

# Genetic Selection in Coastal Douglas-fir for Tolerance to Swiss Needle Cast Disease

Keith J.S. Jayawickrama,<sup>1</sup> David Shaw,<sup>2</sup> and Terrance Z. Ye<sup>1</sup>

## Introduction

Swiss needle cast (SNC) of Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco), caused by the ascomycete fungus *Phaeocryptopus gaemannii*, is associated with significant volume growth losses (20 to 50 percent) along the Oregon Coast. Although the pathogen is endemic, disease symptoms have intensified in coastal forests of Oregon and Washington since the early 1990s, reaching a peak of 177,691 symptomatic hectares detected in the 2011 aerial survey of western Oregon (fig. 1). This symptom expression is the highest in 16 years of survey, despite the conversion of tens of thousands of pure Douglas-fir plantations to mixed or alternate species over that period. Regular surveys have not been done in Washington State in the same way, but in 1999 and 2000, about 75,000 ha with visible symptoms were detected, and the disease continues to affect stands.

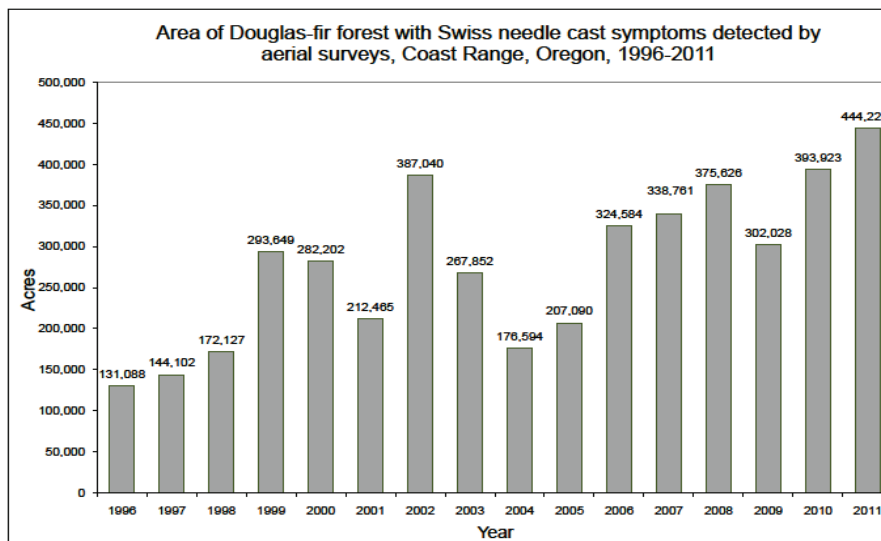


Figure 1—Area of Douglas-fir forest in western Oregon with symptoms of Swiss needle cast detected during aerial surveys conducted from April-June, 1996-2011. (Figure from Alan Kanaskie and Mike McWilliams, Oregon Department of Forestry)

Coastal Douglas-fir is an enormously important timber species for Oregon; consequently, there has been considerable interest and investment in understanding the disease, quantifying its impact, finding silvicultural and management solutions, and developing seed sources suitable for this zone. The Swiss Needle Cast Cooperative (SNCC) based at Oregon State University (OSU) and several breeding and testing cooperatives (supported by the Northwest Tree Improvement Cooperative also based at OSU) are working toward these goals.

<sup>1</sup> Department of Forest Ecosystems and Society, Oregon State University (OSU), Corvallis, Oregon.

<sup>2</sup> Department of Forest Engineering, Resources, and Management, OSU.

Corresponding author: jayawickrama@oregonstate.edu.

Douglas-fir everywhere are naturally infected with *P. gaeumannii*, yet the disease only develops in certain geographic settings where pseudothecia are produced on 1- and 2-year-old needles. Needle retention (NR) is directly related to tree productivity. Trees with less than 2 years NR are significantly less productive than normal NR (3 years or more). Severely infected trees have <1 year foliage retention. Fungal infection and needle colonization occur passively, through needle stomata and the needle apoplast, respectively, and neither process requires physical or enzymatic penetration of host tissue that might trigger a host defense response. Climatic conditions near the Oregon coast are often conducive to SNC disease development. Mild winter temperatures and spring/summer leaf wetness are key.

There are no known resistance mechanisms, as all foliage and all trees are susceptible given the right climatic conditions during spore dispersal and colonization. No significant differences were found between families in fungal DNA content (Temel 2002). Nonetheless, tolerance to the disease has been well documented, with some families continuing to grow well in the presence of SNC, and adequate family-mean narrow-sense heritabilities for foliage traits are present.

