ARMILLARIA ALTIMONTANA IS NOT ASSOCIATED WITH REDUCED GROWTH OR SURVIVAL OF WESTERN WHITE PINE (*PINUS MONTICOLA*) PLANTED IN NORTHERN IDAHO

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INTRODUCTION

Armillaria altimontana and *A. solidipes* frequently co-occur (McDonald et al. 2000) and are commonly found in association with western white pine (*Pinus monticola*). *Armillaria solidipes* (as *A. ostoyae*) is well-known as a virulent primary pathogen on diverse conifers within inland western regions of the contiguous USA (Lockman and Kearns 2016), whereas *A. altimontana* is considered to be a weak or secondary pathogen (Brazee et al. 2012). However, little has been documented about the impact of *A. altimontana* on tree health and growth.

In 1971, a provenance planting of western white pine was established at the Priest River Experimental Forest in northern Idaho, USA (940 m.a.s.l., ca. 48° 21' 48.75" N, -166° 49' 25.36" W) to examine variation in growth and survival among seed sources. In 1987, at 16 years post-planting, all of the remaining trees in the planting were measured, inspected, and sampled for *Armillaria* spp. before the planting was thinned.

The objective of this study was to: 1) identify *Armillaria* isolates sampled from 1,852 planted western white pine trees, 2) describe their demography and spatial distribution, and 3) assess the relationship among *Armillaria* spp. and growth and survival of western white pine.

METHODS

A provenance planting of western white pine was established in 1971 on a 0.8-ha plot at the Priest River Experimental Forest in northern Idaho, USA to examine variation in growth and survival among elevational seed sources (Figures 1 and 2A).

In 1987, after 16 years of field growth, ca. 1,852 living and recently dead trees were measured (e.g., survival, height growth, and diameter) and sampled for *Armillaria* to determine potential influences of *Armillaria* on growth and survival (Figure 2B).

Surveys for mycelial fans, wood root, and resinosis were conducted in 1987. The root collar and major lateral roots of all remaining trees were inspected for *Armillaria* by excavating 0.3-m deep to a distance of ca. 1-m away from the stem in three directions. Rhizomorphs, mycelial fans, and rotten wood were used as sources to establish *Armillaria* isolates in culture following the methods of McDonald et al. (1987).

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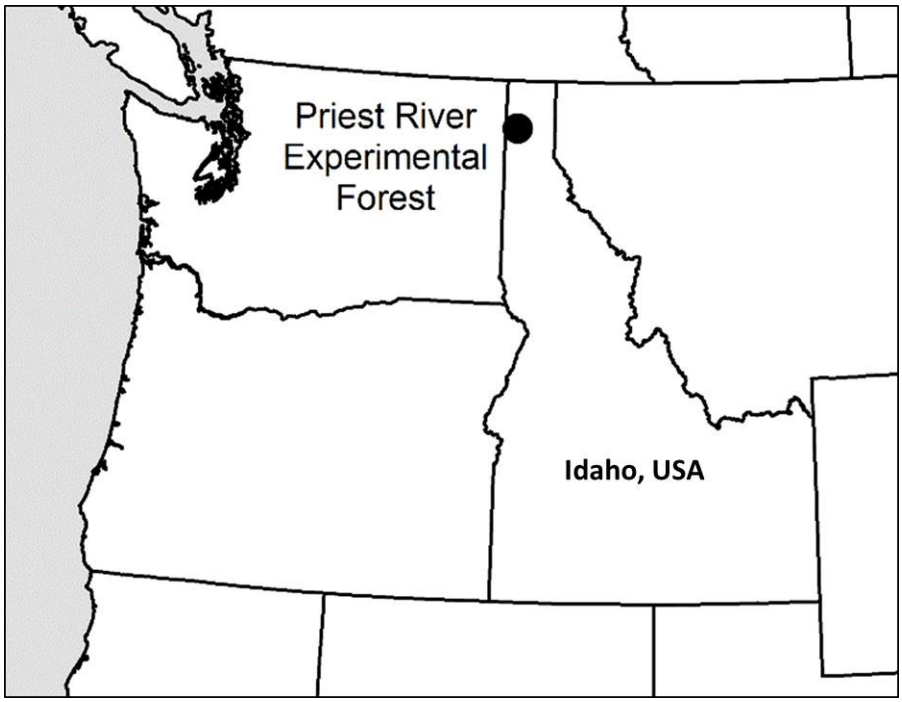

Figure 1. The provenance planting of western white pine is located at the Priest River Experimental Forest in northern Idaho.

