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# Effects of *Arceuthobium americanum* on Twig Growth of *Pinus contorta*

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## Abstract

Patterns of branch growth in *Pinus contorta* Dougl. ex Loud. (lodgepole pine) on the east side of the Cascade Range in Oregon were significantly altered by *Arceuthobium americanum* (lodgepole pine dwarf mistletoe). There were decreases in the number, length, and mass of needles, as well as in the length and mass of twigs. These reductions were correlated with the infection status of individual branches. Generally, twigs from uninfected branches supported the greatest number, size, and mass of needles, as well as the greatest twig mass. Twigs from branches having localized infections were intermediate for these same characteristics, whereas twigs from systemically infected branches were lowest. These differences suggest that changes in metabolic function of the host result from infection by dwarf mistletoe. The changes are probably among the factors that contribute to host decline correlated with increases in severity of infection.



Keywords: Parasites (plant) (-forest damage, dwarf mistletoe, *Arceuthobium americanum,* lodgepole pine, *Pinus contorta.*

## Introduction

*Arceuthobium*[1/] is a genus of flowering plants comprised of approximately 40 taxa. Members of this genus parasitize all of the genera of the family Pinaceae that occur in the Pacific Northwest (Hawksworth and Weins 1972). Because the members of the genus *Arceuthobium* cannot obtain water and nutrients directly from abiotic sources and because they can provide only 25 to 30 percent of their own energy requirements through photosynthesis (Hull and Leonard 1964, Miller and Tocher 1975), essentially all their metabolic needs must be provided by their host. This contributes to changed growth patterns and to increased mortality rates for the host (Hawksworth and Weins 1972).

Most coniferous species are valuable for timber, so the effects of *Arceuthobium* spp. are usually assessed in terms of damage to, or loss of, fiber or lumber. Although *Arceuthobium* spp. measurably reduce productivity of forests, little information is available about specific alterations of branch structure of the host (the sites of photosynthesis) that are caused by infection. Tinnin and Knutson (1980) reported that branches of *Pseudotsuga menziesii,* when heavily infected with

[1/]Common names are listed under "Scientific and Common Names."

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*A. douglasii,* supported twigs that were longer and needles that were more numerous but had a lower individual biomass than similar parts from healthy branches.

More detailed information about changes in branch structure resulting from infection by *Arceuthobium* is needed to thoroughly describe the causes of decline in host trees. Hence, our purpose was to quantify changes in the branch structure of *Pinus contorta* associated with infection by *Arceuthobium americanum,* as correlated with local and systemic infection. We worked with *P. contorta* because it shows the same general response to infection by *Arceuthobium* as do other host species, a loss of growth and an increased rate of mortality (Baranyay 1970, Baranyay and Safranyik 1970, Gill and Hawksworth 1964, Johnson and others 1980); because it is of convenient size for detailed work with crown parts; and because it typically supports both local and systemic infections of *A. americanum.*

## Methods

Two sample sites were chosen in which almost all the trees present were *Pinus contorta* and in which *Arceuthobium americanum* was found. Both sites were on the east side of the Cascade Range in Oregon. The Sisters site is 21 km (13 mi) south of the town of Sisters on USFS Road 16 (R. 9 E., T. 16 S., sec. 34, 35) at an elevation of about 2000 m (6,550 ft). The Crescent site is southeast of Crescent Lake and about 1.5 km (0.9 mi) south of highway 58 along USFS road 243-I (R. 7 E., T. 24 S., sec. 29) at an elevation of about 1750 m (5,750 ft).

Each site was divided into nine 1-ha (2.47-acre) plots, from which three plots were randomly chosen. Within these plots, study trees were randomly chosen from among the dominant and codominant individuals, excluding spike-topped and double-trunked trees. Each tree was given a dwarf mistletoe rating (d.m.r.) according to its level of infection by *A. americanum*—zero for no infection and six for heavy infection (Hawksworth 1977). An increment core was taken from each tree 1.4 m (4.5 ft) above ground level—diameter at breast height (d.b.h.)—to determine stand age and growth characteristics, and tree height was determined with a clinometer.