## Work in First Generation Programs

Several studies have centered on the Nehalem progeny trial series of 400 first-generation families established on 10 sites in the northern Oregon coast range in 1986 and subject to moderate to heavy SNC disease pressure. This series was measured for the fourth time in summer 2010, and age-26 diameter growth (DBH) from 200 families on five sites were obtained. Data have also been collected from other first-generation programs near the coast. Some key conclusions from Nehalem and other first-generation programs are as follows:

- (1) Foliage traits are heritable (individual  $h^2 \approx 0.10$  to 0.23), but less heritable than growth traits ( $h^2 \approx 0.3$ ) (table 1). This could be from foliage traits being subjectively scored.
- (2) Crown density was seen as a better indicator of genetic tolerance than NR (Johnson 2002), but due to extensive use of NR by the SNCC it has been adopted in tree improvement programs as well.
- (3) Growth after age-11 was more strongly associated with age-11 tree size (type-B correlations  $\approx 0.7$ ) than with foliage traits (type B correlations  $\approx 0.2$  to 0.5). However, rank changes have taken place for DBH between age-11 and age-26.
- (4) Usable gains for DBH were seen even at age-26. The top 10 percent of parents for DBH-26 had predicted gains of 18.2 percent over population mean, and predicted gains of 23.7 percent over population mean for DBH-18 to -26 increments.
- (5) In areas with >2 years of foliage, gains from selection for DBH should be adequate to offset volume growth losses from SNC and keep Douglas-fir as a viable plantation species.
- (6) Selecting on an index of age-11 crown density + age-11 DBH ( $\approx 13.8$  percent gain) was only slightly better than age-11 DBH alone ( $\approx 13.4$  percent gain) in improving age-26 DBH.
- (7) Selecting for NR alone, foliage color or crown density at age-11 gave little to modest ( $\approx 1$  percent, 2.2 percent, and 5.7 percent) gains in age-26 DBH.

**Table 1—Heritabilities obtained from the Nehalem first-generation Douglas-fir program**

Trait	Across sites	
	Individual	Family mean
Height 11	0.30	0.81
Volume index 11	0.29	0.80
DBH 11	0.27	0.79
DBH 17/18	0.35	0.82
DBH 26	0.36	0.70
DBH increment (age-11 to 17/18)	0.32	0.80
Needle retention: 1993 secondary laterals	0.23	0.77
Crown density	0.18	0.71
Foliage color	0.11	0.59

## Second-Cycle Trials

One second-cycle program has been established in Washington (Washington coast), and four on the Oregon coast:

- (1) South Central Coast (SCC) in the south, with the mainline in the core Douglas-fir area, and a smaller satellite program in the zone most affected by SNC.
- (2) Plum Creek's CL98 program adjacent to South Central Coast.
- (3) Trask in the north, with a coast program (moderately affected by SNC), and an inland program (little affected by SNC).
- (4) Plum Creek's Toledo program in the same geographic area as Trask coast.

These five programs have 40 progeny test sites planted between 1997 and 2008. Key points about the second-cycle work to date:

- (1) Needle retention is being assessed at age-7 and age-12 and DBH is being assessed at age-7 and age-12 so that an age-7 to age-12 DBH increment can be calculated. There may be additional (later) DBH assessments to confirm continued growth in DBH.
- (2) Ability to maintain height and diameter growth, and good needle retention scores, will be the primary selection criteria within these trials.
- (3) Relative heritability patterns for growth traits vs. NR are similar to the first-generation (NR is less heritable than growth).
- (4) No molecular marker work has been done to date or is currently planned. It is speculated that the ability to grow in the presence of SNC is controlled by many small-effect genes.
- (5) A cloned breeding population might provide additional gains compared to a seedling breeding population, but due to the difficulty of rooting Douglas-fir, it would be expensive.

- (6) No early (e.g., age-2) testing has been implemented. Research done by Temel et al. (2005) indicated that such testing would provide gains in foliage traits, but little in the way of growth gains even at age-10.
- (7) Tested 2nd-cycle families have shown large realized gains in growth over unimproved Douglas-Fir in the SNC zone. In SCC, the tested families had 39.9 percent age-7 volume index (DBH<sup>2</sup> x height) gains over unimproved controls (on SNC sites) and 2.8 percent gains for NR. For Trask, the corresponding numbers for the top 50 families were 48.2 percent and 5.7 percent.