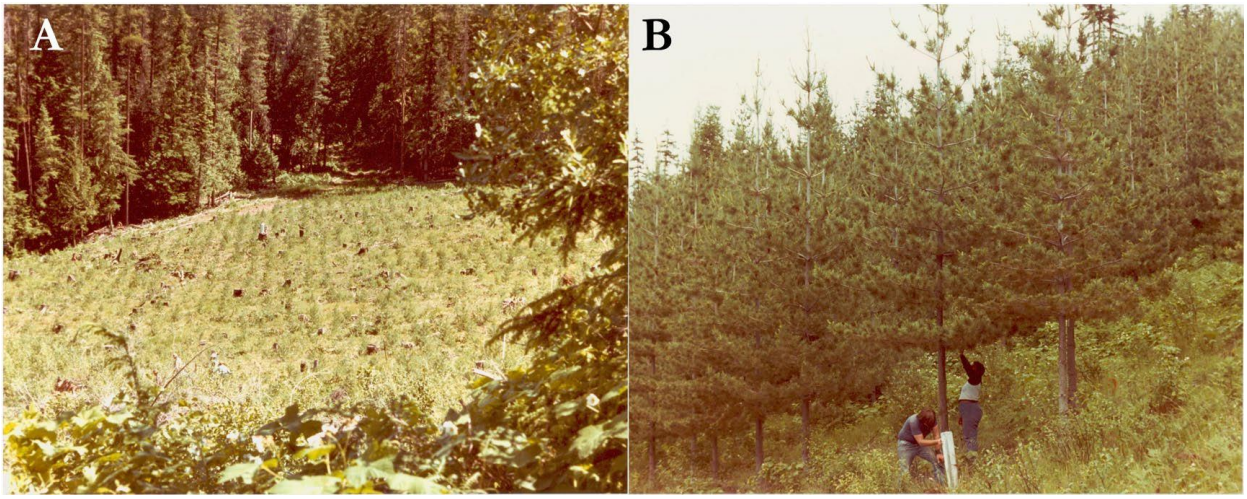

Figure 2. Plot photos. **A**: planting of western white pine (*Pinus monticola*) in 1971 at the Priest River Experimental Forest in northern Idaho, USA; **B**: measurements and surveys of western white pine trees in 1987.

Following the 1987 sample collections, all cultured isolates were paired against each other to delineate genets using the techniques described in Wu et al. (2003). A final round of diploid-diploid pairings with representatives of each genet were paired against known testers to identify species. Species determinations were confirmed using translation elongation factor 1-α (*tef1*) sequences.

Generalized linear mixed-effects models (GLMM) using the lme4 function (Bates et al. 2013) in R (R Core Team 2015) were used to assess relationships between *Armillaria* spp, white pine blister rust, and white pine growth and survival. The analysis used only trees from Idaho provenances.

RESULTS AND DISCUSSION

Preliminary results using the 1987 survey revealed that *Armillaria* was associated with ca. 54% of surveyed trees. Based on somatic pairing and *tef1* sequencing, ca. 84% of the *Armillaria* isolates comprised two genets of *A. altimontana* (Figure 3A), and ca. 16% of the isolates comprised five genets of *A. solidipes* (Figure 3B). No significant relationship ($P < 0.05$) was detected between the occurrence of Armillaria root rot and white pine blister rust. Consequently, trees with white pine blister rust where removed from further analysis to avoid obscuring the analysis of white pine performance in association with Armillaria spp. Regression analyses showed that *A. solidipes* was associated with decreased tree growth and survival (Figure 4). In contrast, *A. altimontana* was not associated with decreased tree growth and survival, suggesting that *A. altimontana* was not damaging to western white pine in northern Idaho (Figure 4). Furthermore, *A. solidipes* was less common in some areas dominated by *A. altimontana*. The wide coverage of individual *Armillaria* genets suggest that both *Armillaria* spp. have occupied this site for more than 250 years. Understanding the interactions of these two *Armillaria* species appears key to understanding Armillaria root disease in this region.

