Variation in branch growth characteristics of Pinus contorta infected with Arceuthobium americanum

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Title: Variation in Branch Growth Characteristics of *Pinus contorta* Infected with *Arceuthobium americanum*.

APPROVED BY MEMBERS OF THE THESIS COMMITTEE:

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Arceuthobium americanum is a flowering plant which parasitizes *Pinus contorta* (Lodgepole pine). This study examined branch performance of *P. contorta* infected to varying degrees with *A. americanum*.

When uninfected branches were compared to heavily infected branches, a differences in branch growth was observed.

In comparison of uninfected, locally infected, and systemically infected samples from a given dwarf mistletoe rating (DMR), no

significant differences in branch growth could be determined in most cases. When samples from uninfected, locally infected, or systemically infected branches were analyzed to determine a difference in branch growth at different DMRs, no consistent pattern in branch growth could be determined for the variables measured.

It is speculated that the system used to assess the level of infection is too refined to accurately account for the observed differences in branch growth.

VARIATION IN BRANCH GROWTH CHARACTERISTICS OF

PINUS CONTORTA INFECTED WITH

ARCEUTHOBIUM AMERICANUM

BY

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INTRODUCTION

Arceuthobium comprises approximately 40 taxa of flowering plants commonly referred to as dwarf mistletoes. Members of this genus parasitize all of the species of the family Pinaceae which occur in the Pacific Northwest (Hawksworth and Weins, 1972), although some only occasionally. Members of the genus *Arceuthobium* can meet only 25 to 30 percent of their own energy requirements through photosynthesis (Hull and Leonard, 1964 and Miller and Tocher, 1975). The remaining energy must be obtained from the host. This places a demand on the host which often results in a change in host growth patterns and early host death (Childs and Shea, 1967).

In the Pacific Northwest, conifer species are a very valuable resource. Because of this, the reported damage caused by *Arceuthobium* spp. is usually assessed in terms of damage to or loss of fiber or lumber.

In a 1979 assessment of dwarf mistletoe damage to *Pinus contorta* (Lodgepole pine) on Colorado National Forest lands, it was found that 46.6 percent of the trees were infected with *A. americanum*. This represents a loss of 8.9 cu ft/A/yr of merchantable timber (Johnson, Hawksworth, and Drummond, 1980). A 1972 survey of Oregon, Washington, and California reported that 1.4×10^6 of 2.5×10^6 acres of *P. contorta* (57 percent) were infected with *A. americanum* (Bolsinger, 1978). In Alberta, Canada the annual timber loss of *P. contorta* and

P. banksiana attributable to Arceuthobium spp. is 9,582,000 cu ft. This places dwarf mistletoe as the number one disease of pine in the Province of Alberta (Baranyay, 1970).

Dwarf mistletoes are also known to cause tree death. In stands heavily infected with Arceuthobium spp., mortality rates were found to be twice the rates of healthy stands (Gill and Hawskworth, 1964). Research limited to P. contorta concluded that young infected stands did not exhibit any increase in mortality over healthy stands (Baranyay and Safranyik, 1970). This situation changed when mature stands of P. contorta were observed. It was reported that the mortaility rate for mature stands of P. contorta infected with A. americanum was 26 percent higher than healthy stands (Baranyay and Safranyik, 1970).

Much of the timber loss is not a decrease in tree volume but in timber quality. A. americanum infected P. contorta are often observed having large knots, stem cankers, and other wood abnormalities (Gill and Hawksworth, 1964).

Although the above data concretely demonstrate that Arceuthobium spp. causes measurable reduction in the productivity of forests, little information is available concerning the damage done by Arceuthobium spp. to the limbs of individual trees. Preliminary research indicates that there is a difference in twig growth between healthy branches and branches heavily infected with Arceuthobium spp. Heavily infected branches of Pseudotsuga menziesii were reported to be longer and have a greater biomass than healthy branches. Needles from infected branches were more numerous and had a lower biomass than needles from healthy branches (Tinnin and Knutson, 1980).

The purpose of this study was to collect detailed preliminary data on effects of Arceuthobium americanum Nutt.[1] on twig length, needle length, needle number, and combined twig and needle biomass of one host, Pinus contorta var. latifolia Engelm. It was speculated that these variables would demonstrate a difference in host branch growth with varying degrees of parasite infection. The results are compared to the previously published data on Pseudotsuga menziesii, and they provide a basis for evaluating the usefulness of exhaustive studies of this kind of the growth of infected P. contorta.

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[1] All scientific names used are from Hitchcock and Cronquist, 1973.

LIFE HISTORY OF Arceuthobium americanum

Arceuthobium americanum is a parasitic flowering plant found growing primarily on Pinus contorta (fig. 1). This dwarf mistletoe species is also found parasitizing P. banksiana, P. ponderosa, and occasionally other conifer species (Hawksworth and Wiens, 1972.) Hawksworth (1965) outlined the complete life history of A. americanum.

Flowering of this species of Arceuthobium occurs in April and May. The plants are dioecious and the flowers are highly reduced and born on vegetative stalks (called aerial shoots) protruding from the host stem. These shoots are photosynthetic and are the only portions of the parasite external to the host. A. americanum is wind pollen-ated (Whitehead, 1969). Mature fruits are released in August and September of the year following pollination.

Each fruit contains a single seed (Hawksworth and Wiens, 1972). The seed is dispersed explosively up to a distance of about 10 m from its host. Dwarf mistletoe seeds are covered with a sticky gelatinous substance called viscin. Viscin allows the seed to adhere to any object it encounters in its path of flight. The seeds are often intercepted by needles or twigs of the host tree or of a neighboring tree, although a large number of seeds are not intercepted and are lost. Rain causes the viscin to become slippery and allows the seeds on the needles to slide to the twig where germination occurs in the following spring.

The parasite radical penetrates and grows into the host tissue. A swelling of host tissue often occurs following penetration by the

Figure 1. Aerial Shoots of Arceuthobium americanum

parasite.

After 2 to 6 years from the time of infection, *A. americanum* will begin to produce aerial shoots. These shoots immediately begin to produce flowers.

MATERIALS AND METHODS

Site Selection and Description

Two sample sites were chosen and were composed of essentially pure stands of *Pinus contorta* infected with *Arceuthobium americanum*. The two sites were chosen to provide a wide range of infection levels. Both sites were located on the east side of the Cascade Mountain Range.

The first site was located 21 km south of the town of Sisters, Oregon on road 1534 (Sections 34 & 35, R9E,16S, Willamette Meridian). It will be referred to as the "Sisters" site (fig. 2). It was located on a very slight slope at an elevation of 1780 m. Rainfall at the town of Sisters averaged 32.9 cm for the years 1975 through 1979, with an average July temperature of 17.5°C and an average January temperature of -1.3°C for the same years (Table I).