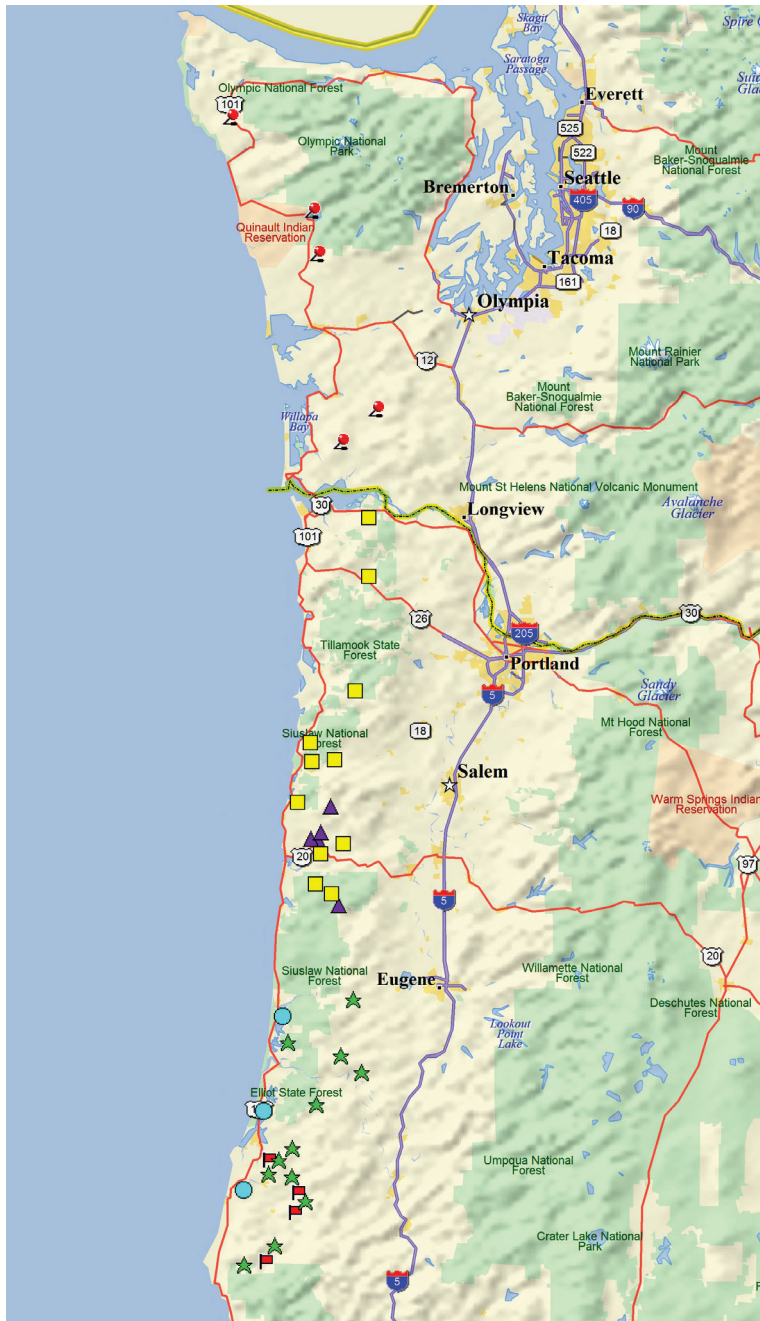
## **Seed Orchards and Deployment**

Orchard blocks (such as Georgia-Pacific's Toledo block, the Forest Service's Hebo block, and the Nehalem block at the Schroeder seed orchard complex near St Paul, Oregon) serving the northern Oregon coast were established between the 1970s and 1990s. The Oregon Department of Forestry (ODF) had a strong commitment to growing a proportion of Douglas-fir on the coast, and a large area under timber management. The ODF saw tree improvement as the main viable tool to counteract SNC and continue growing Douglas-fir, and took the lead in developing a "needlecast-tolerant" orchard block around 2002 built around the Nehalem orchard block.

This orchard incorporated elite selections from the Nehalem and other coastal breeding units on the Oregon coast. The orchard is 2.4 ha in extent, and other cooperators have subsequently joined. Other blocks are being established, and ability to grow in the presence of SNC will remain a priority as selections are added from the 2nd-cycle and beyond. Tree-form, wind-pollinated orchards are likely to be the predominant engine for producing tolerant seed. Mixtures of family lots are used. The goal is to develop seed sources capable of acceptable growth rates on sites averaging  $\geq 2$  years of needle retention.

## **Alternate Species**

In areas with higher disease pressure and foliage retention  $\leq 2$  years, it may be prudent to use alternate timber species such as western hemlock, western red cedar, red alder, western white pine, and Sitka spruce. Many forest owners have been making this switch during the past 10 to 15 years. Either through complete replacement as described above or through mixed species plantings with a component of Douglas-fir (in moderate SNC areas); pure Douglas-fir stands are gradually being replaced. One consequence of SNC infection has been strong support for cooperative genetic improvement of western hemlock (Jayawickrama 2003) which is now entering into a third cycle of breeding and testing.



-  Washington Coast (5 sites)
-  Trask Coast (11 sites)
-  Toledo T96 (5 sites)
-  South Central Coast Main (12 sites)
-  South Central Coast SNC (3 sites)
-  Coos Bay CL98 (4 sites)

Figure 2—Second-cycle Douglas-fir test sites established on the Oregon and Washington coasts.

## Literature Cited

- Jayawickrama, K.J.S. 2003.** Genetic improvement and deployment of western hemlock in Oregon and Washington: review and future prospects. *Silvae Genetica*. 52: 25–36.
- Johnson, G.R. 2002.** Genetic variation in tolerance of Douglas-fir to Swiss needle cast as assessed by symptom expression. *Silvae Genetica*. 51: 80–86.
- Temel, F. 2002.** Early testing of Douglas-fir (*Pseudotsuga menziesii* var. *menziesii* (Mirb.) Franco) for Swiss needle cast tolerance. Corvallis, OR: Oregon State University. 177 p. Ph.D thesis.
- Temel, F.; Johnson, G.R.; Adams, W.T. 2005.** Early genetic testing of coastal Douglas-fir for Swiss needle cast tolerance. *Canadian Journal of Forest Research*. 35: 521–529.