

Screening Sitka Spruce for Resistance to Weevil Damage in British Columbia

René I. Alfaro¹ and John N. King²

Abstract

The white pine weevil, *Pissodes strobi* (Coleoptera, Curculionidae), has serious impacts on Sitka (*Picea sitchensis* (Bong.) Carrière), Engelmann (*P. engelmannii* Parry ex Engelm.), and white spruce (*P. glauca* (Moench) Voss) plantations in British Columbia (BC), Canada. This weevil attacks the terminal leader of the tree, causing significant growth loss and deformities. Genetic resistance to this insect was demonstrated in early provenance trials in BC. This encouraged us to initiate a systematic search for resistant trees to confirm this resistance and to improve parent source selections, especially in the Sitka spruce breeding program. Test plantations were initiated and, to accelerate the screening process and create a uniform weevil pressure, insect populations were artificially augmented at many of these trial sites. Artificial infestation provided quick and effective screening and allowed us to proceed with the construction of an F-1 population, and to understand the mechanisms and heritability of resistance. Seed orchards have been established and weevil resistant seedlings are now available for operational planting.

Key words: spruce, weevil, genetic resistance, tree improvement, pest management

Introduction

The white pine weevil, *Pissodes strobi* (Coleoptera, Curculionidae), is an important native pest that limits Sitka (*Picea sitchensis* (Bong.) Carrière), Engelmann (*P. engelmannii* Parry ex Engelm.), and white spruce (*P. glauca* (Moench) Voss) reforestation in western Canada. This insect lays its eggs on the uppermost shoot or leader of the tree. Upon hatching, the larvae mine under the leader bark, causing the destruction of the leader. Although this insect does not destroy the entire tree, a weevil attack leads to deformity and a reduction of growth, thereby making the tree economically unsuitable as a timber resource. By preventing restocking with spruce, the natural species for certain sites, the weevil also affects non-timber values such as biodiversity.

In order to find a natural solution to the problem, we searched for trees that are naturally resistant to the weevil. Several spruce provenances and genotypes with heritable resistance were found and are now included in seed orchards and reforestation programs in British Columbia (BC). To further understand the inheritance of resistance, we investigated resistance of progeny from selected crosses (F1) from parents with different levels of resistance. We also conducted studies aimed at understanding the basis for the observed resistance.

Materials and Methods

Sources Tested for Resistance

Seed was collected by BC Ministry of Forests and Range personnel from potentially resistant trees throughout the range of Sitka spruce in Coastal BC and the United States in Alaska, Washington, Oregon, and California. Seedlings produced from the collected seed were planted and tested in field trials (fig. 1) located in BC and Oregon and screened by Canadian Forest Service personnel. Plantations included block and family replication to allow statistical comparisons and heritability calculations.

¹ Canadian Forest Service, Pacific Forestry Centre, Victoria, BC, Canada.

² BC Ministry of Forests and Range (retired), Victoria, BC, Canada.

Corresponding author: ralfaro@pfc.forestry.ca.

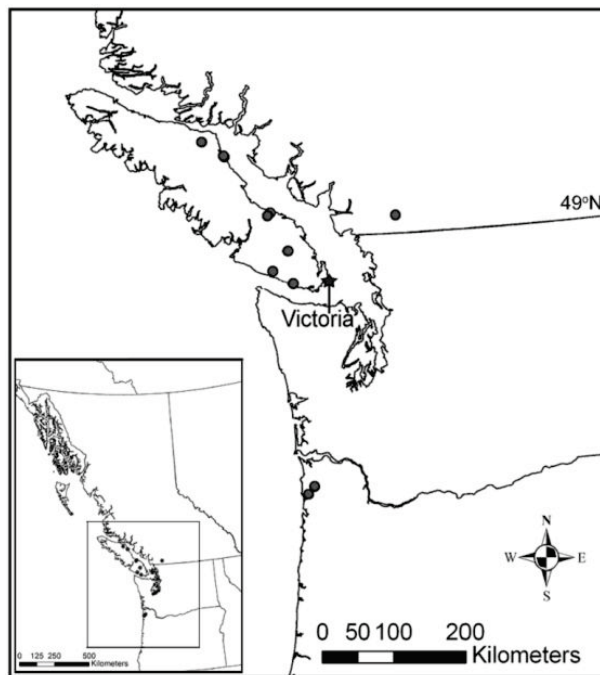


Figure 1—Locations of Sitka spruce screening trials on the west coast of North America.

Screening Methods

Screening of over 29,000 trees was conducted by artificially releasing laboratory-reared weevils (fig. 2) into the test plantations (for methods, see Alfaro et al. 2008) and then conducting annual evaluations of attack rates on the tested genotypes. Statistical analysis determined if particular families were resistant to attack and the heritability statistics.



Figure 2—Weevil release in Sitka spruce screening trial to screen genotypes for resistance to white pine weevil.

Results

Our trials indicated significant provenance variation in weevil resistance (fig. 3), with some open-pollinated parents consistently producing offspring with statistically demonstrable resistance to *P. strobi* (Alfaro et al. 2008). These parents are now in seed orchards and producing resistant seed for reforestation. We have also determined that resistance is both heritable and stable.