This stand of trees was moderately to heavily infected with *A. americanum*. Density of *P. contorta* was 1.2 trees/m^2 with a 0.28 trees/m^2 density of climax trees. A random sample of climax trees indicated that the average age was 83.76 years, diameter at breast height (DBH) was 24.80 cm, height was 16.92 m, with an estimated lateral growth rate of 0.30 cm/yr (Table II).

Ground cover was scarce and primarily composed of *Lupinus* spp. and unidentified grasses.

Figure 2. Sisters Site

TABLE I

CLIMATOLOGICAL DATA FROM 1975-1979
(Temperature °C)

Chemult[a]

Year	Jan	Feb	Jun	Jul	Aug	Dec	Annual Rainfall (cm)
1975	-3.3	-2.6	10.5	16.4	13.2	-0.8	81.9
1976	-2.5	-2.1	10.0	15.3	12.7	-4.2	36.5
1977	-5.2	0.4	14.4	15.2	16.9	-1.8	64.3
1978	-0.1	-0.8	12.1	15.6	14.9	m[b]	48.5
1979	-7.6	-1.1	12.6	15.7	14.4	-[c]	61.3
Mean	-3.7	-1.2	11.9	15.6	14.4	-2.3	58.5

Sisters[d]

Year	Jan	Feb	Jun	Jul	Aug	Dec	Annual Rainfall (cm)
1975	-3.4	-1.1	12.2	18.4	14.7	1.6	42.5
1976	0.8	0.9	11.7	17.7	15.1	-0.7	27.9
1977	-2.8	3.7	16.3	16.4	19.7	0.9	32.2
1978	0.3	1.9	14.7	17.6	15.8	m[b]	32.6
1979	m[b]	1.1	12.4	17.5	15.8	-[c]	29.6
Mean	-1.3	1.3	13.4	17.5	16.2	0.6	32.9

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[a] Located approximately 10 km SSE of Crescent site.
[b] Data missing.
[c] Not reported.
[d] Located approximately 18 km NNE of Sisters site.

TABLE II

MEAN GROWTH CHARACTERISTICS
OF SAMPLE TREES

Sisters

DMR	Average Age (yr)	Average DBH (cm)	Average Height (m)	Average Lateral Growth (cm/yr)
3	71.25	23.40	15.95	0.33
4	64.80	25.40	17.78	0.39
5	80.23	26.50	16.84	0.33
6	94.00	24.00	17.11	0.25
GRAND	83.76	24.80	16.92	0.30

Crescent

DMR	Average Age (yr)	Average DBH (cm)	Average Height (m)	Average Lateral Growth (cm/yr)
1	69.00	22.90	17.03	0.33
2	72.33	23.50	15.62	0.32
3	80.25	27.50	21.06	0.31
4	86.67	29.40	18.63	0.34
5	89.00	27.50	17.80	0.26
GRAND	79.45	26.20	18.03	0.33

The second site was located southeast of Crescent Lake (Section 29, R7E,24S, Willamette Meridian). It will be referred to as the "Crescent" site (fig. 3).

It was located on a relatively flat area at an elevation of 1442 m above sea level. Rainfall at the nearby town of Chemult averaged 58.5 cm for the years 1975 through 1979, with an average July temperature of 15.6°C and an average January temperature of -3.7°C (Table I).

This stand of trees was uninfected to heavily infected with A. americanum. Density of P. contorta was 1.8 trees/m^2 with a 0.15 trees/m^2 density of climax trees. A random sample of climax trees indicated that the average age was 79.45 years, DBH was 26.20 cm, height was 18.03 m, and the estimated lateral growth rate was 0.33 cm/ yr (Table 2).

Ground cover was scarce and primarily composed of unidentified grasses and small shrubs.

Sample Selection

Each site was subdivided into nine 1-hectare plots. Three sample plots were randomly chosen from among the group at each site. Sample trees were then chosen from these plots.

Within the sample plots, all dominant trees were considered possible research individuals, with the exception of spike-topped and double-trunked trees. The acceptable trees were rated according to theirs level of infection with A. americanum from 0 to 6, 0 denoting an uninfected tree, and 6 denoting a tree whose entire crown is heavily

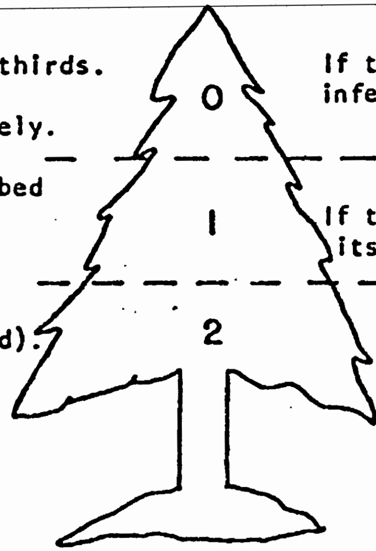
Figure 3. Crescent Site

INSTRUCTIONS

STEP 1. Divide live crown into thirds.

STEP 2. Rate each third separately. Each third should be given a rating of 0, 1 or 2 as described below.
(0) No visible infections.
(1) Light infection (1/2 or less of total number of branches in the third infected).
(2) Heavy infection (more than 1/2 of total number of branches in the third infected).

STEP 3. Finally, add ratings of thirds to obtain rating for total tree.



EXAMPLE

If this third has no visible infections, its rating is (0).

If this third is lightly infected, its rating is (1).

If this third is heavily infected, its rating is (2).

The tree in this example will receive a rating of 0 + 1 + 2 = 3.

__Figure 4.__ The 6-Class Dwarf Mistletoe Rating System (from Hawksworth, 1977)

infected with A. americanum (fig. 4) [Hawksworth, 1977]. This numerical code will be referred to as the dwarf mistletoe rating (DMR) of the trees.

From each plot, six trees were randomly selected from each DMR present. Branch samples were taken from these trees.

Three branches were taken from the southeast side of each tree. Samples were taken at a height of approximately 6.0 m above ground level. A core was taken from each tree at breast height to determine age. The approximate height of each tree was determined with the aid of an inclinometer.

As the samples were collected, each branch was classified according to the type of A. americanum infection present. The sample was designated uninfected, locally infected, or part of a systemic broom. A branch was considered locally infected when isolated point infections were observed. These infections were identified by branch swellings often accompanied by aerial shoots. A systemic broom was typified by a dense array of twigs having a globulous appearance and originating from a single branch (figs. 5 and 6). The mistletoe was spread throughout the entire broom (Baranyay, 1970). The type of infection present will be referred to as the branch classification.

