

# Volume loss of Douglas-fir infected with *Armillaria ostoyae*

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## INTRODUCTION

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Armillaria root disease is responsible for mortality of all types of woody plant species worldwide. The effects of non-lethal infection on the roots of these same woody species are less well known. As early as 1874, Robert Hartig published a description of the infection process that included observations on reduced annual height and ring width, and the difficulty of identifying symptoms of root infections above ground. Over the range of the fungus in southern British Columbia, the Interior Cedar–Hemlock biogeoclimatic zone (ICH) is the most affected area. In this ecosystem, the background level of below-ground infection of juvenile trees ranges from about 15% in non-symptomatic areas to about 35% near trees with symptoms (Morrison et al. 1999). In older stands, the infection rate in non-symptomatic stands can range as high as 80%. In all stands, the incidence of infection increases with tree size.

Previous studies indicate that growth loss occurs upon root contact with inoculum of all root diseases. Losses due to *Armillaria* species are probably the highest given its wide distribution and its ability to spread via root contacts and rhizomorphs. Volume losses in old-growth Interior Douglas-fir are estimated to be 1% per year starting at age 50 (Bloomberg and Morrison 1989). The epidemiology in planted juvenile stands is expected to be different from old-growth stands because silvicultural practices alter the development of the disease. This study documents the epidemiology of *Armillaria* root disease in juvenile stands and determines what effect non-lethal root infections might have on our young trees at one site near Kaslo, B.C.

## METHODS

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Eighteen-year-old Douglas-fir trees were pulled out of the ground using a pop-up spacer so that roots and tops were intact. The root system of each tree was surveyed for presence of *Armillaria ostoyae* infection (fans). The roots were sectioned at the root collar and proximal to each infection to determine the infection date. The infection date for a tree was the oldest infection. The proportion of infected roots per tree was calculated using main lateral roots only (> 15 mm).

Top measurements were taken of height increment for the past 10 years, and stem cross-sectional disks were taken at the soil line and at breast height. Stem cross-sectional area was marked for the first 10 years, and then 4-year periods after that. This information was then digitized. Volume was calculated using the area and height measurements.

All analyses were performed using SAS (PROC GLM). The analysis for volume reduction used final volume as the dependent variable, with initial volume, infection age classes, and proportion of infected

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roots as independent variables. The infection classes consisted of no infection, infected 1–4 years ago, and infected 5–8 years ago.

## RESULTS

Infection date and proportion of infected roots does affect cross-sectional area at breast height. Trees were initially infected at about age 5 and infection peaked at about age 14. Tree radial growth before infection showed that the dead trees had been growing more quickly (about 25%) than the others. Losses accumulated shortly after infection and were positively correlated with increasing time and percentage of infected roots.

Disease affected cumulative height in a similar way. Dead trees had greater height growth before infection and greater loss occurred with increasing time and infection. Even within dead trees, death occurred sooner when the trees were growing more rapidly in the first 10 years.

Table 1 shows parameters important for modelling volume loss. The initial volume was the most important main effect in the model. Infection period, not significant as a main effect, interacts with initial volume ( $A \times B$ ). This interaction indicates that trees initially growing more rapidly show more volume loss with increasing time since infection than smaller trees (about 40% over 4–8 years). The proportion of infected roots was marginally significant as a main effect. No other interactions were significant.

## CONCLUSIONS

This analysis of growth reduction indicates that time since infection is more important than the amount of infection a root system has sustained. Soon after a main lateral root becomes infected, the effect of loss can be detected in the stem. This effect lasts at least 8 years. Larger trees lose more volume than smaller trees probably because they are putting on more increment. Volume reduction could occur because of loss of vascular tissue, loss of energy to defense, or replacement of new tissues such as callus and new roots.

Heavily infected trees do not show a period of appreciable volume loss because they become girdled and die quickly. Why increased growth and mortality seemed related is not clear; however, these

TABLE 1 *Analysis model for the final volume of infected and uninfected trees*

	Parameter		
	<i>F</i>	<i>P</i>	<i>R</i> <sup>2</sup>
Model	30	0.0001	0.64
Independent variables:			
A: initial volume before infection	224	0.0001	
B: infection period	1.27	0.2837	
C: proportion of infected roots	3.17	0.0770	
$A \times B$	8.7	0.0003	
$A \times C$	2.16	0.1258	
$B \times C$	0.93	0.3370	
$A \times B \times C$	0.62	0.4313	

characteristics have been noted by others (Hrib et al. 1983). Faster-growing trees may die more quickly because they touch the stump inoculum sooner when the fungus is at a higher inoculum potential, or they allocate less energy to defense.

These results indicate that *Armillaria* root disease in the Interior affects larger, more vigorous juvenile trees more strongly in many ways. Many silvicultural techniques aim to increase the growth of the trees in the first 20 years; consequently, trees become infected sooner, and all tree species are susceptible at this time. Techniques such as brushing and weeding, planting, burning, and juvenile spacing (and more recently breeding) all shorten the time to contact with stump inoculum. Furthermore, harvesting increases the volume of inoculum on-site because the fungus can colonize the stumps and spread to the surrounding crop trees.

This study relates loss to individual trees; however, at the stand level, losses should be proportional to the area of stand infected. The high level of root infection in the ICH (mostly undetectable) probably ensures that the full potential of these sites is not being realized. Increased growth of surrounding trees may occur near centre openings, if the edge trees do not become infected. This is a large assumption and recent evidence (Morrison et al. 1999) suggests that the incidence of infection around a dead or infected tree is higher than in non-symptomatic areas and that larger trees are more likely to become infected. The effect of non-lethal infections (the highest fraction) at stand level remains. These trees provide competition for many years. Stands in which trees are progressively infected over the rotation should reach a given volume later than stands without disease. Given the wide distribution of this fungus in Canada and worldwide, and the potential to amplify the inoculum by forest activities, the long-term threat to forest productivity is considerable.

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