Impacts of Armillaria root disease

on stand productivity

in the southern interior

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Abstract

The primary objective of this ongoing project is to quantify the growth loss attributable to sub-lethal Armillaria infection (DRA) in Douglas-fir plantations in the southern interior. New and existing data will be used to derive and update the effects of Armillaria for the TASS/TIPSY suite of growth and yield models.

Introduction

Armillaria ostoyae (Romagn.) Herink causes Armillaria root disease (DRA) of conifers and has a circumpolar distribution in the northern hemisphere (Watling et al. 1991), including the southern one-third of British Columbia (BC) (Morrison et al. 1985). In the southern interior, the disease is found in the IDF, MS, SBS, ICH and ESSF (lower elevations) biogeoclimatic (BEC) zones (Morrison et al. 1992). The fungus is a normal component of the flora on (nearly all) sites in those BEC zones, with incidence of diseased trees in mature stands ranging from 10% in the IDF to 80% in the ICH (Morrison et al. 2001). After harvest, stumps of infected trees are colonized by the fungus and become inoculum. Infection of plantation trees begins about age 6 in the ICH, with incidence of diseased trees increasing gradually until it is 30-35% at age 20 (Morrison et al. 2000). The fungus has a very broad host range, including all species of trees and many shrubs. Damage occurs throughout the rotation and is caused as growth loss in trees with non-lethal disease and mortality at a rate up to 2% per annum. Precommercial and commercial thinning and selective cutting increase the incidence of trees with DRA by increasing the amount of fungal inoculum (Cruickshank et al. 1997, Morrison et al. 2001). Use of these practices, especially selective cutting, is increasing in the southern interior, and their use increases the incidence of mortality and living, DRA-diseased trees. These results raise the question “what are the effects of non-lethal infections on productivity of the stand?”. The primary objective of this ongoing project is to quantify the growth loss attributable to sub-lethal Armillaria infection in Douglas-fir plantations in the southern interior. Armillaria operational adjustment factors (OAFs) are reduction factors created specifically to account for the disease impacts, and have been programmed into the TIPSY growth and yield model previously.

Methods

About 1000 trees in approximately 25 10-meter radius plots are removed from the soil at each site after stem mapping. For a sample of 150 Douglas-firs, root systems are mapped and examined for root infections, stem disks are taken for volume determination, crown characteristics are measured, and the infection age of all lesions is determined. Stem disk areas were determined by digital methods (Cruickshank 2002). Losses are determined by the volume or basal area difference between the healthy and infected trees. Multiple regression analysis is used for determining fungal spread rates and losses. This year two ICH sites were sampled, Chuck Creek and McMurphy near Clearwater BC, in addition to the 2 sites last year near Enderby BC.
Results and Discussion

A) Field sampling

1. Incidence and host reactions

The belowground incidence of trees infected with Armillaria root disease (DRA) in the two new stands this year was 27% for McMurphy (age 24), 35% for Chuck Creek (age 34), and last year was 53% for Kingfisher (age 30) and 39% for Hidden Lake (age 24). Trees with all root lesions contained (callused) for McMurphy was 15%, Chuck Creek 13%, and last year for Kingfisher was 21% and Hidden Lake 31%. Trees with one or more lesions contained for McMurphy was 92%, for Chuck Creek 80%, and last year for Kingfisher was 94% and Hidden Lake 93%.

There are still many lesions spreading, and this agrees with the recent infection ages of the lesions. The fungus spreads progressively through the root system over time on many trees. Mortality may not occur for many years until the root system becomes progressively covered in lesions.

2. Growth losses

Trees that are able to contain the fungus completely and survive suffer growth losses. Individual tree losses for McMurphy range from 5-55% and 0-61% for Chuck Creek and last year for Kingfisher range from 37-49% and 6-41% for Hidden Lake. Larger trees lose more volume even on a relative basis.

Stand level losses are 8% for McMurphy and 9% for Chuck Creek, and last year were 13% for Kingfisher and 7% for Hidden Lake. The tree starts losing volume from the first infection event on the roots. Growth losses accumulate as the stand ages and the incidence of infection rises, and are significant even when mortality losses are not included.

3. Compensatory growth

Compensatory growth, where healthy trees show increased growth due to their proximity to infected competitor neighbors did not occur. A competitor tree is a neighbor tree that is taller than a 60-degree angle line drawn vertically up from the base of the base of the center tree. A center tree’s infection status had no effect on its competitor neighbor’s basal area, and the infection status of neighbors had no effect on the center tree basal area. The basal area of neighbor trees surrounding dead trees did not change after the death of the center tree. Compensatory growth, if it did occur, would be short lived as the percentage of healthy trees in stands steadily diminishes to a low percentage by age 60. Healthy trees cannot be relied upon to compensate for growth losses in infected trees mostly because of the high incidence of infection as the stands age.

B) Modeling

1. Growth and yield model TASS
The crown length and annual branch increments were not different between healthy and infected trees resulting in similar crown shape and size for both categories. There were no differences between diseased and healthy trees in the amount of leaf area within the crown, or area increment distribution along the bole, although the trend was towards reduced radial increment below live crown in infected trees.

There was a significant difference in the relationship between the crown volume and annual bole volume increment. Infected trees had less bole increment (relative to healthy trees) for a given crown volume amounting to a loss of up to 28% of annual increment after the tree had been infected for 20 years. This is close to the figures generated by Bloomberg and Morrison (1989) in their study of growth losses in stems of 100-year-old Douglas-fir (about 33% loss in 20 years) in trees between the ages of 50 and 100 years.

