

INTRODUCTION

Swiss needle cast (SNC), caused by the fungus *Phaeocryptopus gaeumannii*, is one of the most damaging diseases of coast Douglas-fir (*Pseudotsuga menziesii* var. *menziesii*) in the Pacific Northwest (Hansen and others 2000, Mainwaring and others 2005, Shaw and others 2011). Biological impact is particularly acute on the Oregon and Washington coasts, one of the most productive regions for temperate forest growth. In 2011, an aerial detection survey of coastal Oregon mapped more than 444,000 acres of Douglas-fir forest with obvious symptoms of SNC, the highest acreage recorded since surveys started in 1996. Annual Douglas-fir volume-growth losses from SNC are estimated at about 23 percent over 187,000 acres, with some stand-level volume losses as high as 52 percent in northwest Oregon (Maguire and others 2002, 2011).

Although defoliation from SNC occurs in the northern Cascade Mountains of Oregon, it is believed to be less damaging than in the Oregon Coast Range probably because of differences in sites, stands, and the pathogen. In particular, persistent wet conditions in the spring and early summer, during the sporulation and infection period, and mild winter temperatures are believed to provide ideal conditions for disease development. In 2001, baseline monitoring plots were established in 59 stands representing 2 million acres in the Cascade Mountains in Oregon using Forest Health Monitoring Program funding. These plots must be remeasured after 5 and 10 years in order to determine the impact

of SNC on Douglas-fir growth. These plots currently are the only source of data for SNC impact in the Oregon Cascade Range.

Primary objectives of our project were to determine changes after 5 and 10 years (2001 to 2011) in (1) tree diameter, (2) total-height growth, (3) live-crown ratio (LCR), and (4) SNC severity as estimated by needle retention and density of stomata occlusion in 59 stands in the northern Oregon Cascade Mountains. In 2011, our secondary objective was to compare foliage retention estimates in the field with those in the laboratory.

METHODS

From April to June 2001, prior to Douglas-fir budbreak, transects were installed in 59 stands. Sampled stands were initially 10 to 23 years old and contained more than 50 percent Douglas-fir. Stands were systematically located on public and private lands in the western Oregon Cascade Mountains (Freeman 2001).

Ten Douglas-fir trees were sampled per stand, for a total of 590 trees. Branches were sampled at mid-crown for foliage retention and needle stomata occlusion associated with SNC. Each stand had one transect with five sample plots located at 50-foot intervals. Transects were established in a location representative of each stand, based on aerial photos. Stand data collected in 2001 included (1) elevation, (2) slope aspect (eight cardinal points), (3) slope percent, and (4) Global Positioning System (GPS) coordinates at the reference point at the start of each transect.

CHAPTER 16.

Impacts of Swiss Needle Cast in the Cascade Mountains of Northern Oregon: Monitoring of Permanent Plots After 10 Years (Project WC-EM-B-11-01)

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At each plot, the nearest codominant or dominant Douglas-fir on each side of the transect was selected. Data collected for each tree in 2001 included (1) stand, plot, and tree number; (2) diameter at breast height (d.b.h., at 4.5 feet aboveground, nearest 0.1 inch); (3) total height (nearest foot); (4) height to lowest live branch (nearest foot); (5) ocular estimation of foliage retention in the mid-crown (0 to 8 years); and (6) foliage-retention index, calculated for each sampled branch. For estimating foliage retention in the mid-crown (0 to 8 years), a tree that had 100 percent of 1-year-old needles, 100 percent of 2-year-old needles, 60 percent of 3-year-old needles, and 20 percent of 4-year-old needles would be rated 2.7 years. Heights were measured in 2001 with a clinometer. LCRs were calculated by subtracting height to lowest live branch from total tree height to get live-crown length, and then dividing live-crown length by total tree height and multiplying by 100.

Foliage-retention index was calculated for each sample tree as follows. A live branch at mid-crown was selected on the south side of the sample tree and cut from the stem with a pole pruner. For trees with a mid-crown height greater than 25 feet (most trees in 2011), the tree was climbed by a certified climber, and the selected branch was severed at the trunk with a hand saw. From the cut branch, a secondary lateral branch that was at least 4 years old was selected, and the amount of foliage remaining in each needle age class (up to 4 years) was rated and recorded as: 0 = 0 to 10 percent of full complement present, 1 = 11 to 20 percent present, 2 = 21 to 30 percent present, ... 9 = 90

to 100 percent present. Ratings were summed for a minimum score of 0 and a maximum of 36 for each branch. Foliage retention has been shown to be the most reliable and efficient variable when estimating SNC severity in terms of tree volume-growth loss (Filip and others 2000, Hansen and others 2000, Maguire and others 2002). Foliage retention estimates from the mid-crown are considered more reliable than upper or lower crown estimates, especially in larger trees.