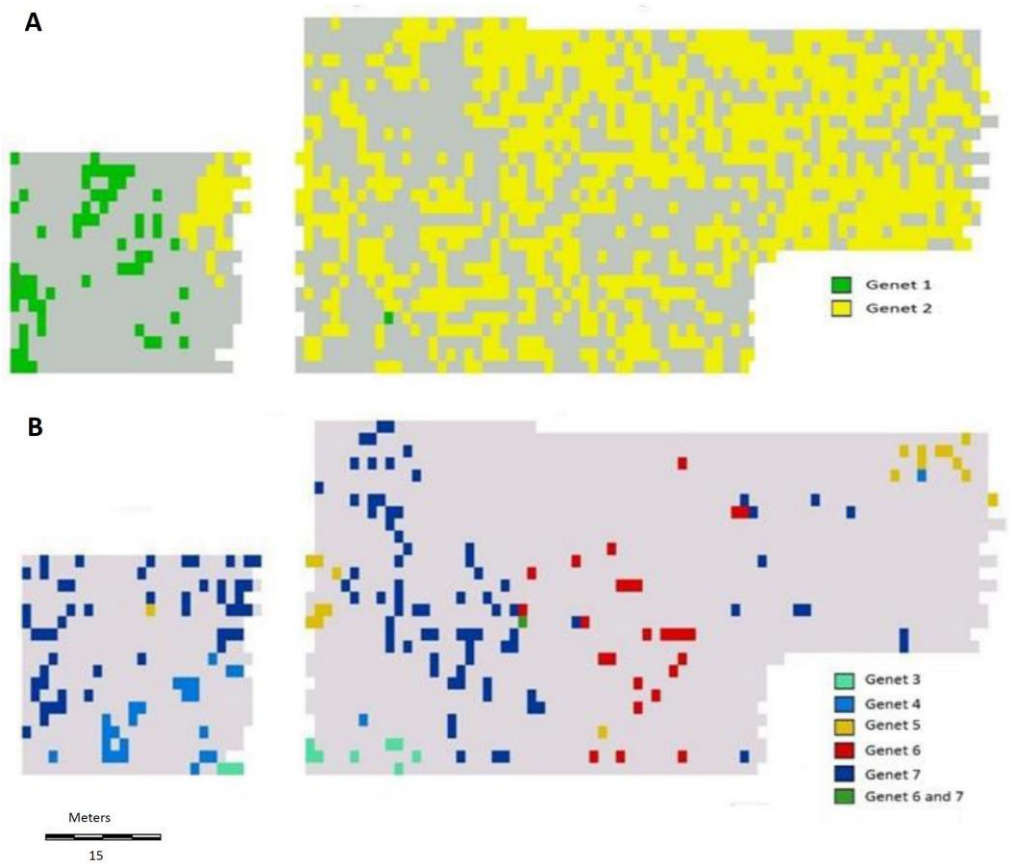

Figure 3. *Armillaria* species and genet distribution in western white pine (*Pinus monticola*) planting site located at the Priest River Experimental Forest in northern Idaho, USA. **A**: Spatial distribution of *A. altimontana* genets (1 & 2); **B**: Spatial distribution of *A. solidipes* genets (3, 4, 5, 6 & 7).

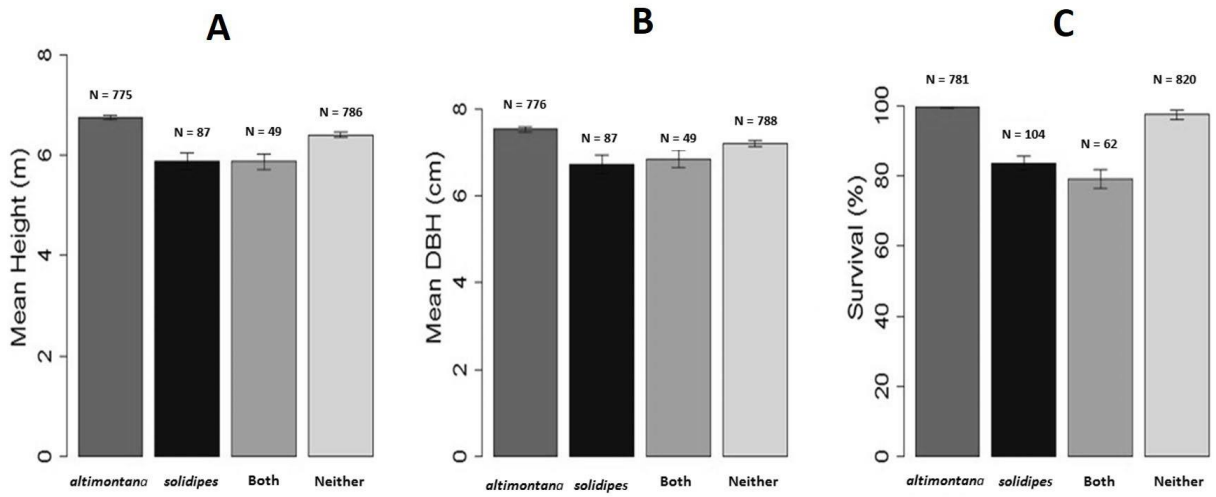

Figure 4. A: mean height; **B**: mean diameter at breast height (DBH); and **C**: percent survival among western white pine (*Pinus monticola*) growing in association with *Armillaria altimontana*, *A. solidipes*, both *A. altimontana* and *A. solidipes*, or neither *Armillaria* species at 16 years post-planting at Priest River Experimental Forest, northern Idaho, USA.

Further research is needed to determine if, how, and when survival and growth of western white pine is enhanced by *A. altimontana*. Studies are currently underway at this site using a metagenomics approach to determine soil properties and soil microbes associated with potentially beneficial *A. altimontana* versus virulent *A. solidipes*. At this time, it remains unknown how the spatial distribution of these *Armillaria* species and genets may have changed over the last 30 years on this site.

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