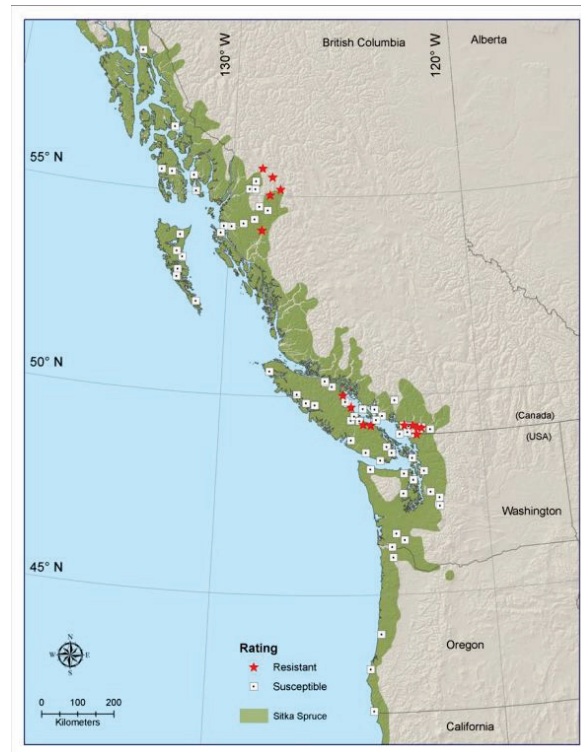


Figure 3—Range of Sitka spruce in western North America (green). Dots indicate sources tested for genetic resistance to weevil damage. Red dots indicate sources found to consistently produce progeny with resistance.

Artificial infestations allowed us to quickly and effectively proceed with the construction of an F1 population, to determine the heritability of resistance, and to further our understanding of the mechanisms that underlie weevil resistance. This F1 population is now screened (Moreira et al. 2011) using the same methodology as is used for the parent populations. Weevil resistance in the F1 spruce progeny demonstrated that progeny from resistant parents ($R \times R$ progeny) sustained significantly fewer weevil attacks than progeny from susceptible parents ($S \times S$ progeny) or progeny with one resistant and one susceptible parent ($R \times S$ progeny). Individual and family heritability estimates of the weevil resistance were 0.5 and 0.9, respectively. We also related the level of resistance in the F1 crosses to two constitutive mechanisms of resistance: the density of cortical resin canals and the amount of sclereid cells in the leader cortex (Moreira et al. 2011). Constitutive defenses were significantly higher in $R \times R$ progeny than in $R \times S$ or $S \times S$ progeny. We observed a negative correlation between the percentage of trees attacked in each cross and the average density of the resin canals or sclereid cells for each cross.

Our results indicated that effective screening for weevil resistance can be accomplished by using artificial weevil infestation. At the time of weevil release, trees need to be of susceptible height, i.e., outplanted for approximately 3 to 4 years in coastal BC. Once plantations are artificially infested, they should be monitored for at least 4 years to ensure that resistance is stable, i.e., that the selected genotypes sustain consistently low attack rates. This is a fairly quick turnaround time for studying

resistance of forest trees from temperate regions. This is a promising result, which should encourage resistance studies for other regeneration pests.

Production and Deployment of Resistant Trees

The resistant genotypes identified through this program now form the basis for the successful establishment of Sitka spruce plantations in BC. Using our selections of weevil resistant parents, seed orchards have been established and are producing regeneration material for operational planting (seeds and seedlings) (fig. 4).

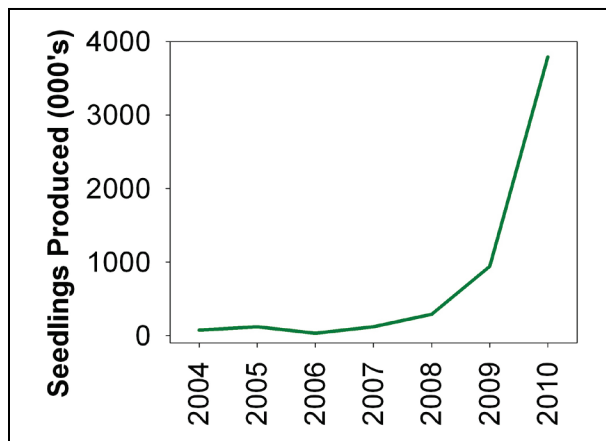


Figure 4—Annual amount resistant seedlings produced in British Columbia at Western Forest Products nursery in Saanich, BC.

While in the past, BC provincial coastal reforestation guidelines for high weevil hazard areas have recommended exclusion or limited planting of spruce, current guidelines indicate that up to half of the stand could be planted with Sitka spruce in moderate- or high-hazard areas if “A+” seed (from selected orchard-grown, weevil-resistant trees [R+87]) is used, and about a third if “B+” seed is used (from naturally resistant stands [R+64]) (Heppner and Turner 2006).

Conclusions

- The screening of putative parents for weevil resistance has been successfully completed (over 29,000 trees screened).
- Resistant Sitka spruce parents have been selected.
- Resistance is heritable and stable.
- An F1 progeny test was produced from control crosses of Resistant x Resistant, Resistant x Susceptible, and Susceptible x Susceptible parents.
- Breeding for resistance: Individual and family heritability estimates of weevil resistance were 0.5 and 0.9, respectively.
- Seed orchards are now producing the first generation of resistant seed for BC’s next forest crop.

Acknowledgments

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Literature Cited

- Alfaro, R.I.; King, J.N.; Brown, R.G.; Buddingh, S.M. 2008.** Screening of Sitka spruce genotypes for resistance to the white pine weevil using artificial infestations. *Forest Ecology and Management*. 255: 1749–1758.
- Heppner, D.; Turner, J. 2006.** British Columbia's coastal forests: spruce weevil and western spruce budworm forest health stand establishment decision aids. *BC Journal of Ecosystems and Management* .7(3):45–49. http://www.forrex.org/publications/jem/ISS38/vol7_no3_art6.pdf. (29 January 2012).
- Moreira, Xoaquín; Alfaro, R.I.; King, J.N. 2011.** Constitutive defenses and damage in Sitka spruce progeny obtained from crosses between white pine weevil resistant and susceptible parents. *Forestry*. doi:10.1093/forestry/cpr060.