Data Collection and Analysis

A soil sample was taken from a central point in each study site for analysis at the Soil Testing Laboratory, Oregon State University. Each sample was analyzed for pH, various inorganic ions, organic

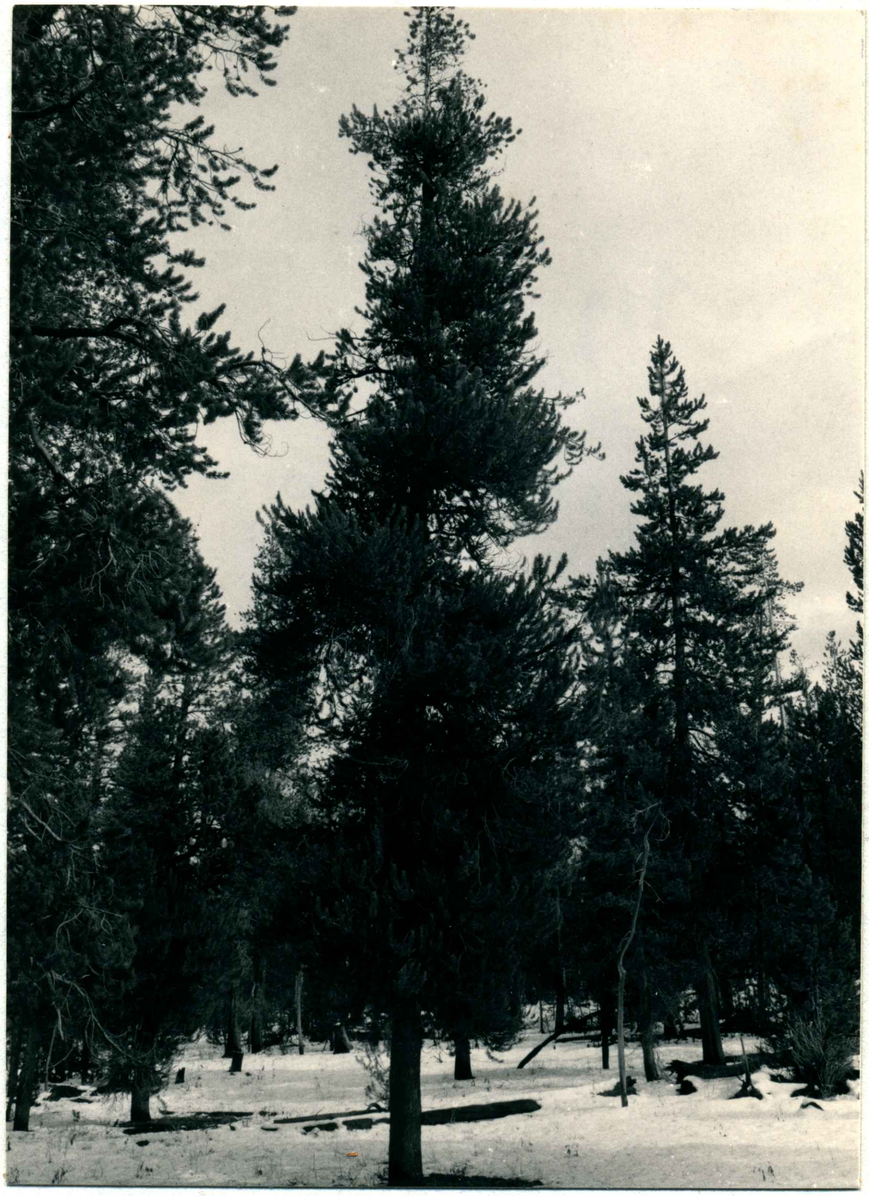


Figure 5. Systemic Brooms on *Pinus contorta* Infected with *Arceuthobium americanum*

Figure 6. Systemic Broom of Arceuthobium americanum on Pinus contorta

matter, cation exchange capacity, and percent moisture by weight. These variables may influence tree growth.

Data on twig growth were recorded from the four most recent years of twig growth (1976-1979) from each sample collected. The year segments were identified by bud scars. For each year the following variables were measure: twig length, needle number, needle length, and total segment (needle and twig combined) dry weight. Twig and needle lengths were measured to the nearest 1.0 mm. Segment dry weight was recorded to the nearest 10^{-5} gm.

The data were, depending on the specific treatment, analyzed by means of one way analysis of variance (ANOVA) or two way nested ANOVA (Sokal and Rohlf, 1969). Determination of required sample sizes, based on observed variance, was completed following the procedure outlined by Brower and Zar (1977). T tests were completed on selected values (Sokal and Rohlf, 1969).

RESULTS

Site Comparison

Baseline data were collected to determine if the two sites were comparable with respect to several physical variables and to general growth characteristics of trees found at each site. This procedure was used to determine how best the data from the two sites might be treated in later studies.

Table I summarizes climatological data recorded near the two sites. The differences in temperature were not great; the difference in rainfall was large.

Table II summarizes mean values for the data collected on tree growth at each site. Although there is not a significant difference in the overall lateral growth rate between trees at the two sites, there are differences between the sites at a given DMR as determined by t tests. These data illustrate the difference in tree growth between the two sites.

Table III is a summary of the analysis of soil samples from the two sites. The observed differences suggest different growth potentials for trees at the two sites. Without a more thorough treatment of soil conditions, the actual impact on tree growth remains unknown. Limitation of funds prevented a more detailed evaluation as part of this study.

TABLE III

ANALYSIS OF SOIL SAMPLES FROM STUDY SITES

Site	Sample Depth (in)	pH	P (ppm)	K (ppm)	Ca (meg/100g)	Mg (meg/100g)	Na (meg/100g)	B (ppm)	Salts (mmhos/cm)	Organic Matter %	Total N %	Cation Exchange Capacity (meq/100g)	Moisture Tension 0.3atm
Crescent	24.0	5.6	20.0	98.0	5.6	0.93	0.15	0.39	0.30	5.46	0.15	15.7	27.3
Sisters	24.0	5.8	29.0	86.0	2.2	0.48	0.17	0.25	0.20	5.30	0.18	13.4	24.5

On the basis of the observed differences of soils and of tree growth, I will not assume there is even approximate equivalence of potential for tree growth at the two sites. The data from the two sites are therefore analyzed separately.

Analysis of Growth Variables

Growth from the year 1978 was treated by means of one way ANOVA and two way nested ANOVA. This segment represents mature tissue that has not begun to deteriorate.

One way ANOVA was used to test the similarity between the four sampled variables of branch growth from uninfected branches, locally infected branches, and systemically infected branches without consideration of the level of dwarf mistletoe infection.

At Sisters, samples were combined from DMR 3 through 6 for analysis. This analysis relates trees that were lightly infected to those that were heavily infected. When all samples were compared, regardless of DMR, a significant difference was observed between moderately and heavily infected samples in twig length, total segment dry weight, and average needle number (see Table IV).

At Crescent, samples were combined from DMR 0 through 5 for analysis. This represents trees that are uninfected to heavily infected. When these samples were compared, a significant difference was observed between needle number only (see Table V).