In order to handle the disease effects in annual bole increment, TASS has been programmed to reduce the increment each year in infected but living trees after they become infected.

### 2. Root disease simulator ROTSIM

ROTSIM, a Phellinus root disease model, was updated to simulate DRA in Douglas-fir plantations in the ICH. ROTSIM represents the root system, and is linked to TASS, which simulates the aboveground stem and crown disease impacts. Both models operate concurrently. ROTSIM required some extensive modifications in order to handle DRA correctly. The data was collected from a sample of stumps that were brought back to the Canadian Forest Service lab in Victoria BC from each site.

ROTSIM uses the length of the lesion formed to track how far the fungus spreads on the root system over time. The fungus spreads from the point of contact. The length of lesion is given by the fungal time to spread and the fungal spread rate randomly assigned to the lesion at the time of contact. The fungal time to spread at lesions was found to increase with increasing percent infected roots on the tree at both the root collar and on the roots. The spread rate of the fungus was correlated with the tree size (DBH) and the type of lesion the fungus formed on the root (patch or girdled infection). Infections that initially girdled the root, and were on larger trees, spread more quickly (up to twice as fast) than others. Infections contained to one side of the roots (patches), spread more slowly. Patch lesions (lesions on one side of the root) spread less quickly probably because the initial inoculum that created them was low. Roots that become girdled are allowed to produce rhizomorphs and infect additional roots. Rhizomorphs are simulated by increasing the root contact probabilities in the cells where infected roots occur.

A separate time to spread and spread rate was added this year for the root collar. The root collar is a very important area for both the tree and fungus because the tree can be girdled easily from this position. The fungal time to spread was also found to increase with increasing percent infected roots. Fungal spread rates at the collar lesions behave much the same as the roots except that they spread about one half as fast. Collar lesions spread more quickly around the bole of larger trees when they are caused by a girdled root.
3. TASS/ROTSIM disease simulations

The TASS/ROTSIM model was extensively reprogrammed to handle the biology and impacts of the fungus *Armillaria ostoyae* in Douglas-fir in the ICH ecosystem. The TIPSY model was modified earlier to handle Armillaria specific OAFs using data from destructive sampling and long-term sample plots monitored by the Canadian Forest Service. The disease effects from TASS/ROTSIM simulations are discussed below by contrasting them to TIPSY (Armillaria OAFs) and TASS (no disease effects) model simulations for a stand with site index of 28 and 1600 stems/ha planted initially.

The largest effect on timber volume was the level of initial starting inoculum conditions. High and low inoculum represents the number of infected stumps at the start of the simulation. The low inoculum simulations predict maximum yields to be between about 600 m$^3$/ha (TASS/ROTSIM stand age 80) and 500 m$^3$/ha (TIPSY stand age 130). At stand age 100 the low inoculum simulations predict that diseased stands have 45% and 28% lower yields for TASS/ROTSIM and TIPSY respectively. The high inoculum simulations predict that the stand yields were 47% and 61% lower with disease for TASS/ROTSIM and TIPSY respectively. The TASS/ROTSIM model predicts that stands will fall apart sooner than anticipated for the low inoculation simulations. TASS predicts that the long term yields would be greater than 1000 m$^3$/ha in the absence of disease in this ecosystem.

Conclusions and Implications

Recent research has shown that disease dynamics are not static despite the absence of above ground symptomology (Morrison et al. 2000 and 2001, Cruickshank et al. 1997), and impacts of the disease have been shown to continue to accumulate in stands over 100 years of age (Bloomberg and Morrison 1989) both from mortality and growth losses. The incidence of the fungus is high in the ICH ecosystem with discontinuous but significant distribution in adjacent biogeoclimatic zones in the southern interior (Cruickshank et al. 1997; Morrison et al. 2001). Research from this project combined with past research has clearly identified that Armillaria root disease exerts a strong effect on Douglas-fir stand development including:

- Minimum harvestable age (volume and piece size)
- Stand tending
- Planting
- Species composition

Currently the OAFs used in BC use a combined reduction factor for OAF1 and OAF2 of 20%. These model runs suggest that the actual impact of Armillaria in Douglas-fir is higher than this at age 100. A timber supply analysis was completed using the TISPY Armillaria OAFs (Stearns-Smith et al. 2004) showing that the impact of Armillaria in Douglas-fir plantations at the landscape level is about 7% of a timber supply area, but this figure does not account for the disease effects in other species or the effect in unmanaged Douglas-fir stands.
Although the study focuses on Douglas-fir, many of the key concepts and model building steps are the same for other species once calibrated and can be extended with more limited sampling. Research here and abroad also suggests that these effects are not solely limited to Douglas-fir as all conifers and many deciduous species also are affected. Unfortunately, most of the disease effects occur well after the free-growing assessment and are overlooked. What impact occurs in these species is a question that remains to be answered.

This study does not specifically provide direct data on treatment economics, but it does provide a tool to determine the possible benefits of reducing the disease. The impacts for Armillaria in Douglas-fir alone indicate that the disease places a large constraint on the site potential of infected stands. Currently little is done to treat the disease given the uncertainty surrounding treatment benefits and costs, but this might change if stakeholders become aware of short- and long-term benefits. At the very least, managing root disease inoculum loads and carefully choosing species mixtures, to avoid inoculum increases, may be the best option in the ICH.
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Literature cited