From April to July 2006 and 2011, the 59 stands sampled in 2001 were relocated using reference maps, aerial photos, and GPS coordinates. The same data collected in 2001 were collected for each tree in the 59 stands. If a sample tree was dead or severely broken, the cause was recorded and the nearest live Douglas-fir tree was selected as a replacement. Data from replacement trees, however, were not used in our analyses. Total height and height of the lowest live branch were measured with a laser height measurer (Laser Technology, Inc.).

In 2006 and 2011, for all 10 sample trees per stand, foliage from severed branches was placed in a sample bag, labeled with stand and tree number, and processed in the Weyerhaeuser Corp. laboratory (Centralia, WA) for pseudothelial counts and foliage retention (2011 only). Pseudothelial density, measured as the percentage of needle stomata occluded, is a direct method of determining the presence of *Phaeocryptopus gaeumannii* and severity of the disease. Measurements were made on 2-year-old needles only. In 2002, foliage from 10 of 37

stands was sampled for fungal DNA to determine fungal lineage (Freeman 2002, Winton and Stone 2004).

For pseudothecial counts in 2006 and 2011, sampled needles were placed under a camera (Big-C Dino-Lite Pro AD413T [USB] 12x~200X) connected to a laptop computer, and the percentage of occluded stomata was recorded at 200X magnification. Foliage retention during the last 4 years also was calculated in the lab in the same manner as was done in the field on a scale of 0 to 36.

Because some stands were thinned and stand density can influence tree growth, total basal area per acre and basal area per acre of Douglas-fir were calculated in 2006 and 2011 around one tree at each of the five sample points. Total plot basal area was measured around each sample tree by counting all in-trees with a 10-factor prism and multiplying by a basal-area factor of 10. All trees greater than or equal to 1.0 inch d.b.h. of any species were counted. All data were entered into an Excel spreadsheet where R^2 values were calculated from selected graphed data.

RESULTS AND DISCUSSION

From the 59 sampled stands, numbers of stands by each management agency were: Salem Bureau of Land Management = 16; Willamette National Forest = 12; Weyerhaeuser Corp. = 9; Mt. Hood National Forest = 7; Eugene Bureau of Land Management = 6; Port Blakely = 6;

Longview Fibre Co. = 2; and Oregon Department of Forestry = 1. Stands ranged in elevation from 500 to 4,200 feet and percent slope from 0 to 60. Total basal area per acre in 2011 averaged 108 square feet (range = 34 to 198). Douglas-fir basal area per acre averaged 95 square feet (range = 34 to 198).

Some stands had been precommercially thinned either before or after initial plot establishment in 2001. Between 2001 and 2011, 46 plot trees (8 percent) were accidentally felled, broke, or died; these plot trees were replaced with other trees. The plot trees and their replacements were not included in stand means. Other major stand species besides Douglas-fir included western hemlock (*Tsuga heterophylla*) at the lower elevations and noble fir (*Abies procera*) at the upper elevations.

Mean 10-year d.b.h. growth was 4.2 inches (range = 1.8 to 6.0) and total-height growth was 24.7 feet (range = 8.3 to 31.8). Mean LCR decreased by 15.5 percent (range = 3.7 percent increase to 40.8 percent decrease) over 10 years; 6 of 43 (14 percent) stands increased in mean LCR. Sixteen trees were not measured for LCR in 2001. Correlations between total plot basal area and tree growth were poor, at $R^2 = 0.004$ for d.b.h. growth and 0.15 for height growth.

From field measurements, mean foliage-retention index decreased by 0.4 (range = -15.8 to 8.6) over 10 years. If lab measurements are used, however, foliage-retention index increased by 3.2 in 10 years. Ground-based estimates of

mid-crown foliage retention increased by 1.2 years (range -0.7 to 3.1) from 2001 to 2011. In 2006 and 2011, many trees had a partial 5th- year complement of needles and some trees as many as 8 years of needles, but these were not reflected in retention indices that scored only the last 4 years of needles. Mid-crown foliage ratings did capture 5- to 8-year-old needles. Correlations between field foliage-retention index and mid-crown foliage retention years were moderate, at $R^2 = 0.68$ in 2001, 0.54 in 2006, and 0.46 in 2011. Mid-crown foliage retention averaged 4.7 years, and only three stands had less than 3 years of foliage in 2011.

In 2011, foliage-retention index was measured in the field and again in the lab on a scale of 0 to 36. Correlation between the two sampling methods was moderate ($R^2 = 0.31$). Foliage-retention index measured in the lab was generally higher than measured in the field. We

speculate that the lab estimates probably are more accurate than the field estimates because they were supervised by trained pathologists, while the field estimates mainly were conducted by the newly hired tree-climbing crew. Also, the lab estimate of an increase in 10-year foliage-retention index was in the same positive direction as the 10-year mid-crown foliage-retention ratings ocularly estimated from the ground.