Each DMR was analyzed to determine if there were any significant differences in growth variables between samples from the three branch classifications collected from given DMR. Two way nested ANOVA

TABLE IV

ANALYSIS OF BRANCH CLASSIFICATIONS FROM *PINUS CONTORTA* INFECTED WITH *ARCEUTHOBIUM AMERICANUM* AT SISTERS USING ONE WAY ANOVA

Source of Variation		df[a]	SS[b]	MS[c]	F
Twig Length	Among Branch Classification	2	6.31	3.15	5.41[d]
	Among Trees	131	76.34	0.58	
	Total	133	82.65		
Needle Number	Among Branch Classification	2	686.91	343.45	0.91[e]
	Among Trees	131	49448.59	377.47	
	Total	133	50135.49		
Total Segment Weight	Among Branch Classification	2	5.31	2.66	10.47[d]
	Among Trees	131	33.24	0.25	
	Total	133	38.55		
Average Needle Length	Among Branch Classification	2	3.72	1.86	3.15[f]
	Among Trees	131	77.28	0.59	
	Total	133	80.99		

[a] - degrees of freedom
[b] - sum of squares
[c] - mean squares
[d] - significant at 0.01
[e] - not significant
[f] - significant at 0.05

TABLE V

ANALYSIS OF BRANCH CLASSIFICATIONS FROM *PINUS CONTORTA* INFECTED WITH *ARCEUTHOBIUM AMERICANUM* AT CRESCENT USING ONE WAY ANOVA

Source of Variation		df[a]	SS[b]	MS[c]	F
Twig Length	Among Branch Classification	2	2.15	1.08	1.93[d]
	Among Trees	105	58.47	0.56	
	Total	107	50.63		
Needle Number	Among Branch Classification	2	5200.32	2600.16	6.57[e]
	Among Trees	109	43141.36	395.79	
	Total	111	48341.68		
Total Segment Weight	Among Branch Classification	2	0.93	0.47	1.90[d]
	Among Trees	106	25.94	0.24	
	Total	108	26.87		
Average Needle Length	Among Branch Classification	2	0.08	0.04	0.05[d]
	Among Trees	105	78.51	0.75	
	Total	107	78.59		

[a] - degrees of freedom
[b] - sum of squares
[c] - mean squares
[d] - not significant
[e] - significant at 0.01

nested ANOVA was used to indicate variation between branch classifications. Table VI summarizes the results of this procedure. Detailed results are listed in Appendix A.

Two way nested ANOVA produced mixed results at both sites when branch classifications of a given DMR were compared.

At Crescent, twig length was useful in noting variation between branch classifications for samples from DMR 3 and 4. Needle number distinguished between branch classifications of DMR 3 only. Total segement weight discriminated between branch classifications of DMR 4. Average needle number separated branch classifications of DMR 1.

At Sisters, a significant level of variation was noted between branch classificatons of DMR 3 for the variable twig length. Needle number discriminated between branch classificaitons of DMR 4. Total segment weight was useful in separating branch classifications of DMR 4. Average needle length allowed discrimination between branch classifications of DMR 4, 5, and 6.

Each branch classification was also analyzed using two way nested ANOVA to determine if there were any significant differences in the growth of samples collected from varying DMRs but of only one branch classification. Table III summarizes the results of this procedure. Detailed results are listed in Appendix B.

At Crescent, the four growth variables measured noted variation bewteen DMRs when locally infected samples were compared.

At Sisters, twig length discriminated between samples from varying DMRs only when the samples were systemically infected. Needle number noted differences between DMRs of locally infected

TABLE VI

RESULTS OF DMR ANALYSIS USING
TWO WAY NESTED ANOVA

Crescent

Variable	DMR	Level of Significance*
Twig Length	1	ns
	3	0.05
	4	0.05
Needle Number	1	ns
	3	0.05
	4	ns
Total Segment Weight	1	ns
	3	ns
	4	0.5
Average Needle Number	1	0.05
	3	ns
	4	ns

Sisters

Variable	DMR	Level of Significance*
Twig Length	3	0.05
	4	ns
	5	ns
	6	ns
Needle Number	3	ns
	4	0.05
	5	ns
	6	ns
Total Segment Weight	3	ns
	4	0.05
	5	ns
	6	ns
Average Needle Number	3	ns
	4	0.05
	5	0.01
	6	0.05

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* ns = not significant

TABLE VII

RESULTS OF BRANCH CLASSIFICATION ANALYSIS
USING TWO WAY NESTED ANOVA

Crescent

Variable	Branch Classification	Level of Significance*
Twig Length	Uninfected	ns
	Local	0.01
	Systemic	ns
Needle Number	Uninfected	ns
	Local	0.01
	Systemic	ns
Total Segment Weight	Uninfected	ns
	Local	0.05
	Systemic	ns
Average Needle Number	Uninfected	ns
	Local	0.01
	Systemic	ns

Sisters

Variable	Branch Classification	Level of Significance*
Twig Length	Uninfected	ns
	Local	ns
	Systemic	0.01
Needle Number	Uninfected	ns
	Local	0.05
	Systemic	ns
Total Segment Weight	Uninfected	ns
	Local	ns
	Systemic	ns
Average Needle Number	Uninfected	ns
	Local	0.05
	Systemic	0.05

* ns = not significant

samples. Average needle number was useful in separating DMRS of locally infected and systemically infected samples.

DISCUSSION

The results from the one way ANOVA did not totally agree with the results reported by Tinnin and Knutson (1980) [Table VIII]. In both studies, a difference between uninfected and heavily infected branches was observed. At Sisters, the mean values for all measured variables decreased with an increase in branch infection (uninfected to systemic). This shift was found to be significant for all variables with the exception of needle number. At Crescent, all mean values for measured variables increased with an increase in branch infection. Of the four measured variables, only the values for needle number were found to be statistically different. I suggest that the differences in results between the two sites is a numerical basis for infected twigs from heavily infected trees at Sisters and lightly infected trees at Crescent being compared with uninfected twigs.

Tinnin and Knutson (1980) reported that heavily infected branches had longer twigs and more needles than uninfected branches, but there was no significant difference between the combined twig and needle mass of uninfected branches and heavily infected branches.

The differences in reported values is more than likely due to the small sample sizes used in both studies. It is also possible that the two host species studied (*Pinus contorta* in this study, *Pseudotsuga menziesii* in the Tinnin and Knutson study) are responding differently to the presence of *Arceuthobium* spp.

TABLE VIII

COMPARISON OF BRANCH GROWTH CHARACTERISTICS OF *PINUS CONTORTA* AND *PSEUDOTSUGA MENZIESII*

VARIABLE	*Pinus contorta* SISTERS	*Pinus contorta* CRESCENT	*Pseudotsuga menziesii**
Twig Length	significant	not significant	significant
Needle Number	not significant	significant	significant
Segment Weight	significant	not significant	not significant
Average Needle Length	significant	not significant	not applicable

* Data from Tinnin and Knutson, 1980.

The two way nested ANOVA produced mixed results. When this procedure was used to distinguish branch classification of samples from a given DMR, no consistency was observed. The differences between uninfected samples from infected trees and heavily infected samples demonstrated in the one way ANOVA were not observed when only one DMR was analyzed using a two way ANOVA. Similarly, when a two way ANOVA was used to distinguish between DMRs of a single branch classification, the results were mixed. Only locally infected branches demonstrated any consistency among the measured variables in discriminating between DMRs.

