Options for Using Major Gene Resistance to *Cronartium ribicola* in *Pinus monticola* in Oregon and Washington

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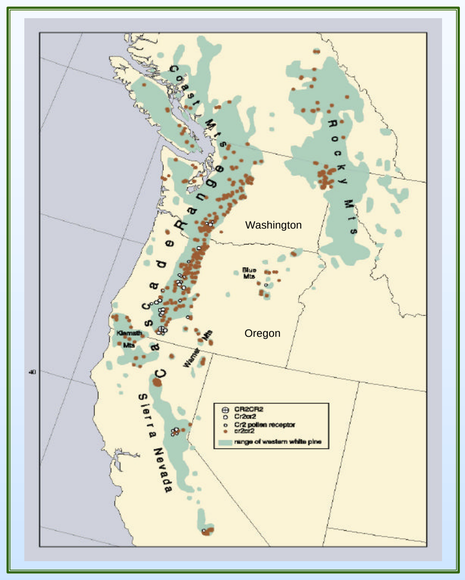
Introduction:

Western white pine (*Pinus monticola* Dougl.) is an important species of forest ecosystems in western North America. White pine blister rust (*Cronartium ribicola* J. C. Fisch.) was introduced to North America around 1910 and has caused widespread mortality in many of the 5-needle pines. The rust has severely impacted forest ecosystems and reduced planting of *P. monticola* and other 5-needle pines. The USDA Forest Service and USDI Bureau of Land Management have been cooperatively involved in screening and breeding for resistance to *C. ribicola* in both *P. monticola* and *P. lambertiana* for over 40 years in Oregon and Washington.

Cronartium ribicola:

Native to Asia, this stem rust is now widely distributed in Europe, Asia, and North America on *Pinus* spp. within the foxtail, stone, and white pine groups of sub-genus *Strobus*. Genetic variability of this stem rust in western North America is likely less than in Asia, due to its single introduction around 1910. It is a heteroecious rust with five spore stages. The telia host of *C. ribicola* in North America is *Ribes* spp.; aecial hosts are the white pines. The geographic range of both pine and *Ribes* spp. overlap considerably in many parts of western North America. Basidiospores of *C. ribicola* from the *Ribes* infect pines through the stomata of needles in late summer or early fall.



Range of *Pinus monticola* and geographic distribution of Cr2*

Rust mortality

(a)

(b)

Select trees (Cr2) in Champion Mine area before (a) and after (b) occurrence of vcr2 strain of the rust

Pinus monticola:

Breeding efforts to date have focused almost exclusively on *C. ribicola* resistance and maintaining genetic diversity in production populations. Based on common garden studies, breeding zones of this forest tree species have been established in Oregon and Washington, and these zones are generally much broader than for other associated forest species. Much of the natural genetic variation within this species is within stands and not among populations. In Oregon and Washington, *P. monticola* is usually planted in a mixture with other species or in small block plantings.

(a)

(b)

Infected (a) and uninfected (b) trees at high hazard site

(a)

(b)

(a) Hypersensitive necrosis on Cr2 genotype

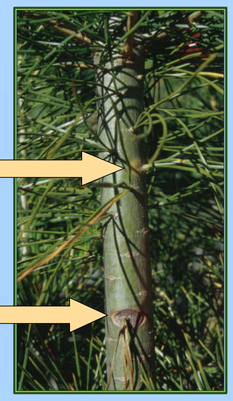
(b) Susceptible reaction on Cr2 genotype*

Needle lesions on seedling

Inoculation chamber at Dorena

(a)

(b)



Normal infection (a) and bark reaction (b) on young tree

Rust testing at Dorena (note surviving trees with major gene)

Screening and Breeding for Resistance:

Approximately 5000 *P. monticola* parent trees from throughout Oregon and Washington have been phenotypically selected in natural stands and screened for rust resistance. Several types of resistance are identified following artificial inoculation of seedlings and observations over the subsequent 5-year evaluation period. One of these, a major dominant gene, **Cr2**, conditions a classic hypersensitive reaction **HR** in the needles and prevents stem infection (Kinloch et al. 1999). Cr2 genotypes are low in frequency and limited geographically (unpublished data; also see map). 'Slow rusting' traits also appear to be present, but more information is needed concerning inheritance and durability of the complex of these traits (as used here, 'slow rusting' denotes a type of resistance associated with reduced infection rate or differential rates of mortality (Kinloch and Davis 1996)). Field validation tests are relatively young, but will serve to validate the screening results and examine durability of several resistance mechanisms. Current production orchards include both Cr2 (in some breeding zones) and 'slow rusting' resistance, but breeding will focus on the 'slow rusting' traits.

Seed orchard

Field test age 30 (>92% of trees are infected and >40 cankers per tree)

'Slow rusting family'

vcr2 strain

Avirulent for vcr2

Deployment of Major Gene Resistance:

Although Cr2 is very strong, a strain of blister rust with specific virulence to it is known:

- An investigation to determine the geographic distribution of this putative gene, vcr2, is underway.
- Relative site hazard for blister rust may ultimately determine how durable Cr2 is on these long-lived forest trees. Different sites can vary greatly in their rust hazard (even within a breeding zone), but there are also 'wave' years where almost all sites are impacted.
- The impact of vcr2 will also depend somewhat on the size of the trees being infected, with larger trees surviving longer or having the potential for greater effectiveness of some 'slow rusting' mechanisms.

Seed orchards (that rely on wind-pollination) have been established for most breeding zones, and some of these contain parents with Cr2:

- **Geographic Deployment of Cr2**: There is interest in adding parents with Cr2 to orchards lacking this resistance; and current debate is how to maximize the utility of Cr2 in areas where it is now utilized, and whether to restrict its geographic deployment. The main areas where Cr2 is used are in central and southern Oregon, which coincide fairly well with the natural occurrence of this major gene. However, small amounts of seed and pollen from trees with Cr2 have also been utilized in testing or small-scale plantings in other areas of Oregon, Washington, and British Columbia.
- **Gene Pyramids**: Other types of resistance, notably 'slow rusting' resistance (SRR), are being incorporated into resistance programs, but less is currently known about these mechanisms, and they are more difficult to assess. Future efforts are needed to more precisely delineate the makeup of 'slow rusting' types of resistance as well as their inheritance and ways to effectively introduce them into the production populations. In forest trees the predominant production system is usually a wind-pollinated orchard consisting of an array of 30+ parents. Present plans are to use both Cr2 and SRR parents in the open-pollinated orchards in southwestern Oregon, and primarily 'slow rusting' resistance in other breeding zones. Pyramiding Cr2 with SRR should provide a high percentage of canker-free trees from both the SRR and Cr2 components, while providing additional resistance if a virulent strain renders Cr2 ineffective in some areas. Alternatives such as the use of multi-lines are also being considered in some areas.

References:

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