The trees at the Sisters site were moderately to heavily infected (d.m.r. 3-6) by *A. americanum.* The density of *P. contorta,* all ages included, was 1.2 trees/m$^2$ (4,850 trees/acre) with a density of 0.3 mature tree/m$^2$ (1,225 mature trees/acre). A random sample of mature trees exhibited an average age of 84 years, a d.b.h. of 25 cm (9.8 in), a height of 13 m (42.5 ft), and an estimated lateral growth rate of 0.6 cm (0.24 in) per year averaged over the 1977-81 period.

The trees at the Crescent site were uninfected to moderately infected (d.m.r. 0-4) by *A. americanum.* The density of all age classes of *P. contorta* was 1.8 trees/m$^2$ (7,275 trees/acre) with a density of 0.2 mature tree/m$^2$ (800 mature trees/acre). A random sample of mature trees at this site had an average age of 88 years, a d.b.h. of 26 cm (10.2 in), a height of 14 m (46.0 ft), and an estimated lateral growth rate of 0.5 cm (0.20 in) per year averaged over the 1977-81 period. These stand data are summarized in tables 1 and 2.

**Table 1—Mean growth characteristics of sample trees from the Sisters, Oregon, site (± standard error)**

| Dwarf mistletoe rating | Trees | Mean age at breast height, 1981 | Mean d.b.h., 1982 | Mean height, 1982 | Mean lateral growth, 1977-81 |
|---|---|---|---|---|---|
| | no. | yr | cm 1/ | m 2/ | cm/yr 1/ |
| 3 | 6 | 53±12 | 22±2 | 11±1 | 0.7±0.09 |
| 4 | 8 | 83± 8 | 25±2 | 13±1 | .5± .06 |
| 5 | 23 | 81± 5 | 26±1 | 13±1 | .6± .05 |
| 6 | 16 | 102± 4 | 24±1 | 12±1 | .4± .07 |
| Total (mean) | 53 | 84 | 25 | 13 | .6 |

1/ 1 cm = 0.39 in.

2/ 1 m = 3.28 ft.

**Table 2—Mean growth characteristics of sample trees from the Crescent, Oregon, site (± standard error)**

| Dwarf mistletoe rating | Trees | Mean age at breast height, 1981 | Mean d.b.h., 1982 | Mean height, 1982 | Mean lateral growth, 1977-81 |
|---|---|---|---|---|---|
| | no. | yr | cm 1/ | m 2/ | cm/yr 1/ |
| 0 | 3 | 64± 8 | 21±2 | 12±0.3 | 0.8±0.10 |
| 1 | 6 | 93±12 | 25±4 | 14±2 | .6± .05 |
| 2 | 6 | 84± 6 | 25±2 | 14±2 | .5± .07 |
| 3 | 7 | 95±10 | 28±2 | 15±1 | .6± .16 |
| 4 | 8 | 91± 3 | 28±2 | 16±1 | .4± .04 |
| Total (mean) | 30 | 88 | 26 | 14 | .5 |

1/ 1 cm = 0.39 in.

2/ 1 m = 3.28 ft.

Twig samples were obtained from three branches on the southwest side of each study tree at a height of 6 m (20 ft) or less from the ground. Each sample was classified as being taken from an uninfected, a locally infected, or a systemically infected branch. A branch was considered locally infected when the infections were confined to a small portion of the branch, whereas a systemically infected branch had dwarf mistletoe growing throughout many or all of the twigs. Aerial shoots of *A. americanum* distributed over some distance along a twig was evidence of the latter condition.

Samples were collected in 1981. Data on twig growth were recorded for the 1979 annual growth segment. This age class was selected because the segments were fully developed and vigorous at the time of collection. For each sample we measured twig length, twig dry mass, needle number, needle length, and needle dry mass. Twig and needle lengths were measured to the nearest millimeter. Segment dry mass was recorded to the nearest 0.1 mg after the tissues were dried at 80 °C for 48 h.

The data were analyzed by means of a two-level nested analysis of variance in which sample replicates were nested under source branch and source branch under branch infection class (Sokal and Rohlf 1969).

## Results and Discussion

For the growth segments sampled, we found a significant decrease in mean number, length, and biomass of needles and in the mean length and biomass of twigs from *Pinus contorta* infected with *Arceuthobium americanum* (table 3). In most cases our measures showed the greatest growth for needles and twigs from uninfected branches, less growth for locally infected branches, and the least growth for systemically infected branches. Twig length is an exception to this pattern because locally infected branches show the least twig elongation.