An attempt was made to analyze those sets of data which compared branch classifications of DMRs that produced significant results using a Student-Neuman-Kuels test (Sokal and Rohlf, 1969). This test would have identified which branch classifications or DMRs were significantly different. However, due to the amount of variation between the measured variable means, it was not possible to use this test.

This study was a first attempt to systematically analyze four variables of branch growth. In analyzing the data it was realized that there was too much variation between samples of one DMR or one branch classification to establish a significant distinction between DMRs or branch classifications. Tables IX and X indicate the sample sizes needed to account for this variation. The sample sizes required are well beyond the scope of this study and will probably prove to be prohibitive to similar research in the future.

TABLE IX

SAMPLE SIZES NEEDED TO ACCOUNT
FOR OBSERVED VARIATION
AT SISTERS

Uninfected Branches

VARIABLE	LEVEL OF PRECISION	NEEDED NUMBER OF SAMPLES
Twig Length	0.1 cm	5.0×10^4
Needle Number	1.0 needles	800
Segment Weight	0.1 g	5.0×10^4
Average Needle Length	0.1 cm	5.0×10^4

Locally Infected Branches

VARIABLE	LEVEL OF PRECISION	NEEDED NUMBER OF SAMPLES
Twig Length	0.1 cm	1.0×10^6
Needle Number	1.0 needles	1.0×10^4
Segment Weight	0.1 g	1.0×10^6
Average Needle Length	0.1 cm	1.0×10^6

TABLE IX--continued

Systemically Infected Branches

VARIABLE	LEVEL OF PRECISION	NEEDED NUMBER OF SAMPLES
Twig Length	0.1 cm	$1.5x10^6$
Needle Number	1.0 needles	$1.5x10^4$
Segment Weight	0.1 g	$1.5x10^6$
Average Needle Length	0.1 cm	$1.5x10^6$

TABLE X

SAMPLE SIZES NEEDED TO ACCOUNT
FOR OBSERVED VARIATION
AT CRESCENT

Uninfected Branches

VARIABLE	LEVEL OF PRECISION	NEEDED NUMBER OF SAMPLES
Twig Length	0.1 cm	5.0×10^4
Needle Number	1.0 needles	800
Segment Weight	0.1 g	5.0×10^4
Average Needle Length	0.1 cm	5.0×10^4

Locally Infected Branches

VARIABLE	LEVEL OF PRECISION	NEEDED NUMBER OF SAMPLES
Twig Length	0.1 cm	1.5×10^6
Needle Number	1.0 needles	2.0×10^4
Segment Weight	0.1 g	1.5×10^6
Average Needle Length	0.1 cm	1.5×10^6

TABLE X--continued

Systemically Infected Branches

VARIABLE	LEVEL OF PRECISION	NEEDED NUMBER OF SAMPLES
Twig Length	0.1 cm	$2.0x10^5$
Needle Number	1.0 needles	$3.0x10^3$
Segment Weight	0.1 g	$2.5x10^6$
Average Needle Length	0.1 cm	$2.0x10^5$

Comparisons of the results from the two way nested ANOVA were made between overlapping DMRs at the two sites to see if any continuity existed in the response of the host trees to A. americanum at the two sites. DMR 3 and DMR 4 are found in abundance at both sites. Because the results are not consistent between DMR 3 or DMR 4 samples at the two sites, the reported results cannot be interpreted as a general trend for all infected stands of P. contorta. Again, the reported results may be distorted due to small sample sizes.

The results from both one way ANOVA and two way nested ANOVA indicate that the dwarf mistletoe rating system devised by Hawksworth (1977) may be too refined to categorize growth response of branches of Pinus contorta infected with Arceuthobium americanum. The results from one way ANOVA established a difference between the growth of uninfected and heavily infected branches when the dwarf mistletoe rating of the samples is not considered. Conversely, when a single DMR was analyzed, there was no significant difference that consistently appeared between uninfected and heavily infected samples.

Other investigators have created systems for assessing the extent of dwarf mistletoe infection to a host tree. Baranyay and Safranyik (1970) used a four class system to differentiate between levels of A. americanum infection in P. contorta. The classes distinguished healthy trees, trees with light branch infection with less than 50 percent of the crown infected, trees with heavy branch and stem infections with more than 50 percent of the crown infected, and trees that displayed witches brooms, branch, and stem infections with more than 50 percent of the crown infected. This type of system may be more helpful in assessing the impact of Areuthobium spp. on its host, at least when branch growth of P. contorta is considered.

The effects of site characteristics on tree growth were not fully addressed in this study. As stated above, the two sites displayed enough differences to require the data from the two sites to be analyzed independently.

Pierce (1960) compared the growth of infected Douglas fir and larch on varying types of soil. As a result of this study, it was concluded that a decrease in soil quality resulted in a decrease in tree growth.

Baranyay and Safranyik (1970) observed that infected P. contorta growing on dry sites displayed greater changes in growth in response to A. americanum infections than P. contorta growing on wet sites. Rainfall may also be a factor in this study. Crescent receives a much higher amount of rainfall than Sisters. This variable, combined with the severity of the infection at Sisters, may account for the easily detected changes in branch growth between uninfected and heavily infected samples at Sisters.

CONCLUSIONS

The preliminary analysis of growth variables conducted by Tinnan and Knutson (1980) was partially confirmed using large samples sizes and the host tree Pinus contorta. This confirmation was observed only when the samples were analyzed without regard to the dwarf mistletoe rating of the samples. When the dwarf mistletoe rating is considered, no consistent significant results can be determined between branch classifications or between DMRs when only one branch classification is considered. Too much variation existed between samples of a given DMR or branch classification to allow for detection of significant differences. The number of samples needed to account for the observed variation tends to make similar research on this topic prohibitive.

Further investigations on the effects of site characteristics on infected tree growth is needed. Such work could account for much, if not most, of the variation observed.