Mean percentage of stomata occluded by pseudothecia was 8.7 percent for 2-year-old needles sampled in 2011; this needle cohort initially was infected as new growth after budbreak in 2009. No stands had mean stomata-occlusion densities greater than 34 percent in 2011. Correlation between 2011 field foliage-retention index and 2-year-old needle stomata occlusion was moderate, at $R^2 = 0.25$ (fig. 16.1). Correlation between 2011 lab foliage-retention

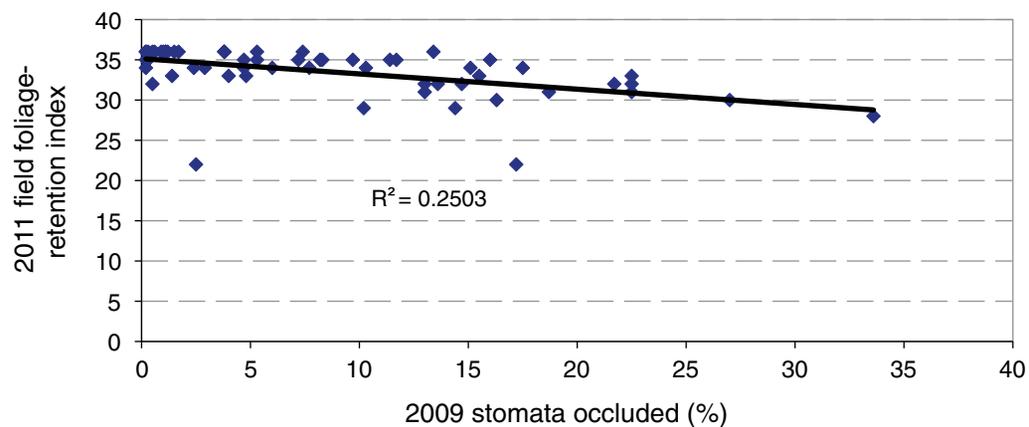


Figure 16.1—2011 field foliage-retention index vs. 2009 (2-year-old) needle-pseudothecial density (stomata occluded). From Filip and others (2012).

index and 2009 needle stomata occlusion also was moderate, at $R^2 = 0.25$. Other factors besides occluded stomata, such as tree genetics and soil-nutrient levels, are known to affect foliage retention.

In the Oregon Coast Range, Hansen and others (2000) showed that increasing proportions of stomata occupied by pseudothecia were associated with increasing defoliation. They recorded mean pseudothecial densities up to 50 percent in 1-year-old foliage and foliage retention as low as 1 year. In contrast, in 2011, our highest mean pseudothecial density was 33.6 percent in 2-year-old needles, and our lowest mean foliage retention was 2.3 years. All pseudothecia collected in the Cascade Range in 2002 were from lineage 1 (Winton and Stone 2004).

There was a moderate correlation between stand elevation and either 2011 foliage-retention index ($R^2 = 0.52$) or 2009 (2-year-old) needle-stomata occlusion ($R^2 = 0.52$; fig. 16.2). In general, there was more foliage and fewer pseudothecia at the higher elevations.

There were poor correlations between 2011 mid-crown foliage (yrs) and either 10-year d.b.h. growth ($R^2 = 0.05$; fig. 16.3) or total height growth ($R^2 = 0.01$; fig. 16.4). There were also poor correlations between diameter and height growth and 2011 foliage-retention index ($R^2 = 0.02$ and 0.06). Poor correlations occurred between 2009 (2-year-old) needle-stomata occlusion and either 10-year d.b.h. growth ($R^2 = 0.00$) or total height growth ($R^2 = 0.11$).