The trees at the Sisters site showed greater growth for each variable measured. The two sites are different in several ecologically important ways, so the difference in growth of branch parts from the two sites is not surprising.

The data in table 3 imply the action of certain mechanisms leading to host decline after infection. Although the data are not consistent for both sites, a reduction in the numbers and sizes of needles at either site, when correlated with infection, implies that infection affects the photosynthetic efficiency of branches. We presently have no reason to assume that the changed structure of infected branches compensates for the observed reduction in photosynthetic tissue on individual twigs.

**Table 3—Mean growth of branch parts of *Pinus contorta* in response to infection by *Arceuthobium americanum* 1/**

| Site and branch classification | Needles: Number | | Needles: Length | Needles: Dry mass | Dry mass per needle | Twigs: Length | | Twigs: Dry mass | Dry mass per cm |
|---|---|---|---|---|---|---|---|---|---|
| | | | cm | g | g | cm | | g | g |
| Crescent Lake: | | | | | | | | | |
| Uninfected | 58.1 | n=6 | 3.5 | 0.7818 | 0.131 | 2.4 | n=7 | 0.1773 | 0.0730 |
| Local | 41.5 | n=11 | 2.9 | .3902 | .0091 | 1.5 | n=11 | .0857 | .0561 |
| Systemic | [55.0] | n=2 | [1.7] | [.2730] | [.0048] | [4.0] | n=2 | [.1771] | [.0441] |
| Probability 2/ | .05 | | NS | .05 | .05 | .001 | | .001 | .05 |
| Sisters: | | | | | | | | | |
| Uninfected | [84.5] | n=2 | [4.1] | [1.5884] | [.0202] | [3.6] | n=2 | [.4260] | [.1234] |
| Local | 52.6 | n=20 | 3.4 | .6840 | .0130 | 1.9 | n=20 | .1726 | .0852 |
| Systemic | 46.9 | n=9 | 2.1 | .3224 | .0065 | 2.7 | n=9 | .1626 | .0583 |
| Probability 2/ | NS | | .001 | .01 | .001 | NS | | NS | .01 |

1/ Each element is the mean of all samples for a given classification; "n" is the number of trees sampled. Data in brackets were not considered during statistical evaluation because of small sample size. 1 cm = 0.39 in; 1 g = 0.04 oz.

2/ NS = not significant.

Tinnin and Knutson (1980) reported similar data for the growth of branches of *Pseudotsuga menziesii* infected by *Arceuthobium douglasii* (table 4). They found no significant difference in total needle mass between healthy and infected twigs, but they did find that infected branches were much more massive than uninfected branches. In short, the equivalence of the photosynthetic potential of uninfected and infected branches is in question. Detailed comparative work is needed to elucidate the physiological response to infection by various host species.

In addition to the significant changes in branch structure that result from the infection of *P. contorta* by *A. americanum,* it is known that the starch content of needles increases (Broshot and Tinnin 1986), respiratory rates decrease (Wanner and Tinnin 1986), and patterns of carbon allocation change (Leonard and Hull 1965). The many changes in structure and function that occur after infection are at least related to, if not part of, the mechanisms that cause host decline.

**Table 4—Comparison of branch characteristics for *Pinus contorta* and *Pseudotsuga menziesii* infected with *Arceuthobium* 1/**

| Characteristic | P. contorta 2/ | P. menziesii 3/ |
|---|---|---|
| Needle number | 4/< | > |
| Needle length | 4/< | NA |
| Total needle mass | < | ns |
| Mass per needle | < | < |
| Twig length | 4/< | > |
| Twig mass | 4/< | ns |
| Twig mass per cm | < | < |

1/< indicates significant decrease; >, significant increase; ns, no difference; NA, data not available--compared with twigs from uninfected branches.
2/ Data from current study.
3/ From Tinnin and Knutson (1980).
4/ The differences at only 1 sample site were significant.

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## Scientific and Common Names

| | |
|---|---|
| *Arceuthobium americanum* Nutt. ex Engl. | Lodgepole pine dwarf mistletoe |
| *Arceuthobium douglasii* Engl. | Douglas-fir dwarf mistletoe |
| *Pinus contorta* Dougl. ex Loud. | Lodgepole pine |
| *Pseudotsuga menziesii* (Mirb.) Franco | Douglas-fir |

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