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APPENDIX A

RESULTS OF TWO WAY ANOVA COMPARING BRANCH CLASSIFICATIONS OF A GIVEN DMR

TABLE XI

ANALYSIS OF BRANCH CLASSIFICATIONS FROM PINUS CONTORTA INFECTED WITH ARCEUTHOBIUM AMERICANUM AT CRESCENT USING TWO WAY ANOVA

Twig Length

Source of Variation		df[a]	SS[b]	MS[c]	F
DMR 1	Among Branch Classification	1	1.31	1.31	1.98[d]
	Among Trees	5	4.23	0.85	1.52[d]
	Among Tree Samples	13	5.55	0.43	
DMR 3	Among Branch Classification	1	0.89	0.89	8.39[e]
	Among Trees	9	16.25	1.81	0.49[d]
	Among Tree Samples	21	4.52	0.22	
DMR 4	Among Branch Classification	1	0.97	0.97	7.01[e]
	Among Trees	6	6.32	1.05	0.89[d]
	Among Tree Samples	15	2.25	0.15	

[a] - degrees of freedom
[b] - sum of squares
[c] - mean squares
[d] - not significant
[e] - significant at 0.05

TABLE XII

ANALYSIS OF BRANCH CLASSIFICATIONS FROM PINUS CONTORTA
INFECTED WITH ARCEUTHOBIUM AMERICANUM
AT SISTERS USING TWO WAY ANOVA

Twig Length

Source of Variation		df[a]	SS[b]	MS[c]	F
DMR 3	Among Branch Classification	1	6.42	6.42	5.42[d]
	Among Trees	8	7.75	0.97	6.63[e]
	Among Tree Samples	20	3.57	0.18	
DMR 4	Among Branch Classification	2	0.20	0.10	1.41[f]
	Among Trees	6	2.13	0.36	0.27[f]
	Among Tree Samples	16	4.02	0.25	
DMR 5	Among Branch Classification	1	0.44	0.44	1.01[f]
	Among Trees	7	3.59	0.51	0.86[f]
	Among Tree Samples	17	8.63	0.51	
DMR 6	Among Branch Classification	2	6.70	3.35	1.10[f]
	Among Trees	9	2.28	0.25	12.97[e]
	Among Tree Samples	18	4.13	0.23	

[a] - degrees of freedom
[b] - sum of squares
[c] - mean squares
[d] - significant at 0.05
[e] - significant at 0.01
[f] - not significant

TABLE XIII

ANALYSIS OF BRANCH CLASSIFICATIONS FROM *PINUS CONTORTA* INFECTED WITH *ARCEUTHOBIUM AMERICANUM* AT CRESCENT USING TWO WAY ANOVA

Needle Number

Source of Variation		df[a]	SS[b]	MS[c]	F
DMR 1	Among Branch Classification	1	85.95	85.95	1.00[d]
	Among Trees	5	1669.71	333.94	0.26[d]
	Among Tree Samples	13	4351.33	334.71	
DMR 3	Among Branch Classification	1	1443.55	1443.55	5.66[e]
	Among Trees	9	7129.69	792.19	1.64[d]
	Among Tree Samples	21	2938.00	139.90	
DMR 4	Among Branch Classification	1	9.46	9.46	1.07[d]
	Among Trees	6	3273.20	545.53	0.02[d]
	Among Tree Samples	15	7617.17	507.81	

[a] - degrees of freedom
[b] - sum of squares
[c] - mean squares
[d] - not significant
[e] - significant at 0.05

TABLE XIV

ANALYSIS OF BRANCH CLASSIFICATIONS FROM *PINUS CONTORTA* INFECTED WITH *ARCEUTHOBIUM AMERICANUM* AT SISTERS USING TWO WAY ANOVA

Needle Number

Source of Variation		df[a]	SS[b]	MS[c]	F
DMR 3	Among Branch Classification	1	13.14	13.14	0.61[d]
	Among Trees	8	1944.89	243.11	0.05[d]
	Among Tree Samples	20	7923.33	396.17	
DMR 4	Among Branch Classification	2	1308.44	654.22	6.28[e]
	Among Trees	6	5781.56	963.59	0.67[d]
	Among Tree Samples	16	2454.67	153.42	
DMR 5	Among Branch Classification	1	198.86	198.86	1.05[d]
	Among Trees	7	1701.69	243.10	0.82[d]
	Among Tree Samples	17	3941.33	231.84	
DMR 6	Among Branch Classification	2	9793.30	4896.65	2.51[d]
	Among Trees	9	3211.67	356.85	12.00[f]
	Among Tree Samples	18	2554.50	141.93	

[a] - degrees of freedom
[b] - sum of squares
[c] - mean squares
[d] - not significant
[e] - significant at 0.05
[f] - significant at 0.01

TABLE XV

ANALYSIS OF BRANCH CLASSIFICATIONS FROM PINUS CONTORTA INFECTED WITH ARCEUTHOBIUM AMERICANUM AT CRESCENT USING TWO WAY ANOVA

Total Segment Weight

Source of Variation		df[a]	SS[b]	MS[c]	F
DMR 1	Among Branch Classification	1	0.18	0.18	0.57[d]
	Among Trees	5	0.35	0.07	2.69[d]
	Among Tree Samples	13	1.58	0.12	
DMR 3	Among Branch Classification	1	0.01	0.01	3.42[d]
	Among Trees	9	3.22	0.36	0.03[d]
	Among Tree Samples	21	2.20	0.10	
DMR 4	Among Branch Classification	1	0.37	0.37	5.69[e]
	Among Trees	6	4.92	0.82	0.44[d]
	Among Tree Samples	15	2.16	0.14	

[a] - degrees of freedom
[b] - sum of squares
[c] - mean squares
[d] - not significant
[e] - significant at 0.05

TABLE XVI

ANALYSIS OF BRANCH CLASSIFICATIONS FROM PINUS CONTORTA INFECTED WITH ARCEUTHOBIUM AMERICANUM AT SISTERS USING TWO WAY ANOVA

Total Segment Weight

Source of Variation		df[a]	SS[b]	MS[c]	F
DMR 3	Among Branch Classification	1	1.19	1.19	1.29[d]
	Among Trees	8	3.39	0.42	2.80[e]
	Among Tree Samples	20	6.58	0.33	
DMR 4	Among Branch Classification	2	0.15	0.08	4.94[e]
	Among Trees	6	2.44	0.41	0.16[d]
	Among Tree Samples	16	1.32	0.08	
DMR 5	Among Branch Classification	1	0.74	0.74	4.05[d]
	Among Trees	7	1.43	0.20	3.57[f]
	Among Tree Samples	17	0.86	0.05	
DMR 6	Among Branch Classification	2	10.90	5.45	3.60[d]
	Among Trees	9	4.45	0.49	9.40[f]
	Among Tree Samples	18	2.48	0.14	

[a] - degrees of freedom
[b] - sum of squares
[c] - mean squares
[d] - not significant
[e] - significant at 0.05
[f] - significant at 0.01

TABLE XVII

ANALYSIS OF BRANCH CLASSIFICATIONS FROM *PINUS CONTORTA* INFECTED WITH *ARCEUTHOBIUM AMERICANUM* AT CRESCENT USING TWO WAY ANOVA

Average Needle Length

Source of Variation		df[a]	SS[b]	MS[c]	F
DMR 1	Among Branch Classification	1	1.52	1.52	8.70[d]
	Among Trees	5	13.35	2.67	0.55[e]
	Among Tree Samples	13	4.30	0.33	
DMR 3	Among Branch Classification	1	0.19	0.19	3.67[e]
	Among Trees	9	11.23	1.25	0.15[e]
	Among Tree Samples	21	7.15	0.34	
DMR 4	Among Branch Classification	1	0.86	0.86	4.41[e]
	Among Trees	6	7.96	1.32	0.63[e]
	Among Tree Samples	15	4.49	0.30	