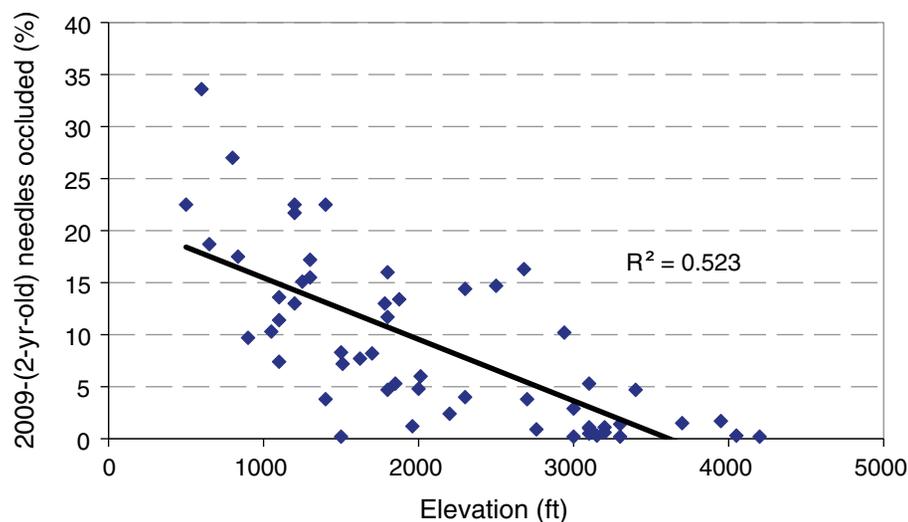


Figure 16.2—2009 (2-year-old) needle-pseudothecial density (stomata occluded) and elevation. From Filip and others (2012).

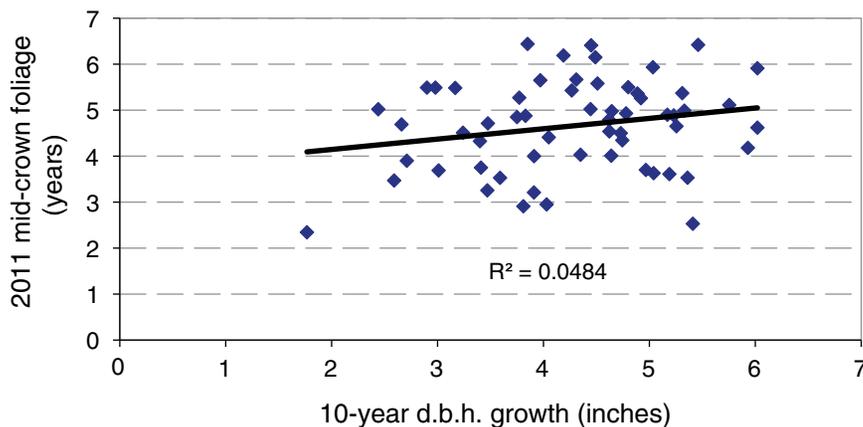


Figure 16.3—2011 mid-crown foliage retention and 10-year diameter-at-breast-height growth. From Filip and others (2012).

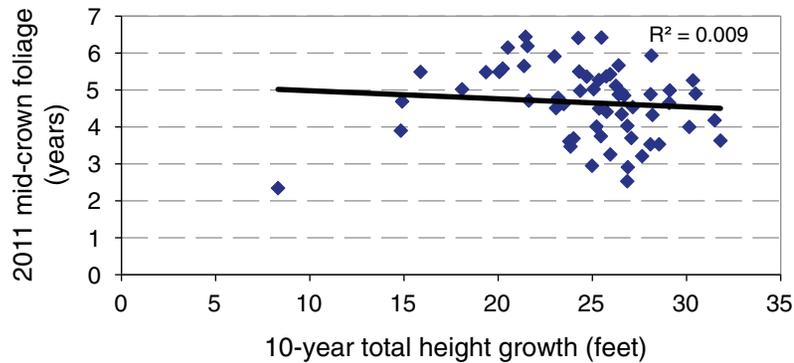


Figure 16.4—2011 mid-crown foliage retention and 10-year total height growth. From Filip and others (2012).

CONCLUSIONS

No effect of SNC on Douglas-fir growth is apparent from 2001 to 2011 in the stands sampled in the Cascade Range. There are at least three possible reasons why this is so:

1. SNC levels during the past 10 years in the Cascade Range are not as severe as in the Oregon Coast Range. Only a few stands sampled in the Cascades have mean foliage retention of less than 3 years. There were no stands with mean stomata occlusion densities greater than 50 percent on 2-year-old needles in 2001, 2006, and 2011.
2. Oregon Cascade Range site characteristics, including plant associations, soil chemistry and parent material, air temperatures, and monthly precipitation and leaf wetness may not be as conducive to elevated populations of

the causal fungus, *Phaeocryptopus gaeumannii*, and subsequent severe defoliation as in the Coast Range.

3. The genetics (lineage 1) of isolates of the causal fungus in the Oregon Cascades more closely resemble isolates from Idaho, Europe, and New Zealand than isolates from the Oregon Coast Range (Winton and Stone 2004). Also, lineage 2, which is abundant in the Oregon Coast Range, has not been reported in the Cascade Mountains.

Based on our results, forest managers do not need to change their current practices in the northern Oregon Cascades because of SNC. Managing a mix of Douglas-fir and western hemlock (at lower elevations) and noble fir (at higher elevations), however, will help offset any future stand-growth declines due to SNC or other pest outbreaks should such develop.

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