavily infested plots than in healthy plots. Mortality of large sawtimber was from three to eight times greater in the most heavily infested plots (Table 1).

Nearly half of the dead spruce that could be accurately assigned a DMR were rated as class 6 trees (Table 2). This was true for all size classes except the small sapling class where approximately one-third of the trees were rated as class 5 or 6. The percentage of dead trees rated as class 4 ranged from 6% for the small sawtimber size class to 20% for the small saplings. Few dead spruce were rated as class 2 or 3 in the sapling size classes, and none were rated 2 or 3 in the pole and sawtimber size classes.

EFFECT ON VOLUME GROWTH.—Mean ten-

TABLE 4. Percent infection of live trees by DMR and 0.5 $\overline{\text{DMR}}$ classes[1].

$\overline{\text{DMR}}$ class	Dwarf mistletoe rating 0	1	2	3 (Percent)	4	5	6
0.1–0.5	82	13	4	1	0	0	0
0.6–1.0	50	32	6	8	2	1	1
1.1–1.5	40	25	14	9	5	4	3
1.6–2.0	23	32	17	15	6	4	3
2.1–2.5	16	26	11	19	10	11	7
2.6–3.0	8	19	19	19	9	12	14
3.1–3.5	6	19	12	22	19	14	8
3.6–4.0	2	7	12	22	21	20	16
4.0+	1	6	10	11	20	29	23

[1]All spruce combined

year periodic annual volume increment (cubic feet/year) was determined for all spruce greater than 6.0 inches (DBH) for DMR classes 0-6 (Table 3). The results do not include growth loss due to mortality of individual trees.

INFECTION AND GROWTH LOSS ON A STAND BASIS.—The percentage of live trees infected for both Engelmann and blue spruce by individual tree DMR and by 0.5 $\overline{\text{DMR}}$ classes are presented in Table 4. The percentage of trees in the heaviest infection class (DMR 6) ranged from 0% in $\overline{\text{DMR}}$ class 0.1–0.5 to 23% in $\overline{\text{DMR}}$ class 4.0+. A summary of the percentage of trees in DMR classes 4–6 (those in which significant growth loss occurs) is as follows:

$\overline{\text{DMR}}$ class	Percentage of trees in DMR class 4–6
0.1–0.5	0
0.6–1.0	4
1.1–1.5	12
1.6–2.0	13
2.1–2.5	28
2.6–3.0	35
3.1–3.5	41
3.6–4.0	57
4.0 +	72

Stand growth loss was estimated by the distribution of infected spruce by $\overline{\text{DMR}}$ classes (Table 4), and based on the following estimates of growth loss for individual trees by DMR class (Page 6): DMR 1—0%, DMR 2—0%, DMR 3—5%, DMR 4—10%, DMR 5—25%, DMR 6—40%. Stand growth loss by 1.0 $\overline{\text{DMR}}$ classes based on the above estimates was:

$\overline{\text{DMR}}$ class	Estimated percent loss on a stand basis
0.1–1.0	1
1.1–2.0	3
2.1–3.0	9
3.1–4.0	12
4.0 +	20

DISCUSSION

Mortality of Engelmann and blue spruce in mixed conifer stands moderately to heavily infested with western spruce dwarf mistletoe is from two to five times greater than for healthy stands in the White Mountains, Arizona. Approximately 20% to 35% of the spruce sampled in heavily infested stands were dead, indicating western spruce dwarf mistletoe is a primary factor associated with spruce mortality. Hawksworth and Graham (1963) also reported high mortality rates for spruce in western spruce dwarf mistletoe–infested mixed conifer stands in the White Mountains.

Nearly half of the dead trees that could be accurately assigned dwarf mistletoe ratings were class 6 trees. Approximately one-tenth and one-third of these dead spruce were in DMR class 4 and 5, respectively. This was true for all size classes of spruce except the small sapling size class, where more dead saplings were rated as class 4. The high mortality rate in class 5 trees for spruce contrasts to mortality patterns in dwarf mistletoe-infected pines, where mortality is predominantly in class 6 trees (Hawksworth and Lusher 1956).

Heavy dwarf mistletoe infection (DMR 5-6) severely reduces volume increment of spruce in the White Mountains. Lightly infected spruce (DMR 1-2) do not suffer any detectable growth loss and moderately infected spruce (DMR 3-4) only suffer losses ranging from approximately 5% to 10%. These results are similar to those reported for southwestern dwarf mistletoe (*Arceuthobium vaginatum* subsp. *cryptopodum* [Engelm.] Hawksw. & Wiens) parasitizing ponderosa pine (*Pinus ponderosa* Laws.) in the Southwest (Hawksworth 1961).

Estimates of growth losses on a stand basis ranged from approximately 10% to 20% for heavily infested stands ($\overline{DMR}$ greater than 2.0). Lightly to moderately infested stands are estimated to have losses less than 3%. Our estimates of the effects of western spruce dwarf mistletoe on the growth of spruce are the first reported for this parasite-host combination.

Western spruce dwarf mistletoe is a common parasite of spruce in mixed conifer stands in the White Mountains, Arizona. Because heavy infection by western spruce dwarf mistletoe severely reduces the growth of trees and stands and is associated with increased spruce mortality, silvicultural control of the parasite should be a primary concern of resource managers. Heavily infected spruce should be removed from infested stands whenever possible to reduce the impact of this parasite on forest productivity.

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