[a] - degrees of freedom
[b] - sum of squares
[c] - mean squares
[d] - significant at 0.05
[e] - not significant

TABLE XVIII

ANALYSIS OF BRANCH CLASSIFICATIONS FROM *PINUS CONTORTA* INFECTED WITH *ARCEUTHOBIUM AMERICANUM* AT SISTERS USING TWO WAY ANOVA

Average Needle Length

Source of Variation		df[a]	SS[b]	MS[c]	F
DMR 3	Among Branch Classification	1	0.90	0.90	2.11[d]
	Among Trees	8	4.26	0.53	1.69[d]
	Among Tree Samples	20	5.05	0.25	
DMR 4	Among Branch Classification	2	2.75	1.38	4.75[e]
	Among Trees	6	8.08	1.35	1.01[d]
	Among Tree Samples	16	4.54	0.28	
DMR 5	Among Branch Classification	1	1.12	1.12	21.63[f]
	Among Trees	7	18.45	2.65	0.42[d]
	Among Tree Samples	17	2.07	0.12	
DMR 6	Among Branch Classification	2	7.21	3.61	4.28[e]
	Among Trees	9	12.99	1.44	2.11[d]
	Among Tree Samples	18	6.06	0.34	

[a] - degrees of freedom
[b] - sum of squares
[c] - mean squares
[d] - not significant
[e] - significant at 0.05
[f] - significant at 0.01

APPENDIX B

RESULTS OF TWO WAY ANOVA COMPARING INFECTION LEVELS OF A GIVEN BRANCH CLASSIFICATION

TABLE XIX

ANALYSIS OF INFECTION LEVELS OF PINUS CONTORTA
INFECTED WITH ARCEUTHOBIUM AMERICANUM
AT CRESCENT USING TWO WAY ANOVA

Twig Length

Source of Variation		df[a]	SS[b]	MS[c]	F
Uninfected	Among DMRs	1	0.24	0.24	2.27[d]
	Among Trees	3	3.98	1.33	0.18[d]
	Among Tree Samples	10	5.85	0.58	
Local	Among DMRs	4	6.17	1.54	6.39[e]
	Among Trees	18	19.75	1.10	1.43[d]
	Among Tree Samples	43	7.39	0.17	
Systemic	Among DMRs	2	1.61	0.81	4.68[d]
	Among Trees	6	7.93	1.32	0.68[d]
	Among Tree Samples	16	4.52	0.28	

[a] - degrees of freedom
[b] - sum of squares
[c] - mean squares
[d] - not significant
[e] - significant at 0.01

TABLE XX

ANALYSIS OF INFECTION LEVELS OF PINUS CONTORTA
INFECTED WITH ARCEUTHOBIUM AMERICANUM
AT SISTERS USING TWO WAY ANOVA

Twig Length

Source of Variation		df[a]	SS[b]	MS[c]	F
Uninfected	Among DMRs	2	3.80	1.90	8.39[d]
	Among Trees	2	2.43	1.21	1.57[d]
	Among Tree Samples	10	1.45	0.14	
Local	Among DMRs	3	6.18	2.06	1.92[d]
	Among Trees	15	8.95	0.60	3.38[e]
	Among Tree Samples	35	10.85	0.31	
Systemic	Among DMRs	3	5.27	1.76	6.30[e]
	Among Trees	20	26.98	1.35	1.18[d]
	Among Tree Samples	39	8.35	0.21	

[a] - degrees of freedom
[b] - sum of squares
[c] - mean squares
[d] - not significant
[e] - significant at 0.01

TABLE XXI

ANALYSIS OF INFECTION LEVELS OF PINUS CONTORTA
INFECTED WITH ARCEUTHOBIUM AMERICANUM
AT CRESCENT USING TWO WAY ANOVA

Needle Number

Source of Variation		df[a]	SS[b]	MS[c]	F
Uninfected	Among DMRs	1	683.38	683.38	0.03[d]
	Among Trees	3	256.22	85.41	8.00[e]
	Among Tree Samples	10	2829.33	282.93	
Local	Among DMRs	4	3137.05	784.26	4.14[e]
	Among Trees	18	17390.93	966.16	0.83[d]
	Among Tree Samples	43	10037.83	233.44	
Systemic	Among DMRs	2	73.79	36.89	1.54[d]
	Among Trees	6	2891.88	481.98	0.08[d]
	Among Tree Samples	16	5006.33	312.90	

[a] - degrees of freedom
[b] - sum of squares
[c] - mean squares
[d] - not significant
[e] - significant at 0.01

TABLE XXII

ANALYSIS OF INFECTION LEVELS OF PINUS CONTORTA INFECTED WITH ARCEUTHOBIUM AMERICANUM AT SISTERS USING TWO WAY ANOVA

Needle Number

Source of Variation		df[a]	SS[b]	MS[c]	F
Uninfected	Among DMRs	2	11921.38	5960.69	0.22[d]
	Among Trees	2	254.89	127.44	46.77[e]
	Among Tree Samples	10	5739.33	573.93	
Local	Among DMRs	3	704.19	234.73	3.53[f]
	Among Trees	15	7973.51	531.57	0.43[d]
	Among Tree Samples	35	5276.67	150.76	
Systemic	Among DMRs	3	2210.71	736.90	1.42[d]
	Among Trees	20	6460.29	323.01	2.20[f]
	Among Tree Samples	39	8871.00	227.46	

[a] - degrees of freedom
[b] - sum of squares
[c] - mean squares
[d] - not significant
[e] - significant at 0.01
[f] - significant at 0.05

TABLE XXIII

ANALYSIS OF INFECTION LEVELS OF *PINUS CONTORTA* INFECTED WITH *ARCEUTHOBIUM AMERICANUM* AT CRESCENT USING TWO WAY ANOVA

Total Segment Weight

Source of Variation		df[a]	SS[b]	MS[c]	F
Uninfected	Among DMRs	1	0.02	0.02	1.13[d]
	Among Trees	3	0.54	0.18	0.11[d]
	Among Tree Samples	10	1.57	0.16	
Local	Among DMRs	4	2.62	0.66	3.86[e]
	Among Trees	18	9.08	0.50	1.32[d]
	Among Tree Samples	43	5.62	0.13	
Systemic	Among DMRs	2	0.25	0.13	2.57[d]
	Among Trees	6	3.45	0.57	0.24[d]
	Among Tree Samples	16	3.58	0.22	

[a] - degrees of freedom
[b] - sum of squares
[c] - mean squares
[d] - not significant
[e] - significant at 0.05

