Monitoring of Blister Rust Resistance, Pathogen Virulence, and Genetic Adaptability of Western White Pine (*Pinus monticola*) at Six Sites in Western Washington, USA

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INTRODUCTION

Western white pine (WWP, *Pinus monticola*) is a wide-ranging, long-lived native conifer species in western North America. It is highly susceptible to the introduced fungal pathogen *Cronartium ribicola*, causative agent of white pine blister rust (WPBR). The impacts of the blister rust have reduced the incidence of WWP in natural ecosystems and have led to reluctance in using the species in both restoration and reforestation. Research and operational programs to develop genetic resistance to WPBR have been ongoing for more than five decades, with regional programs based in Oregon (USA), Idaho (USA), and British Columbia (Canada). Progeny of thousands of parent trees have been screened for rust resistance in short-term artificial inoculation trials, and several types of resistance have been uncovered (Sniezko et al. 2014). Seed orchards have been established using the products of the earlier resistance work, and breeding to increase the level of genetic resistance continues. However, relatively few field trials, and notably multisite field trials with a diverse array of geographic sources and types of resistance, have been established to examine field resistance and durability of resistance (Sniezko et al. 2012).

This series of field trials examines WWP families and orchard seedlots from a wide array of geographic origins (British Columbia, Idaho, Oregon, Washington) at six diverse sites in western Washington (USA). The group of families and orchard seedlots includes materials that should encompass most (if not all) of the known types of resistance to white pine blister rust in WWP, and represents among the best resistant seedlots currently available from the three operational screening programs working to develop resistance to WPBR. In addition to testing the efficacy and durability of the different types of resistance in the field, these sites can help increase our understanding of the dynamics of rust infection over time, refine rust hazard guidelines, and determine whether seedlots from other breeding zones are adapted to sites in western Washington.

OBJECTIVES

The current and future objectives for this study include:

1. Assessing the current rust incidence and impacts (mortality). Establishing baseline for long-term monitoring.

2. Examining growth, vigor, and reproductive status of western white pine. Establishing baseline for long-term monitoring.

3. Assessing impacts of abiotic and biotic agents on WWP seed sources from diverse geographic origins.

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4. Assessing the level and durability of partial resistance over an array of environments.

5. Monitoring durability of major gene resistance (MGR).

6. Providing updates to landowners and aerial surveyors in western Washington on the levels of rust incidence and field resistance currently available.

METHODS

Six 3-ac (1.21-ha) trials were established in 2006 across western Washington. Thirty-six seedlots were planted across the sites (two sites had 30), with 1,269 to 1,365 individual seedlings planted at each site. A randomized complete block design was used, with seven blocks per site and three to seven seedlings per seedlot per block. The seedlots originated from many areas across the region, including the Gifford Pinchot National Forest (NF), Mount Baker-Snoqualmie NF, Olympic NF, Wenatchee NF, and Colville NF in Washington; Mount Hood NF, Umpqua NF, and Confederated Tribes of Warm Springs in Oregon; British Columbia; and the Bingham F2 seed orchard in Idaho.

Incidence and severity assessments of WPBR were made in 2010, 2011, and 2013. During the assessments tree damage, tree vigor, and rust severity, including the number of WPBR cankers, were measured. During the 2013 assessments, tree height and reproductive status were also measured. HOBO® (Onset®, Bourne, Massachusetts, USA) weather stations were installed at each site in 2013 to measure temperature and relative humidity.

RESULTS AND DISCUSSION

In 2013, overall survival—taking into account all mortality agents, including root disease and animal damage—was 90 percent or greater at all sites, even in the known WPBR-susceptible seedlots (fig. 1a). WPBR mortality was generally less than 1 percent across all sites, with the greatest amount of mortality from rust at the Cayuse and Rocky Raccoon sites (fig. 1b). As expected, WPBR infection levels were higher than the mortality, with most seedlots having less than 25 percent of the trees infected, except at Shuwah Jigsaw (fig. 1c). At the Shuwah Jigsaw site, 47 percent of the trees were infected and there was an average of 4.3 infections per tree (fig. 1d). The susceptible control had the highest overall infection (45 percent) across the six sites and was the family with the highest percentage stem infection on four of the six sites, including 98 percent at the Shuwah Jigsaw site (where it averaged more than nine cankers per tree). The low-to-moderate level of rust infection is encouraging, but it is likely due to a combination of genetic resistance and initial low rust hazard. A few trees putatively originating from a parent homozygous for major gene (Cr2) resistance now show cankers, potentially indicating the presence of a low frequency of virulent genotypes (vcr2), or environmental conditions such that the resistance is not 100 percent effective. Further investigations are pending. As with other sites, the level of rust infection and mortality are expected to increase over time (Sniezko et al. 2012), hence the importance of a network of "permanent" field trials such as this to monitor rust infection over time in a changing environment.

Less than 10 percent of the trees on most sites had pollen or cones, but the trees on Shuwah Jigsaw stand out again, as 50 percent of some seedlots had reproductive features (fig. 1e). The height data show that generally the fast growing seedlots at one site are also fast growing at other sites; trees were notably shorter at the Caveman site (fig. 1f). Six similar sites will be established in eastern Washington in 2015 (and one site in western Oregon in December 2014). Future analyses will look at more details of the geographic origin of the parent trees and their performance in western Washington.