TABLE XXIV

ANALYSIS OF INFECTION LEVELS OF *PINUS CONTORTA* INFECTED WITH *ARCEUTHOBIUM AMERICANUM* AT SISTERS USING TWO WAY ANOVA

Total Segment Weight

Source of Variation		df[a]	SS[b]	MS[c]	F
Uninfected	Among DMRs	2	8.25	4.12	0.40[d]
	Among Trees	2	0.42	0.21	19.46[e]
	Among Tree Samples	10	5.27	0.53	
Local	Among DMRs	3	8.8×10^8	2.9×10^8	1.41[d]
	Among Trees	15	4.5×10^9	3.0×10^8	0.96[d]
	Among Tree Samples	35	7.5×10^9	2.1×10^8	
Systemic	Among DMRs	3	0.24	0.08	2.41[d]
	Among Trees	20	5.52	0.28	0.27[d]
	Among Tree Samples	39	4.47	0.11	

[a] - degrees of freedom
[b] - sum of squares
[c] - mean squares
[d] - not significant
[e] - significant at 0.01

TABLE XXV

ANALYSIS OF INFECTION LEVELS OF PINUS CONTORTA
INFECTED WITH ARCEUTHOBIUM AMERICANUM
AT CRESCENT USING TWO WAY ANOVA

Average Needle Length

Source of Variation		df[a]	SS[b]	MS[c]	F
Uninfected	Among DMRs	1	1.13	1.13	5.60[d]
	Among Trees	3	9.06	3.02	3.02[d]
	Among Tree Samples	10	5.39	0.54	
Local	Among DMRs	4	7.47	1.87	5.89[e]
	Among Trees	18	33.57	1.87	1.02[d]
	Among Tree Samples	43	13.61	0.32	
Systemic	Among DMRs	2	0.26	0.13	4.60[d]
	Among Trees	6	5.98	1.00	0.15[d]
	Among Tree Samples	16	3.47	0.22	

[a] - degrees of freedom
[b] - sum of squares
[c] - mean squares
[d] - not significant
[e] - significant at 0.01

TABLE XXVI

ANALYSIS OF INFECTION LEVELS OF PINUS CONTORTA
INFECTED WITH ARCEUTHOBIUM AMERICANUM
AT SISTERS USING TWO WAY ANOVA

Average Needle Length

Source of Variation		df[a]	SS[b]	MS[c]	F
Uninfected	Among DMRs	2	3.95	1.97	1.80[d]
	Among Trees	2	1.24	0.62	3.20[d]
	Among Tree Samples	10	3.43	0.34	
Local	Among DMRs	3	0.03	0.01	3.36[e]
	Among Trees	15	30.70	2.05	0.01[d]
	Among Tree Samples	35	21.29	0.61	
Systemic	Among DMRs	3	1.81	0.60	4.22[e]
	Among Trees	20	21.39	1.07	0.52[d]
	Among Tree Samples	39	9.88	0.25	

[a] - degrees of freedom
[b] - sum of squares
[c] - mean squares
[d] - not significant
[e] - significant at 0.05

APPENDIX C

MEAN VALUES FOR MEASURED VARIABLES

TABLE XXVII

MEAN VALUES FOR MEASURED VARIABLES AT CRESCENT

Twig Length

DMR	UNINFECTED	LOCAL	SYSTEMIC
0	2.1 ± 0.19	—	—
1	2.3 ± 0.50	1.7 ± 0.11	—
2	—	3.8 ± 0.13	—
3	—	2.3 ± 0.22	2.5 ± 0.19
4	—	3.4 ± 0.12	2.1 ± 0.30
5	—	2.5 ± 0.31	2.9 ± 0.35

Needle Number

DMR	UNINFECTED	LOCAL	SYSTEMIC
0	49 ± 3.5	—	—
1	41 ± 5.2	36 ± 4.6	—
2	—	58 ± 4.0	—
3	—	51 ± 5.4	61 ± 5.1
4	—	47 ± 5.6	60 ± 8.0
5	—	47 ± 10.5	57 ± 13.5

TABLE XXVII—continued

Total Segment Weight

DMR	UNINFECTED	LOCAL	SYSTEMIC
0	0.7831 ± 0.12	—	—
1	0.7080 ± 0.19	0.5015 ± 0.07	—
2	—	1.0795 ± 0.12	—
3	—	0.8241 ± 0.11	0.8701 ± 0.09
4	—	0.6973 ± 0.10	1.0479 ± 0.26
5	—	1.0012 ± 0.32	1.1294 ± 0.23

Average Needle Length

DMR	UNINFECTED	LOCAL	SYSTEMIC
0	3.4 ± 0.31	—	—
1	3.9 ± 0.51	3.3 ± 0.24	—
2	—	4.0 ± 0.20	—
3	—	3.4 ± 0.23	3.6 ± 0.17
4	—	3.7 ± 0.21	3.8 ± 0.27
5	—	4.4 ± 0.41	3.8 ± 0.15

TABLE XXVIII

MEAN VALUES FOR MEASURED VARIABLES AT SISTERS

Twig Length

DMR	UNINFECTED	LOCAL	SYSTEMIC
3	2.7 ± 0.22	2.5 ± 0.13	1.7 ± 0.03
4	1.8 ± 0.12	1.9 ± 0.15	2.4 ± 0.33
5	—	2.4 ± 0.21	2.0 ± 0.12
6	3.3 ± 0.20	1.7 ± 0.12	1.8 ± 0.97

Needle Number

DMR	UNINFECTED	LOCAL	SYSTEMIC
3	53 ± 9.1	52 ± 2.9	30 ± 5.3
4	32 ± 1.2	55 ± 5.7	59 ± 3.7
5	—	61 ± 3.5	52 ± 3.5
6	115 ± 1.3	56 ± 6.6	55 ± 3.3

TABLE XXVIII—continued

Total Segment Weight

DMR	UNINFECTED	LOCAL	SYSTEMIC
3	1.2430 ± 0.28	0.7133 ± 0.09	0.5787 ± 0.10
4	0.5804 ± 0.05	0.8005 ± 0.13	0.8053 ± 0.05
5	—	0.9802 ± 0.09	0.7405 ± 0.06
6	2.8162 ± 0.04	0.7117 ± 0.07	0.8439 ± 0.13

Average Needle Length

DMR	UNINFECTED	LOCAL	SYSTEMIC
3	3.8 ± 0.24	3.4 ± 0.11	4.0 ± 0.35
4	3.3 ± 0.29	3.3 ± 0.22	3.5 ± 0.18
5	—	3.8 ± 0.29	3.4 ± 0.10
6	4.9 ± 0.01	3.3 ± 0.24	3.3 ± 0.20

APPENDIX D

SAMPLE SIZES

TABLE XXIX

SAMPLE SIZES

DMR	CRESCENT			SISTERS		
	Uninfected	Local	Systemic	Uninfected	Local	Systemic
0	9	--	--	--	--	--
1	6	14	--	--	--	--
2	--	15	--	--	--	--
3	--	17	13	9	18	3
4	--	17	9	3	15	15
5	--	6	2	--	15	26
6	--	--	--	3	6	18