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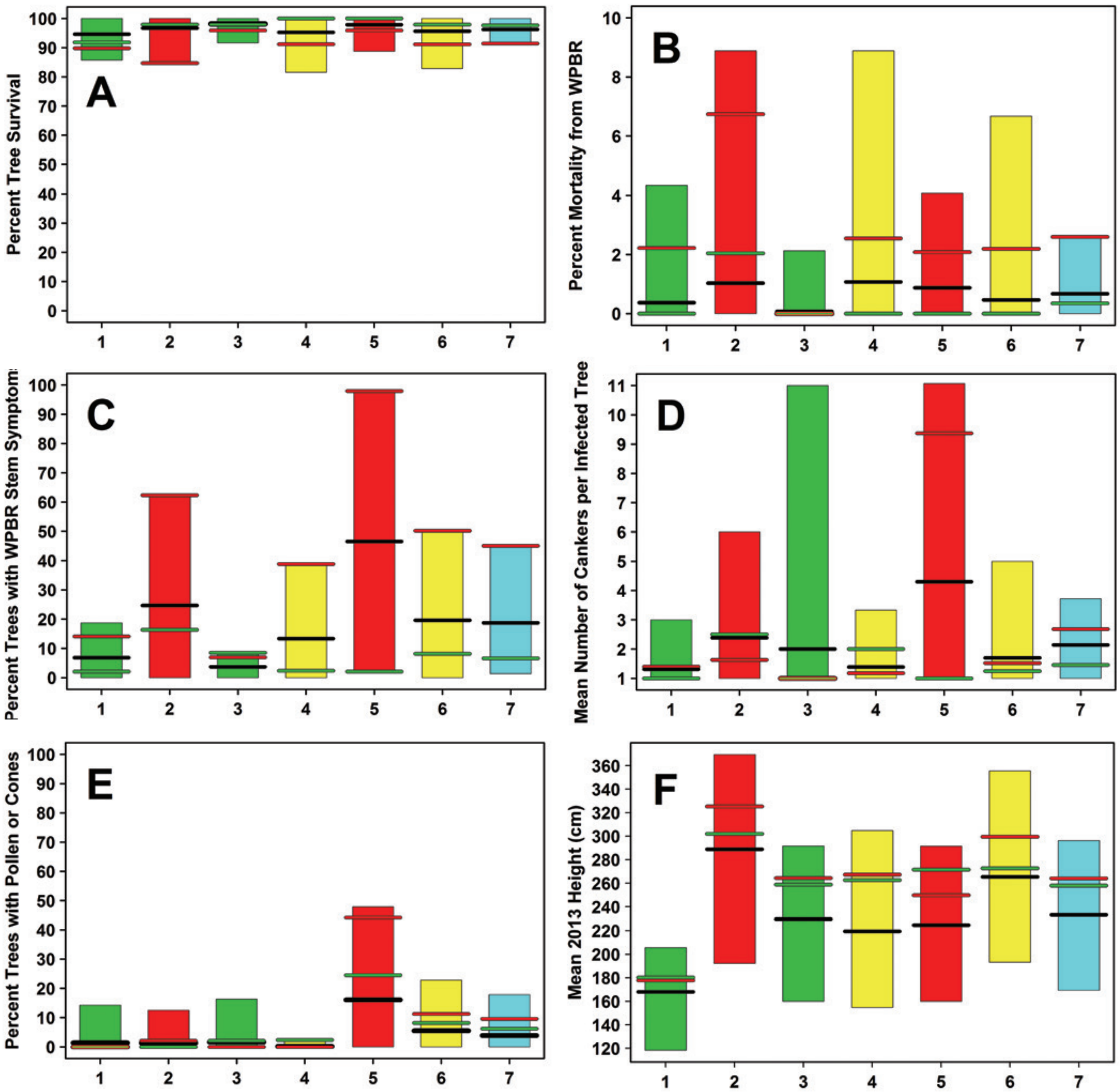

Figure 1—Growth, survival, white pine blister rust (WPBR) impacts and cone and/or pollen reproduction in six western white pine (*P. monticola*) genetic trials through 2013 (sites planted in 2006): (a) percent tree survival by site, (b) percent mortality from WPBR, (c) percent trees with WPBR stem symptoms, (d) mean number of cankers per infected tree, (e) percent trees with pollen or cones, and (f) mean 2013 height (cm). (Note: X-axis is site location/name: 1 = Caveman, 2 = Cayuse, 3 = High Chaparral, 4 = Rocky Raccoon, 5 = Shuwah Jigsaw, 6 = Stevens Left, 7 = Mean performance over all six sites. Each bar spans the range of the seedlot means at each site (30 or 36 seedlots, depending on the site) so that the minimum and maximum for each trait can be compared. The black line is the overall site average. The green line is the seedlot mean for a seedlot known to have Major Gene Resistance. The red line is the seedlot mean for a known susceptible seedlot. Green bars represent the 2 sites with lowest percentage of trees with stem symptoms, red bars for the highest 2 sites and yellow bars for the 2 intermediate sites.)